THE UNIVERSITY of ADELAIDE

Socio-Economic Inequalities in Different Australian Dental Service Providers

Thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy

By

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August 2022

This is for you, Mum.
However, nothing can compensate for our separation...

“Human beings are members of a whole
In creation of one essence and soul
If one member is afflicted with pain
Other members uneasy will remain
If you have no sympathy for human pain
The name of human you cannot retain.”

~ Saadi Shirazi (1210 AD, Persian Poet) ~

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Research Outputs

Peer-reviewed journal articles

During the learning process of this PhD candidature, the following five studies were conducted in an article format, two of which have now been published, one is under revision, and the other two are under review:

1- Ghanbarzadegan, A., Bastani, P., Luzzi, L., Brennan, D. Inequalities in utilization and provision of dental services: a scoping review. Systematic reviews. 2021 Dec;10(1):1-1.

2- Ghanbarzadegan, A., Balasubramanian, M., Luzzi L., Brennan, D., Bastani, P. Inequality in dental services: a scoping review on the role of access toward achieving universal health coverage in oral health. BMC Oral Health. 2021 Dec;21(1):1-1.

3- Ghanbarzadegan, A., Bastani, P., Balasubramanian, M. *et al.* The triangle of inequality in dental services: arguments for a new conceptual framework. *Arch Public Health* **80,** 60 (2022).

4- Ghanbarzadegan A, Mittinty M, Brennan DS, Jamieson LM. Income-based inequalities in dental service utilization: A multiple mediation analysis. Community Dent Oral Epidemiol. 2022;00:1-7.

5- Ghanbarzadegan, A., Mittinty, M., Brennan, D., Jamieson, L. Education effect on Dental Services Utilisation Patterns in Different Sectors: A Multiple Mediation Analysis. Submitted to Community Dentistry and Oral Epidemiology Journal, January 2022.

In addition to the above studies, I have collaborated in several studies during my PhD candidature, two of which were relevant to this thesis's topic and examined aspects of inequality specifically in vulnerable communities; therefore, I included those as supplementary papers in appendix VI. The results of these studies contributed to the foundation of the concept in Chapter 5:

1- Bastani, P., Sarikhani, Y., Ghanbarzadegan, A., Ostovar, F., Samadbeik, M., Jamieson, L. Challenges in the provision and utilization of oral health services among the Australian Indigenous population: a scoping review. Journal of Public Health. 2021 Oct 16:1-0.

2- Bastani, P., Mohammadpour, M., Ghanbarzadegan, A., Rossi-Fedele, G., Peres, MA. Provision of dental services for vulnerable groups: a scoping review on children with special health care needs. BMC Health Services Research. 2021 Dec;21(1):1-2.

Note: Another mediation paper using the method I developed and utilised in this thesis and using the same survey data is in progress. This study will explore the provision of public dental services for older South Australian adults.

Presentations

1. *2021. 14th European congress of public health. European public health association.* Oral presentation with the abstract published in the conference proceeding as*:*

   Ghanbarzadegan, A., Bastani, P., Luzzi, L., Brennan, D. Inequalities in Utilisation and Provision of Dental Services: A Scoping Review. European Journal of Public Health. 2021 Oct;31(Supplement_3): ckab165-274.

2. *2021. 14th European congress of public health. European public health association.* Poster presentation with the abstract published in the conference proceeding as*:*

   Ghanbarzadegan, A., Balasubramanian, M., Luzzi, L., Brennan, D., Bastani, P. A Scoping Review on the Role of Access toward achieving Universal Health

Coverage in Oral Health. European Journal of Public Health. 2021 Oct;31(Supplement_3): ckab164-581.

3. *2021. Florey Research conference. The University of Adelaide. Poster presentation with the title:* Income-based Inequalities in Dental Service Utilisation
4. *2020. Australian Research Centre for Population Oral Health (ARCPOH) Seminars,* The University of Adelaide. Oral presentation with the title*: "Causal Multiple mediation in dental science".*
5. *2021. Oral Epidemiology Unit, The University of Queensland. Oral presentation of thesis findings.*
6. *2021. Dental Public Health and Preventive Dentistry, Griffith University. Oral presentation of thesis findings.*
7. *2020. Florey Research conference. The University of Adelaide.* The University of Adelaide. Poster presentation with the title*:* Inequalities in utilization and provision of dental services.
8. *2020.Australian Research Centre for Population Oral Health (ARCPOH) Seminars,* The University of Adelaide. Oral presentation with the title*: "Scoping reviews and inequality policy questions"*

Thesis Abstract

Background

Australia is a vast country with cultural, religious, racial, sexual and geographical diversity. Australia's Indigenous population has suffered many injustices in the past and to date. Australia also has a large culturally and linguistically diverse population (CALD) as an immigration destination. These challenges along with different socio-economic status are sources of inequality in the Australian health system. Taking a specific lens at health services and considering that dental services have the least government support, and along with the minimum insurance coverage and the fact that only 15% of services are provided in the public sector, the importance of investigating inequalities in dental services is critical. Therefore, the aim of this PhD is to investigate the inequalities in dental services in Australia with a focus on different dental service sectors.

Methods

This project was carried out in two main phases with different methodologies. In the first phase, two scoping reviews were performed with a systematic approach. Determinants of inequalities in dental services were determined by qualitative content analysis. In the first study, determinants of utilisation and provision of dental services, and in the second study, the determinants of access were identified. Also, the role of access in achieving universal health coverage in dental services was discussed.

In the second phase, statistical modelling was performed by considering this synthesised knowledge. Using Flexible Mediation Analysis and Ratio of Mediator Probability Weighting Approach, data from 4494 South Australian adults from the Dental Care and Oral Health Study were analysed. In the first empirical study, income-

based inequalities and financial burden in dental services were examined. The direct and indirect effect of income through mediators such as insurance, concession cards and dental service sectors (public/private) on avoiding or delaying dental services were investigated.

The second empirical study investigated sociocultural inequality in Australian public and private sectors using a similar population. This study investigated the direct and indirect effects of education through mediators including oral health, smoking status, and tooth brushing on utilisation patterns of dental services.

Results

According to the review chapters, a conceptual model of inequality (named as the Triangle of Inequality) in dental services was designed in the third study. The second phase results showed that people with lower income experienced more financial burden to receive dental services regardless of their insurance, concession card holding status, and the dental service sectors they attend. The findings showed that people with less education received fewer dental services. Low education was associated with emergency and treatment visits. Examining the effect modification of the dental service sector, it was observed that utilisation of services was better among less educated people who visited the public sector.

Conclusion

These findings highlight the importance of income inequality and highlight the fact that facilitators such as insurance, concession card holding status, and the dental service sector are ineffective in reducing the financial burden on contemporary dental services. The findings of the second empirical study indicate that the public sector could improve the utilisation of dental services in people with low education.

Thesis Declaration

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint award of this degree.

The author acknowledges that copyright of published works contained within the thesis resides with the copyright holder(s) of those works.

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Dr Arash Ghanbarzadegan

29/07/2022

Acknowledgements

When I started this journey, I did not imagine it would be the most grievous time of my life. While doing my PhD, COVID-19 incredibly transformed the world, and misery and disease spread worldwide. As an international student, I was separated from my beloved family back home and experienced tough days while worrying about the health and well-being of my dearest ones. Sadly, I lost my benevolent and lovely mother Fouzieh Niknezhad (فوزیه نیک نژاد) because of Covid-19, and I deeply regret that I could not be by her side and take care of her. I am speechless to describe the pain and grief I have in my day-to-day life; however, this pain motivates me to work harder towards success to acknowledge her efforts and dedication. I hope she forgave me for leaving her alone. I owe my success to my supportive mother, who sacrificed her life for her children's prosperity, and I dedicated my thesis to my mother's memory for her endless love. I hope the achievement of PhD degree will make her proud. I am greatly indebted to my father Mohammad Mehdi Ghanbarzadegan (محمد مهدی قنبرزادگان) for his wisdom, and guidance and I never forget all your efforts for my life. In pursuing this journey, my lovely wife and soulmate Fatemeh stood by my side patiently, and whenever I needed help, she was there for me selflessly. She has come as a blessing in my life and gone through every up and down during my PhD. Dear Fatemeh, you are a strong and wise woman, and I will never forget the tears of joy and sorrow we shared. Thank you, Fatemeh, for giving me your unconditional love and support; I will love you forever. It would be a great pleasure to acknowledge my parents-in-law for their spiritual support.

I owe my deepest gratitude to my supervisors, Professor Lisa Jamieson, Professor David Brenan and Dr Murthy Mittinty, for their support and encouragement. Without

their guidance, this study would hardly have been completed. I am profoundly grateful to my principal supervisor Prof. Lisa Jamison for believing in my potentials and giving me the opportunity to learn and grow throughout my candidature. She is an inspiring person, and I sincerely admire her scientific knowledge and human qualities. I also extend my most profound appreciation to Prof. David Brenan. He initially accepted me as a PhD candidate and, even after his retirement, it was my pleasure to keep him on my supervisory panel. I acknowledge his invaluable advice and feedback for my research and wish him a wonderful retirement filled with joy and bliss. Last but not least, I would like to thank Dr Murthy Mittinty for his exceptional statistical knowledge that helped me promote the level of my research analysis. I always remember his sympathy and support during my grief and sharing his life story to comfort me and ease the pain of my loss.

I am highly thankful to Dr Liana Luzzi (The University of Adelaide), Dr Peivand Bastani (The University of Queensland) and Dr Madhan Balasubramanian (Flinders University) for their collaborations through my research outputs and publications.

My sincere thanks to former and current members of the Australian Research Centre for Population Oral Health (ARCPOH), Prof. Marco Peres, Prof. Loc Do, Dr Diep Ha, Dr Xiangqun Ju, Dr Dandara Haag, Dr Kostas Kapellas, Sergio Chrisopoulos, Helen Mills, Jacqueline Aldis, Joanne Hedges, Dr Davi Manzini, Dr Pedro Santiago, Dr Gustavo Hermes Soares, Dr Sathvika Justine, Dr Mi Du, Dr YoungHa Song, Dr Sneha Sethi, Dr Anna Ali, Dr Mehrsa Zakershahrak, Dr Sonia Nath, Dr Emilija Jensen and Briana Poirier.

I would also like to acknowledge the University of Adelaide for offering me this PhD position and scholarship which covered tuition fee and living allowance during my candidature.

I acknowledge that this PhD research was conducted on the traditional country of the Kaurna people of the Adelaide Plains. I recognise and respect their cultural heritage, beliefs and relationship with the land. I acknowledge that they are of continuing importance to the Kaurna people living today.

Chapter 1 - Introduction

1. Introduction

1.1. Health as a human right

Starting my thesis by saying that health is a human right, especially after the progress of the last century, may seem like a cliché. But when we thought we were past the scourge of contagious diseases like the plague, the COVID-19 epidemic showed how fragile and interdependent our human health is. Humans have always sought to cure diseases and promote health, and medicine has been praised like religions. Decades ago, the World Health Organization (WHO) introduced the health for all policy at the Alma Ata Conference (World Health Organization 1978). Although the policy focused on Primary Health Care, it was not welcomed by some countries (Hall and Taylor 2003). Thirty-seven years later, in 2015, while health was not being granted for all, the United Nations set the Sustainable Development Goals (SDGs) to be achieved by 2030. SDGs target different aspects, but SDG3 is to: "Ensure healthy lives and promote well-being for all ages" (World Health Organization 2017). So why are we still facing so many health challenges despite these goals? To answer this question, we must return to the basic premise of whether health is a fundamental right or not? Although this presupposition seems to be universally accepted, some views have different legal perspectives, and this poses challenges to achieving universal health coverage (UHC). Rights make sense when they have a clear definition and framework. For example, if we say that freedom is an unconditional human right, then when one person's freedom impairs another's freedom, we are faced with a paradox. In addition to setting boundaries for rights, it is also important clarify who is responsible for enforcing those rights.

For this reason, some divide rights into two categories of negative and positive rights. In this restricted notion of rights, negative rights are legitimate rights while positive rights are not. Opponents of the UHC argue that human rights should be limited to negative rights such as life, liberty, and happiness. They believe that health is not a negative right, and therefore it should not impose any obligation on governments to provide it (Peikoff 1993). Bradley (2010) argued with this distinction and led the discussion favouring the "Equality of Opportunity" approach (Daniels 1985). In this view, governments have an obligation to provide equal opportunities for people to flourish. Since health is a prerequisite for the prosperity of society, individuals should also have equal chances of having health.

1.2 Equality and Equity

Inequality in having health opportunities leads to inequity in health. Health equity has various dimensions. Vertical equity is established when people with different needs receive the right level of service. Horizontal inequity happens when people with similar conditions receive different levels of health care (Morris et al. 2005). Equalities in opportunities can be measured, but it requires need variables to measure existing inequalities. Throughout this thesis, the same approach is used to redefine need variables and concepts which create inequality in Australian dental services.

While some ideologies challenge the notion of the right to health, international statements endorse it. For example, the United Nations Committee on Economic Social and Cultural Rights has stated that "health is a fundamental human right indispensable for exercising other human rights. Every human being is entitled to the enjoyment of the highest attainable standard of health conducive to living a life in

dignity". Australian law guarantees the health of the community. In addition to Australia's adherence to international declarations, some national laws also endorse this right. Two examples of these laws are the *National Health Act 1953,* which guarantees pharmaceutical, sickness and hospital benefits and medical and dental services, and the *Health Insurance Act 1973* on the Medicare scheme, medical benefits, and hospital services coverage (Australian Attorney-General's Department 2021).

Resources are limited, even in developed countries such as Australia. Therefore, governments must prioritise available resources (i.e., Rationing in resources) to achieve UHC, which happens by determining who receives what services and how much (Lamm 1991). To better understand the mechanisms that lead to prioritisation in the Australian health system and the challenges of inequality, we need to understand its context better.

This context must therefore be considered uncensored. Today's Australia is about two hundred and thirty years old, but life in Australia dates back to fifty to sixty-five thousand years ago. Europeans first invaded Indigenous Australians who lived in the land for thousands of years in the early seventeenth century, but Australia officially became a British colony in 1788.

Ardill argues that sociobiology in colonisation led to structural racism in Australian law doctrine and continues today. He introduces sociology as a set of ideologies defining human's place in the natural environment around them. These ideologies at the time of Australian colonisation included Christian thought and Darwinism. In the Christian view, there are two stereotypes. One is that humans are descendants of

Adam and Eve, and after the flood in the time of Noah, different races continued from Noah's three children. In this view, non-Christians are less favoured by God. In another perspective, God created different races for different climates, so some are better endowed than others. Conversely, Darwin's Theory of Evolution was the basis of many biological studies to prove that some races were evolutionary more privileged, considering the size of the skull and brain. Ardill saw these views as the foundation of structural racism in Australian laws (Ardill 2009).

1.3 Health inequality in Australia

1.3.1 health

Since colonisation and the separation of children from their families (the Stolen Generation), Indigenous Australians have experienced sustained historical trauma (Gone 2013). Australia was ranked second rank in the global Human Development Index (HDI) in the latest version of the human development report announced by the United Nations Development Programme (UNDP) (Jāhāna 2015). However, when considered in isolation, Indigenous Australians had the lowest life expectancy at birth compared with other Indigenous populations in high income and developed countries such as Canada, the United States, and New Zealand (Anderson et al. 2016). Furthermore, according to the population study conducted by the Lancet-Lowitja in 2016, poverty was common among Australians, with high rates of child malnutrition, childhood and adulthood obesity (Anderson et al. 2016). These disparities are more pronounced in Indigenous people living in remote and disadvantaged regions. In 2017, 86% of Indigenous Australians who speak Indigenous languages lived in the most disadvantaged areas, while only 1.2% lived

in advantaged regions (Australian Bureau of Statistics 2017). Indigenous Australians living in remote areas have limited access to transportation facilities and health care systems, leading to a higher mortality rate and disease burden (Tyas and Indraharan 2014). Moreover, disparities in other health determinants including education, employment status, home, and work environment result in poorer health status in people compared with their non-Indigenous counterparts (O'Sullivan 2012).

1.3.2 Health in CALD communities

This discrimination is not limited to Indigenous Australians. As Australia is a multicultural country, these inequalities include many immigrants, different religious groups, and sexual orientations (Babacan and Gopalkrishnan 2016; Holt 2021; Moran and Mallman 2019). Immigration has shaped the cultural fabric of Australia. Since the establishment of Australia as a federated nation in 1901, Australia has been identified as a multicultural society with ethnic diversity. According to the latest release of the statistics on Australia's international migrations, about one-third of Australians were born overseas, and 7.6 million migrants are living in Australia, indicating a large proportion of the population (Australian Bureau of Statistics 2019). In such a society, ethnicity and cultural differences must be recognised and appreciated as well as emphasising the shared national identity highlighting the role of equality in the community (Babacan and Gopalkrishnan 2016). Australian people are from 200 countries with over 300 ethnic backgrounds (Australian Bureau of Statistics 2016). These statistics regarding the diverse ancestries clearly demonstrates that Australians are from

Culturally and Linguistically Diverse (CALD) communities. Nearly 20% of Australians speak a non-English language at home. The proportion of people living in disadvantaged areas who speak English at home (18%) is equal to the proportion of people speaking non-English languages (19%) at home. However, there is equality among the people who speak non-English languages. For example, approximately 30 per cent of people speaking Mandarin or Cantonese at home live in advantaged areas. In contrast, 42 per cent of Vietnamese or 31 per cent of Arabs live in the most disadvantaged areas highlighting the discrimination among different nations (Australian Bureau of Statistics 2017). Living in deprived or remote areas can hinder access to health care services complex leading to health inequality. Along with access difficulties, people who belong to the CALD communities in Australia are struggling in the utilisation of the health services, resulting in health disparities (Smith 2015). The lower utilisation of health care services among CALD communities is not only limited to the unavailability of services, but also cultural and linguistic differences, perceived racism, and misunderstandings. For instance, a study conducted among Sudanese, Afghan, Pacific Islander and Burmese communities in Queensland revealed that despite having physical access to health care services, CALD communities were reluctant to use services due to the unfamiliarity with health settings and difficulty in communication with health care professionals in English (Henderson and Kendall 2011). Similarly, Asian migrants of Australia suffer from anxiety and confusion when trying to understand Australian health settings, discouraging them from using health services (Harrison et al. 2020).

The concern around health disparities among CALD populations has grown, with several programs designed and implemented to address the diversity in culture, language, and ethnicity. However, none of the agendas was significantly successful in improving the health condition of CALD communities (Anderson et al. 2003; Harrison et al. 2020). All the above pose severe challenges to providing equitable health care in Australia.

1.4 Inequality in oral health

There are several paradoxes in dental care services in Australia. Oral health as a health care service with minor government subsidies has been a significant public health concern in Australia. For example, 85% of dental services are provided through the private sector, and insurance coverage for these services is limited (Spencer et al. 2003). However, recent evidence emphasises that with this limited governmental support, only 23% of eligible adults receive public dental services, while nearly 80% of eligible adults do not receive public services (Australian Institute Of Health Welfare 2020, Council of Australian Governments 2015). This is a sign of poor universal coverage of dental services in various aspects, such as financial support and the proportion of people covered.

1.4.1 Oral health and socioeconomic status

Socioeconomic status plays a critical role in the oral health status of Australians. For example, people from higher SES groups with higher education and income have a set of advantages, one of which is the ability to afford private dental care and with better access to services, they would have better oral health conditions. People with middle to low-income face barriers such as affordability of dental care

due to its cost. Furthermore, an analysis of the 2013 National Dental Telephone Interview Survey (N = 2798) showed that the prevalence of poor oral health in low-income people who experienced racism was two-fold higher than the high-income people who did not report perceived racism (Schuch et al. 2021). It is worth mentioning that people who experience racism and social discrimination show high-risk health behaviours and poor adherence to health recommendations affecting their health status and well-being (Williams et al. 2019). Racism is an important determinant of health disparities (DeGrazia 1991).

1.4.2 Oral health and Age

Along with socioeconomic status, age can determine oral health status. The Australian government has invested in several free or low-cost school dental care programs to enhance dental care for children across Australia. For example, in South Australia (SA), dental services are free for all children under the age of 18 years in the form of school dental services, but for adults, only people with concession cards can use public dental services. These cards include most low-income and vulnerable people. Acceptable cards in SA are the Centrelink Pensioner Concession Card (Human Services), Centrelink Pensioner Concession Card Veterans' Affairs and Centrelink (Human Services) Health Care Card (Government of South Australia- SA-Health 2021). Such programs have made Australia the second-best country in child oral health. In contrast, the oral health of Australian adults from 35 to 44 years old is ranked third last among 29 OECD (Organisation for Economic Co-operation and Development) countries raising a public health concern. As with other developed countries, Australia’s population is ageing

rapidly. Unexpectedly, people in retirement age reside in the suburbs with the least access to private or public dental practice (Tennant and Kruger 2013). A study published in 2021 showed that 61% of older adults live in regions more than 5 km from public dental practices in Western Australia and Tasmania, highlighting the necessity of dental care provision equally for all age groups (Kamil et al. 2021).

1.4.3 Uneven geographic distribution of dental practices

Another challenge in the oral health of Australia is the uneven geographic distribution of dental practices. Most dental clinics are located in urban areas to secure their business, leading to unequal access to dental services for the people who live in remote and rural areas or suburbs far from the city centre. Moreover, most rural practices only operate part-time, while many government practices suffer long waiting lists and workforce shortages. A study on the distribution of dental practices in Australia, including only suburbs of less than 10,000 km^2, revealed that 6,446 out of the 8,402 suburbs have no dental care service. The distribution of such suburbs is different across all Australian states and territories. For example, the highest proportion of suburbs without dental practice is 95% across the Northern Territory, while the lowest proportion is 58% across the Australian Capital Territory. Nearly 7.1 million of the Australian population reside in suburbs without a dental practice, with the largest number of 2.3 million living in New South Wales. Overall, dental practices are not available for approximately 77% of suburbs and on average, 30 per cent of the population of each state live in these suburbs. Only 20% of suburbs contain one to five dental practices, with 46% of the Australian population residing in these suburbs (Tennant and Kruger 2013). The disparity in

dental care distribution needs to be adequately addressed to alleviate oral health inequalities.

2. Background

These challenges in the structure of the Australian health system and the knowledge gap in the mechanisms of inequality in public and private oral health sectors formed the main idea of this project. The main objectives of the project are reported in detail in Chapter Two. In the continuation of this chapter, I will review the current literature on inequalities in the Australian oral health system.

In 2019-2020, 16.3% of Australia's budget was spent on health (Phillips et al. 2020). Previously, it had been reported that the share of dental services was almost 6% of national health care expenditure (Australian Institute Of Health Welfare 2015), which means that dental services have the lowest government subsidies. Out-of-pocket payments for these services are subsequently high. The history of the Commonwealth government's limited support for adult dental services dates back to the mid-1990s and the short-lived Commonwealth Dental Health Program (CDHP) for lower-income individuals. Brennan and Spencer (2004) explored the Australian oral health status after this program was ceased in 2001-2002 and found an increase in DMFT index (Decayed, Missed and Filled Teeth) compared to 1995- 1996. In a follow-up study in 2008, Brennan and Spencer argue that those disparities and unfair distribution in dental public services access were persisted evident a decade later. They reported that this decline in DMFT in 1995- 1996 was related to the CDHP implementation (Brennan et al. 2008).

Later in 1999, government support continued under the Private Health Insurance Incentives Scheme (PHIIS). In this program, the government increased the target

population and provided all private insurers with a 30% rebate on premiums regardless of their income level.

Harford and Spencer (2004) examined the structure and context of Australian government subsidies in dental services. They concluded that PHIIS aimed to establish more significant equity in utilising services, private insurance support and reducing pressure on the public sector. However, in practice, it resulted in more dental service utilisation in the middle- and upper-income individuals with private health insurance and better oral health status and it generated more inequality.

Hopkins et al. (2013) also investigated the association between private insurance and the utilisation of dental services in Australian adults. This study showed that insured people received more services. The authors acknowledged that this likely comes at the cost of increasing inequality to uninsured and socioeconomic disadvantaged individuals.

The study by Anikeeva et al. (2013) showed similar results. People with private insurance received more dental services. They reported that the interaction between income and insurance status modified this association. Lower-income and insured individuals have more utilisation than their uninsured counterparts.

Few studies in Australia have investigated inequalities in public and private dental services sectors. Brennan et al. (2008) utilised The National Survey of Adult Oral Health data (NSAOH) of 5,505 people aged over 15 years. They reported that tooth extraction was higher in the public sector, while preventive and prosthetic treatments were far lower than in the private sector. This pattern shows the disparity in dental service utilisation of socioeconomically disadvantaged individuals.

Brennan (2009) published more details of this survey in another report. He reported that the present teeth of concession card holders referred to the private or public sector were equal in all age groups except 65 years and over. In this group, cardholders who went to the private sector had more teeth. They also did not report a significant difference in periodontal status between the different groups, stating that regardless of the place of their last dental visit, these similarities indicated a similar oral health status in concession cardholders. Therefore, there is still a need to examine the service patterns in the private and public sectors separately.

In addition to existing challenges, the Australian Health Ministers' Advisory Council (AHMAC) reported that oral disease is one of the significant constituents of disease in Australia (Spencer and Harford 2001). Although there are many studies around oral health disparities, there is insufficient information around the mechanisms leading to such inequities (Sanders et al. 2006). To better contrast dental visiting patterns in private and public sectors, there is a need to compare the same measures to eliminate methodological biases.

References

Anderson I, Robson B, Connolly M, Al-Yaman F, Bjertness E, King A, Tynan M, Madden R, Bang A, Coimbra Jr CE. 2016. Indigenous and tribal peoples' health (the lancet–lowitja institute global collaboration): A population study. The Lancet. 388(10040):131-157.

Anderson LM, Scrimshaw SC, Fullilove MT, Fielding JE, Normand J, Services TFoCP. 2003. Culturally competent healthcare systems: A systematic review. American Journal of Preventive Medicine. 24(3):68-79.

Anikeeva O, Brennan DS, Teusner DN. 2013. Household income modifies the association of insurance and dental visiting. BMC Health Services Research. 13(1):1-7.

Ardill A. 2009. Sociobiology, racism and australian colonisation. Griffith Law Review. 18(1):82-113.

Australian Attorney-General's Department. 2021. Right to health. https://www.ag.gov.au/rights-and-protections/human-rights-and-anti-discrimination/human-rights-scrutiny/public-sector-guidance-sheets/right-health.

Australian Bureau of Statistics 2016. 2024.0–Census of population and housing: Australia revealed. Canberra: Australian Bureau of Statistics; 2016.

Australian Bureau of Statistics 2017. 2071.0-Census of population and housing: Reflecting Australia-stories from the census, 2016. Canberra: Australian Bureau of Statistics; 2017.

Australian Bureau of Statistics. 2019. Statistics on Australia's international migration, internal migration (interstate and intrastate), and the population by country of birth. Canberra: Australian Bureau of Statistics; 2019

Australian Institute of Health and Welfare 2020. Australia's National Oral Health Plan 2015–2024: performance monitoring report in brief. Cat. no. DEN 234. Canberra: AIHW.

Australian Institute Of Health Welfare 2015. Health expenditure Australia 2013-14. https://www.aihw.gov.au/reports/health-welfare-expenditure/health-expenditure-australia-2013-14/contents/table-of-contents.

Babacan H, Gopalkrishnan N. 2016. Public policy, immigrant experiences, and health outcomes in australia. Immigration, public policy, and health: newcomer experiences in developed nations, Canadian Scholars' Press Inc, Toronto.59-95.

Bradley A. 2010. Positive rights, negative rights and health care. Journal of Medical Ethics. 36(12):838-841.

Brennan D, Spencer A. 2004. Changes in caries experience among australian public dental patients between 1995/96 and 2001/02. Australian and New Zealand Journal of Public Health. 28(6):542-548.

Brennan DS. 2009. Oral health of health cardholders attending for dental care in the private and public sectors. Dental Statistic and Rsearch Series, Canberra: AIHW. Cat. no. DEN 196(50).

Brennan DS, Luzzi L, Roberts-Thomson KF. 2008. Dental service patterns among private and public adult patients in australia. BMC Health Services Research. 8(1):1-8.

Council of Australian Governments. Australia's National Oral Health Plan 2015–2024. Canberra.

Daniels N. 1985. Fair equality of opportunity and decent minimums: A reply to buchanan. Philosophy & Public Affairs.106-110.

DeGrazia D. 1991. Grounding a right to health care in self-respect and self-esteem. Public Affairs Quarterly. 5(4):301-318.

Gone JP. 2013. Redressing first nations historical trauma: Theorising mechanisms for indigenous culture as mental health treatment. Transcultural psychiatry. 50(5):683-706.

Government of South Australia- SA-Health. 2021. Dental services for adults. https://www.sahealth.sa.gov.au/wps/wcm/connect/public+content/sa+health+internet/services/dental+diagnostic+and+pharmacy+services/dental+services/dental+services+for+adults.

Hall JJ, Taylor R. 2003. Health for all beyond 2000: The demise of the Alma-Ata declaration and primary health care in developing countries. The Medical Journal of Australia. 178(1):17-20.

Harford J, Spencer AJ. 2004. Government subsidies for dental care in Australia. Australian and New Zealand Journal of Public Health. 28(4):363-368.

Harrison R, Walton M, Chitkara U, Manias E, Chauhan A, Latanik M, Leone D. 2020. Beyond translation: Engaging with culturally and linguistically diverse consumers. Health Expectations. 23(1):159-168.

Henderson S, Kendall E. 2011. Culturally and linguistically diverse peoples' knowledge of accessibility and utilisation of health services: Exploring the need for improvement in health service delivery. Australian Journal of Primary Health. 17(2):195-201.

Holt M. 2021. Introduction to sexual orientation inequality in Australia. Sexual orientation equality in schools. Palgrave Macmillan, Cham.

Hopkins S, Kidd MP, Ulker A. 2013. Private health insurance status and utilisation of dental services in Australia. Economic Record. 89(285):194-206.

Jāhāna S. 2015. Human development report 2015: Work for human development. United Nations Development Programme.

Kamil W, Kruger E, McGeachie J, Jean G, Tennant M. 2021. Distribution of Australian dental practices in relation to the ageing population. Gerodontology.

Lamm RD. 1991. Rationing of health care: Inevitable and desirable. U Pa L Rev. 140:1511.

Moran A, Mallman M. 2019. Social cohesion in rural Australia: Framework for conformity or social justice? Australian Journal of Social Issues. 54(2):191-206.

Morris S, Sutton M, Gravelle H. 2005. Inequity and inequality in the use of health care in England: An empirical investigation. Social Science & Medicine. 60(6):1251-1266.

O'Sullivan D. 2012. Justice, culture and the political determinants of Indigenous Australian health. Ethnicities. 12(6):687-705.

Peikoff L. 1993. Health care is not a right. Conferencia pronunciada en el Town Hall en el Clinton Health Plan Red Lion Hotel.

Phillips J, Grove A, Cook L. 2020. Budget review 2019–20 index. https://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/pubs/rp/BudgetReview201920/Health.

Sanders AE, Spencer AJ, Slade GD. 2006. Evaluating the role of dental behaviour in oral health inequalities. Community Dentistry and Oral Epidemiology. 34(1):71-79.

Schuch HS, Haag DG, Bastos JL, Paradies Y, Jamieson LM. 2021. Intersectionality, racial discrimination and oral health in Australia. Community Dentistry and Oral Epidemiology. 49(1):87-94.

Smith L. The health outcomes of migrants: a literature review. Migration Council of Australia, Canberra. 2015.

Spencer A, Teusner D, Carter K, Brennan D. 2003. The dental labour force in Australia: The position and policy directions. Australian Institute of Health and Welfare (Media and Publishing Unit).

Spencer AJ, Harford JE. 2001. Oral health of australians: National planning for oral health improvement. South Australian Department of Human Services.

Tennant M, Kruger E. 2013. A national audit of Australian dental practice distribution: Do all Australians get a fair deal? International Dental Journal. 63(4):177-182.

Tyas J, Indraharan D. 2014. Mortality inequalities in Australia 2009–2011.

Williams DR, Lawrence JA, Davis BA, Vu C. 2019. Understanding how discrimination can affect health. Health Serv Res. 54 Suppl 2(Suppl 2):1374-1388.

World Health Organization. 1978. Declaration of Alma-Ata: International conference on primary health care, Alma-Ata, USSR, 6–12 september 1978.

World Health Organization. 2017. Promoting health in the SDGS: Report on the 9th global conference for health promotion, Shanghai, China, 21–24 November 2016: All for health, health for all. World Health Organization.

Chapter 2 - Aims and Objectives

Research Questions

1) What are the determinants of dental service inequalities in a developed country such as Australia?
2) How related are inequalities and universal health coverage in dental services in a developed country such as Australia?
3) How can dental service inequality be conceptualised in a developed country such as Australia?
4) What are the mechanisms of financial barriers in adult dental services among Australian public and private sectors?
5) How are socioeconomic, oral health habits and behavioural variables associated with Australian adult dental service utilisation patterns?

General Aim

The aim of this study is to identify socioeconomic inequalities in dental services in Australia with a focus on public and private dental service sectors.

Specific Objectives

In order to achieve this aim and answer the research questions, I will explore the following objectives (1- 4):

1- Systematically identify determinants of dental service inequality in a developed country such as Australia (questions 1,2).
   - To achieve this aim, scoping review protocols were utilised to fill the current knowledge gap (Chapters 3,4).

2- Combine all synthesised evidence to conceptualize a model for dental service inequality in a developed country such as Australia (question 3).

- To reach this aim, the *"Triangle of Inequality"* in dental services was developed as a conceptual model (Chapter 5).

3- Identify financial barriers in dental services among private and public patients (question 4, chapters 6, 7).

4- Identify how education and behavioural variables (e.g. Smoking, Tooth brushing) are associated with Australian adult dental service utilisation patterns (question 5).

- To reach these aims, flexible mediation models were utilised to investigate how mediation models play a critical role in causing financial burden or changing adult dental service utilisation patterns in Australian public and private sectors (Chapters 6,8).

Table 1 summarises the following research question and aims according to the thesis phases.

Thesis Structure

This thesis was conducted in two main phases (Table 1). Phase 1 includes the literature reviews and concept model and is the foundation for phase 2 (empirical studies).

In chapters 1 and 2, an introduction to the concepts and objectives of this thesis have been provided.

Based on the primary purpose of this thesis to identify socioeconomic inequalities in the Australian health system and to address the lack of clarity about inequality mechanisms in adult dental services in Australia, there was a need to use rigorous statistical methods.

Concept and Context

For accurate statistical modelling, a comprehensive background of the subject is required. Therefore, Chapters 3 and 4 provide a systematic review of the literature. Scoping review studies are more comprehensive than other review studies and are appropriate when a knowledge gap exists. To clarify the causes of inequality in developed countries such as Australia, the context of the study was not limited to Australia, and studies conducted in OECD countries were included. Chapter 3 (Paper 1) investigates the causes of inequality in the two dimensions of utilisation and provision of dental services. Chapter 4 (Paper 2) addresses the other cause of inequality, namely access. In addition to redefining concepts of utilisation, provision and access in the dental literature, the role of access in universal coverage of dental services is discussed.

Studies one and two were the most comprehensive review studies on the issue of inequality in dental services to date. In these studies, in addition to the conventional synthesis of the results, trend analysis were performed for the first time in scoping review studies. In Chapter 5 (Paper 3), the findings of these studies were merged and synthesised, and the conceptual model of inequality in dental services (Triangle of Inequality) was designed.

Empirical Studies

Chapters 3 to 5 provide the foundation of the statistical models used in Chapters 7 and 8 (Papers 4 and 5). The Multiple Flexible Meditation Method was used in these empirical studies, as described in Chapter 6. For conducting mediation analysis with one mediator using the Ratio of Mediator Probability Weighting (RMPW), one may also use the R libraries *Medflex* and *RMPW*, but due to the lack of suitable packages for multiple mediations using the RMPW approach, the codes used for the mediation analysis in this thesis were a modification of the codes published by Lange et al. (Lange T, Rasmussen M, Thygesen LC. Assessing natural direct and indirect effects through multiple pathways. American journal of epidemiology. 2014 Feb 15;179(4):513-8).

There was also no package for sensitivity analysis of models with several mediators using RMPW. Therefore, I had to modify the functions in R package *RMPW* and write a specific R function suitable for multiple mediators. This currently does not exist in any libraries in R and is provided in appendix V. Chapter 9 is this thesis's final considerations and conclusions.

Table 1- Summary of research questions and objectives

	Research Questions	Objectives	Chapter
	Background and objectives		1, 2
Phase 1: Conceptual modelling and review	1) What are the determinants of dental service inequalities in a developed country such as Australia?	Systematically identify determinants of dental service inequality in a developed country such as Australia	3
	2) How related are inequalities and universal health coverage in dental services in a developed country such as Australia?	Systematically identify determinants of dental service inequality in a developed country such as Australia	4
	3) How can dental service inequality be conceptualised in a developed country such as Australia?	Combine all synthesised evidence to conceptualize a model for dental service inequality in a developed country such as Australia	5
Phase 2: Empirical studies	4) What are the mechanisms of financial barriers in adult dental services among Australian public and private sectors?	Identify financial barriers in dental services among private and public patients	7 (chapter 6 is the required method)
	5) How are socioeconomic, oral health habits and behavioural variables associated with Australian adult dental service utilisation patterns?	Identify how education and behavioural variables (e.g. Smoking, Tooth brushing) are associated with Australian adult dental service utilisation patterns	8 (chapter 6 is the required method)
	Final discussion and conclusion		9

Main Sample

The population surveyed in the empirical studies was the over 18-year population participating in Dental Care and Oral Health Study (DCOHS). The DCOHS was a state study conducted in South Australia designed to examine oral health outcomes in various sectors.

DCOHS was funded by the National Health and Medical Research Council (NHMRC CRE grant: 1031310). However, NHMRC had no role in any steps of this thesis, from design to interpretation and publication of articles. DCOHS was conducted in accordance with the Helsinki Declaration of Research Ethics and was approved by the Human Research Ethics Committee of The University of Adelaide (Appendix 1 / H-288-2011).

DCOHS was a prospective study that collected information using a mailed self-completed questionnaire in 2015-2019 (Appendix 2). In this thesis, DCOHS baseline data (2015) were used. Questionnaires were sent to 12,450 adult South Australian residents who had been randomly selected from the Electoral Roll (Australian Electoral Commission base). Of these, 4494 questionnaires were completed and returned (response rate: 44.6%). Measurement variables details are given in Chapters 7 and 8 (Papers 4,5).

Appendices

Appendices 1 and 2 are the Ethics Committee approval and DCOHS questionnaire. Appendices 3 and 4 are supplementary information and articles included in papers 1 and 2. Appendix 5 is the R functions and codes used in papers 4 and 5. Appendix 6 is additional published articles that are relevant but outside the main scope of this thesis.

These papers were completed in collaboration with other researchers during my learning journey and helped me gain greater perspective of inequality and challenges in dental services provision for vulnerable groups such as Indigenous Australians (supplementary paper 1) and children with special health care needs (supplementary paper 2).

Chapter 3 - Inequalities in utilisation and provision of dental services

Chapter 3 - **Inequalities in utilisation and provision of dental services**

Linkage to the thesis

The aim of this thesis was to identify inequalities in various Australian oral health system sectors. To better inform the modelling process, we needed this background to be well-reviewed. Also, there was no comprehensive inequality conceptual model specific to dental services which addressed the multi-level determinants of inequality. Therefore, before statistical modelling, I reviewed the determinants of inequality in dental services. In this chapter, the determinants of inequality in utilisation and provision of services are investigated.

Highlights

- Structural concepts such as utilisation, provision and access are sometimes mistakenly used interchangeably in the oral health literature. Service utilisation is the preventive or curative use of health services; service provision is the process of providing services using the available resources, and access is the timely use of health services to achieve health.
- This chapter identified the associated factors of inequalities in the two dimensions of utilisation and provision of dental services. Utilisation determinants included individual, social, cultural, and economical, and provision determinations included health policy and availability of services.
- The complexity and multiplicity of these determinants challenge oral health policies. Therefore, to reduce the inequalities in dental services, policymakers should pay attention to all determinants in addition to distinguishing between different dimensions of inequality.

Note: Supplementary information of the paper in this chapter is available in appendix III.

Statement of Authorship for paper 1

Title of Paper	Inequalities in utilization and provision of dental services: a scoping review
Publication Status	■ Published ☐ Accepted for Publication ☐ Submitted for Publication ☐ Unpublished and Unsubmitted work written in manuscript style
Publication Details	

Principal Author

Name of Principal Author (Candidate)	Arash Ghanbarzadegan		
Contribution to the Paper	Conceptualised the idea, Conceived the research question, designed the study, Analysed the data, Wrote the paper draft and conducted all revisions.		
Overall percentage (%)	75%		
Certification	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		Date	29/07/2022

Co-Author Contributions

By signing the Statement of Authorship, each author certifies that:

I. the candidate's stated contribution to the publication is accurate (as detailed above);
II. permission is granted for the candidate in include the publication in the thesis; and
III. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

Name of Co-Author	Peivand Bastani		
Contribution to the Paper	Contributed in study designing, data analysis, drafting and revising the paper. Acted as the corresponding author for the publication process.		
Signature		Date	8.03.2022

Name of Co-Author	Liana Luzzi		
Contribution to the Paper	Contributed in study designing, conceiving the research question, data analysis, drafting and revising the paper. Supervised the study.		
Signature		Date	10 March 2022

Name of Co-Author	David Brennan		
Contribution to the Paper	Contributed in study designing, conceiving the research question, data analysis, drafting and revising the paper. Supervised the study.		
Signature		Date	11/07/2022

Paper 1

Ghanbarzadegan *et al. Systematic Reviews* (2021) 10:222
https://doi.org/10.1186/s13643-021-01779-2

Systematic Reviews

RESEARCH Open Access

Inequalities in utilization and provision of dental services: a scoping review

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Abstract

Background: There are many determinants that can affect inequality in oral and dental health. This study is aimed to explore the main determinants of inequality in both utilization and provision of dental services in Organization for Economic Co-operation and Development (OECD) countries.

Methods: Four databases including PubMed, ISI WOS, Scopus, and ProQuest were searched up to 8 Aug 2020, applying the relevant keywords. Thematic analysis was used for synthesizing and extracting data. Trend analysis was applied to determine the trends of the inequality determinants.

Results: Thematic analysis led to 6 main themes, 13 sub-themes, and 53 sub-sub-themes. The main themes represent the main inequality determinants for both utilization and provision of dental services. The streamgraph illustrated that fewer studies have been conducted on social and cultural determinants, and for almost all determinants the trend of published articles has been increasing since 2007, with the exception of health policies.

Conclusions: Inequality in the utilization and provision of dental services is addressed by various factors including individual, social, cultural and economic determinants, health policies, and availability of services. The first four determinants are related to utilization and the last two are related to the provision of services. All these aspects must be considered to reduce inequality in dental services.

Keywords: Disparities, Oral health, Developed countries

Background

There are multiple determinants which can affect health status. For instance, it has been reported that people of a lower socioeconomic level experience more burden from morbidity and mortality of diseases compared with other groups [1, 2]. Oral health is also believed to be highly associated with socioeconomic status [3]. Dental diseases are among the most prominent public health issues, due to their high universal prevalence and direct effect on quality of life [4].

Inequality in oral health has drawn the attention of worldwide stakeholders beyond community oral health in several countries [5, 6]. Notably, even in well-developed countries, there are instances of large disparities within different social classes [7]. Many studies have been conducted to show inequalities in oral health. Provision of dental care services is a matter of public health concern for socio-economically disadvantaged people who, as a priority group, demand more support [8].

While talking about inequality and disparity in healthcare, different determinants will be discussed. Utilization, provision, and access to services are three related different terms, and are often used interchangeably in the dental literature. Access to services has three dimensions which are financial, physical, and acceptability [9]. The utilization of medical services describes the use of services by individuals for preventive or curative care, while the provision of services deals with the process of providing services according to the various available inputs

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(human resources, physical capital, and consumables) in the health system [10, 11].

There are many studies around oral health disparities, but there is insufficient information around the mechanisms [12]. In two separate studies in 2018, Reda et al. systematically investigated the inequalities reported globally in the utilization of dental services, as well as the impact of sociodemographic factors on inequality [13, 14]. However, they did not consider factors affecting the provision of dental services, as a dominant element in inequality. In addition, due to their methodology for investigating the inequality in the utilization of dental services, the underlying mechanisms in inequality in dental services have not been explained by any review with a systematic approach so far.

In spite of presenting the systematic results of the aforementioned studies, since the contextual and underlying factors differ globally, it seems necessary to conduct an up-to-date study of effective social, individual, and contextual determinants of inequality in the utilization of dental services in homogeneous countries. At the same time, the concept of inequality from the perspectives of utilization and provision of dental services needs further exploration. In particular, understanding what the main determinants of inequality are from a utilization and provision of dental services perspective, while considering the socio-economic and cultural contexts.

To better investigate the aforementioned topic and to address the knowledge gaps, there is a need for a narrowed scoping review. This kind of review will enable oral health policymakers to identify the whole concept and its related determinants, as well as conducting a comprehensive map [15] to integrate the related pieces of evidence to achieve evidenced-based decision and policy making. Although at first glance, the inequalities and disparities are assumed to occur in poor and less developed contexts, this may intensify among the rich and developed countries with different levels of utilization to healthcare resources. Therefore, this review aimed to identify the most cited determinants of inequality in the utilization and provision of dental services as an outcome of the oral health system in Organization for Economic Co-operation and Development (OECD) countries to help stakeholders and policymakers with the future planning of dental services to ensure a more equitable provision of services.

Methods

This scoping review follows the Joanna Briggs Institute (JBI) scoping reviews framework provided by Arksey and O'Malley [16, 17]. In this five-step framework, after identifying research questions and database searching, the relevant studies are selected, summarized, and synthesized. As per the framework, this study was conducted in five steps, which are described in detail below.

Step 1—Identification of the research question

The main research question was "What are the main effective determinants of inequality in utilization and provision of dental services in OECD countries?" OECD countries define as those countries which are the member of Organization for Economic Co-operation and Development. When we are talking about the key determinants, it should be mentioned that, those are some key factors that directly or indirectly can affect the provision and utilization of dental services among the people in OECD countries that can make inequality.

According to JBI's interpretation, a research question of a scoping review should cover the population, the concept, and the context [16]. According to the research question, the population was limited to all OECD countries. The concept included various effective determinants of inequality on utilization and provision of dental services on oral health outcomes, and the context contained the comprehensive cultural, political, and behavioral background within the population.

Step 2—Identifying the relevant studies

Keywords for the study were selected following a preliminary review of the literature. The selected keywords, based on their relevant Medical Subject Headings (MeSH), were searched in various databases up to and including 8 Aug 2020. These databases included PubMed, International Science Indexing Web of Science (ISI WOS), Scopus, and ProQuest. The general search strategy including the main keywords is shown in Table 1. For more clarification, the search strategies syntax for each database is presented in the supplementary file. The logical operators, "OR" and "AND," were used to increase the search sensitivity. EndNote reference manager X9 (Clarivate Analytics, Philadelphia, PA, USA) was used to manage the retrieved references.

Table 1 Search strategy

Search engines: PubMed, ProQuest, ISI Web of Science, Scopus
Limits: Time: up to 8 Aug 2020, Language: English
Strategy: #1 AND #2 AND #3
#1 ("Dental Health Surveys" OR "Dental Care" OR "Oral Health" OR "Dental Health Services")
#2 ("Socioeconomic Factors" OR "Hierarchy, Social" OR "Healthcare Disparities" OR "Health Status Disparities" OR "Social Determinants of Health" OR "Social Class")
#3 ("dental services" OR "dental visits" OR "utilization" OR "provision" OR "use of services")

Step 3—Study selection

In this step, the achieved articles from the systematic search of the forth databases were reviewed first by the title and abstract and then their full texts. All of these processes were conducted by two researchers separately and independently (AG and PB). Review articles were subsequently excluded from the review process while all other types of studies such as original articles, commentaries, and letters with different methodologies (qualitative, quantitative, and mixed-method) were included. Quality appraisal of the retrieved studies is not obligatory in scoping reviews [18]. However, for assuring the eligibility of the included full-texts, another researcher (DB) screened the full-text studies, in line with the inclusion criteria and aim of the study. Figure 1 illustrates the initial search using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) study selection flowchart. A relevant extraction form was developed according to the review's aim by the research team. The form was applied to extract the relevant data including the author's name, study aim, study population, year of publication, study design, study place, and the key determinants of dental inequalities regarding the utilization and provision of the services (Table S1-supplement).

Step 4—Charting the data

Two members of the research team (AG and PB) simultaneously and jointly charted the studies [19]. They updated the data charting form and performed the charting

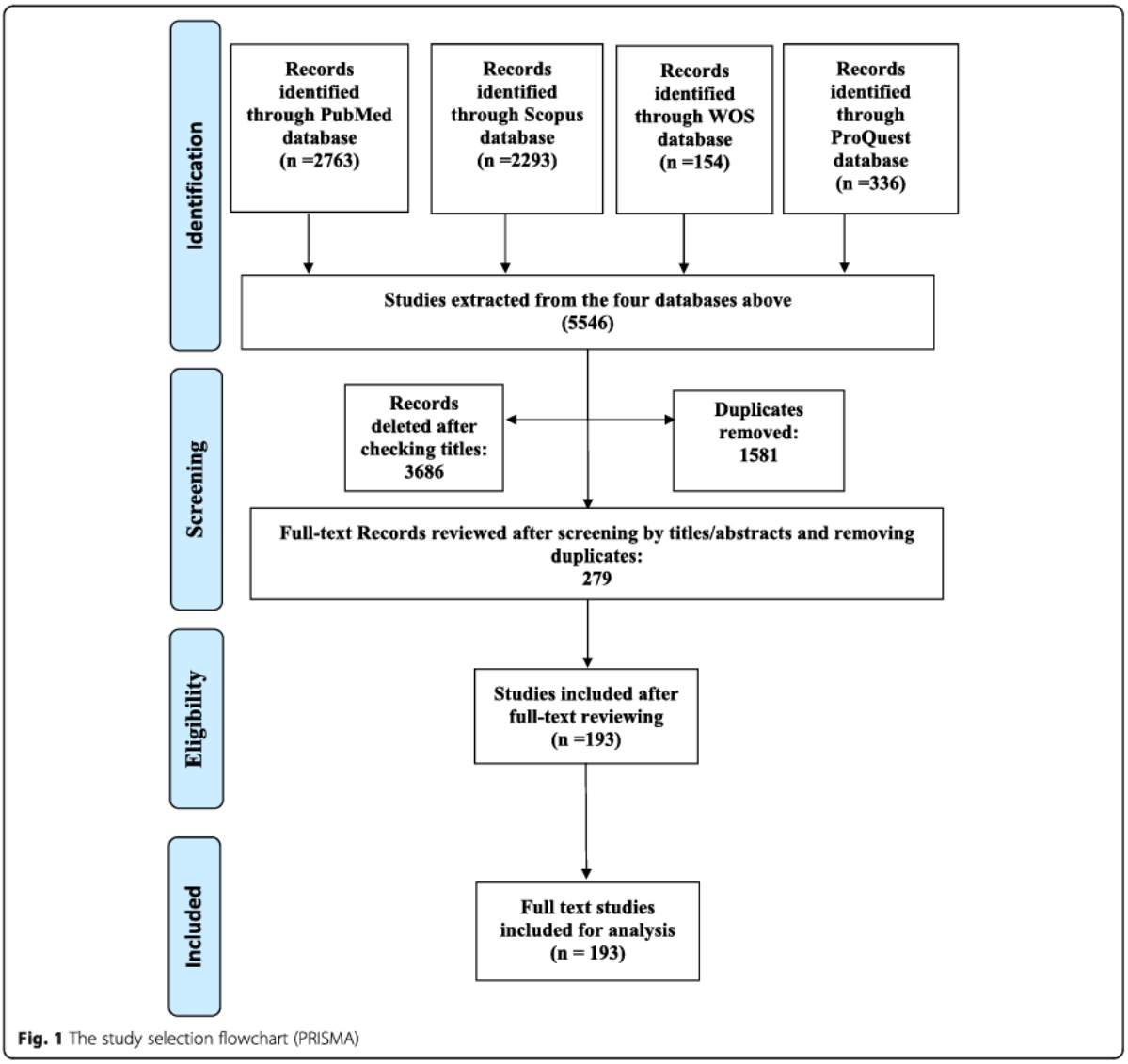

Fig. 1 The study selection flowchart (PRISMA)

process in an iterative process. In this regard, the author's name, year of publication and place of publication, study's aim, design, main findings, and implications were extracted and charted in the data extraction form.

Step 5—Collating, summarizing, and reporting the results

The member of the research team (PB), who was more familiar with the content-analysis, coded the studies based on a qualitative thematic approach [20]. In this regard, the initial codes were extracted from the meaningful units achieved from each article. These meaningful units were the essence of findings interpreted by the researcher (PB) and identified according to the aim of the review. Then, in a reciprocal process between the initial codes and the original extracted data and the meaningful units, the final codes emerged. Following revision, integration, and classification of the final codes, the main related themes and sub-themes were identified and subsequently tabulated. Thus, the main determinants and sub-determinants of inequality in dental services, from a utilization and provision perspective, were defined by the research team. To better understand the concept, Microsoft PowerPoint (Microsoft, Redmond, Washington, USA) was used to design a conceptual map to illustrate the concepts. In addition, viewpoints of other experts in the field were included in the final map. For assuring the rigor of qualitative data analysis, some of the criteria proposed by Guba and Lincoln were fulfilled [21]. To assure the transferability of the results that indicate the ability of transferring the findings to the similar contexts, we have tried to present a thick description of the results. Also, to reach the dependability of the results, the process of data collection and data analysis are clarified in detail to facilitate the possibility of auditing. And, finally to achieve confirmability, the researchers have tried to minimize the investigator bias via bracketing their predisposition and suppositions and differentiating them from the included data to the analysis process.

Trend analysis

Trend analysis was added as a new step of the scoping review, as this study tries to demonstrate the trends of studies focusing on the inequality determinant. To illustrate the over-time trend of conducting studies, the publication year of the studies related to each sub-theme was specified. A Location-Time stacked bar chart was drawn using the SPSS software version 26.0 (SPSS, Chicago, Illinois, USA). To draw streamgraphs of time trends, after identifying the sub-sub-themes and articles related to each, the total number of articles in each main theme and sub-theme was determined. Then, the articles in each category were sorted based on their publication year. The streamgraphs were illustrated using PlotDB (www.plotdb.com) which is an open license website.

Results

According to the PRISMA flowchart, in the initial search, a total of 5546 studies were identified, 1581 and 3686 studies were excluded due to duplication and mismatch of their titles respectively. Of the 279 studies that met the inclusion criteria and had their full-text reviewed, 193 full-text original studies were selected (Fig. 1).

Thematic analysis

Thematic analysis of the included studies led to the extraction of 6 main themes, 13 sub-themes, and 53 sub-sub-themes (Table 2). All the related references are presented in Table S2- supplement. The main themes are discussed in detail below.

I- Individual determinants

Numerous individual factors were identified as being associated with inequality in dental service utilization. Age, as one of the main individual factors, can be the basis of different needs. This difference in need leads to the utilization of specialized treatments such as prosthetic treatments in the elderly or orthodontic treatments in children and adolescence [22, 23].

Personal conditions vary according to age. Loneliness in the elderly was also recognized as one of the factors influencing the inequality in dental service utilization [24].

Dealing with diseases or functional disabilities can lead to reduced dental service utilization [25]. One study examined the use of routine dental services in cancer patients and reported that service utilization declined even after receiving advice to increase the number of visits to the dentist [26]. Racial and ethnic factors in minorities have also been identified in many articles as determinants of dental service utilization.

II- Social determinants

While individual factors are more closely related to independent individual indicators, social determinants are more concerned with social factors and interactions.

Various studies claim that people living in capital areas receive more services than people living in non-capital areas, which is related to both the provision and utilization of dental services [27, 28].

Employment and its types, immigration, and education were identified as effective social determinants [29, 30]. The association between the level of health literacy and inequality in the utilization of dental services was also mentioned in some articles [31], while more attention was paid to the association between the level of

Table 2 Determinants of inequality in the utilization and provision of dental services in OECD countries

Main themes	Sub-themes	Sub-sub themes	Number of articles
Utilization of services			
Individual determinants	**Demographic determinants**	Gender	18
		Race and ethnicity	25
		Nationality/mother nationality	4
		Age	42
		Marital status	3
	Self-rated health status	Functional abilities	4
		Quality of life	3
		Special health needs/minorities	3
		Oral health status	10
		Disease and health status	8
Social determinants	**Social status**	Residential location	20
		Vulnerable groups	9
		Population density	1
		Occupation/employment	5
		Immigrant and refugees	11
	Literacy	Education level	32
		Health literacy	4
Economic determinants	**Micro-economic**	Income	58
		Wealth	7
		Poverty	11
	Macro-economic	Macro-economic crisis/condition	5
		Macroeconomic revenue collection	1
		Gini index	5
		GDP per capita/country revenue	2
		Economic disparities	4
Cultural determinants	**Macro cultural factors**	Time and technology	9
		Environmental condition	1
	Micro cultural factors	Oral health behavior	6
		Primary language spoken (fluency)	5
		Lifestyle	6
		Attitude	8
Provision of services			
Health policy	**Policy implementation**	Appropriate policies	7
		Target population concentration	1
		National interventions	8
	Policy formulation	Health basic insurance/public insurance	13
		Supplementary insurance	35
		Private insurance	5
		Cardholder status	2
Availability of services	**Type of available services**	Advice services/regular visiting pattern	10
		Emergency visits	7
		Service coverage	4
		Specialized services	8

Table 2 Determinants of inequality in the utilization and provision of dental services in OECD countries *(Continued)*

Main themes	Sub-themes	Sub-sub themes	Number of articles
		Preventive care	13
		Pharmacists consultation	1
		School dental nurses and dental hygienists	1
	Distribution of services	Geographic location/dentist distribution	15
		Distribution of dental schools	3
	Management of services	Inadequate private services	1
		Waiting time in public sector	2
		Cost of service	11
		Service satisfaction	1
		Dentists recall and follow-up	2

academic education and the degree of utilization which was higher in people with university education and managerial jobs [32].

III- Economic determinants

The impact of economic conditions on both macro and micro levels was examined. At the macro-level, national economic crisis and economic differences between different parts of countries are known factors influencing inequality in utilization and provision of dental services [33, 34]. In economic crisis, the rate of utilization decreases, while after that, the situation improves [35].

At the microeconomic level, various concepts such as wealth, poverty, and income have been studied. Although there is a conceptual difference between income and wealth, in the studies that examined both, wealth was considered more related to service utilization. To clarify it, people's wealth and assets may be higher in different cases. For instance, affordability for people who have a home without a loan or debt may differ compared to others not in a similar position [36]. However, the determinant that most studies addressed was income.

The overall analysis of the articles pointed to a direct relationship between increased income and utilization. In higher-income groups with higher socioeconomic status, the rate of utilization of dental services, as well as annual dental visits, were higher than in lower-income groups.

IV- Cultural determinants

Although few of the included studies investigated cultural indicators associated with the utilization of dental services, at the macro-level, various cultural factors were considered associated with the level of dental services utilization. In general, with the passage of time, improvement of environmental conditions, technological advancement, and introduction of more appropriate and wider services have been reported to be associated with an increasing dental services utilization rate [37].

At the micro-cultural level, oral health behaviors, lifestyle, and self or parents' attitude are known to be associated factors [38]. For instance, it has been reported that people who engage in high-risk behaviors, such as smoking or alcohol consumption and who pay less attention to oral hygiene or have a negative attitude toward it, consequently, have a lower rate of utilization of dental services [25].

V- Health policy

Although oral health reform policies have reduced the inequality in the utilization and provision of dental services, it has still remained among the population after the implementation of the reform in most cases. Policy appropriateness for the target population and national or local level of policy implementation are reported to be associated with the utilization and provision of dental services [39].

One of the determinants that has been mentioned many times as an important enabling factor in the utilization of dental services was insurance. Being covered by insurance, whether it be primary, supplementary, private, or public, is associated with the increased utilization of dental services [40]. This determinant of course can be affected by the policy-making process from agenda setting to policy formulation and implementation.

VI- Availability of service

While health policies are mostly related to the provision of dental services, another determinant related to the provision of services is the availability of services. Distribution of services, distribution and density of dental schools, clinics, and dental offices, was among the subthemes [41]. Types of available services whether public or private, long waiting time for public services, cost of

services, service satisfaction, the regularity of dental visits, and follow-up sessions were other sub-themes related to the availability of services.

Conceptual map

Based on the main themes, the reported rational associations in the reviewed studies and consensus among the research team, the concept map of the topic was developed. It conceptualizes the determinants of inequality by the two dimensions of provision and utilization of dental services (Fig. 2). According to Fig. 2, socio-economic and cultural determinants, as external macro factors, can affect individual characteristics and utilization of services. At the same time, provision of the adequate, high quality and need-oriented services can affect service utilization. The provision of dental services is influenced by macro and micro level policies and availability of the services. Thus, inequality in the provision and utilization of dental services will be determined by their underlying determinants.

Trend analysis

The time trend of publications based on their proportion to the total number of published articles in the same year and stratified by country of their target population (Asia, Australia and Oceania, Canada, Europe, South America, and the USA) was obtained (Fig. 3). The lowest percentage of studies was conducted in South America (3.48%). However, the general trend shows a decrease in the share of European countries and the USA and an increase in the share of Asian and South American countries in the last decade.

Time trend of the studies based on the main themes and the most covered sub-themes are shown in Fig. 4. In these streamgraphs, the colors blue, bright, and dark yellow are related to the sub-themes of each determinant,

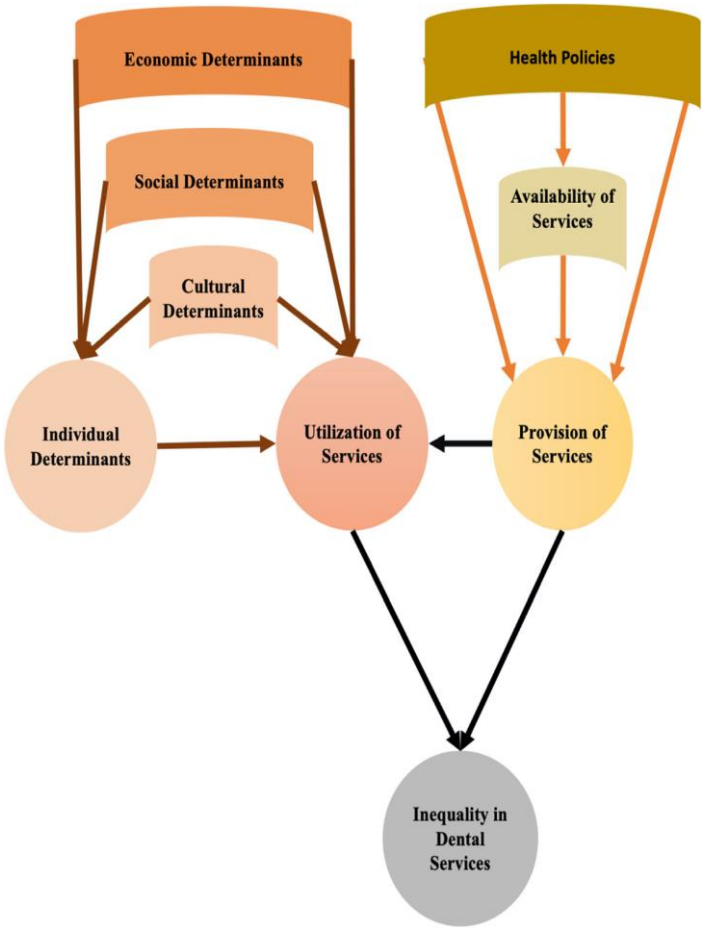

Fig. 2 The concept map of inequality by the two dimensions of provision and utilization

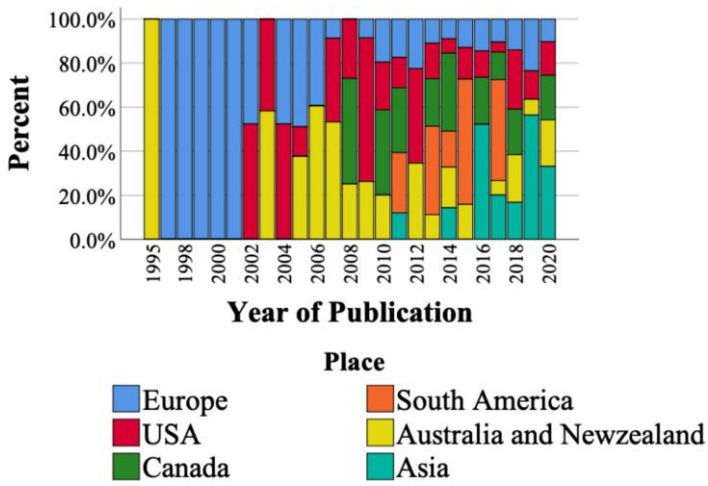

Fig. 3 The time trend of publications based on their year and country of publication

while orange represents the main theme, and in fact, represents the sum of the top section and total numbers of the articles related to the main theme. It illustrates that fewer studies have been conducted on social and cultural determinants, and in almost all determinants, the trend of publishing has been increasing since 2007, while studies examining health policy determinants have been decreasing since 2015.

Discussion

Considering the present results, there is a parallel way leading to inequality in dental health. In other words, challenges in provision of appropriate and need-based dental services or lack of utilizing the services by the target population can play a role in creating inequality in dental services [42, 43].

According to the concept map, it may be argued that there is no starting point whether in the provision of services or the utilization of services which causes inequality in dental services that leads us to consider all identified determinants together to tackle the inequality in dental services. To the best of our knowledge, even lack of appropriate provision of dental services or the low level of utilization of these services among the population can lead to inequality [44]. Considering that, these results can contribute to the present knowledge that every mechanism on the area of changing or improving the policies or any action toward increasing the availability of dental services can improve the provision aspect. Notably, simultaneous attention to the macro determinants, the same as social, cultural, or economic, can enable the population to utilize different dental services. Only in the logical tradeoff among appropriate, need-oriented provision of dental services, and the adequate and effective utilization of the services can assure a more equitable oral health system.

This inference is consistent with the results of studies examining the impact of policy reforms [45–47]. Most of these studies reported a persistent inequality among the population after the reform. In comparison, Shin et al. in 2020 reported that the slope of the inequality associated with the rate of dental caries in Korean children disappeared after the introduction of the new sealant therapy policy [39].

It seems that except when all the determinants in the target community or population group are considered, inequality in dental services would not be eliminated with a reform policy in the short term [48], but if the determinants of social, cultural, economic, and availability of services are in good shape, then we can expect an improvement in equality of dental services.

At the same time, it can be considerable for health policy makers to understand whether they have to change each of the policymaking chains; agenda setting, policy formulation, policy implementation, policy evaluation; for better results and reduction of inequalities.

This logic can be seen in the study of other determinants as well. Regarding individual determinants, a 1997 study by Honkala et al. found that there was a correlation between occupation, education, and dental visits in the Finish population until 1983, but there has been no such correlation since then [33]. In another study in Australia, Singh et al. reported that there is not only a positive relationship between income and oral health outcomes but also a negative one. They attributed the contextual differences in Australia compared with other

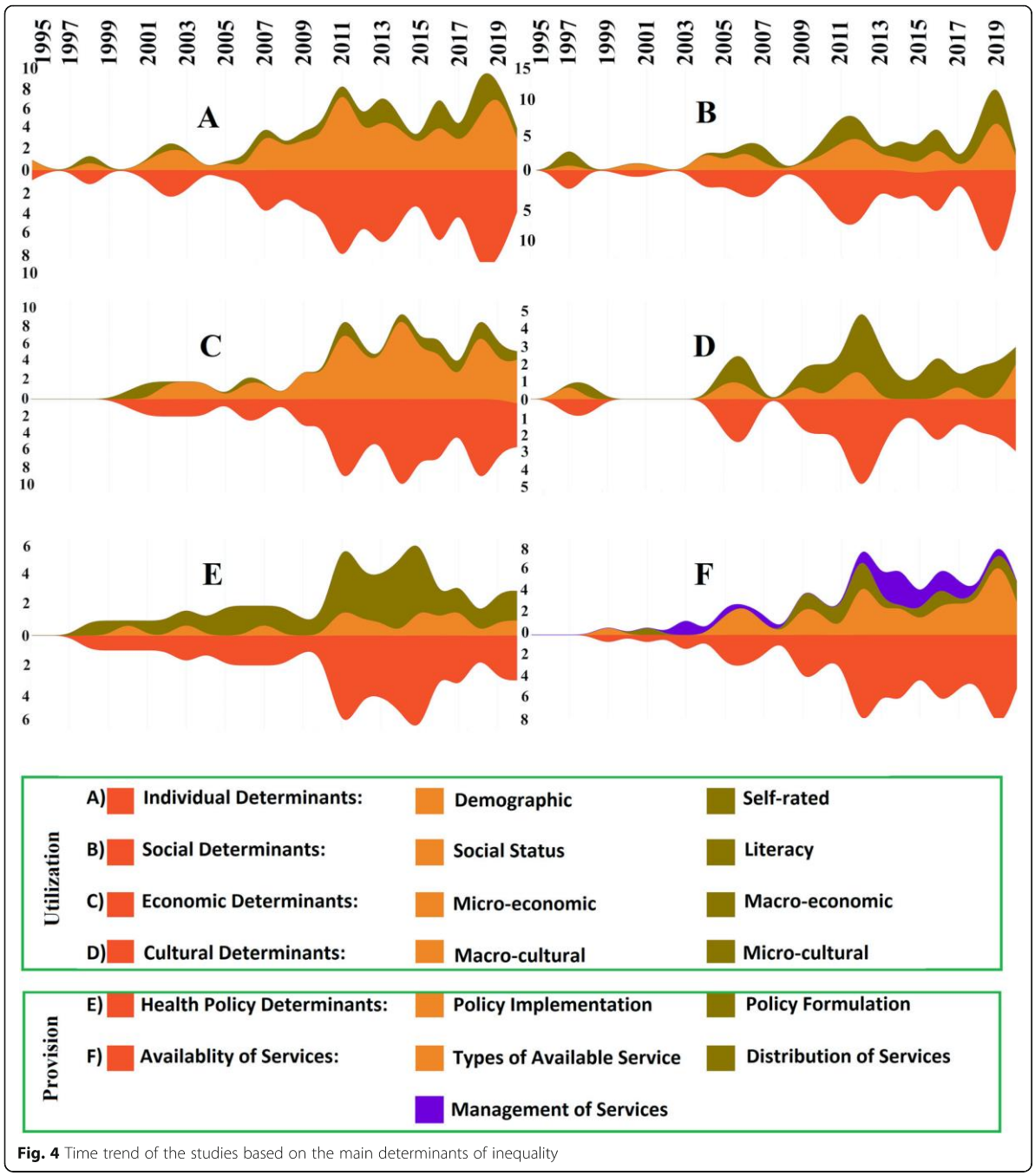

Fig. 4 Time trend of the studies based on the main determinants of inequality

countries [49]. To put it in a nutshell, as the map shows, the way to tackle the inequality in dental services is to target all determinants at the same time.

According to the publishing trends of articles, although this trend has been consistent and increasing since 2017, it may be argued that there has not been enough research related to determinants of social, cultural, and health policies. In other words, most of the researchers' focus on specific factors such as income caused a variety of replicated studies. Therefore, research on other aspects of inequality in dental services is pertinent.

Utilization and access to services are often used interchangeably in the dental literature. In this study, in addition to trying to differentiate between the concepts of utilization and provision of dental services, we tried to determine the determinants and sub-themes of each to design a relevant concept map to help researchers and policymakers to better address this issue. This study is one of the largest reviews in the study of inequality in dental services in terms of the number of included studies and is unique in terms of the methodology. However, due to the large number of studies reviewed, the purpose and methodology of the study, we excluded the inequality related determinants of access to dental services and should be considered separately. Therefore, the need to identify the determinants of the third edge of the "inequality triangle" in dental services (access) is still necessary.

Conclusion

In conclusion, various factors are related to inequality in the utilization and provision of dental services. These include individual, social, cultural, and economic determinants that are related to the utilization of services. On the other hand, there are health policies and availability of services, which relate to the provision. Disparities in each of these determinants can lead to inequality in utilization and provision of dental services. In conclusion, all these aspects must be considered to reduce inequality in dental services.

Abbreviations

OECD: Organization for Economic Co-operation and Development

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13643-021-01779-2.

Additional file 1: Utilization/Provision of Dental Services Search Strategies Syntax. **Table S1.** Data extraction form of the scoping review. **Table S2.** Determinants of inequality in utilization and provision of dental services in OECD countries.

Authors' contributions

The research has been designed in the research team, while all authors participated in all methodological steps, they have read and revised the final manuscript. AG searched the relevant studies. AG and PB selected and charted them. PB analyzed the content. The author(s) read and approved the final manuscript.

Funding

There was no funding.

Availability of data and materials

While identifying/confidential patient data should not be published within the manuscript, the datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

There were no ethical considerations.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Received: 20 January 2021 Accepted: 28 July 2021
Published online: 10 August 2021

References

1. Wilkinson RG. Putting the picture together: prosperity, redistribution, health and welfare. Soc Determinants Health. 1999;256:74.
2. Marmot M, Friel S, Bell R, Houweling TA, Taylor S. Health CoSDo. Closing the gap in a generation: health equity through action on the social determinants of health. Lancet. 2008;372(9650):1661–9.
3. Capurro DA, Davidsen M. Socioeconomic inequalities in dental health among middle-aged adults and the role of behavioral and psychosocial factors: evidence from the Spanish National Health Survey. Int J Equity Health. 2017;16(1):34.
4. Petersen PE, Bourgeois D, Ogawa H, Estupinan-Day S, Ndiaye C. The global burden of oral diseases and risks to oral health. Bull World Health Organ. 2005;83:661–9.
5. McClelland A, Pirkis J, Willcox S. Enough to make you sick: how income and environment affect health: National Health Strategy Unit; 1992.
6. Shaw M, Dorling D, Gordon D, Smith GD. The widening gap: health inequalities and policy in Britain: Policy Press; 1999.
7. Smith GD, Bartley M, Blane D. The Black report on socioeconomic inequalities in health 10 years on. BMJ: Br Med J. 1990;301(6748):373.
8. Nutbeam D, Wise M, Bauman A, Harris E, Leeder S. Goals and targetsfor Australia's health in the year 2000 and beyond. In: Report to Commonwealth Department of Health, Housing and Community Services Canberra. Australia: Australian Government Publishing Service; 1993.
9. Evans DB, Hsu J, Boerma T. Universal health coverage and universal access. Bull World Health Organ. 2013;91(8):546–546A.
10. Carrasquillo O. Health care utilization. In: Gellman MD, Turner JR, editors. Encyclopedia of Behavioral Medicine. New York, NY: Springer New York; 2013. p. 909–10.
11. Adams O, Shengeila B, Stilwell B. Provision of personal and non-personal health services. In: Proposal for monitoring. Geneva: WHO; 2002.
12. Sanders AE, Spencer AJ, Slade GD. Evaluating the role of dental behaviour in oral health inequalities. Community Dent Oral Epidemiol. 2006;34(1):71–9.
13. Reda SM, Krois J, Reda SF, Thomson WM, Schwendicke F. The impact of demographic, health-related and social factors on dental services utilization: systematic review and meta-analysis. J Dent. 2018;75:1–6.
14. Reda SF, Reda SM, Thomson WM, Schwendicke F. Inequality in utilization of dental services: a systematic review and meta-analysis. Am J Public Health. 2018;108(2):e1–7.
15. Munn Z, Peters MD, Stern C, Tufanaru C, McArthur A, Aromataris E. Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. BMC Med Res Methodol. 2018;18(1):143.
16. Peters MD, Godfrey CM, McInerney P, Soares CB, Khalil H, Parker D. The Joanna Briggs Institute reviewers' manual 2015: methodology for JBI scoping reviews; 2015.
17. Arksey H, O'Malley L. Scoping studies: towards a methodological framework. Health Info Libr J. 2005;8(1):19–32.
18. Grant MJ, Booth A. A typology of reviews: an analysis of 14 review types and associated methodologies. Health Information & Libraries Journal. 2009;26(2):91–108.
19. Bengtsson M. How to plan and perform a qualitative study using content analysis. NursingPlus Open. 2016;2:8–14.
20. Thomas J, Harden A. Methods for the thematic synthesis of qualitative research in systematic reviews. BMC Med Res Methodol. 2008;8(1):45.
21. Maher C, Hadfield M, Hutchings M, de Eyto A. Ensuring rigor in qualitative data analysis: a design research approach to coding combining NVivo with

traditional material methods. Int J Qual Methods. 2018;17(1): 1609406918786362.
22. Simon L, Choi SE, Ticku S, Fox K, Barrow J, Palmer N. Association of income inequality with orthodontic treatment use. J Am Dent Assoc. 2020;151(3): 190–6.
23. Moeller JF, Chen H, Manski RJ. Diversity in the use of specialized dental services by older adults in the United States. J Public Health Dent. 2019; 79(2):160–74.
24. Lee YS, Kim HG, Hur JY, Yang K. Oral health in low-income older adults in Korea. J Community Health Nurs. 2016;33(2):98–106.
25. Kengne Talla P, Gagnon MP, Dramaix M, Leveque A. Barriers to dental visits in Belgium: a secondary analysis of the 2004 National Health Interview Survey. J Public Health Dent. 2013;73(1):32–40.
26. Smith DK, Castellanos EH, Murphy BA. Financial and socio-economic factors influencing pre- and post-cancer therapy oral care. Support Care Cancer. 2018;26(7):2143–8.
27. Crocombe LA, Stewart JF, Brennan DS, Slade GD, Spencer AJ. Is poor access to dental care why people outside capital cities have poor oral health? Aust Dent J. 2012;57(4):477–85.
28. Armfield JM. Socioeconomic inequalities in child oral health: a comparison of discrete and composite area-based measures. J Public Health Dent. 2007; 67(2):119–25.
29. Caban-Martinez AJ, Lee DJ, Fleming LE, Arheart KL, Leblanc WG, Chung-Bridges K, et al. Dental care access and unmet dental care needs among U. S. workers: the National Health Interview Survey, 1997 to 2003. J Am Dent Assoc. 2007;138(2):227–30.
30. Lee H, Seo S, Kang R, Kim Y, Hyun HK. Increasing access to oral healthcare for marriage-immigrant women in South Korea: programme design to policy recommendation. Int Dent J. 2019;69(5):354–60.
31. Jones K, Parker E, Jamieson L. Access, literacy and behavioural correlates of poor self-rated oral health amongst an indigenous south Australian population. Community Dent Health. 2014;31(3):167–71.
32. Cheema J, Sabbah W. Inequalities in preventive and restorative dental services in England, Wales and Northern Ireland. Br Dent J. 2016;221(5):235–9.
33. Honkala E, Kuusela S, Rimpelä A, Rimpelä M, Jokela J. Dental services utilization between 1977 and 1995 by Finnish adolescents of different socioeconomic levels. Community Dent Oral Epidemiol. 1997;25(6):385–90.
34. Rodriguez-Alvarez E, Lanborena N, Borrell LN. Place of birth inequalities in dental care use before and after the economic crisis in Spain. Int J Environ Res Public Health. 2019;16(10):1691–1702.
35. Leinsalu M, Reile R, Vals K, Petkeviciene J, Tekkel M, Stickley A. Macroeconomic changes and trends in dental care utilization in Estonia and Lithuania in 2004-2012: a repeated cross-sectional study. BMC Oral Health. 2018;18(1):199.
36. Allin S, Masseria C, Mossialos E. Equity in health care use among older people in the UK: an analysis of panel data. Appl Econ. 2011;43(18):2229–39.
37. FitzGerald EM, Cunich M, Clarke PM. Changes in inequalities of access to dental care in Australia 1977–2005. Aust Econ Rev. 2011;44(2):153–66.
38. Nota A, Caruso S, Cantile T, Gatto R, Ingenito A, Tecco S, et al. Socioeconomic factors and oral health-related behaviours associated with dental caries in preschool children from central Italy (Province of Ascoli Piceno). Biomed Res Int. 2019;2019:7981687.
39. Shin BM, Jung SH, Kim MH, Ryu JI. Did the extended coverage policy contribute to alleviating socioeconomic inequality in untreated dental caries of both children and adolescents in South Korea? BMC Oral Health. 2020; 20(1):124.
40. Ku L. Medical and dental care utilization and expenditures under Medicaid and private health insurance. Med Care Res Rev. 2009;66(4):456–71.
41. Pegon-Machat E, Faulks D, Eaton KA, Widstrom E, Hugues P, Tubert-Jeannin S. The healthcare system and the provision of oral healthcare in EU Member States: France. Br Dent J. 2016;220(4):197–203.
42. Garrido-Cumbrera M, Borrell C, Palencia L, Espelt A, Rodriguez-Sanz M, Pasarin MI, et al. Social class inequalities in the utilization of health care and preventive services in Spain, a country with a national health system. Int J Health Serv. 2010;40(3):525–42.
43. Locker D, Maggirias J, Quinonez C. Income, dental insurance coverage, and financial barriers to dental care among Canadian adults. J Public Health Dent. 2011;71(4):327–34.
44. Kino S, Bernabe E, Sabbah W. Social inequalities in use of preventive dental and medical services among adults in European countries. Int J Environ Res Public Health. 2019;16(23):4642–51.
45. Moffat SM, Foster Page LA, Thomson WM. New Zealand's school dental service over the decades: its response to social, political, and economic influences, and the effect on oral health inequalities. Front Public Health. 2017;5:177.
46. Celeste RK, Nadanovsky P, Fritzell J. Trends in socioeconomic disparities in the utilization of dental care in Brazil and Sweden. Scand J Public Health. 2011;39(6):640–8.
47. Costacurta M, Epis M, Docimo R. Evaluation of DMFT in paediatric patients with social vulnerability conditions. Eur J Paediatr Dent. 2020;21(1):70–3.
48. Newacheck PW, Hung YY, Jane Park M, Brindis CD, Irwin CE Jr. Disparities in adolescent health and health care: does socioeconomic status matter? Health Serv Res. 2003;38(5):1235–52.
49. Singh A, Harford J, Antunes JLF, Peres MA. Area-level income inequality and oral health among Australian adults-a population-based multilevel study. PLoS One. 2018;13(1):e0191438.

Publisher's Note

Chapter 4 - Inequality in Dental Services: The Role of Access Toward Achieving Universal Health Coverage in Oral Health

Chapter 4 - **Role of Access Toward Achieving Universal Health Coverage in Oral Health**

Linkage to the thesis

This chapter continues the effort to identify the determinants of inequality and addresses another dimension, access to services. In addition to redefining access, and the determinants leading to inequality in access to dental services, it has been shown how these determinants are related to different dimensions of universal health coverage (UHC).

Highlights

- Seven determinants, including family conditions, cultural, health demands, affordability, availability, socioenvironmental and geographic distance, were identified as the cited factors leading to inequality in access to dental services.
- These determinants were aligned with different dimensions of access to services as well as the dimensions of universal health coverage. Policymakers and researchers need to consider these alignments to reduce the inequality in dental services and to improve universal health coverage for dental services.

Note: Supplementary information of the paper in chapter is available in appendix IV.

Statement of Authorship for paper 2

Title of Paper	Inequality in dental services: a scoping review on the role of access toward achieving universal health coverage in oral health
Publication Status	■ Published ☐ Accepted for Publication ☐ Submitted for Publication ☐ Unpublished and Unsubmitted work written in manuscript style
Publication Details	**Inequality in dental services: a scoping review on the role of access toward achieving universal health coverage in oral health** **Author:** Arash Ghanbarzadegan et al SPRINGER NATURE **Publication:** BMC Oral Health **Publisher:** Springer Nature **Date:** Aug 17, 2021 *Copyright © 2021, The Author(s)* **Creative Commons** This is an open access article distributed under the terms of the Creative Commons CC BY license, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. You are not required to obtain permission to reuse this article. CC0 applies for supplementary material related to this article and attribution is not required.

Principal Author

Name of Principal Author (Candidate)	Arash Ghanbarzadegan		
Contribution to the Paper	Conceptualised the idea, Conceived the research question, designed the study, Analysed the data, Wrote the paper draft and conducted all revisions.		
Overall percentage (%)	75%		
Certification	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		Date	29/07/2022

Co-Author Contributions

By signing the Statement of Authorship, each author certifies that:

I. the candidate's stated contribution to the publication is accurate (as detailed above);
II. permission is granted for the candidate in include the publication in the thesis; and
III. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

Name of Co-Author	Madhan Balasubramanian		
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Signature		Date	8/03/2022

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Contribution to the Paper	Contributed in study designing, conceiving the research question, data analysis, drafting and revising the paper. Supervised the study.		
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Contribution to the Paper	Contributed in study designing, data analysis, drafting and revising the paper. Acted as the corresponding author for the publication process.		
Signature		Date	8/03/2022

Paper 2

Ghanbarzadegan *et al. BMC Oral Health* (2021) 21:404
https://doi.org/10.1186/s12903-021-01765-z

BMC Oral Health

RESEARCH ARTICLE Open Access

Inequality in dental services: a scoping review on the role of access toward achieving universal health coverage in oral health

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Abstract

Background: Improving access to health services is a way towards achieving universal health coverage (UHC) in oral health. The purpose of this review was to map the determinants of access to dental services within a UHC framework.

Method: Scoping review methods were adopted for the review. PUBMED, Scopus, ISI Web of Science and ProQuest were searched for academic literature on determinants of access to dental services in OCED countries. Articles published in the last 20 years were included. No restriction was placed on study methods; only articles in English language were included. Qualitative synthesis was conducted, along with a trend analysis and mapping exercise.

Result: A total of 4320 articles were identified in the initial search; 57 articles were included in the qualitative synthesis. The results indicate 7 main themes as the determinants of access to dental services: family condition, cultural factors, health demands, affordability of services, availability of services, socio-environmental factors, geographical distance. Defined determinants of access to dental services, family condition, cultural factors and geographical access to dental services can fill the population axis of the UHC cube. Health demands and affordability of services fill the gap of financial protection as another axis of the UHC cube and finally, availability of dental services and socio-environmental factors are aligned with the appropriateness of services, the third axis of the UHC cube.

Conclusion: According to the results, family condition and cultural, health demands, affordability and availability of services, social environment, and geographic factors can affect dental health access and equality. Socio-cultural determinations also need to be considered in applied planning. Addressing these factors to improve access to dental services can pave the way for achieving universal health coverage in oral health and should be considered in different levels of policymaking.

Keywords: Disparities, Oral health, High-income countries, Dental care

Background

All members of the World Health Organization (WHO) are committed towards achieving universal health coverage (UHC) [1]. UHC can be argued as a practical expression of health equity and is reached when individuals and communities can receive the health services they need without facing any financial barriers [2]. UHC would be achievable when people do not face excessive financial contributions to meet their preventive, curative or rehabilitative needs [3]. Although UHC is one of the post-2015 United Nations' Sustainable Development Goals (SDGs) [2, 4], and it has been well addressed in the WHO 2010 report [5], this goal has not yet been achieved in most societies.

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Busse et al. [6] introduced the three dimensions of coverage which are adopted by WHO in their reports [5, 7] to show the way toward UHC and is commonly known as the UHC cube (Fig. 1). According to the cube, these three dimensions of UHC are service, cost and population coverage. To fill this cube and increase universal health, coverage in these three dimensions must improve.

As a separate concept, access to health services refers to the timely use of health services by individuals and the community to achieve the best health outcomes [8]. This concept has different dimensions, including financial access, physical access and acceptability. According to Evans et al. [9], physical accessibility is understood as the availability of good health services within reasonable reach of those who need them and of opening hours, appointment systems and other aspects of service organisation and delivery that allow people to obtain the services when they need them. At the same time, according to Busse et al. [6], if we improve access determinants, we could improve the coverage of services. These two concepts, individuals' acceptability (population coverage) and fair financial access (cost coverage), as two of the three dimensions of the UHC, are reminiscent of the dimensions of access to services Besides those dimensions, service coverage, as the third dimension of the UHC, entails the range of services provided by the health systems. Therefore, it may be argued that in order to achieve the UHC, the dimensions of access should be reached as a proxy for the dimension of the UHC in the populations [9, 10].

At the same time, Campbell et al. [11] have referred to the accessibility of the services as a combination of physical or geographic access, affordability and availability. According to their framework, accessibility of the health services is an important dimension that can affect the quality of the services [11]. In rapid incorporation of the concept from different aforementioned authors, it seems that in spite of different defined components and determinants of access, previous knowledge has emphasised the relationship of access to health services and better performance of health systems toward quality, equality and UHC. So synthesising an overall and comprehensive viewpoint can be fruitful for the health policymakers and health intervention designers.

In addition, although oral health is one of the forgotten levels in macro health policies setting, its importance should not be overlooked [12]. According to Mathur et al. [13], despite the important role of oral health in the community's overall health, well-being, and quality of life, this area has not been adequately considered in many global health plans and strategies. Fisher et al. [14] emphasised the importance of oral diseases as comorbidity factors for sustainable development goals (SDGs) that aim to reduce the burden of diseases and to improve maternal, child and sexual health. Approximately 4.6% of the total health expenditure in the world is for the treatment of oral diseases [15]. Between 3 and 4 billion people suffer from untreated decayed teeth. It should be noted that oral diseases are the most common diseases that human beings suffer from. Oral diseases are among the hundred

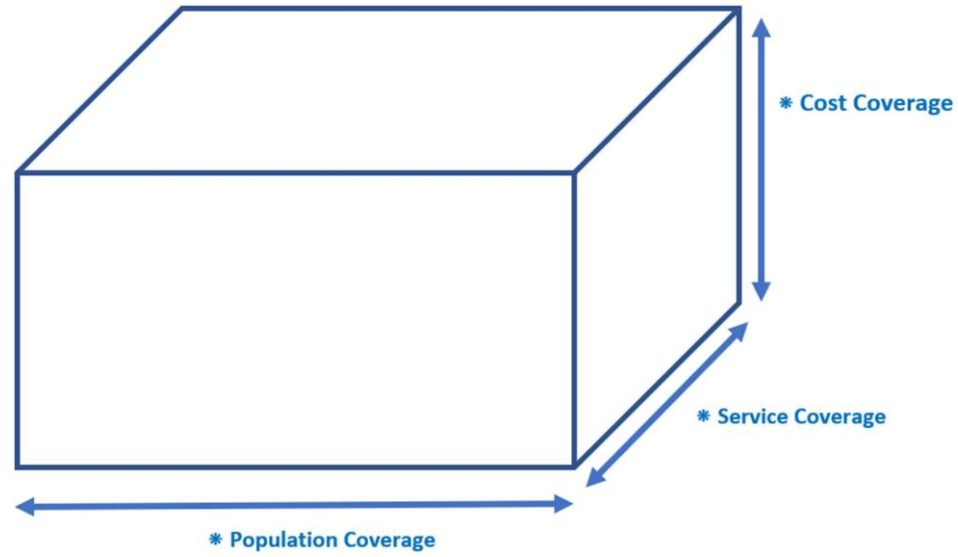

Fig. 1 UHC cube [6] adopted from Busse et al

diseases that cause the most disability-adjusted life years (DALY), and it is even more than the average lost years for a moderate heart failure. Approximately 224 years per 100,000 lives are lost due to disability caused by oral diseases [16].

Oral health and access to dental services should be acknowledged similarly to other health services under UHC to reduce the existing inequalities in the populations. It has been reported that the elimination of financial hardship is not enough to achieve a sustainable improvement in equity unless other factors like geographical access are considered [17]. However, in the dental literature, most studies have addressed physical and geographical access to services which is only one aspect of UHC cube and access to services. Therefore, it is essential to conduct a focused review to determine all dimensions and determinants of access to dental services.

Inequality in dental services has been reported in all societies, including high-income countries, but no framework addressing determinants of access-related inequalities in dental services has yet been reported. Challenges to accessing dental services are seen in most countries, although these challenges are greater in low- and middle-income countries. There are more inconsistencies and knowledge gaps in oral policies in these countries [13, 18]. At the same time, other evidence has implied that socioeconomic factors may affect the style and prevalence of oral and dental challenges in a different way. For instance, a strong negative association has been considered between sugar consumption and caries ($B = -2.80$, $R2 = 0.17$) in both high and low-income countries. Similarly, a strong positive relationship has been reported between DMFT and per capita sugar consumption ($B = -0.89$, $R2 = 0.20$) in high and low-income countries but not among the middle-income ones [19]. These pieces of evidence can highlight the need for attention to this area among high-income countries, as well as the others.

On the other hand, many countries of the Organization for Economic Co-operation and Development (OECD) have adopted different strategies to increase access to dental services that emphasise the need for these countries to manage and improve equality in this area [20]. Among them, we can refer to increasing teledentistry, including dentistry services in insurance packages, supporting rural, remote or tribal areas [21], provision of oral and dental services by physicians and dentists, revising dental and medical schools' curricula, improving the collaborations among dentists and physicians and so on [22]. Thus, to more accurately investigate this inequality in access to dental services, this study aims to examine the determinants of these access-related inequalities in the OECD countries to date (August 2020). Additionally, this study aims to map the determinants of access-related inequality in dental services to help researchers and policymakers to synthesise the relevant evidence and enable evidence-based policymaking. This map is not only a summary of the access-related inequalities in dental services of OECD countries but also can be a supportive piece of evidence for evidence-based policymaking in other countries.

Methods

A scoping review methodology was applied to allow the inclusion of a variety of relevant and heterogeneous literature simultaneously. Scoping reviews enable determining the main aspects of a concept and making a comprehensive map of evidence [23]. In this regard, Joanna Briggs Institute (JBI) methodology for scoping reviews was adopted. The JBI scoping review guideline has considered three different approaches in conducting a scoping review; a six-step approach of Arksey and O'Malley [24], that of Levac et al. [26] and the nine-step approach of Peter et al. [25]. We have followed Levac, Colquhoun and O'Brien approach [26]. Table 1 shows the review steps and clarifies the Levac interpretation of the Arkey and O'Mally framework as well.

According to Table 1, The three components of the study design are as follows:

1. Identifying research question, search strategy, data extraction

Table 1 The six-step approach of Levac et al. [26] for a scoping review

Step (JBI) [25]	Description (Levac et al.)
Identifying the research question	Clarifying the review propose and linking the purpose and research question
Identifying relevant studies	Feasibility balancing with breadth and comprehensiveness of the scoping process
Study selection	Using an iterative team approach for study selection and data extraction
Charting the data	Including a numerical summary and qualitative thematic analysis
Collating, summarising, and reporting the results	Identifying the implications of the study findings for policy, practise or research
Consultation (optional)	Adopting consultation as a required component of scoping study methodology

This main component has included the initial three steps of Table 1. These three steps are considered as follows:

2. Clarifying and linking the purpose and research question
   The study aimed to explore the main determinants of access-related inequalities in dental services among the OECD countries. In this regard, the main research question was defined as: What are the main determinants affecting access to dental services in the OECD countries?
3. Feasibility balancing with the comprehensiveness of the scoping process
   In this step, the relevant keywords were selected to set the search strategy. The systematic search had been conducted from 01/01/2000 up to 08/08/2020 in 4 scientific databases, including PUBMED, Scopus, ISI Web of Science and ProQuest (Additional file 1: Table S1). Systematic management of the retrieved studies was done using the EndNote reference manager X9 (Clarivate Analytics, Philadelphia, PA, USA).
4. Using an iterative team approach to select studies and extract data
   Inclusion and exclusion criteria were defined. Original articles with different methodological designs (quantitative, qualitative or mixed-method studies) which were available in English full-text and fulfilled the study purpose, were included. On the other hand, review articles (unless reviewing, analysing and reporting a national survey), conference proceedings, editorials and commentaries were excluded from the study. Articles were first screened based on their titles and abstracts, then the full texts of the retrieved abstracts were thoroughly reviewed by two research team members (AG and PB) separately. At the time of any disagreement between the reviewers for including the material, the third person (DB) studied the paper and made the final decision. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) was applied for illustrating the approach (Fig. 2) [27].
5. Thematic analysis and Mapping exercise (towards UHC themes)
   This component has contained the final two steps of Table 1 as follows:
6. Incorporating a numerical summary and qualitative thematic analysis
   A data extraction form (Additional file 1: Table S2) was applied to record the authors' name, place of the studies, publication year, and the study's main finding. Subsequently, thematic analysis was utilised to analyse and synthesise the data by one researcher who has more reflexivity with qualitative research (PB).
7. Identifying the implications of the study findings for policy, practise or research
   The Graneheim and Lundman [28] approach was applied through the following steps: first, extracted data were reviewed several times, initial codes were made and then labelled. Secondly, all initial codes were reviewed and merged to reach the final codes according to the aim of the study. At the third step, final codes were categorised to achieve the subthemes and the main themes of access to dental services in the OECD countries. Finally, all subthemes and main themes were tabulated and discussed among the research team to investigate the implications for policymakers. At the same time, data synthesis was conducted from two perspectives: 1. matching the thematic analysis findings with the dimensions of access to services 2. aligning the defined themes with the dimensions of the UHC cube [7].
8. Trend analysis
   This scoping review also utilises trend analysis to illustrate the trends of publications categorised in each of the emerging determinants. To investigate the publication trend of determinants and dimensions of access to dental services, the number of articles in each section was determined, and the relevant bar chart was drawn using Microsoft Excel Version 16 for MAC (Microsoft Corporation, Redmont, WA).

Results

Results of the study are presented in two sections: first, the description of the characteristics of the included studies and then the results of the thematic analysis and the thematic map.

Characteristics of the included studies

According to the present search strategy (Additional file 1: Table S1), a total of n = 4320 studies were identified in the title, abstract and keyword search. Following the exclusion of duplicates (n = 1356), a total of 2964 records were screened. 82 articles were selected for full-text reading, and 57 articles included in the final qualitative synthesis (see Fig. 2—PRISMA flowchart). The last 25 articles were omitted for two particular reasons: no evidence relevant to access to dental services (7 articles) and/or aiming for other aspects of inequality such as utilisation and provision rather than access (18 articles).

The characteristics of the included articles showed that most of the studies were conducted in the United States of America (20 articles). Sorting the included studies by the publication year also revealed that most of the studies

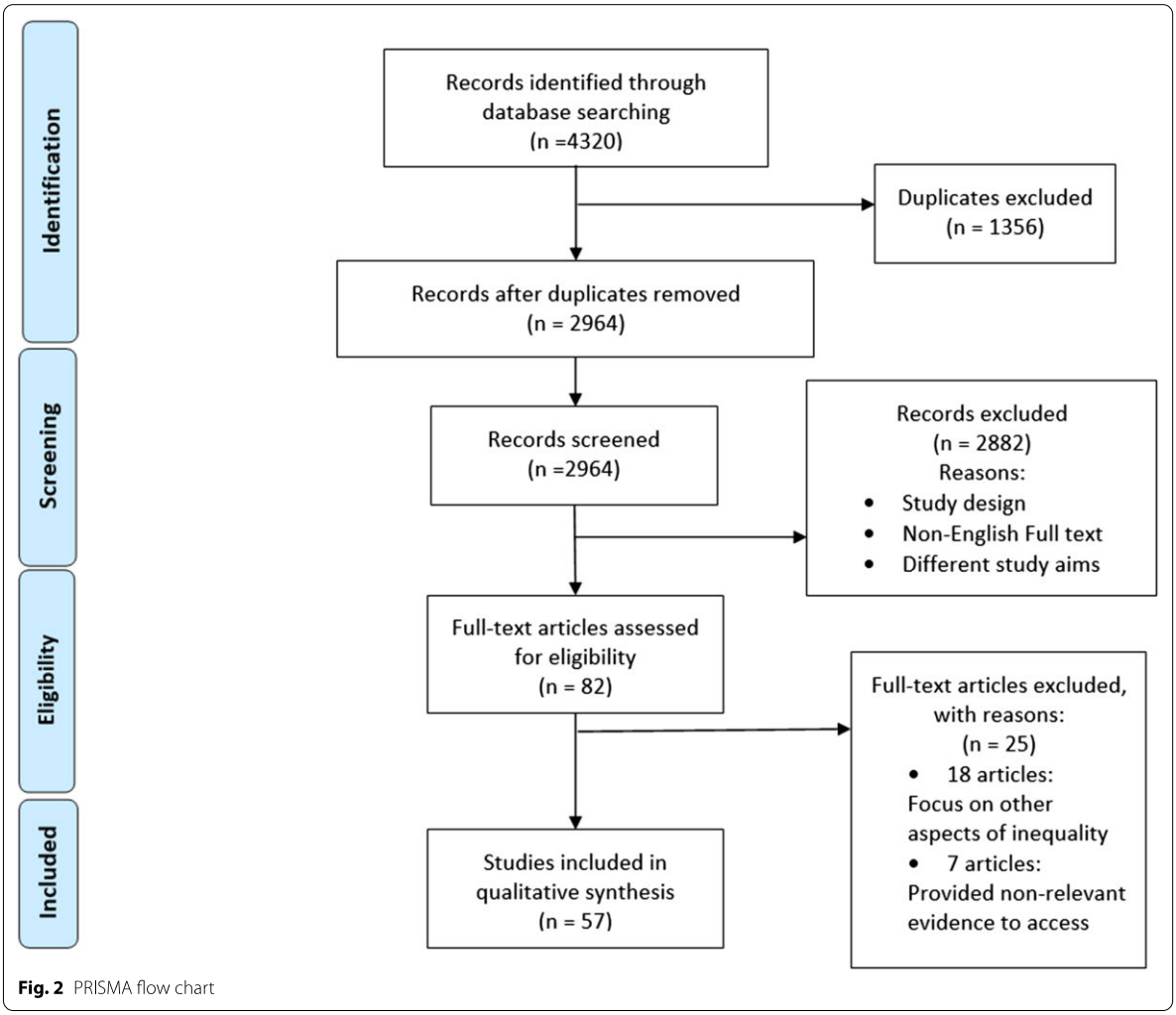

Fig. 2 PRISMA flow chart

had been published in the last decade (40 articles). More information about these patterns is available in the Additional file 1: Figures S1 and S2.

Thematic analysis

Thematic analysis of the included studies led to 7 main determinants of access-related inequality in dental services as follows: family condition factors, health demands, cultural factors, affordability of services, availability of services, socio-environmental factors and geographical access (Table 2). Included articles are mentioned in an additional column in the Additional file 1: Table S3.

Considering the 3 main dimensions of access to health services; financial, physical and acceptability of the services, Table 2 depicts that the family condition factors and cultural factors can affect the acceptability of access to dental services.

As one of those determinants, family condition factors consist of different subthemes such as being a child, an elder or pregnant family member [29, 30], race or aboriginality [31–33] of the family. Each of the aforementioned factors can have a negative or positive effect on access to dental health services. In other words, according to the included studies, those families with a larger size, those who belong to an the ethnic minority or involve aboriginality and families with a lower educational level along with those who live alone or with a different primary spoken language at home, may have lower access to dental health services while the existence of the elderly, a pregnant mother or having a child at home may intensify the access to dental services particularly at the time of benefiting supportive health benefit packages.

Table 2 Determinants of access to dental services

Dimensions of access	Main determinants	Sub determinants
Acceptability of services	Family condition	Existence of an elderly member in the family
		Existence of a child in the family
		Families living in poverty
		Race/ethnic minority/aboriginality of a family
		Occurring pregnancy in the family
		Member living alone
		Education level of the whole family
		Primary language spoken at home
		Number of children at the shelter
	Cultural factors	Fear of dental treatment or phobias
		Oral health beliefs
		Victimisation
		Poor oral health behaviours
Financial	Health demands	Unmet oral healthcare needs
		Health problems
		Poor oral condition
	Affordability of services	Income
		Health insurance
		Cost of services (out of pocket payment)
		Medicaid and medicare
		Federal government's funding
Physical	Availability of services	Oral health delivery system
		Public coverage of dental services
		Dentists visits/preventive care
		Specialised treatment
		Virtual dental home
		Long waiting time
		High proportion of dentists
		Shelter based care
		Access to oral hygiene products
		Pensioners
	Socio-environmental factors	Refugees
		Immigrants
		Disadvantages people
	Geographical distance	Geographical access
		Travel time
		Using public transportation
		Rural populations
		Living in census areas
		Living in the regions outside major cities

Besides family condition, culture and attitudes toward oral health beliefs and behaviours can raise access related inequality in dental services [34].

Health demands along with the affordability of the services by the patients are aligned with the financial dimension of the access to dental services. Health demands, in the reviewed literature, mainly emphasises the population's oral health and dental needs. Therefore, society's unmet needs can impose a high financial burden on access to dental services [35] and should be considered along with the revealed needs and the real demands.

Family income [36] or insurance coverage [37, 38] enhance the affordability of the services, particularly those social and basic health benefit packages with a wide

coverage of dental services, while out of pocket payment at the time of the need for services may negatively impact access to dental services [39, 40].

Availability of dental services, living or environmental conditions and geographical access are aligned with the physical dimension of access to dental services. Dental visit waiting-time [41] and applying virtual services and telehealth [38, 42] may affect the availability of services and, consequently, access dental services in different ways. Geographical access, travelling time [43] and public transportation utilisation [44] are other determinants of physical access.

In sum, these three dimensions of access; financial, physical and acceptability of services, along with their determinants, are considering as the main dimensions and the sub-dimensions of access to dental services, which have influenced the inequality in terms of access to dental services in the OECD countries (Table 2).

Trend analysis of the publications showed that the most published dimension of access to dental services is the physical dimension. Regarding the determinants, most studies covered the affordability of services (32 articles), while a small proportion covered cultural factors (4 articles) and socio-environmental factors (5 articles) (Fig. 3).

Besides the aforementioned synthesis, the evidence can also be aligned with the UHC dimensions. In this regard, family condition, culture, and geographical access to dental services can fill the population aspect of the UHC cube, which extends the coverage toward the population. Socio-environmental determinants and affordability fill another axis of the UHC cube, financial protection, which is similar to the financial dimension of access to services. Financial protection is mainly emphasised on the power of the health system for progressive and equitable funding of the services by allocated taxed or insurance premiums rather than out of pocket (OOP) payments. The potentiality of the health system also influences the affordability of the dental services to provide appropriate services to the community with affordable prices. This factor and the socio-environmental status of the people representing their financial status, insurance status, and power of paying OOP can be considered Financial protection of the UHC cube.

Service coverage as the third axis of the UHC cube defines how extensively a health system covers different

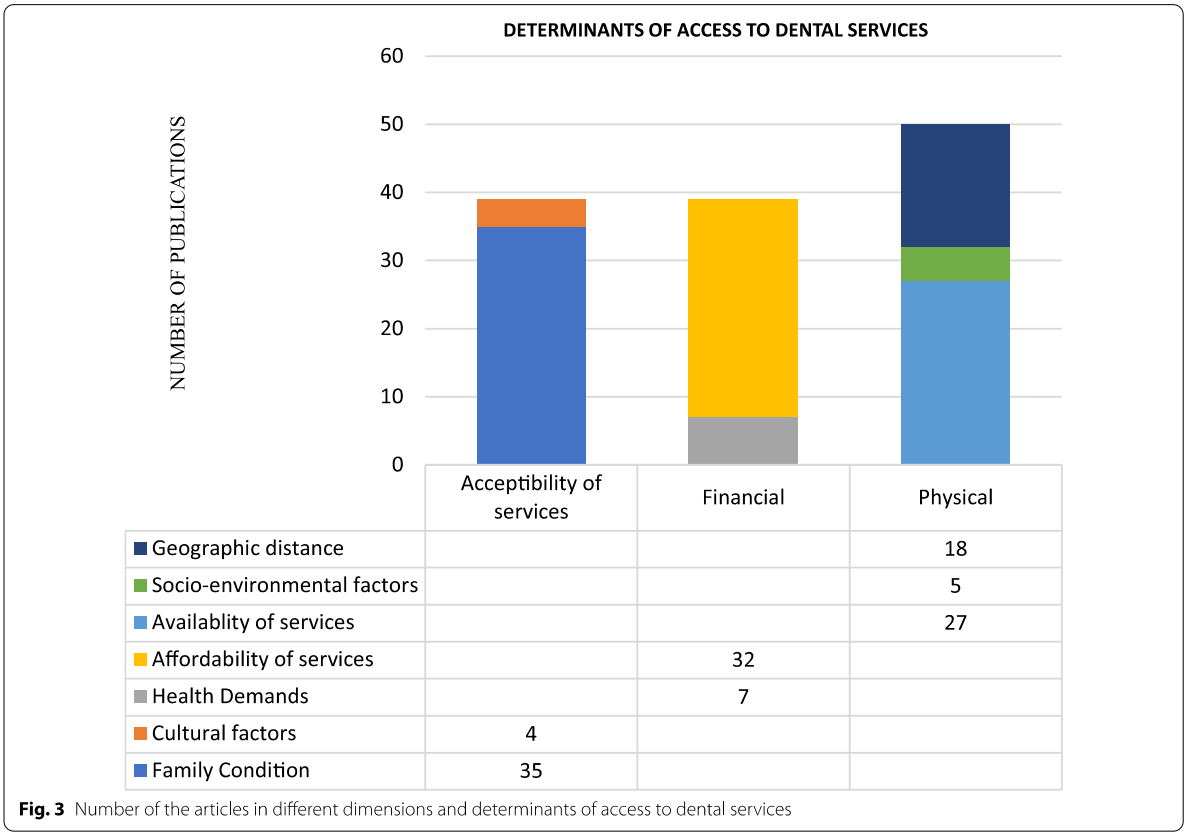

Fig. 3 Number of the articles in different dimensions and determinants of access to dental services

services. This dimension can be adjusted by the availability of dental services and the individual's health status (Fig. 4).

Discussion

In this study, we discussed different determinants of access to dental services among OECD countries. According to the current results, access to dental services includes a vast dimension of physical access, financial access, and acceptability.

Physical access is divided into the categories of availability of services, social environment and geographic and transportation regarding the current results. Similarly, according to the literature, geographical access to dental services is only one determinant of access to services [45]. Although geographical access is the clearest determinant, this factor cannot solely determine the population's access to services. It would be significant for policymakers to pay adequate attention to other factors such as culture and other family conditions. These three factors together can be highly influential in determining the rate of access and utilisation to oral health services. At the same time, affordability of the services can significantly affect the dimension of access which emphasised access of all populations without any financial hardship. This factor, and the community's health demands can shed light for policymakers to plan for increasing access to oral health services and universal health coverage. Finally, the concept of UHC has made the coverage of high-quality services as another prerequisite. According to the current results, policymakers should be sensitive to the availability of oral services for all populations, such as those in rural and remote areas.

Although many OECD countries are at a high individual and national level of wealth and income, even among these countries, income distribution is not fair [46]. This inequality can affect people's access to dental services. Some examples of income inequalities in accessing dental services at the ecological and individual level are as follows: a study in Norway found that counties with higher revenue collections also had higher access rates to dental centres [47]; while when considering individual income, various studies have shown that people with lower income had a lower rate of affordability of services [36, 38, 48].

To increase the affordability of dental services, it is not sufficient to pay attention only to people's income. Another determinant that can improve this dimension of access to dental services is being covered by insurance. Holding any type of health insurance, not just dental insurance can reduce health expenditures and thus increase the ability of people to pay for dental expenses

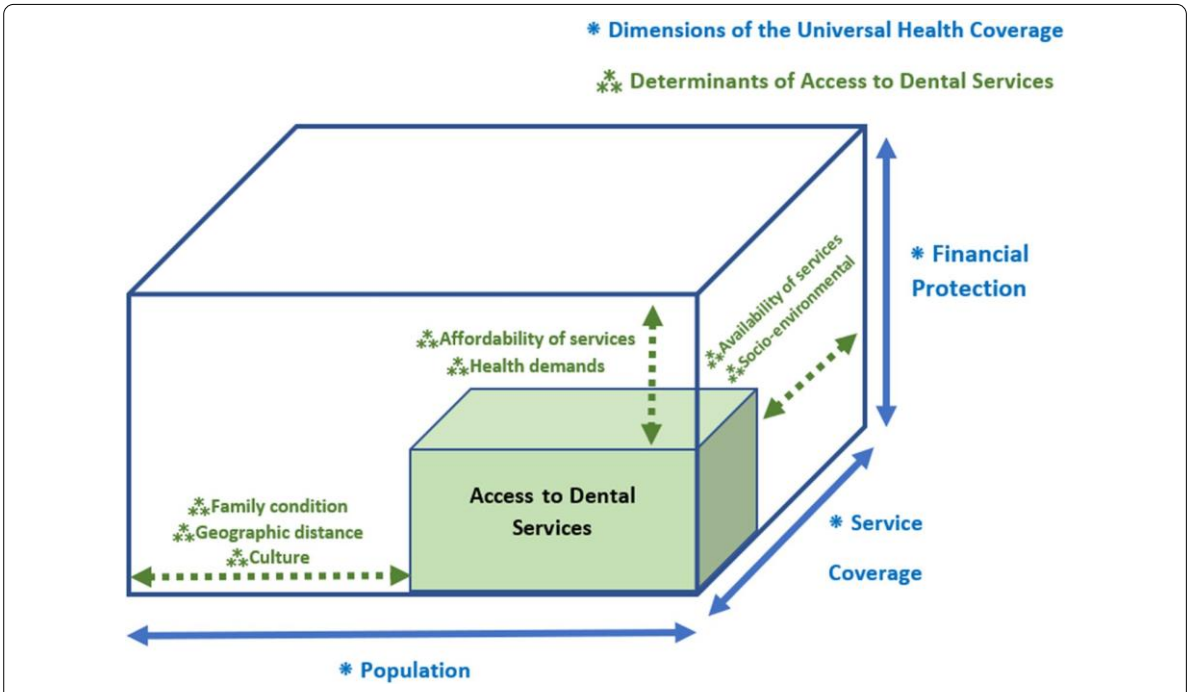

Fig. 4 Determinants of access to dental services aligned with the previously introduced Busse et al. cube [6] which was modified as the WHO's UHC cube [7]

[41, 49]. However, Newacheck et al. [50] stated that even after insurance expansion for adolescents, disparities remained. Such a discussion can be justified considering that dental services coverage may lead to a restricted scope of care via an insurance scheme enrollment. These schemes can present different facilities and access to services that depends on the government funds, patients' premiums and the nature of the private or public sector scheme [51]. Therefore, to achieve a desirable outcome, all determinants should be addressed, and at the same time, it should not be neglected that the association and relevance of insurance as a determinant of access is needed to be considered according to the context of universal, public care systems.

Finally, family condition and cultural factors affect access to services in terms of the acceptability of services. Many studies addressed specific family and individual circumstances, such as age, pregnancy and education [30, 52, 53]. While, within the family condition factors, race and ethnicity have been the most studied determinants.

In addition to racial factors, cultural determinants should be considered to increase the acceptability of services. In the included studies, the least attention was paid to these factors, while victimisation and oral health attitudes can affect the level of access to services [34]. This existing gap can be addressed by taking into consideration cultural factors, as well as stigma and social isolation in different social groups.

In sum, inequality in dental health services can be caused as a result of inappropriate access to such services. At the same time, lack of physical and financial access and also the acceptability of dental services can deepen the inequality, particularly among those families with lower socio-cultural and income level. The role of public benefit packages the same as insurance coverage, should not be neglected [54], and both revealed, and the unmet needs of the population should be considered by policymakers to be assured of restricting the inequality by increasing the access to dental services.

Despite the discussion about the dimensions of access and the UHC cube, according to Sanders et al. [51] there is need for further attention to Social Determinants of Health (SDH) and the concepts of community participation and advocacy via UHC. It should not be forgotten that some basic concepts, the same as PHC can be merged with UHC and facilitate the context of better oral and general health for the community. All these concepts should be considered in a comprehensive approach by policymakers depending on the countries context for moving forward towards better access to dental services. Besides considering inequalities in access to dental services, to eliminate inequalities, other aspects of the "triangle of inequalities in dental services" such as inequalities in utilisation and provision of dental services, must be considered [55].

Conclusions

According to the results, family condition and cultural factors, health demands, affordability and availability of services, social environment, and geographic factors can affect dental health access and equality. Socio-cultural determinants also need to be considered in applied planning. Addressing these factors to improve access to dental services can pave the way for achieving universal health coverage in Oral Health and should be considered in different levels of policymaking.

Strengths and limitations

As a focused scoping review requires a homogeneous population, we have limited this study to the OECD countries. Since access determinants to dental services in low- and middle-income countries can be different from the findings of this study, studying that context is also recommended. On the other hand, many the comprehensive studies conducted in OECD countries along with a separate review of two members of the research team who are familiar with the methodology, increased the robustness of the findings. In this study, due to the limitation in translating non-English texts, studies in languages other than English were excluded, which was one of the limitations of this project. We have tried to reduce the selection bias by conducting a scoping review that is more comprehensive than the other types of systematic reviews. However, this bias is an inevitable part of a review, so we encourage researchers to consider this. Distinguishing between the concepts of access and utilisation of services and mapping the identified determinants of access with the UHC dimensions was a novel aspect of this study and could help researchers and policymakers and thus be effective for the community.

Abbreviations

UHC: Universal health coverage; OECD: Organisation for Economic Co-operation and Development; SDG: Sustainable development goals; WHO: World Health Organization; DALY: Disability-adjusted life year.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12903-021-01765-z.

Additional file 1. Search strategy syntax and results.

Acknowledgements

The authors acknowledge all experts who participated in data synthesis and aligning the defined themes with the dimensions of the UHC cube.

Authors' contributions
AG has systematically searched the databases, retrieved the articles, and implemented the data analysis. PB has contributed to data analysis and prepared the initial draft of the article. DB has supervised the study, LL has technically edited the manuscript, and MB has contributed in data synthesis. All authors read and approved the final manuscript.

Funding
AG supported by the University of Adelaide International Scholarship.

Availability of data and materials
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
There was no ethical consideration.

Consent for publication
Not applicable.

Competing interests
There was no competing interest.

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Received: 16 December 2020 Accepted: 12 July 2021
Published online: 17 August 2021

References

1. World Health Organization. The world health report 2013: research for universal health coverage. Geneva: WHO; 2013. p. 2014.
2. World Health Organization. Positioning health in the post-2015 development agenda. Geneva: WHO; 2012.
3. Kutzin J. Health financing for universal coverage and health system performance: concepts and implications for policy. Bull World Health Organ. 2013;91:602–11.
4. Vega J. Universal health coverage: the post-2015 development agenda. Lancet (London, England). 2013;381(9862):179.
5. World Health Organization. The world health report: health systems financing: the path to universal coverage: executive summary. Geneva: World Health Organization; 2010.
6. Busse R, Schreyögg J, Gericke C. Analysing changes in health financing arrangements in high-income countries: a comprehensive framework approach. Washington: The World Bank; 2007.
7. World Health Organization. Research for universal health coverage. Geneva: World Health Organization; 2013.
8. Gulliford M, Figueroa-Munoz J, Morgan M, Hughes D, Gibson B, Beech R, et al. What does' access to health care'mean? J Health Serv Res Policy. 2002;7(3):186–8.
9. Evans DB, Hsu J, Boerma T. Universal health coverage and universal access. SciELO Public Health; 2013;91(8):546–546A. https://doi.org/10.2471/BLT.13.125450
10. McIntyre D, Mooney G. The economics of health equity. Cambridge: Cambridge University Press; 2007.
11. Campbell SM, Roland MO, Buetow SA. Defining quality of care. Soc Sci Med. 2000;51(11):1611–25.
12. Benzian H, Hobdell M, Holmgren C, Yee R, Monse B, Barnard JT, et al. Political priority of global oral health: an analysis of reasons for international neglect. Int Dent J. 2011;61(3):124–30.
13. Mathur M, Williams D, Reddy K, Watt R. Universal health coverage: a unique policy opportunity for oral health. Los Angeles: SAGE Publications Sage CA; 2015.
14. Fisher J, Selikowitz H-S, Mathur M, Varenne B. Strengthening oral health for universal health coverage. The Lancet. 2018;392(10151):899–901.
15. Listl S, Galloway J, Mossey P, Marcenes W. Global economic impact of dental diseases. J Dent Res. 2015;94(10):1355–61.
16. Marcenes W, Kassebaum NJ, Bernabé E, Flaxman A, Naghavi M, Lopez A, et al. Global burden of oral conditions in 1990–2010: a systematic analysis. J Dent Res. 2013;92(7):592–7.
17. Brennan DS, Spencer AJ, Slade GD. Provision of public dental services in urban, rural and remote locations. Community Dent Health. 1996;13(3):157–62.
18. Mohammadpour, M., Bastani, P., Brennan, D. et al. Oral health policy-making challenges in Iran: a qualitative approach. BMC Oral Health. 2020;20(1):158. https://doi.org/10.1186/s12903-020-01148-w.
19. Masood M, Masood Y, Newton T. Impact of national income and inequality on sugar and caries relationship. Caries Res. 2012;46(6):581–8.
20. Paris V, Devaux M, Wei L. "Health Systems Institutional Characteristics: A Survey of 29 OECD Countries", OECD Health Working Papers, No. 50, OECD Publishing, Paris. 2010. https://doi.org/10.1787/5kmfxfq9qbnr-en.
21. Khemka S, Baliga S, Thosar N. Approaches to improve access to dental care services. Int Dent Medi J Adv Res. 2015;1(1):1–4.
22. Manski RJ, Hoffmann D, Rowthorn V. Increasing access to dental and medical care by allowing greater flexibility in scope of practice. Am J Public Health. 2015;105(9):1755–62.
23. Munn Z, Peters MD, Stern C, Tufanaru C, McArthur A, Aromataris E. Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. BMC Med Res Methodol. 2018;18(1):143.
24. Arksey H, O'Malley L. Scoping studies: towards a methodological framework. Health Info Libr J. 2005;8(1):19–32.
25. Aromataris E, Munn Z. Joanna Briggs Institute reviewer's manual. The Joanna Briggs Institute. 2017;299.
26. Levac D, Colquhoun H, O'Brien KK. Scoping studies: advancing the methodology. Implement Sci. 2010;5(1):69.
27. Moher D, Liberati A, Tetzlaff J, Altman DG, Group P. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med. 2009;6(7):e1000097.
28. Graneheim UH, Lundman B. Qualitative content analysis in nursing research: concepts, procedures and measures to achieve trustworthiness. Nurse Educ Today. 2004;24(2):105–12.
29. Carrion IV, Castañeda H, Martinez-Tyson D, Kline N. Barriers impeding access to primary oral health care among farmworker families in Central Florida. Soc Work Health Care. 2011;50(10):828–44.
30. Council on Access P, Interprofessional R, Robinson LA. Private sector response to improving oral health care access. Dent Clin N Am. 2009;53(3):523–35.
31. Jean G, Kruger E, Tennant M. The distribution of allied dental practitioners in australia: socio-economics and rurality as a driver of better health service accessibility. Aust Dent J. 2019;64(2):153–60.
32. Martin-Kerry JM, Whelan M, Rogers J, Raichur A, Cole D, de Silva AM. Addressing disparities in oral disease in Aboriginal people in Victoria: where to focus preventive programs. Aust J Prim Health. 2019;25(4):317–24.
33. Kilpatrick NM, Neumann A, Lucas N, Chapman J, Nicholson JM. Oral health inequalities in a national sample of Australian children aged 2–3 and 6–7 years. Aust Dent J. 2012;57(1):38–44.
34. DiMarco MA, Ludington SM, Menke EM. Access to and utilisation of oral health care by homeless children/families. J Health Care Poor Underserved. 2010;21(2):67–81.
35. Crete P, Boyd LD, Fitzgerald JK, LaSpina LM. Access to preventive oral health services for homebound populations: a pilot program. Am Dent Hyg Assoc. 2018;92(6):24–32.
36. Northridge ME, Kumar A, Kaur R. Disparities in access to oral health care. Annu Rev Public Health. 2020;41:513–35.
37. Ramraj C, Sadeghi L, Lawrence HP, Dempster L, Quiñonez C. Is accessing dental care becoming more difficult? Evidence from Canada's middle-income population. PLoS ONE. 2013;8(2):e57377.
38. Bailit H, D'Adamo J. State case studies: improving access to dental care for the underserved. J Public Health Dent. 2012;72(3):221–34.

39. Currie R, Pretty I, Tickle M, Maupomé G. Letter from America: UK and US state-funded dental provision. Community Dent Health. 2012;29(4):315.
40. Abdus S, Decker SL. Association between Medicaid adult nonemergency dental benefits and dental services use and expenditures. J Am Dent Assoc (1939). 2019;150(1):24–33.
41. Jang Y-E, Kim C-B, Kim N-H. Utilisation of preventive dental services before and after health insurance covered dental scaling in Korea: 2009 to 2014 Community Health Survey. Asia Pac J Public Health. 2017;29(1):70–80.
42. Dounis G, Ditmyer MM, McCants R, Lee Y, Mobley C. Southern Nevada assisted living residents' perception of their oral health status and access to dental care. Gerodontology. 2012;29(2):e150–4.
43. Jean G, Kruger E, Tennant M. Universal access to oral health care for Australian children: comparison of travel times to public dental services at consecutive census dates as an indicator of progressive realisation. Aust J Prim Health. 2020;26(2):109–16.
44. Kiuchi S, Aida J, Kusama T, Yamamoto T, Hoshi M, Yamamoto T, et al. Does public transportation reduce inequalities in access to dental care among older adults? Japan Gerontological Evaluation Study. Commun Dent Oral Epidemiol. 2020;48(2):109–18.
45. Rebelo Vieira JM, Rebelo MAB, Martins NMDO, Gornes JFF, Vettore MV. Contextual and individual determinants of non-utilisation of dental services among Brazilian adults. J Public Health Dent. 2019;79(1):60–70.
46. Tridico P. The determinants of income inequality in OECD countries. Camb J Econ. 2018;42(4):1009–42.
47. Grytten J, Lund E, Rongen G. Equity in access to public dental services: the experience from Norway. Acta Odontol Scand. 2001;59(6):372–8.
48. Lee YS, Kim HG, Hur JY, Yang K. Oral health in low-income older adults in Korea. J Community Health Nurs. 2016;33(2):98–106.
49. Biordi DL, Heitzer M, Mundy E, DiMarco M, Thacker S, Taylor E, et al. Improving access and provision of preventive oral health care for very young, poor, and low-income children through a new interdisciplinary partnership. Am J Public Health. 2015;105(Suppl 2):e23–9.
50. Newacheck PW, Hung YY, Jane Park M, Brindis CD, Irwin CE Jr. Disparities in adolescent health and health care: does socioeconomic status matter? Health Serv Res. 2003;38(5):1235–52.
51. Sanders D, Nandi S, Labonté R, Vance C, Van Damme W. From primary health care to universal health coverage—one step forward and two steps back. The Lancet. 2019;394(10199):619–21.
52. Hunter LP, Yount SM. Oral health and oral health care practices among low-income pregnant women. J Midwifery Womens Health. 2011;56(2):103–9.
53. Lebrun LA, Shi L. Nativity status and access to care in Canada and the U.S.: factoring in the roles of race/ethnicity and socioeconomic status. J Health Care Poor Underserved. 2011;22(3):1075–100.
54. Ghanbarzadegan A. Rationale approaches, from prioritization to service packages. InIranian Health System: A Critical Review. 11th National Congress of Progress Pioneers; Center for Iranian Islamic Progress, Tehran. 2017.
55. Ghanbarzadegan A, Bastani P, Luzzi L. et al. Inequalities in utilization and provision of dental services: a scoping review. Syst Rev. 2021;10:222. https://doi.org/10.1186/s13643-021-01779-2

Publisher's Note

Chapter 4 - **Role of Access Toward Achieving Universal Health Coverage in Oral Health**

Chapter 5 - Triangle of Inequality in Dental Service

Chapter 5 - **The Triangle of Inequality in Dental Services: Arguments for a New Conceptual Framework**

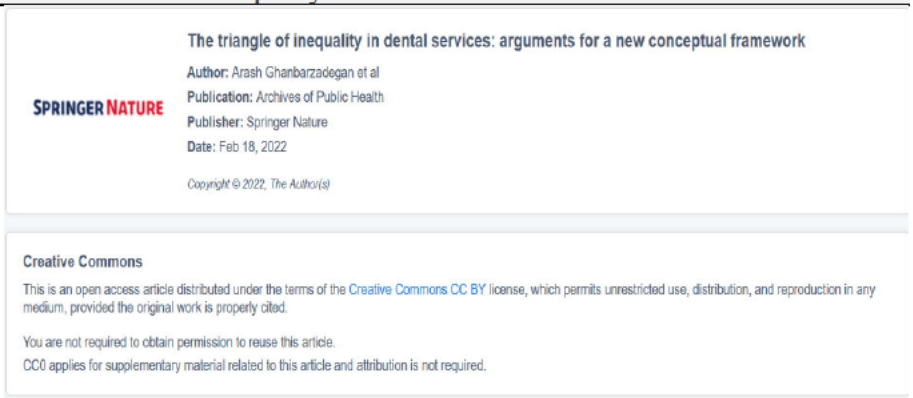
Linkage to the thesis

The studies of the previous two chapters are the most comprehensive review studies on inequality in dental services to date. Based on these findings, a conceptual model of inequality in dental services was designed for the first time. This model, called the *Triangle of Inequality*, shows how different aspects of inequality are related in the dental literature. Utilisation, provision and access are three known dimensions of inequality in dental services. Each of these dimensions has different determinants, which all should be considered.

Highlights

- Health policies as an upstream determinant determine the framework for the provision of dental services. These policies specify the distribution of the workforce, the coverage of public services, insurance coverage for dental services, eligible target groups, number and type of public service providers, and many other factors that determine the availability of dental services. Although availability of services is one of the most influential determinants of access to services, access has other determinants.
- Different dimensions of access, including the acceptability of services, financial and physical factors, determine access to services in conjunction with provision and utilisation.
- The dimensions of a Triangle of Inequality are intertwined, and each dimension may play a role in forming the dental inequality. Thus, policymakers need to consider these determinants together to reduce inequality.

Statement of Authorship for Commentary Paper 3

Title of Paper	The Triangle of Inequality in Dental Services
Publication Status	■ Published ☐ Accepted for Publication ☐ Submitted for Publication ☐ Unpublished and Unsubmitted work written in manuscript style
Publication Details	

Principal Author

Name of Principal Author (Candidate)	Arash Ghanbarzadegan		
Contribution to the Paper	Conceptualised the idea, Conceived the research question, designed the study, Analysed the data, Wrote the paper draft and conducted all revisions.		
Overall percentage (%)	75%		
Certification	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		Date	29/07/2022

Chapter 5 - **The Triangle of Inequality in Dental Services: Arguments for a New Conceptual Framework**

Co-Author Contributions

By signing the Statement of Authorship, each author certifies that:

I. the candidate's stated contribution to the publication is accurate (as detailed above);
II. permission is granted for the candidate in include the publication in the thesis; and
III. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

Name of Co-Author	Peivand Bastani		
Contribution to the Paper	Contributed in study designing, data analysis, drafting and revising the paper. Acted as the corresponding author for the publication process.		
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Chapter 5 - **The Triangle of Inequality in Dental Services: Arguments for a New Conceptual Framework**

Paper 3

Ghanbarzadegan *et al.*
Archives of Public Health (2022) 80:60
https://doi.org/10.1186/s13690-022-00826-1

Archives of Public Health

COMMENTARY Open Access

The triangle of inequality in dental services: arguments for a new conceptual framework

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Abstract

This short communication paper aimed to compile the main determinants of inequality in dental services by distinguishing between access, utilisation, and provision of dental services. Recent findings integrated, and a dedicated conceptual framework entitled "Triangle of inequality in dental services" has been suggested. These can contribute a rich knowledge in this area and open a new window for policymakers and researchers to seek applied interventions to decrease inequality and improve access and utilisation in communities. This paper aims to synthesise the available evidence and add value to the scope. It highlights a dedicated concept for inequality in dental services beyond other areas of public health.

Keywords: Access, Utilisation, Provision, Oral and dental health

Background

Oral health is integral to general health and wellbeing and is considered a global public health concern, particularly in many low- and middle-income countries (LMICs) [1]. Considering that oral disease is still a major public health burden worldwide with the greater global burden on the deprived and poor population [2], integrating oral health to general health globally can be among health policymakers' interests [3]. Moreover, the direct and lasting impact of oral health on general health makes the policymakers prioritise access to dental services by the whole community at the top of agenda-setting.

Lack of integration between oral health and global public health with a population health approach can lead to many health concerns. Inequality in providing and utilising dental services can worsen these concerns. According to the evidence, many social, economic, cultural and environmental determinants at the macro and micro levels along with meso elements related to insurance, providers and policies and practices are among the determinants that lead to inequality in the area of oral health in LMICs [4]. Inequality in utilisation of dental services even in developed countries is severe and influenced by many factors. Individual, social, economic, and cultural determinants are the main determinants of inequality in utilisation of dental services. In addition to this, health policies and availability of services are indicators of provision of dental services that lead to inequalities in such services [5]. For instance, changes in oral health policies during the COVID-19 pandemic with greater emphasis on providing emergency services at the peak of the outbreak, along with restricting non-emergency dental services, have significant impacts on the population's access and utilisation of dental services [6].

Evidence emphasises the necessity of policymakers' particular attention to appropriate access to dental services to decrease inequalities and improve the oral health of a given population. Despite identifying the above determinants, the nature of dental services is uniquely different from public health services. In other words, although oral health should be considered as part

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of global public health, because of the different nature of oral health and in particular dental services, inequality in dental services can be intensified and should be regarded as a serious concern. Therefore, it is essential that policymakers focus on a dedicated model to better understand inequality mechanisms in dental services. Some reasons can justify the necessity of such a model.

In the dental literature, access, utilisation and provision of dental services are terms often used interchangeably. However, to better address the determinants of inequality in dental services, it is essential to distinguish between these concepts. In health sciences, service utilisation is defined as the individual's preventive or curative service use; service provision deals with the process of providing services according to the available resources (human resources, physical capital and consumables) [5, 7]. Access to health services is the timely use of these services to achieve the best health outcomes both at individual and population levels [8].

Dental services are uniquely different from other public health and primary health care services. Dental services often have higher costs with limited comprehensive insurance coverage, so the out-of-pocket payments are relatively high for dental services. This creates a model of care that favours emergency dental visits. A cycle of delayed referrals, specialised needs and higher cost of these specialised services increases the gap in utilisation and therefore leads to a worsening oral health status at the population level [5].

The impact of community diversities in cultural, economic, social and health literacy on the utilisation of dental services should not be under-estimated [9]. Although this is a global issue, it should be formulated and customised according to different contexts, policymakers motivations, priorities and severity of the issue for any context.

A conceptual model is helpful in highlighting the principal elements and strategic points that better facilitate timely and appropriate dental service provision. Such a model should integrate different concepts of access, utilisation and provision of dental services. It clarifies that more appropriate provision of quality services affects higher access and broader utilisation of the services. In addition, different aspects of access, such as physical, geographical, cultural and financial aspects, along with the acceptability of the services [10], lead to higher dental service utilisation, and as a result, a reduction in inequalities in dental services.

Conceptual framework

Ghanbarzadegan et al. (2021) previously introduced the *"Triangle of Inequality"* in dental services concept (Fig. 1) [5, 10]. As illustrated in Fig. 1, provision of dental services in the top of this hierarchy influences access

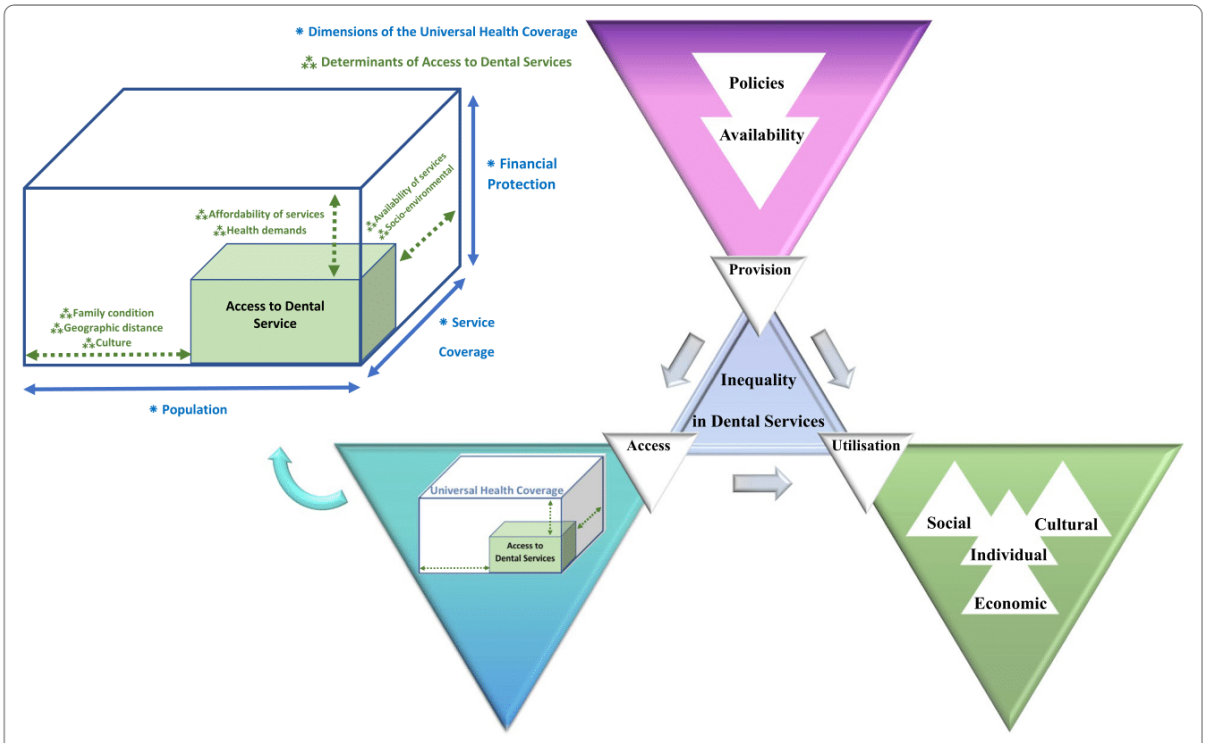

Fig. 1 Triangle of Inequality in dental services, introduced by Ghanbarzadegan et al. [5, 10]

and utilisation of services. In this framework, determinants of access to dental services are aligned with the Universal Health Coverage (UHC) dimensions, with the key to increasing access to dental services being to reduce the existing gap in dental services universal coverage. Each small triangle is also directed to another triangle to show how these determinants are intertwined. For example, in the framework of service provision, oral health policies influence the availability of services and these would define access to dental services from different perspectives such as availability, affordability or even geographic access. Providing need-based dental services at the affordable and acceptable prices improves the access to these services. Simultaneously, the provision of oral and dental services is affected by the availability of the services and oral and dental health policies. According to the triangle, if the services are provided and are accessible to the population, inequality will decrease only by developing service utilisation. This third item will be fulfilled considering the individual, cultural, social and economic determinants of the population.

Policymakers may move to a trade-off among these determinants according to the priorities, community's conditions, financial capability (e.g., GDP per capita allocated specifically for dental health provision), basic health benefit packages and insurance coverage of dental services. Also, in the access aspect of the model, the supply chain, which indicates the dental service providers, availability of human resources and equipment, can be effective along with the demand side of the population and its demographic characteristics as well other determinants of utilisation, provision and access to services previously discussed.

Conclusion

In conclusion, due to the unique nature of dental services and their differences with other health services, the lack of clear definitions of various dimensions of inequality in services and inappropriate and mistakenly interchangeable use of access, utilisation and provision concepts, there is a need to redefine these dimensions in dental services. The "triangle of inequality" as a conceptual model in dental services may assist in ameliorating inequalities in dental services by clarifying the concepts mentioned above and their determinants.

Abbreviation

LMIC: Low- and middle-income countries.

Acknowledgements

Not applicable.

Authors' contributions

AG and PB have designed and drafted the study, MB and DB have contributed in developing the conceptual framework and LJ has supervised the whole work. All the authors read and approved the final manuscript.

Funding

There was no funding.

Availability of data and materials

Are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

There were no competing interests.

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Received: 24 December 2021 Accepted: 8 February 2022
Published online: 18 February 2022

References

1. Peres MA, Macpherson LM, Weyant RJ, Daly B, Venturelli R, Mathur MR, et al. Oral diseases: a global public health challenge. Lancet. 2019;394(10194):249–60.
2. Petersen PE, Bourgeois D, Ogawa H, Estupinan-Day S, Ndiaye C. The global burden of oral diseases and risks to oral health. Bull World Health Organ. 2005;83:661–9.
3. Jin L, Lamster I, Greenspan J, Pitts N, Scully C, Warnakulasuriya S. Global burden of oral diseases: emerging concepts, management and interplay with systemic health. Oral Dis. 2016;22(7):609–19.
4. Bastani P, Mohammadpour M, Mehraliain G, Delavari S, Edirippulige S. What makes inequality in the area of dental and oral health in developing countries? A scoping review. Cost Effect Resour Allocation. 2021;19(1):1–12.
5. Ghanbarzadegan A, Bastani P, Luzzi L, Brennan D. Inequalities in utilization and provision of dental services: a scoping review. Syst Rev. 2021;10(1):1–11.
6. Jiang CM, Duangthip D, Auychai P, Chiba M, Folayan MO, Hamama HHH, et al. Changes in oral health policies and guidelines during the COVID-19 pandemic: University of British Columbia; 2021.
7. Carrasquillo O. Health care utilization. In: Gellman MD, Turner JR, editors. Encyclopedia of behavioral medicine. New York: Springer New York; 2013. p. 909–10.

8. Gulliford M, Figueroa-Munoz J, Morgan M, Hughes D, Gibson B, Beech R, et al. What does' access to health care'mean? J Health Serv Res Policy. 2002;7(3):186–8.
9. Evans DB, Hsu J, Boerma T. Universal health coverage and universal access. Bulletin of the World Health Organization. 2013;91:546–A.
10. Ghanbarzadegan A, Balasubramanian M, Luzzi L, Brennan D, Bastani P. Inequality in dental services: a scoping review on the role of access toward achieving universal health coverage in oral health. BMC Oral Health. 2021;21(1):1–11.

Chapter 5 - **The Triangle of Inequality in Dental Services: Arguments for a New Conceptual Framework**

Chapter 6 – Multiple Flexible Mediation Method

Chapter 6 - **Multiple Flexible Mediation Method**

Mediation Analysis

I was interested in investigating the inequality mechanisms in dental services. Thus, in empirical studies in chapters 7 and 8, I used mediation analysis. This chapter explains the method used in those studies in detail. In this chapter, I cover when to use meditation. Then, I look at the traditional methods in a linear setting. I present the counterfactual mediation as the statistical method of this thesis. Then, I continue this section by introducing the concepts and terminologies of the counterfactual theory, followed by the assumptions that need to be considered. I describe the Ratio of Mediator Probability Weighting (RMPW) approach to performing counterfactual mediation and how Marginal Structural Models can be widely used to parameterise the mediation effects. In the next step, I explain how to conduct this method in the presence of multiple mediators. Finally, I show why sensitivity analysis of unmeasured confounders is essential and how to run this for multiple mediators.

1. Mediation Paths

Research questions often involve mediating variables. For example, we may encounter questions such as the following:

- Does education lead to a change in oral health status and behaviours that leads to more dental service utilisation?
- Can income boost insurance coverage, which leads to eliminating the financial burden on receiving dental services?
- Do oral health habits lead to better oral health status that changes the reason for dental visits?

- If a household's income changes the eligibility to receive public dental services, do individuals' financial burden on receiving dental services change?

The above questions and similar questions, such as the ones in chapters 7 and 8 indicate a situation where an initial variable affects a mediating variable and ultimately affects an outcome variable. Analysis related to these questions where the interest is in decomposing the effect as the effect of exposure on the outcome and the effect of exposure through the mediator onto the outcome is referred to as the mediation analysis (MacKinnon et al. 2007). Directed Acyclic Graphs (DAGS) can be drawn to understand the ordering of variables. The DAG illustrates the directed causal relationships between sets of variables and allows researchers to understand under what assumptions these relationships imply causality (Foster 2010). For example, consider the simple path below, representing the exposure's effect on the outcome (Figure 1). This effect is both the direct and total average causal effect (ACE = *t*).

Figure 1. Simple Causal Path

Causal pathways are not as straightforward as depicted in the above example. However, there can be various confounding variables and mediators in between, such as potential confounders. Figure 2 illustrates a mediation DAG in the presence of mediators and confounders.

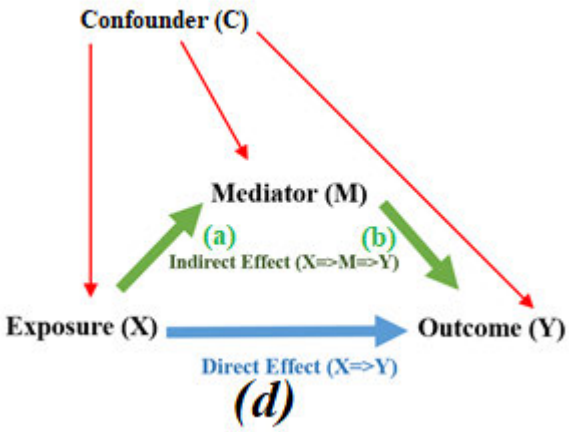

Figure 2. Mediation Path

2. Traditional methods

Statistical methods such as mediation analysis have been used since the 1980s to calculate the meditation effects (Baron and Kenny 1986; Judd and Kenny 1981).

According to Baron and Kenny, to quantify mediation effects (e.g. Figure 2), the total causal effect *(t)*, shown in Figure 1, decomposes into the effect of the exposure on the outcome, referred to as the direct effect *(DE= d)*, and the effect of exposure through the mediating variable on the outcome, referred as the indirect effect. The arrows labelled *(a)* and *(b)* together are the indirect/mediated effects. These effects are estimated by the below equations (Zhao et al. 2010):

$$M = \beta_1 + aX + e_1,$$
$$Y = \beta_2 + dX + bM + e_2,$$
$$Y = \beta_3 + tX + e_3.$$

The indirect effect can be measured in different ways. One approach is the product method, where the indirect effect equals the multiplication of estimates of the

regression model of *M* on *X* and the regression model of the outcome on exposure and mediator *(IE= a*b)*.

Another approach is the difference method, which is computed as the difference in the beta coefficients of the exposure obtained from the regression of *Y* on *X* and the regression coefficient of the regression *Y* on *X* and *M. (IE= t-d)*.

For the linear regression, the estimates computed using the product method or the difference method are equal. However, this may not be the case when these models include confounders, interactions, and non-linear terms. (Baron and Kenny 1986; Judd and Kenny 1981).

3. Counterfactual method

Several attempts have been made to overcome the above limitations of these methods, focusing on the notion of counterfactual or potential outcomes considering the cross-world assumptions explained in the following (Robins and Greenland 1992; VanderWeele and Vansteelandt 2009). These improvements are made to include computation of the mediation effects in a nonlinear setting which allows decomposition of the total effect into direct and indirect effects even in the presence of exposure-mediator interaction (Hong 2010; Imai et al. 2010; VanderWeele and Vansteelandt 2009). Since examining all statistical aspects of this approach is beyond the scope of this thesis, in this chapter, I am focusing on providing a summary of the solutions used in the following two chapters.

The principle of this framework is based on the counterfactual concept, which examines what would have happened if the situation had occurred was otherwise than what has actually been observed.

The outcome that may occur under counterfactual conditions is not actually observed and is therefore missing and unknown. This is called the counterfactual or potential outcome, with both terms used interchangeably. When the estimand of interest is risk difference, the causal effect can be expressed as the difference in the potential outcomes when their exposure is set to treated and untreated for the same individual and every individual in the population (VanderWeele 2015).

Measuring casual effects in perfect Randomized Clinical Trials (RCTs) would not be a problem because there is no confounding bias in the absence of measurement error from the instrument and the information bias. However, such studies are not always possible (e.g. ethical considerations, time and cost limitations), and one may be interested in obtaining a causal estimate and making causal inferences using data from observational studies. To accomplish this, some assumptions need to be satisfied (Cole and Hernán 2008, Gvozdenović et al. 2021):

Consistency (Ignorability): Having a well-defined exposure/treatment. This implies that the exposure/intervention should only define the exposure status and nothing else. This leads to a well-defined relation mapping between the potential outcome and the observed world.

Conditional exchangeability: Exposure/treatment assignment depends on covariates, and the probability of an outcome for different exposure levels with the same characteristic should be similar. This also means that there should be no unmeasured confounding.

Positivity: Conditional probability of treatment/exposure assignment should be more than zero. This means that regardless of individuals' characteristics, they should have a non-zero possibility of having their assigned level of treatment/exposure.

Faithfulness: there should be no cancellation of effects. This means that the observed DAG should be the true form of data generation;

The above assumptions on consistency, exchangeability, positivity and faithfulness are mostly related to how the potential outcome is defined, the distribution of the exposure and how the DAG is consistent with the real word data. However, we need a few more assumptions when it comes to mediation. These assumptions in the literature include that there should be no unmeasured confounder between exposure-outcome, exposure-mediator, and mediator-outcome. Also, there should be no exposure induced mediator outcome confounder (Imai et al. 2010).

Considering the potential outcome terminology, let X denote the exposure ($X= 0$ for unexposed and $X=1$ for exposed individuals) and let Y denote the outcome, then the observed outcome would be $Y(X)$, *where* $X= 0, 1$. The causal effect (*TCE*) at the individual-level (i) can be estimated by comparing $Y_i(1)$ to $Y_i(0)$, and the population average total causal effect would then be defined as:

$$ACE= E[Y(1)-Y(0)].$$

3.1 Counterfactual Mediation with a single mediator

Considering the existence of a mediator, let $M(x)=m$ *where* $x= 0, 1$ denotes the mediator distribution for exposed and unexposed individuals. Therefore, the nested potential outcome would be $Y(x, M(x))$ for different levels of exposure. Thus, the observed outcome in the unexposed group is denoted as $Y(0, M(0))$ and in the exposed group as

Y (1, M (1)) in the presence of a mediator. In such a case, *Y (1, M (0))* is one potential outcome, which denotes the counterfactual outcome of an exposed individual if the exposure does not change the mediator value to that under the exposure group and its value is counterfactually remained as that observed among the unexposed group.

Therefore, the **Natural Indirect Effect *(NIE)*** equals the population average effect of exposure on the outcome through exposure induced change in the mediator value when changing from *M (0) to M (1)* in the exposed group *(X =1):*

$$NIE= E[\ Y(1,\ M(1))\ -Y\ (1,\ M(0))]$$

Similarly, the **Natural Direct Effect *(NDE)*** is equal to the difference of the population average exposure effect on the outcome when *M* has the value of the unexposed individuals:

$$NDE= E[\ Y(1,\ M(0))\ -Y\ (0,\ M(0))]$$

and the **total effect** is equal to the sum of NIE and NDE:

$$\text{Total Causal Effect} = \text{NDE} + \text{NIE}$$

$$= E[\ Y(1,\ M(0))\ -Y\ (0,\ M(0))] +\ E[\ Y(1,\ M(1))\ -Y\ (1,\ M(0))]$$

$$= E[\ Y(1,\ M(1))\ -Y\ (0,\ M(0))]$$

These mediation formulas are not just limited to the any particular type of regression such as linear or logistic (Pearl 2011; 2013).

To calculate the natural mediation effect, we should deal with the missingness as the counterfactual outcomes such as *Y (1, M (0))* have not being observed in reality. To solve this issue, different solutions have been offered (Hong 2010; Lange et al. 2012;

Vansteelandt et al. 2012). In this case, by data expansion and conceiving a parallel pseudo-population dataset, an attempt is made to calculate the average population amount of counterfactual outcome. In this case, for each observed individual, a counterfactual counterpart with an exposure level of $X = x$, mediator value of $M(x')$ considering a counterfactual situation when the subject hold the other exposure value $(X = x' \text{ and } x' \neq x)$ and counterfactual outcome of $Y(x, M(x'))$ are being conceived. Therefore, in the presence of a binary exposure and a single mediator, the expanded data is twice (2^1) as large as the observed data.

Table 1- Schematic display of expanded dataset for the Ratio of Mediator Probability Weighting having a single mediator

Observed Dataset					**Extended Dataset**							
ID	Exposure (*X*)	Mediator (*M*)	Confounders (C)	Outcome (Y)	ID	Exposure (X)	Auxiliary exposure (X')	Mediator (M)	Mediator value for (X')	Confounders (C)	Outcome (Y)	RMPW (Randomized condition)
1	1	M (1)	*c*	Y (1, M (1))	1	1	1	M (1)	M (1)	*c*	Y (1, M (1))	1
2	0	M (0)	*c*	Y (0, M (0))	1	1	0	M (1)	M (0)	*c*	Y (1, M (0))	$\frac{\theta_{M(0)}(C)}{\theta_{M(1)}(C)}$
…	…	…	…	…	2	0	0	M (0)	M (0)	*c*	Y (0, M (0))	1
…	…	…	…	…	2	0	1	M (0)	M (1)	*c*	Y (0, M (1))	$\frac{\theta_{M(1)}(C)}{\theta_{M(0)}(C)}$
…	…	…	…	…	…	…	…	…	…	…	…	…

Table 1 is a schematic display of such an expanded dataset in the presence of counterfactual outcomes and a single mediator. In this regard, one solution is the Ratio of Mediator Probability Weighting (RMPW) approach by Hong and others (Hong 2010; Hong et al. 2015; Qin and Hong 2014).

3.2 Single mediator mediation measurement using RMPW

Marginal Structural Models (MSMs) have been used for the marginal expectation of potential outcomes in counterfactual mediation analysis to parameterise the natural effects (Lange et al. 2014, VanderWeele 2009). Here is a simple MSM for a single mediator mediation:

$$g(E[Y(x,M(x'))]) = \beta_0 + \beta_1 x + \beta_2 x'.$$

g is a link function and can be measured by different models (e.g., logistic) and accept weighting in the estimation process.

As MSMs deal with counterfactual outcomes and, as mentioned earlier, no-unmeasured confounding assumptions are necessary to be held. An MSM is marginal and not conditional on confounders, and it is different from a regression model such as the below:

$$g(E[Y(x,M(x'))]) = \beta_0 + \beta_1 x + \beta_2 x'.$$

However, if the data about confounding paths are available or in the case of time-varying exposure, an MSM can be measured using the Inverse Probability of Treatment Weighting (IPTW) approach (Robins 2000; Rosenbaum 1984). Using the IPTW, coefficients of such regression model (α_1, α_2) may correspond to the coefficients of the

MSM (β_0, β_1) in the presence of confounded exposure-outcome and mediator-outcome paths (VanderWeele 2009).

Hong (2010) showed when cross-world and unmeasured confounding assumptions satisfy, with propensity score-based weighting, the population average outcome equals:

$$E[Y(x, M(x))=E[W_X Y|X=x]$$

and

$$E[Y(x, M(x'))=E[WY|X=x]$$

Based on the IPTW, W_x is the ratio of the probability of being exposed or not being exposed under the control condition. $\theta_x(C)$ is the propensity score for the exposure assignment in the presence of covariates C, and if it is randomly assigned, then it equals one, otherwise:

$$W_x=\frac{pr(X=x)}{\theta_x(C)},\ Where\ \theta_x(C) = pr(X=x|C=c)$$

Therefore, to identify $E\,[Y\,(1, M\,(0)]$ by using RMPW the ratio of mediator probability-weight, for a discrete mediator equals (Hong 2010, Hong et al. 2015, Hong et al. 2018):

$$W= \frac{pr(X=1)}{\theta_1(C)} \times \frac{\theta_{M(0)}(C)}{\theta_{M(1)}(C)}$$

$Here\ \theta_{M(x)}(C) = pr(M=m|X=x, C=C),\ for\ X=0,1$ is the propensity score for the mediator assignment for the individuals with the mediator value m and characteristics C in the exposed group $(X=1)$.

And the exposure has been randomly assigned then it would simply equal to:

$$W= \frac{\theta_{M(0)}(C)}{\theta_{M(1)}(C)}$$

Therefore, it is possible to rewrite the natural mediation effects as follows:

$$NIE= E[W_1\ Y(X=1)]-E[WY(X=1)]$$

and

$$NDE= E[WY(X=1)]-E[W_0\ Y(X=0)].$$

3.3 Extension to multiple concurrent mediators with interaction

In practice, often more than one mediator may influence causal effects. It would be challenging because as the number of mediators and causal paths increase, the complexity of the model increases. Thus, having such a complex model makes it more difficult to decompose the natural effects.

In general, mediators can be concurrent or consecutive. They are concurrent if they are independent of each other under a given exposure/treatment condition. They can interact with each other; however, this independence means that a change in one mediator does not necessarily lead to changes in other mediators. Mediators are conservative if one of them precedes and its change leads to a change in the other mediators. Hong (2015) elaborated on these complex mediation mechanisms in her book entitled "Causality in a social world: Moderation, mediation and spill-over". This thesis focuses on the concurrent mediators, and in chapters seven and eight, mediation paths with three concurrent interacting mediators are examined.

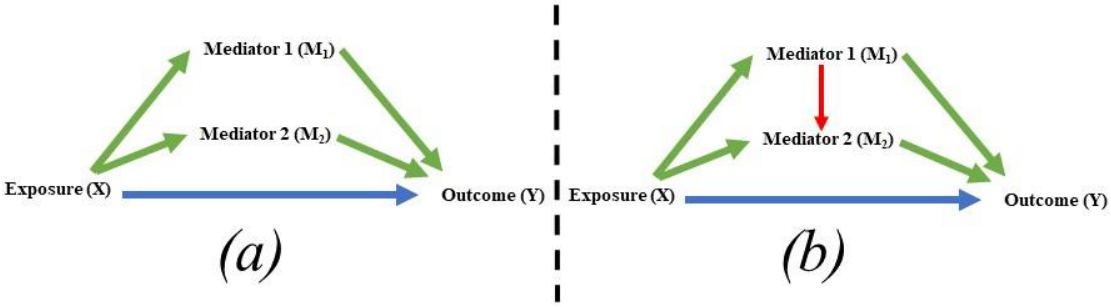

Figure 3- Multiple mediation paths with *(a)* and without *(b)* interaction between mediators

While there are several mediators, more assumptions should be satisfied. For convenience, a situation with two non-interacting and interacting mediators *(M_1, M_2)* have been discussed here. Figure 3 (a, b) shows these multiple mediation paths. However, measured and unmeasured confounders have not been drawn for ease of illustration. Therefore we can reintroduce the general cross-world assumptions mentioned earlier in another form that the 1- given the observed confounders *(C)*, assignment of exposure/treatment *(X)* should be independent of potential mediators and outcomes, 2- Given *X* and *C*, M_1 value assignment should be independent of potential outcomes, 3-Given *X* and *C*, M_2 value assignment should be independent of potential outcomes, and 4- Given *X* and *C*, M_1 and M_2 values should be independent of each other.

Under these assumptions, the total effect is:

$$E[\, Y(1, M_1(1), M_2(1)) - Y(0, M_1(0), M_2(0))]$$

and the direct effect *(X -> Y)* is:

$$E[\, Y(1, M_1(0), M_2(0)) - Y(0, M_1(0), M_2(0))]$$

the total indirect effect can decompose into the indirect effect through M_1 *(X -> M_1 -> Y)*:

$$E[\, Y(1, M_1(1), M_2(0)) - Y(1, M_1(0), M_2(0))]$$

and M_2 *(X -> M_2 -> Y)*:

$$E[\, Y(1, M_1(1), M_2(1)) - Y(1, M_1(1), M_2(0))] \qquad (a)$$

When there is no interaction between the mediators (figure 3 a), the above formula can be rewritten as following regardless of M_1 value:

$$E[\, Y(1, M_1(0), M_2(1)) - Y(1, M_1(0), M_2(0))] \qquad (b)$$

However, if M_1 affects M_2 (figure 3 b), the result of the second formula *(b)* would be greater than the other one *(a)*. This difference *(b - a)* reflects the indirect effect of M_1 on *Y* through M_2 *(X -> M_1->M_2 -> Y):*

$$E[\, Y(1,M_1(1),M_2(1)) - Y(1,M_1(1),M_2(0))] - E[\, Y(1,M_1(0),M_2(1)) - Y(1,M_1(0),M_2(0))].$$

Considering the above formulas, there are five potential outcomes to quantify the natural effects when there are two interacting mediators. Table 2 shows the parametric RMPW for the natural effects.

In the presence of multiple mediators (M_1-M_n), total propensity weight for all mediators (Total RMPW) equals the joint probability of the mediators, which is the multiplication of the propensity weights of each mediator when their values are being set to the auxiliary value of their counterfactuals (Table 2):

$$Total\ RMPW\ =\ RMPW\ for\ M_1 \times RMPW\ for\ M_2 \times \ldots \times RMPW\ for\ M_n.$$

Table 2- Parametric RMPW for the decomposition of the natural effects

Potential Outcome	Exposure (*X*)	Auxiliary exposure (*X'*)	Auxiliary exposure (*X''*)	Mediator value for $M_1(X')$	Mediator value for $M_2(X'')$	Confounders (*C*)	RMPW (Randomized condition) = RMPW for $M_1(X')$ × RMPW for $M2(X'')$
$E[Y(1, M_1(1), M_2(1))]$	1	1	1	M_1 (1)	M_2 (1)	*c*	1×1
$E[Y(1, M_1(0), M_2(0))]$	1	0	0	M_1 (0)	M_2 (0)	*c*	$\frac{\theta_{M_1(0)=M_1(C)}}{\theta_{M_1(1)=M_1(C)}} \times \frac{\theta_{M_2(0)=M_2(C)}}{\theta_{M_2(1)=M_2(C)}}$
$E[Y(1, M_1(1), M_2(0))]$	1	1	0	M_1 (1)	M_2 (0)	*c*	$1 \times \frac{\theta_{M_2(0)=M_2(C)}}{\theta_{M_2(1)=M_2(C)}}$
$E[Y(1, M_1(0), M_2(1))]$*	1	0	1	$M_1(0)$	M_2 (1)	*c*	$\frac{\theta_{M_1(0)=M_1(C)}}{\theta_{M_1(1)=M_1(C)}} \times 1$
$E[Y(0, M_1(0), M_2(0))]$	0	0	0	$M_1(0)$	M_2 (0)	*c*	1×1

*This needs to be considered as a potential outcome in case of M_1 -> M_2 interaction (formula *b*). Otherwise, the other four potential outcomes are enough to be considered.

3.4 Estimation approach for multiple concurrent mediators

Here is an example of a Marginal Structural Model with two concurrent mediators:

$$g(E[Y(X,M_1(X'),M_2(X'')]) = \beta_0 + \beta_1 X + \beta_2 X' + \beta_3 X''.$$

Exposure (*X*) and its auxiliary variables *(X', X'')* reflect the different direct and indirect causal pathways. Lange et al. (2014) introduced a unified method to measure the natural effects in the presence of multiple mediators. Having causal paths and interaction between the mediators (e.g., M_1 -> M_2 in Figure 3 b) is prevented in the Lange et al.

(2014) approach since it would be impossible to distinguish and decompose such effects. However, if someone is not interested in decomposing the indirect effects through the mediators, for example, into $X \rightarrow M_1 \rightarrow M_2 \rightarrow Y$, still can use this approach.

A generalised natural effect model in case of multiple mediators from M_1- M_n and axillary exposures X^1- X^n is:

$$g(E[Y(X,M_1(X^1),\ldots,M_n(X^n)]) = \beta_0 + \beta_1 X + \sum_{n=1}^{n} \beta_n X^n$$

This estimation for multiple concurrent mediators can run using the Lange et al. (2014) approach with the modified following steps:

1- Fit a model for mediators. These models should be conditional on exposure and pretreatment confounders. If there is a mediator interaction, the influenced mediators model should be conditional on the influencing mediators. For example, regarding Figure 3 b, a model for M_2 should be conditional on X, $M1$ and possible confounders. However, the indirect effect of $X \rightarrow M_1 \rightarrow M_2 \rightarrow Y$ will not be decomposed.

2- Construct an extended dataset containing new auxiliary exposures (Table 1). This could be done by repeating each observation K^n times for a discrete exposure and mediator and changing the auxiliary exposure value to a value other than observed each time. Here, K is the number of possible exposure values, and n is the number of auxiliary exposure which also equals the number of mediators. For example, for a binary exposure and three mediators, the extended dataset would be eight times the observed dataset.

3- Compute RMPWs using joint mediators' probabilities as described before (Table 2). This can be done using the *Predict* function in most software.

4- Fit a suitable outcome model conditioning on the exposure and auxiliary variables and possible confounders and interactions to estimate the natural effects and using the probability weights from the last step. One interested in the robust standard errors or bootstrap confidence intervals can easily obtain in most applications.

3. Sensitivity analyses for unmeasured confounding

The inference from the mediation analysis for observational data depends entirely on unmeasured confounding assumptions (Figure 4), which can easily be violated in real data. As the unmeasured confounding assumptions are difficult to attain when estimating the causal effect, sensitivity analyses for unmeasured confounding must be conducted.

Hong et al. (2018) offered a solution to measure this sensitivity via a parameter called *Sensitivity Bias* through a sensitivity analysis for causal mediation studies based on the RMPW approach.

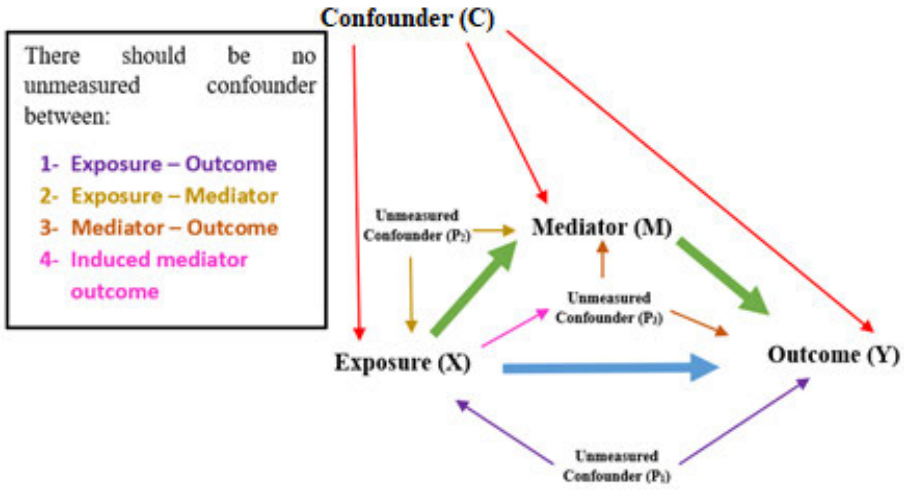

Figure 4. Pre-treatment unmeasured confounders

In reality, there may be an additional unmeasured pre-treatment covariate *P* which can confound the mediation paths independent of the observed covariate *C*. Assuming the existence of the potential unmeasured pre-treatment confounder *(P)*, the new propensity weight which helps identifying *E [Y (1, M (0))]* equals:

$$W_P = \frac{pr(X=1)}{\theta_1} \times \frac{\theta_{M(0)}(C,P)}{\theta_{M(1)}(C,P)}$$

One may estimate the *NIE* omitting the pre-treatment confounder *P*, and this would create a *Sensitivity Bias (SB)*, which equals the difference between *NIE* and NIE_P.

Hong et al. (2018) showed that this *Sensitivity Bias* for the unmeasured pre-treatment confounders *(P*) could be calculated by measuring the mediator's propensity weight discrepancy *(W_p - W)* between the new propensity weight (W_P *RMPW with considering P*) and the original propensity weight *W*.

$$SB_{NIE} = NIE - NIE_P$$

$$= \{E[W_1\, Y(X=1)] - E[WY(X=1)]\} - \{E[W_1\, Y(X=1)] - E[W_P Y(X=1)]\}$$

$$= E[(W_P - W), Y|X=1]$$

$$= cov(W_P - W, Y|X=1) + \underbrace{E[W_P - W|X=1]}_{formula\ c = E[W_p|X=1] - E[W|X=1] = 1-1=0} \times E[Y|X=1]$$

$$= cov(W_P - W, Y|X=1)$$

Formula c equals zero since each of the population average propensity weights (W_p, W) equals 1:

$$E[W|X=1]=\int_c \sum_m \frac{\theta_{M(0)}(c)}{\theta_{M(1)}(c)} \times pr(M=m|X=1,C=c) f(c|X=1)\, dc = \int_c \sum_m \theta_{M(0)}(c) f(c|X=1)\, dc$$

$$= \int_c 1 f(c|X=1)\, dc = 1.$$

As it is shown above, the $SB_{NIE} = cov\,(W_p - W,\ Y|X=1)$. Thus, this *Sensitivity Bias* regarding covariance definition is the product of the two other sensitivity parameters called *Sigma (σ)* and *Rho (ρ):*

$$SB_{NIE} = \sigma \times \rho$$

Here *Sigma (σ)* is the standard deviation of mediators' weights discrepancy $(W_p - W)$:

$$\sigma = \sqrt{var(W_P - W|X=1)}$$

and *Rho (ρ)* is the correlation between the mediators' weights discrepancy $(W_p - W)$ and the outcome:

$$\rho = corr\,(W_P - W, Y|X=1).$$

Referring to the NDE formula, it can be concluded that the bias for NDE has the same magnitude but on the opposite side:

$$SB_{NDE} = -\sigma \times \rho.$$

Hong et al. (2018) also stated that the sensitivity to omitting currently observed pre-treatment confounders *(C)* is an approximation of possible sensitivity in existence of unmeasured confounders *(P)*. Therefore, by eliminating observed confounders and

calculating the *Sensitivity Bias*, an estimation of sensitivity to the unmeasured confounders may be achieved. If the inference of mediation analysis for NIE and NDE is sensitive to eliminating currently observed pre-treatment confounders, then it can be concluded that the causal inference is also sensitive to an unmeasured confounder.

4. Current programs and packages

There are various statistical packages and software for causal meditation analysis such as *Medflex, Mediation* and *Mplus* (Muthén 1998; Steen et al. 2015; Tingley et al. 2014) and *RMPW* Package for mediation and sensitivity analysis (Hong et al. 2018), but at the time of writing this thesis, no package handles counterfactual mediation and sensitivity analyses using the RMPW approach in the presence of multiple interacting mediators. Therefore, as a strength of this thesis, mediation and sensitivity analyses were performed based on the RMPW approach. For the mediation analysis, the codes used in Lange et al. (2014) were modified, and for the sensitivity analysis, the functions used in the *RMPW* R package (Hong et al. 2018) were modified to suit the multiple interacting mediation paths. After calculating the estimates of the mediation analysis, for the sensitivity analysis, new propensity weights (W_p) for multiple mediators were measured. As shown earlier, the total weight equals the multiplication of each mediator's weight (joint probability). Therefore, the new total $RMPW_p$ for all mediators were measured using the discrepancy between the new $RMPW_p$ and the original RMPW; we calculated the sensitivity of our mediation analysis. All codes used in chapters 7 and 8 are available in appendix V.

References

Baron RM, Kenny DA. 1986. The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. Journal of Personality and Social Psychology. 51(6):1173.

Cole SR, Hernán MA. 2008. Constructing inverse probability weights for marginal structural models. American journal of epidemiology. 168(6):656-664.

Foster EM. 2010. Causal inference and developmental psychology. Developmental psychology. 46(6):1454.

Gvozdenović E, Malvisi L, Cinconze E, Vansteelandt S, Nakanwagi P, Aris E, Rosillon D. 2021. Causal inference concepts applied to three observational studies in the context of vaccine development: From theory to practice. BMC medical research methodology. 21(1):1-10.

Hong G. Ratio of mediator probability weighting for estimating natural direct and indirect effects. Proceedings of the American Statistical Association, Biometrics Section; 2010: American Statistical Association Alexandria, VA.

Hong G. 2015. Causality in a social world: Moderation, mediation and spill-over. John Wiley & Sons.

Hong G, Deutsch J, Hill HD. 2015. Ratio-of-mediator-probability weighting for causal mediation analysis in the presence of treatment-by-mediator interaction. Journal of Educational and Behavioral Statistics. 40(3):307-340.

Hong G, Qin X, Yang F. 2018. Weighting-based sensitivity analysis in causal mediation studies. Journal of Educational and Behavioral Statistics. 43(1):32-56.

Imai K, Keele L, Yamamoto T. 2010. Identification, inference and sensitivity analysis for causal mediation effects. Statistical science. 25(1):51-71.

Judd CM, Kenny DA. 1981. Process analysis: Estimating mediation in treatment evaluations. Evaluation review. 5(5):602-619.

Lange T, Rasmussen M, Thygesen LC. 2014. Assessing natural direct and indirect effects through multiple pathways. American journal of epidemiology. 179(4):513-518.

Lange T, Vansteelandt S, Bekaert M. 2012. A simple unified approach for estimating natural direct and indirect effects. American journal of epidemiology. 176(3):190-195.

MacKinnon DP, Fairchild AJ, Fritz MS. 2007. Mediation analysis. Annu Rev Psychol. 58:593-614.

Muthén L. 1998. Mplus user's guide. Muthén & muthén. Los Angeles, CA. 2010.

Pearl J. 2011. The mediation formula: A guide to the assessment of causal pathways in nonlinear models. California Univ Los Angeles Dept of Computer Science.

Pearl J. Direct and indirect effects. arXiv preprint arXiv:1301.2300. 2013 Jan 10.

Qin X, Hong G. 2014. Causal mediation analysis in multi-site trials: An application of ratio-of-mediator-probability weighting to the head start impact study. JSM Proceedings, Social Statistics Section.912-926.

Robins JM. 2000. Marginal structural models versus structural nested models as tools for causal inference. Statistical models in epidemiology, the environment, and clinical trials. Springer. p. 95-133.

Robins JM, Greenland S. 1992. Identifiability and exchangeability for direct and indirect effects. Epidemiology.143-155.

Rosenbaum PR. 1984. The consequences of adjustment for a concomitant variable that has been affected by the treatment. Journal of the Royal Statistical Society: Series A (General). 147(5):656-666.

Steen J, Loeys T, Moerkerke B, Lange T, Vansteelandt S. Medflex: Flexible mediation analysis using natural effect models in r. UK Causal Inference Meeting; 2015.

Tingley D, Yamamoto H, Kentaro M, Princeton H, Keele L. 2014. State p, imai k. Mediation: R package for causal mediation analysis. Journal of Statistical Software.

VanderWeele TJ. 2009. Marginal structural models for the estimation of direct and indirect effects. Epidemiology.18-26.

VanderWeele T. 2015. Explanation in causal inference: Methods for mediation and interaction. Oxford University Press; 2015 Feb 13.

VanderWeele TJ, Vansteelandt S. 2009. Conceptual issues concerning mediation, interventions and composition. Statistics and its Interface. 2(4):457-468.

Vansteelandt S, Bekaert M, Lange T. 2012. Imputation strategies for the estimation of natural direct and indirect effects. Epidemiologic Methods. 1(1):131-158.

Zhao X, Lynch Jr JG, Chen QJJocr. 2010. Reconsidering baron and kenny: Myths and truths about mediation analysis. 37(2):197-206.

Chapter 7- Income-based Inequalities in Dental Service Utilisation

Chapter 7- **Income-based Inequalities in Dental Service Utilisation**

Linkage to the thesis

According to Chapter 5, health policies are at the top of the inequality triangle hierarchy. Health policies define the framework for the provision of dental services, and consequently, provision determinants create the foundation of access to services through its various dimensions of acceptability, physical and availability. Accordingly, statistical mediation models in this chapter assessed whether Australian health policies could ultimately reduce the financial burden and increase economic access to services by introducing facilitators such as insurance, concession cards, and public services.

Highlights

- Income disparities can double avoidance or delay in dental services, regardless of the status of the facilitators.
- Elimination of income disparities is unattainable, but it remains to be seen why these facilitators have not reduced the financial burden of dental services.

Note: Supplementary information of the paper in this chapter at the end of the chapter however R codes are available in appendix V.

Statement of Authorship for Paper 4

Title of Paper	Income-based Inequalities in Dental Service Utilisation: A Multiple Mediation Analysis
Publication Status	■ Published ☐ Accepted for Publication ☐ Submitted for Publication ☐ Unpublished and Unsubmitted work written in manuscript style
Publication Details	COMMUNITY DENTISTRY AND ORAL EPIDEMIOLOGY ORIGINAL ARTICLE | Open Access **Income-based inequalities in dental service utilization: A multiple mediation analysis** Arash Ghanbarzadegan, Murthy Mittinty, David S Brennan, Lisa M Jamieson First published: 09 June 2022 | https://doi.org/10.1111/cdoe.12767

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Name of Principal Author (Candidate)	Arash Ghanbarzadegan		
Contribution to the Paper	Conceptualised the idea, Conceived the research question, designed the study, Analysed the data, Wrote the paper draft and conducted all revisions. Acted as the corresponding author for the publication process.		
Overall percentage (%)	75%		
Certification	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		Date	29/07/2022

Co-Author Contributions

By signing the Statement of Authorship, each author certifies that:

I. the candidate's stated contribution to the publication is accurate (as detailed above);
II. permission is granted for the candidate in include the publication in the thesis; and
III. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

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Contribution to the Paper	Contributed in study designing, conceiving the research question, data analysis, drafting and revising the paper. Supervised the study.		
Signature		Date	28/07/2022

Paper 4

Received: 19 August 2021 | Revised: 24 May 2022 | Accepted: 27 May 2022

DOI: 10.1111/cdoe.12767

COMMUNITY DENTISTRY AND ORAL EPIDEMIOLOGY WILEY

ORIGINAL ARTICLE

Income-based inequalities in dental service utilization: A multiple mediation analysis

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Funding information
Arash Ghanbarzadegan is supported by the University of Adelaide International Scholarship. Data gathered from the Dental Care, and Oral Health Study (DCOHS) was analysed in this study. DCOHS was supported by National Health and Medical Research Council (NHMRC) CRE grant (1031310). The contents are solely the responsibility of the administering institution and authors and do not reflect the views of NHMRC

Abstract

Objectives: With elimination of the financial burden of dental services, one can expect an increase in utilization of dental services. This study aimed to investigate the effective mechanisms of financial barriers to the utilization of dental services in an Australian adult population.

Methods: South Australian survey data from the Dental Care and Oral Health Study (2015) were analysed. Following the flexible mediation approach, the direct effect of income and indirect effect of income through mediators (insurance, concession card and service sector) on the outcomes (visit avoidance and treatment prevention due to the cost) were calculated.

Results: Findings showed that around half of the low-income people and one-third of the high-income South Australians experienced a financial burden on receiving a dental visit or service. The indirect effect of income on both outcomes of financial burden was negligible, while the direct effect was significant. By changing the potential outcome distribution to their counterfactual exposure distribution and if the mediators are drawn from their counterfactual exposure (lower/higher income) distribution, the odds of visit avoidance and treatment prevention due to the cost were almost twice (Odds Ratio: 2.13, 95% CI 1.72–2.60) and 98% (Odds Ratio: 1.98, 95% CI 1.67–2.35) than in the lower-income individuals, respectively.

Conclusions: It can be concluded that the level of household income, directly and regardless of insurance status, concession card ownership and whether the service sector was public or private, affected the financial burden on utilization of dental services.

KEYWORDS
Australia, dental health services, healthcare disparities, insurance, private sector, public sector, socioeconomic factors

1 | INTRODUCTION

Universal Health Coverage (UHC) is one of the sustainable development goals (SDG) demanded by almost all countries.[1,2] Despite the high burden of oral disease, universal coverage of dental services has faced many challenges in most countries.[3]

Ghanbarzadegan et al.[4] introduced the conceptual framework of the '*triangle of inequality*' in dental services, which includes

access to services, utilization and provision of services. In this conceptual framework, determinants such as insurance coverage, distribution of public dental services and dental services tariffs define the availability and affordability of services within the framework of service provision, which eventually defines access to dental services. In this conceptual framework, access itself is aligned with the UHC cube.[5] The UHC cube illustrates how access inequalities should be tackled from different perspectives, such as the amount of financial support, the proportion of eligible services and people covered by the UHC scheme. Together and not separately, these intertwined socioeconomic determinants may promote the utilization of dental services. In contrast, inequality in any of these dimensions, in addition to the individual, sociocultural factors, may lead to inequality in the utilization of dental services.[6] Therefore, eliminating the reasons for not using dental services seems necessary to improve UHC and utilization of dental services. There are several reasons for not using dental services, one of which is financial barriers to the utilization of dental care.[4,6,7]

Policymakers are considering ways to remove financial barriers to utilization of dental services worldwide, including introduction of public insurance, private insurance subsidies, development and extension of public dental services.[6]

In Australia, for example, supportive health policies are primarily limited to insurance rebates for people with private insurance and public dental services for people who have concession cards. However, these services target a small proportion of adults, and around 80 per cent of services in Australia are delivered in the private sector.[8,9]

Various studies have demonstrated a contrast between Australian public and private dental care provision. Although public services cover a wide range of general and specialized services with a small cost, resource constraints within the public sector cause long waiting times.[10] Provision of services within the public sector in Australia leans more towards extractions and emergency care than prevention and tooth maintenance treatments.[11] Considering that prioritizing resource constraints is undeniable, public dental services in Australia only cover people who have a concession card. Eligible concession cards vary in each state and eligible people include vulnerable groups, such as the elderly, low-income or unemployed individuals. However, public dental services are not available to other vulnerable people in the community who do not have a concession card and are not eligible.[12]

Introduction of insurance schemes has been considered another solution in Australia. The government pays a 30% insurance rebate for people who have private insurance. However, only around half of Australians have some sort of private dental health insurance, and therefore, a significant proportion of services and people are not covered.[9,13,14] Hopkins et al. investigated the relationship between utilization of dental services and insurance status in Australia between 1995 and 2001.[15] They found a greater prevalence of dental visits in insured individuals and suggested that Australian private insurance coverage has increased service utilization. However, they declared that this might increase access inequalities among insured and uninsured individuals. This is consistent with Harford and Spencer, who reported that the Australian government's private insurance scheme more favourably targeted higher-income groups.[16]

Due to the lack of studies investigating financial barriers to dental services, the mechanisms of the impact of financial barriers on the avoidance or delay of dental services are still unclear. Notably, a knowledge gap exists on these barring mechanisms in the public and private sectors.

This study aimed to investigate income-related factors that are associated with avoiding or delaying dental service utilization for Australian adults in the public and private sectors. The research question of interest was 'Does income inequality lead to a different choice of service provision sector (Public or private dental service provider) that leads to a decrease in financial burden of dental services (visit/treatment)?' An additional question was whether this mediation would be influenced by other income mediators such as insurance and concession card ownership (Figure 1).

2 | METHODS

This retrospective cross-sectional study utilized baseline data from the Dental Care and Oral Health Study (DCOHS) study, which was conducted in 2015 by the Australian Research Centre for Population Oral Health (ARCPOH) at the University of Adelaide.[17]

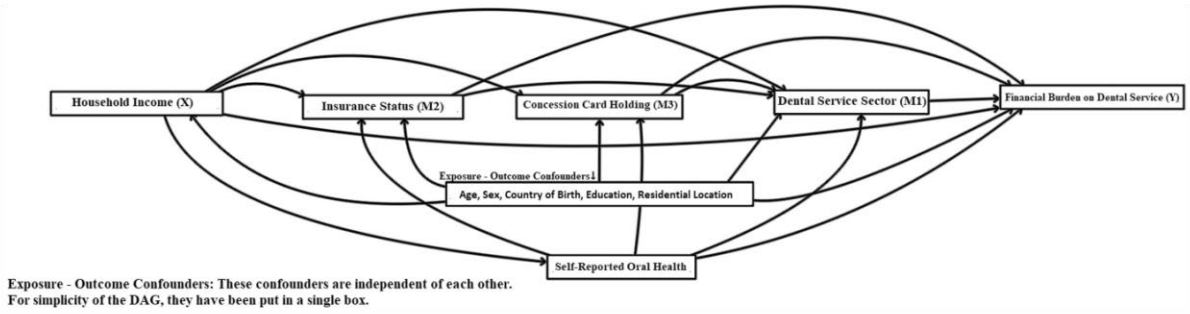

FIGURE 1 Directed Acyclic Graph illustrating the data analysis of the mediation analysis

Questionnaires were sent by email and post to 12245 South Australians from June to November 2015. A total of 4494 responses were received. After adjusting for out-of-scope participants (not residing at listed addresses), the response rate was 44.6%. Data were weighted based on the distribution of age by sex and according to South Australia residential population estimates in 2015 provided by the Australian Bureau of Statistics.

The identity of participants and their information remained confidential. Ethical approval was obtained from the University of Adelaide HREC (H-288-2011).

2.1 | Variables of interest

Household income (Exposure variable)

Participants were asked about their sum of untaxed income from all persons in the household including a range of ten categories (coded as 1–10) with the interval between each category being 20000 Australian Dollars (AUD). Categories were from less than 20000 AUD (initial code was 1) to more than 180000 AUD (initial code was 10). In the analysis, income was dichotomised where ≥80000 AUD was coded as 0 and <80000 AUD coded as 1.

Dental service sector (Mediator 1)

Participants were asked about the sector of the last dental visit choosing between private dental practice (=1) and public dental clinics (=2, including dental hospitals and community clinics).

Insurance status (Mediator 2)

Participants were asked if they had a private insurance coverage excluding the public social health coverage (i.e., Medicare). They responded no (=1) and yes (=2) to this question.

Concession card ownership (Mediator 3)

Participants were asked if they owned any concession cards (including Health Care Card, Pensioner Concession Card, Commonwealth Seniors Card or any other card). From their responses, a new variable named Concession Card Holding (CCH) status was created. If their answer to any of the questions asked was yes, CCH Status was considered to be positive (yes = 2) and otherwise negative (no = 1).

In South Australia, CC holders are the only eligible group to use public adult dental services. However, for several reasons, they may choose to visit the private sector. This current variable is their concession card holding status, while information about which dental sector they actually attended (public or private) was gathered through the Dental Service Sector variable.

Delayed/Avoided dental visits (Outcome for Model 1)

Participants were asked if they had avoided or delayed visiting a dental professional because of cost during the past 12 months (yes = 1, no = 0).

Prevented Treatments (Outcome for Model 2)

Participants were asked whether they had been prevented from accepting a dentist's recommended dental treatment due to cost (yes = 1 and no = 0).

Confounders

Age

Year of birth was collected, with participants' age in 2015 calculated and categorized into three ordinal groups including 18–39 years old (=0), 40–59 years old (=1) and greater than or equal to 60 years old (=2).

Sex

Participants were recorded as male (=0) or female (=1).

Country of birth

Participants were asked about their county of birth, whether Australia (=0) or another country (=1).

Education

Participants were asked about their highest level of education. Options included from no schooling to completed a university degree or tertiary education. If the participant had a university degree, it was coded as university degree/ tertiary education (=1), with other levels of education coded as less than or equal to 12 years of studying (=0).

Residential location

Recorded postcodes were divided into two major categories: greater Adelaide area (Capital area = 0) and the rest of South Australia (Non-capital areas = 1).

Self-reported oral health

Participants were asked to rate their oral health on a 5-point Likert scale (very poor, poor, good, very good, excellent). Responses

were dichotomised as poor (=0, including very poor and poor responses) and good to excellent (=1, including the remaining responses).

As shown in Figure 1, previous confounders were adjusted in all exposure, mediator and outcome paths. However, self-reported health status was considered an induced mediator outcome confounder and was adjusted in mediators' models.

2.2 | Statistical Analysis

To study the effects of income on the financial burden of dental services, we assumed the following simplistic view of the data generating mechanism shown in Figure 1. The directed acyclic graph (DAG) in Figure 1 is usually referred to as the mediation DAG. Confounders included in the analyses and Figure 1 were independent of each other, and only for a simplistic visualization, were they collated into a single box.

Mediation analysis allows studying mechanisms in which exposure affects the outcome through mediators. Following the counterfactual theory proposed by Greenland and Robins[18] and using the Ratio of Mediator Probability Weighting (RMPW) approach,[19,20] we decomposed the effects of income on the financial burden of dental services into the direct and indirect effects (through multiple mediators).

In the counterfactual theory, the total causal effect of the exposure on the outcome (Model 1: avoided dental visits by costs and Model 2: Dental treatments prevented or delayed due to the cost) can be decomposed into the direct and indirect effects. The direct effect expresses the effect of income (changing from high income to low income) on the risk of financial burden on dental services, as it would have been observed if the distribution of the mediators resembled the higher-income people. The indirect effect would express the change in financial burden on dental services when the distribution of the mediators changed to what it would be for lower-income people.

To estimate these direct and indirect effects, we used Marginal Structural Models (MSMs) using the *geeglm* function (family: '*binomial*') from the *Geepack* package and for the mediators model, we used Generalized Linear Models and *glm* function (family: '*binomial*') in R.

This mediation analysis was carried out under four assumptions of unmeasured confounding: a) there should be no unmeasured confounding between exposure and the outcome, b) there should be no unmeasured confounding between the mediator and the exposure, c) there should be no unmeasured confounding between the outcome and the mediator, and d) there should be no exposure induced mediator outcome confounder.

The analysis is not free from the issues of missing data. To handle missing data, we used multiple imputations using the *Mice* package in R. Most of the variables of interest were initially dichotomised. Household income (less/greater than or equal to 80000 AUD), education (year 12/ having a diploma or a degree) and self-reported oral health (bad/good to excellent) were also dichotomised to reduce bias due to individuals' misclassifications.

For double robustness, our models included confounders, including age, sex, country of birth, education, residential location and self-reported oral health. To achieve the bootstrap assessment of estimation uncertainty and repeated measurement of the participants, the code was run with 1000 repetitions. All the estimates were calculated with 95% confidence intervals. All analyses were conducted using RStudio version 1.3.1056 and R version 4.0.4. The R code used in this paper is available in the Appendix S1.

2.3 | Sensitivity Analysis

Sensitivity analysis was performed to determine whether the presence of unmeasured confounders violated the conclusion of inference and the findings. The weighting-based approach introduced by Hong et al.[21] was adopted for conducting the sensitivity analysis. As their method and R package were designed for a single mediator mediation, we have modified it to suit multiple mediation approach by calculating the total mediators' weights and the weight discrepancy between the new weight after omitting an observed confounder and the initial calculated weight. The consequent '*sensitivity bias*' due to omitting currently observed confounders (age, sex, education, country of birth, residential location and education oral health interaction) is comparable to some potential unmeasured confounders. In this approach, three sensitivity parameters were calculated: σ is the standard deviation of mediators' weights discrepancy; ρ is the correlation between the mediators' weights discrepancy and the outcome. Consequently, the sensitivity bias is the multiplication of σ and ρ.

3 | RESULTS

Results are reported based on the weighted imputed sample. Distribution details of all variables are given in Table A of the Appendix S1. The mean age of the population was 48.1 ± 18.2 years, with 51.0% being female. Almost 60% of the population had an income of less than 80000 AUD. The rate of delayed visits (Model 1) and prevented treatments (Model 2) due to cost was 36.3% and 44.0%, respectively, in the population. An unadjusted bivariate analysis depicted a significant association between the exposure and outcomes in both models (Pearson Correlation of the chi-square table: −0.12 and −0.15, p-value <0.001 for Model 1 and 2, respectively). To clarify, 29.2% of high-income individuals reported an avoided dental visit (Model 1) because of cost; in contrast, it was 41.6% in the lower-income group. In Model 2, with a similar pattern, 34.5% of higher-income individuals compared to 50.7% of lower-income individuals, reported prevented dental treatments due to cost. More details of the bivariate analysis are available in Table B in the Appendix S1. Table C in the Appendix S1 also includes cross-tabulationa between the exposure and the mediators.

Table 1 shows that the mediators' total indirect effects were small in both models. However, the direct effect of income was evidently significant in both models. The odds ratio (OR) of the direct effect was 2.13 (95% CI 1.72, 2.60) for avoided or delayed dental visits (Model 1) and 1.98 (95% CI 1.67, 2.35) for prevented treatments (Model 2). According to these findings, if the potential outcome distribution of each individual changes to their counterfactual exposure distribution and their mediators are drawn from their counterfactual exposure (lower/higher income) distribution, then the odds of experiencing financial burden on receiving dental visits or services will be almost twice (lower compared to the higher-income group).

Table 2 shows the total effect and effect decomposition of mediation effects. The total effect was 2.01 (95% CI 1.70, 2.37) for Model 1 and 1.89 (95% CI 1.63, 2.22) for Model 2. Decomposing the total indirect shows that the odds ratio for each mediator is very close to 1 in both models. According to these findings, most of the total effect results from the total direct effect of income. Figure A in the Appendix S1 illustrates the odds ratios as shown in Table 2.

Bias due to omitting the currently adjusted confounders was measured for both models. Based on the sensitivity analysis, omitting any of the observed confounders did not change the conclusion of statistical inference. Hence, the mediation analysis is not sensitive to any single unmeasured confounder bias (Table D & E in the Appendix S1). There is a possibility that the results could be biased for a cumulative unmeasured confounder bias. However, the interaction with the two measured confounders with higher biases (Education * Oral Health Status) did not change the statistical inference.

4 | DISCUSSION

According to the research question, these findings support that income status reduces the financial burden on the utilization of dental services. However, the analysis found no effect of insurance and concession cards on the financial burden of dental service utilization.

Other researchers have reported various factors associated with the utilization of dental services.[14,15,22] For example, Srivastava et al.[23] using the 2004–06 Australian National Survey of Oral Health, declared that dental service use was 43% higher in insured individuals than uninsured Australians.

The findings of the study showed that the indirect effect was negligible (OR≈1), which means that in the studied population, the level of household income through mediators is ineffective in avoidance or prevention of dental visits and treatments. In fact, regardless of the status of the mediators (i.e., insurance status, CCH status and service sector), the status of the outcomes will be the same among groups with different levels of income.

This is a challenging finding. Individuals with insurance, ownership of a concession card and those attending the public dental sector may be expected to receive more services.[14,15,22,23] However, the findings of this study should be used to determine whether these factors alone or in conjunction with income level are causally influential on the financial burden of dental services. The negligible effect of insurance may be due to the fact that most insurance coverage includes basic hospital services. In addition, governmental benefit packages also include less expensive dental services. With regard to concession card ownership, this analysis is more challenging because a concession cardholder can receive dental services at a lower cost in the public sector. So, the question arises as to why having a card had a negligible effect on the financial burden of dental service utilization? Concession cards may not work correctly for various reasons, such as the fact that the card owners are not adequately targeted or the service coverage is insufficient to reduce the financial burden of dental service utilization. Only around 20% of eligible people actually receive public dental service in Australia. Waiting lists are too long.[22] According to the data in Table B (Appendix S1), around 38.4% of participants had a concession card. These figures were 58.8% for low-income and 10.7% for high-income individuals. Furthermore, 7.0% of higher-income people received public services. This confirms that

TABLE 1 Direct effect of income (direct effect) and the total mediating effect of income through the service sector, concession cards and insurance (total indirect effect) on the financial burden of dental services (avoided or delayed visits and treatments)

	Model 1	Model 2
	OR (95% CI)	
Direct effect of income (Reference: ≥80000 AUD)	2.13 (1.72, 2.60)	1.98 (1.67, 2.35)
Total indirect effect of income through all mediators	0.94 (0.85, 1.06)	0.95 (0.90, 1.03)
Age 40–59 year (Reference: 18–39 year)	1.15 (0.93, 1.42)	1.26 (1.03, 1.56)
Age ≥ 60 year (Reference: 18–39 year)	0.43 (0.35, 0.54)	0.66 (0.53, 0.81)
Sex (Reference: Male)	1.36 (1.15, 1.63)	1.29 (1.09, 1.52)
Education (Reference: ≤Year12/Certificate)	0.86 (0.72, 1.04)	0.74 (0.63, 0.88)
Country of birth (Reference: Australia)	1.18 (0.96, 1.46)	1.55 (1.24, 1.91)
Residential location (Reference: Capital area)	1.18 (0.98, 1.47)	1.11 (0.91, 1.35)

Note: Model 1, Avoided or delayed dental visit by cost; Model 2, Prevented dental treatment by cost.

Abbreviations: CI, confidence intervals; OR, odds ratio.

TABLE 2 Effect decomposition of the total effect income on the financial burden of dental services (avoided or delayed visits and treatments) into the direct effect and the total mediating effect of income through the service sector, concession cards and insurance (total indirect effect)

	OR (95% CI)
Model 1	
Income 2 (High) → 1 (Low)	
Direct effect	**2.13 (1.72, 2.60)**
Indirect effect of income through dental service sector (M1)	**1.00 (0.91, 1.12)**
Indirect effect of income through insurance status (M2)	**0.97 (0.96, 0.98)**
Indirect effect of income through concession card holding status (M3)	**0.97 (0.96, 0.98)**
Total effect	**2.01 (1.70, 2.37)**
Model 2	
Income 2 (High) → 1 (Low)	
Direct Effect	1.98 (1.67, 2.35)
Indirect effect of income through dental service sector (M1)	1.00 (0.94, 1.08)
Indirect effect of income through insurance status (M2)	0.97 (0.96, 0.98)
Indirect effect of income through concession card holding status (M3)	0.98 (0.97, 0.99)
Total effect	1.89 (1.63, 2.22)

Note: **Model 1, Avoided or delayed dental visit by cost; Model 2, Prevented dental treatment by cost.**

Abbreviations: CI, confidence interval; OR, odds ratio.

the distribution and utilization of public dental services were not equitable. In addition, data in support of an existing inequality are the magnitude of the direct effect of income; this shows the odds of a dental visit, or service avoidance is almost twice in lower-income individuals than those in the higher income group.

Findings showed that some high-income individuals had access to the concession cards and utilized public services. Insurance also had insufficient coverage with limited dental services included. These are some of the possible structural factors which show why these mediators could not reduce the financial burden of dental services.

Only one-fifth of eligible people can eventually use public services.[9] This means that besides reviewing the current processes, increasing the efficiency of the public sector and increasing insurance coverage, concession cards may be other effective solutions.[24,25] This transformation would face many challenges, and various factors must be considered. Finland, for example, implemented a health transformation plan in 2001–2002 to include subsidized dental services. Although the plan successfully reduced inequality in the short term, inequality indicators in 2007 returned to pre-2001 levels. In such situations, considering the visiting patterns and norms is essential.[26]

To the best of our knowledge, no similar study has examined the mechanisms of financial barriers to dental services with a similar methodology. Another strength of this counterfactual multiple mediation analysis was the sensitivity analysis using the Ratio of Mediator Probability Weighting (RMPW) approach. Despite the robust method and the sensitivity analysis, this study had some limitations. Dichotomisation may lead to information loss, but it assists researchers and policymakers have a better insight with a direct interpretation when we have potential outcomes. On the contrary, if we have a continuous-valued variable, then the corresponding counterfactual values are a distribution compared to a single value, thus posing a challenge in defining randomized trials in the real world. Moreover, the decomposition effect obtained using a continuous exposure could be difficult to interpret. For these reasons, we dichotomised most of the variables. Hence, the findings should be interpreted with caution as they may be sensitive to the cut point used in exposure dichotomisation.

A second limitation was that the data used in this study are from a single cross-sectional sample survey where some of the measures are self-reports and can be subjected to measurement errors. Currently, there is no software or methods for handling measurement error in natural effect mediation models. Therefore, estimates must be interpreted with caution. For estimating the causal effects, future studies must be designed as longitudinal studies as they will be helpful in capturing the time-varying and time-dependent confounding more appropriately. To establish the true causality, we encourage researchers to investigate these mechanisms in other data if it is similar to the one described in this study.

In conclusion, the level of household income, regardless of the status of insurance status, CCH status and service sector, was the most important factor in dental visits avoidance and treatment prevention in the current analysis. Although the level of government support for adult dental services in Australia compared to other health services is minimal, the amount did not reduce the financial burden of utilizing dental services. These findings indicate that the role of private insurance in the Australian healthcare system, alongside other government subsidies such as concession cards and public dental services eligibility, should be reviewed. According to income significant direct effect, policymakers should review the income distribution and equity within the communities.

ACKNOWLEDGEMENT

DB, LJ, MM and AG designed the study. DB collected data and led the survey team. AG and MM analysed the data. All authors wrote and revised the manuscript. We acknowledge all participants of the Dental Care and Oral Health Study.

CONFLICT OF INTEREST

LJ is one of the Journal of Community Dentistry and Oral Epidemiology associate editors.

DATA AVAILABILITY STATEMENT

Research data are not shared.

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REFERENCES

1. World Health Organization. *Positioning Health in the Post-2015 Development Agenda*. WHO; 2012.
2. Vega J. Universal health coverage: the post-2015 development agenda. *Lancet*. 2013;381(9862):179-180.
3. Peres MA, Macpherson LM, Weyant RJ, et al. Oral diseases: a global public health challenge. *Lancet*. 2019;394(10194):249-260.
4. Ghanbarzadegan A, Bastani P, Balasubramanian M, Brennan D, Jamieson L. The triangle of inequality in dental services: arguments for a new conceptual framework. *Arch Public Health*. 2022;80:1-4.
5. World Health Organization. *The World Health Report: Health Systems Financing: the Path to Universal Coverage: Executive Summary*. World Health Organization; 2010.
6. Ghanbarzadegan A, Bastani P, Luzzi L, Brennan D. Inequalities in utilization and provision of dental services: a scoping review. *Syst Rev*. 2021;10(1):1-11.
7. Ghanbarzadegan A, Balasubramanian M, Luzzi L, Brennan D, Bastani P. Inequality in dental services: a scoping review on the role of access toward achieving universal health coverage in oral health. *BMC Oral Health*. 2021;21(1):1-11.
8. Teusner D, Spencer A. *Dental Labour Force, Australia 2000*. Australian Institute of Health and Welfare (Media and Publishing Unit); 2003.
9. Australian Institute of Health and Welfare 2020. *Australia's National Oral Health Plan 2015–2024: Performance Monitoring Report in Brief*. AIHW; 2020 Cat. No. DEN 234.
10. Biggs A. *Overview of Commonwealth Involvement in Funding Dental Care*. Department of Parliamentary Services, Parliamentary Library; 2008.
11. Brennan D, Spencer A. Trends in service provision among Australian private general dental practitioners over a 20-year period. *Int Dent J*. 2006;56(4):215-223.
12. Collyer F, Willis K, Keleher H. The private health sector and private health insurance. In: Willis E, Reynolds L, Rudge T, eds. *Understanding the Australian Health Care System*. Elsevier Health Sciences; 2019:Vol 37.
13. Teusner D, Brennan D, Spencer A. Associations between level of private dental insurance cover and favourable dental visiting by household income. *Aust Dent J*. 2015;60:479-489.
14. Brennan DS, Luzzi L, Roberts-Thomson KF. Dental service patterns among private and public adult patients in Australia. *BMC Health Serv Res*. 2008;8(1):1-8.
15. Hopkins S, Kidd MP, Ulker A. Private health insurance status and utilisation of dental services in Australia. *Econ Rec*. 2013;89(285):194-206.
16. Harford J, Spencer AJ. Government subsidies for dental care in Australia. *Aust N Z J Public Health*. 2004;28(4):363-368.
17. Song Y. *Dentist-Patient Relationships and Oral Health-Related Quality of Life*. The University of Adelaide; 2020.
18. Greenland S, Robins JM. Identifiability, exchangeability, and epidemiological confounding. *Int J Epidemiol*. 1986;15(3):413-419.
19. Lange T, Rasmussen M, Thygesen LC. Assessing natural direct and indirect effects through multiple pathways. *Am J Epidemiol*. 2014;179(4):513-518.
20. Steen J, Loeys T, Moerkerke B, Vansteelandt S. Medflex: an R package for flexible mediation analysis using natural effect models. *J Stat Softw*. 2017;76(11):1-46.
21. Hong G, Qin X, Yang F. Weighting-based sensitivity analysis in causal mediation studies. *J Educ Behav Stat*. 2018;43(1):32-56.
22. Brennan DS, Spencer AJ, Slade GD. Service provision among adult public dental service patients: baseline data from the commonwealth dental health program. *Aust N Z J Public Health*. 1997;21(1):40-44.
23. Srivastava P, Chen G, Harris A. Oral health, dental insurance and dental service use in Australia. *Health Econ*. 2017;26(1):35-53.
24. Pilotto LM, Celeste RK. Contextual determinants for use of dental services according to different healthcare financing systems: Andersen's model. *Community Dent Oral Epidemiol*. 2022;50:99-105.
25. Somkotra T, Detsomboonrat P. Is there equity in oral healthcare utilization: experience after achieving universal coverage. *Community Dent Oral Epidemiol*. 2009;37:85-96.
26. Raittio E, Kiiskinen U, Helminen S, Aromaa A, Suominen AL. Income-related inequality and inequity in the use of dental services in f inland after a major subsidization reform. *Community Dent Oral Epidemiol*. 2015;43:240-254.

SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

How to cite this article: Ghanbarzadegan A, Mittinty M, Brennan DS, Jamieson LM. Income-based inequalities in dental service utilization: A multiple mediation analysis. *Community Dent Oral Epidemiol*. 2022;00:1-7. doi: 10.1111/cdoe.12767

Table A –Variables of interest distributions among the different sample population

	Response Sample (n=4494)		Weighted Sample (n=4494)		Imputed Weighted Sample (n=4494)
	All responses (n=4494)	Complete Cases (n=3831)	All responses (n=4494)	Complete Cases (n=3836)	
Age (years)					
18 - 39	946(21.0)	843(22.0)	1649(36.7)	1449(37.8)	1649(36.7)
40 - 59	1720(38.3)	1532(40.0)	1516(33.7)	1355(35.3)	1516(33.7)
≥60	1828(40.7)	1456(38.0)	1329(29.6)	1031(26.9)	1329(29.6)
Sex					
Male	1976(44.0)	1695(44.2)	2203(49.0)	1899(49.5)	2203(49.0)
Female	2517(56.0)	2136(55.8)	2290(51.0)	1937(50.5)	2291(51.0)
Country of Birth					
Australia	3464(77.1)	3028(79.0)	3575(79.6)	3137(81.8)	3641(81.0)
Other Countries	936(20.8)	803(21.0)	827(18.4)	699(18.2)	853(19.0)
Missing	94(2.1)	---	92(2.0)	---	---
Income (AUD) (Exposure)					
≥80,000	1640(36.5)	1601(41.8)	1774(39.5)	1732(45.2)	1907(42.4)
<80,000	2420(53.8)	2230(58.2)	2291(51.0)	2104(54.8)	2587(57.6)
Missing	434(9.7)	---	429(9.5)	---	
Education					
≤Year12/Certificate	2689(59.8)	2250(58.7)	2622(58.3)	2183(56.9)	2682(59.7)
Diploma/Degree	1713(38.1)	1581(41.3)	1784(39.7)	1653(43.1)	1812(40.3)
Missing	92(2.0)	---	88(2.0)	---	---
Residential Location					
Capital area	3373(75.1)	2899(75.7)	3474(77.3)	2983(77.8)	3474(77.3)
Non-capital area	1121(24.9)	932(24.3)	1020(22.7)	853(22.2)	1020(22.7)
Self-Reported Oral Health					
Poor	534(11.9)	437(11.4)	511(11.4)	419(10.9)	517(11.5)
Good to Excellent	3924(87.3)	3394(88.6)	3953(88.0)	3417(89.1)	3977(88.5)
Missing	36(0.8)	---	30(0.6)	---	---
Dental Visit Avoidance (Outcome one)					
No	2873(63.9)	2476(64.6)	2837(63.1)	2441(63.6)	2861(63.7)
Yes	1570(35.0)	1355(35.4)	1612(35.9)	1395(36.4)	1633(36.3)
Missing	51(1.1)	---	46(1.0)	---	---
Cost Prevented Treatments (Outcome two)					
No	2432(54.1)	2120(55.3)	2489(55.4)	2158(56.3)	2516(56.0)
Yes	2001(44.5)	1711(44.7)	1951(43.4)	1678(43.7)	1978(44.0)
Missing	61(1.4)	---	53(1.2)	---	---
Dental Service Sector (Mediator one)					
Private	3778(84.1)	3354(87.5)	3696(82.2)	3295(85.9)	3783(84.2)
Public	599(13.3)	477(12.5)	677(15.1)	541(14.1)	711(15.8)
Missing	117(2.6)	---	121(2.7)	---	---
Private Insurance Status (Mediator two)					
No	1295(28.8)	1047(27.3)	1359(30.2)	1100(28.7)	1376(30.6)
Yes	3157(70.3)	2784(72.7)	3092(68.8)	2736(71.3)	3118(69.4)
Missing	42(0.9)	---	43(1.0)	---	---
Concession Card Holding Status (Mediator three)					
No	2554(56.8)	2301(60.1)	2747(61.1)	2475(64.5)	2769(61.6)
Yes	1909(42.5)	1530(39.9)	1710(38.1)	1361(35.5)	1725(38.4)
Missing	31(0.7)	---	37(0.8)	---	---

Note: Data reported as the number of cases (Percent), Missing cases less than five have not been reported.

Table B. Distribution of individuals who reported an avoided or delayed dental visits or treatments across the exposure, mediators and confounders variables

		Delayed/Avoided dental visits (Model 1)			Prevented Treatments (Model 2)		
		No	Yes	Total	No	Yes	Total
Income	High	1350 (70.8)	558 (29.2)	1908 (100.0)	1232 (64.6)	676 (35.4)	1908 (100.0)
	Low	1511 (58.4)	1075 (41.6)	2586 (100.0)	1285 (49.7)	1302 (50.3)	2587 (100.0)
Dental Service Sector (M1)	Private	2515 (66.5)	1269 (33.5)	3784 (100.0)	2202 (58.2)	1581 (41.8)	3783 (100.0)
	Public	347 (48.8)	364 (51.2)	711 (100.0)	315 (44.3)	396 (55.7)	711 (100.0)
Private Insurance Status (M2)	No	604 (43.9)	772 (56.1)	1376 (100.0)	556 (40.4)	820 (59.6)	1376 (100.0)
	Yes	2257 (72.4)	861 (27.6)	3118 (100.0)	1960 (69.9)	1158 (37.1)	3118 (100.0)
Concession Card Holding Status (M3)	No	1770 (63.9)	999 (36.1)	2769 (100.0)	1608 (58.1)	1162 (41.9)	2770 (100.0)
	Yes	1091 (63.2)	634 (36.3)	1725 (100.0)	909 (52.7)	816 (47.3)	1725 (100.0)
Age (years)	*18 - 39*	996 (60.4)	653 (39.6)	1649 (100.0)	949 (57.6)	700 (42.4)	1649 (100.0)
	40 - 59	885 (58.4)	631 (41.6)	1516 (100.0)	767 (50.6)	749 (49.4)	1516 (100.0)
	≥60	980 (73.8)	348 (26.2)	1328 (100.0)	800 (60.2)	529 (39.8)	1329 (100.0)
Sex	Male	1466 (66.6)	736 (33.4)	2202 (100.0)	1304 (59.2)	899 (40.8)	2203 (100.0)
	Female	1395 (60.9)	897 (39.1)	2292 (100.0)	1212 (52.9)	1079 (47.1)	2291 (100.0)
Country of Birth	Australia	2328 (63.9)	1314 (36.1)	3642 (100.0)	2102 (57.7)	1539 (42.3)	3641 (100.0)
	Outside Australia	533 (62.6)	319 (37.4)	852 (100.0)	414 (48.6)	438 (51.4)	852 (100.0)
Education	≤Year12/Certificate	1661 (61.9)	1021 (38.1)	2682 (100.0)	1422 (53.0)	1260 (47.0)	2682 (100.0)
	Diploma/Degree	1201 (66.3)	611 (33.7)	1812 (100.0)	1095 (60.4)	717 (39.6)	1812 (100.0)
Residential Location	Capital area	2234 (64.3)	1241 (35.7)	3475 (100.0)	1957 (56.3)	1517 (43.7)	3474 (100.0)
	Non-capital area	627 (61.5)	392 (38.5)	1019 (100.0)	559 (54.8)	461 (45.2)	1020 (100.0)
Oral Health	Poor	162 (31.3)	355 (68.7)	517 (100.0)	135 (26.1)	382 (73.9)	517 (100.0)
	Good to Excellent	2699 (67.9)	1278 (32.1)	3977 (100.0)	2381 (59.9)	1596 (40.1)	3977 (100.0)

Count (% within rows)

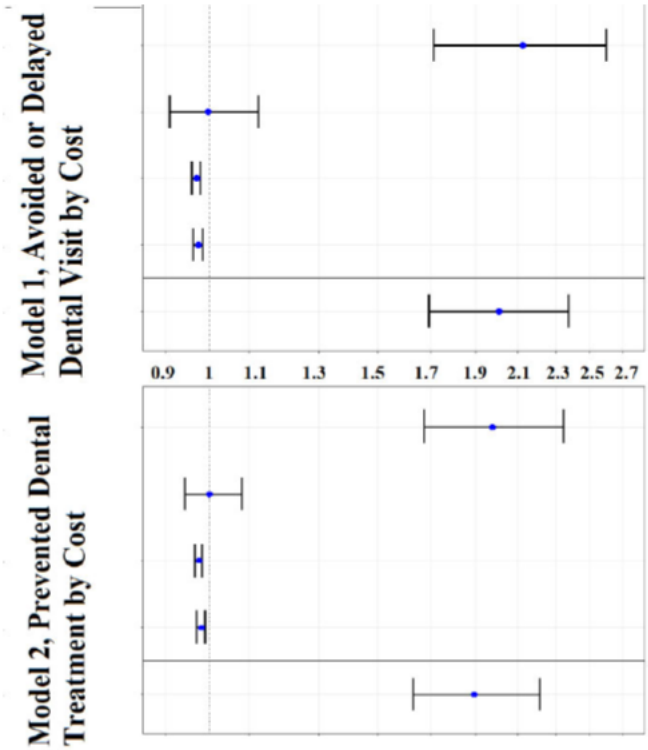

Figure A- Effect decomposition of the total effect income on the financial burden of dental services (avoided visits or treatments because of cost) into the direct effect and the total mediating effect of income through the service sector, concession cards and insurance (total indirect effect) showing the odds ratio for natural effect models

Table C. Bivariate table of income and mediators

		Dental Service Sector (M1)			Private Insurance Status (M2)			Concession Card Holding Status (M3)		
		Private	Public	Total	No	Yes	Total	No	Yes	Total
Income	High	1774 93.0%	133 7.0%	1907 100.0%	289 15.1%	1619 84.9%	1908 100.0%	1703 89.3%	204 10.7%	1907 100.0%
	Low	2009 77.7%	578 22.3%	2587 100.0%	1087 42.0%	1500 58.0%	2587 100.0%	1066 41.2%	1521 58.8%	2587 100.0%

Table D. Sensitivity analysis of pre-treatment confounders. Mode1

			Effect Size of NIE			Effect Size of NDE		
	σ	Ƥ	Bias	Modified OR	Modified OR (95% CI)	Bias	Modified OR	Modified OR (95% CI)
Age	0.477	0.046	0.022	0.984	[0.965, 1.004]	-0.022	1.718	[1.443, 2.052]
Sex	0.022	0.005	0	1.006	[0.986, 1.026]	0	1.680	[1.413, 2.010]
Education	0.052	-0.001	0	1.006	[0.986, 1.026]	0	1.680	[1.413, 2.010]
Oral Health	0.089	0.145	-0.013	0.993	[0.973, 1.013]	-0.013	1.702	[1.430, 2.034]
Country of Birth	0.038	0.005	0	1.006	[0.986, 1.026]	0	1.680	[1.413, 2.010]
Residential location	0.053	0.005	0	1.006	[0.986, 1.026]	0	1.680	[1.413, 2.010]
Education* Oral Health	0.107	0.128	0.014	0.992	[0.972, 1.012]	-0.014	1.704	[1.432, 2.036]

Note: Model 1, Avoided or Delayed Dental Visit by Cost; OR, Odds Ratio; CI, Confidence Intervals; σ = standard deviation of weight discrepancy; Ƥ= correlation between the weight discrepancy and the outcome; Bias= σ *Ƥ; NIE, Natural Indirect Effect; NDE, Natural Direct Effect.

Table E. Sensitivity analysis of pre-treatment confounders. Model2

			Effect Size of NIE			Effect Size of NDE		
	σ	Ƥ	Bias	Modified OR	Modified OR (95% CI)	Bias	Modified OR	Modified OR (95% CI)
Age	0.477	-0.012	-0.006	1.013	[0.997, 1.029]	0.006	1.667	[1.422, 1.966]
Sex	0.022	-0.017	0	1.008	[0.991, 1.024]	0	1.677	[1.429, 1.976]
Education	0.052	-0.003	0	1.007	[0.991, 1.023]	0	1.677	[1.429, 1.976]
Oral Health	0.089	0.126	0.011	0.996	[0.980, 1.012]	-0.011	1.695	[1.446, 2.000]
Country of Birth	0.038	0.018	0.001	1.006	[0.990, 1.023]	-0.001	1.679	[1.430, 1.978]
Residential location	0.053	-0.008	0	1.008	[0.991, 1.024]	0	1.677	[1.429, 1.976]
Education* Oral Health	0.107	0.110	0.012	0.995	[0.979, 1.011]	-0.012	1.697	[1.448, 2.000]

Note: Model 2, Prevented Dental Treatment by Cost; OR, Odds Ratio; CI, Confidence Intervals; σ = standard deviation of weight discrepancy; Ƥ= correlation between the weight discrepancy and the outcome; Bias= σ *Ƥ

Chapter 8 – Education effect on Dental Services Utilisation Patterns in Different Sectors

Chapter 8 - **Education effect on Dental Services Utilisation Patterns in Different Sectors**

Linkage to the thesis

In this chapter, the same approach as the previous chapter was used to examine how individual-level determinants affect the acceptability of using services from the access angle of the triangle and consequently affect another angle of the triangle of inequality, service utilisation. Also, it was examined how health policies from the provision angle which construct the availability of public services, may modify this path. From this perspective, it was examined how education through behavioural mediators such as tooth brushing, smoking and oral health status affect dental services utilisation patterns. The effect modification of service sectors (Public or Private) on these mediation paths was additionally examined.

Highlights

- Lower educational attainment is associated with higher odds of emergency and treatment visits in comparison with routine dental check-ups or examinations.
- Low education, regardless of the status of behavioural mediators (smoking and tooth brushing) and oral health, leads to less dental service utilisation.
- This adverse situation improves among people who attend public services.

Note: Supplementary information of the paper in this chapter is available in appendix V.

Statement of Authorship for Paper 5

Title of Paper	Education effect on Dental Services Utilisation Patterns in Different Sectors: A Multiple Mediation Analysis
Publication Status	☐ Published ☐ Accepted for Publication ■ Submitted for Publication ☐ Unpublished and Unsubmitted work written in manuscript style
Publication Details	Ghanbarzadegan, A., Mittinty, M., Brennan, D., Jamieson, L. Education effect on Dental Services Utilisation Patterns in Different Sectors: A Multiple Mediation Analysis. Submitted to Community Dentistry and Oral Epidemiology Journal, January 2022.

Principal Author

Name of Principal Author (Candidate)	Arash Ghanbarzadegan		
Contribution to the Paper	Conceptualised the idea, Conceived the research question, designed the study, Analysed the data, Wrote the paper draft and conducted all revisions. Acted as the corresponding author for the publication process.		
Overall percentage (%)	75%		
Certification	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		Date	29/07/2022

Chapter 8 - **Education effect on Dental Services Utilisation Patterns in Different Sectors**

Co-Author Contributions

By signing the Statement of Authorship, each author certifies that:

I. the candidate's stated contribution to the publication is accurate (as detailed above);
II. permission is granted for the candidate in include the publication in the thesis; and
III. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

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Paper 5

The effect of education on Dental Service Utilisation Patterns in Different Sectors: A Multiple Mediation Analysis

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Conflict of interest: LJ is one of the associate editors of the Community Dentistry and Oral Epidemiology Journal.

Funding: AG supported by the University of Adelaide International Scholarship. Data gathered from the Dental Care, and Oral Health Study was analysed in this study. This study was supported by National Health and Medical Research Council (NHMRC) CRE grant (1031310). The contents are solely the responsibility of the administering institution and authors and do not reflect the views of NHMRC.

Ethical consideration: Ethical approval was provided for the original survey from the University of Adelaide Human Research Ethics Committee (H-288-2011) and is aligned with the Helsinki Declaration.

Data Availability: Research data are not shared, but the codes used and responses to the reviewers are publicly available in the supplement file.

Acknowledgment

DB, LJ, MM and AG designed the study. DB collected data and led the survey team. AG and MM analysed the data. All authors wrote and revised the manuscript. We acknowledge all participants of the Dental Care and Oral Health Study.

Chapter 8 - **Education effect on Dental Services Utilisation Patterns in Different Sectors**

Abstract

Objective

The aim of this study was to investigate how education level affects dental service utilisation patterns in the Australian adult population. This study tested how education level mediated these service patterns through behavioural mediators such as smoking, tooth brushing and oral health status and investigated these mediation effects in different dental service providers.

Method

Following the flexible mediation approach, the direct and indirect effects of education through behavioural mediators on dental service utilisation patterns (time of last dental visit, reason for last dental visit and frequency of seeking dental care) were calculated for the South Australian population from the Dental Care and Oral Health Study.

Results

Participants with lower educational attainment were 33% (Odds Ratio: 0.67, 95% CI 0.56 - 0.78) and 38% (Odds Ratio: 0.62, 95% CI 0.53 - 0.74). less likely than their counterparts with higher education to visit a dentist or to receive dental care in the last 12 months, respectively. Low education was associated with a 23% increase in odds of receiving emergency and treatment services (Odds Ratio: 1.23, 95% CI 1.05 - 1.43) compared to routine dental check-ups or examinations

Conclusion

Low education, regardless of oral health behaviours and status, reduces the odds of dental service utilisation in terms of frequency of seeking dental care and time of last dental visit. There is more tendency towards receiving emergency and treatment

services compared to routine dental check-ups or examinations in participants with lower educational attainment.

Keywords

Education, Oral Health, Dentistry, Health literacy

Introduction

Dental diseases are among the most well-attended public health issues due to their universal prevalence and direct impact on quality of life[1]. Considering the importance of oral health as a major component of general health, this is also believed to be highly associated with socio-economic status[2]. Several studies have been implemented to outline socio-economic proxy factors affecting oral health, such as health literacy and education. Many studies have demonstrated the association between education and dental care utilisation worldwide[3-5].

In two comprehensive reviews, Ghanbarzadegan et al. (2021) examined various factors that lead to inequality in dental services. They considered three dimensions of utilisation, provision and access as different dimensions of inequality in dental services (*Triangle of Inequality in dental services*). In this model, education level impacts the two dimensions of access and utilisation of services. People with lower levels of education have less acceptance of dental services, affecting their service utilisation. Therefore, differences in education levels can lead to inequality in utilisation and access to dental care[6,7].

Ju et al. (2021), using a robust methodology, investigated the mediation mechanisms of education and oral health literacy and behaviours on tooth loss among Australian adults.

They found a 40% reduction in self-reported missing teeth among lower educated individuals[8].

These findings show the importance of education in achieving optimal oral health status. However, there is not enough knowledge on the mechanisms by which education may affect dental service patterns through behaviours and attitudes and how these mechanisms may vary in different service provider sectors. Understanding the outcome of these disparities may magnify the importance of education as one of the social determinants of health.

Therefore, the aim of this study was to measure the effect of education level on Australian adults' dental service utilisation patterns and investigate how these service patterns may be influenced by other mediating factors such as oral health habits (tooth brushing and smoking) and oral health status. These service patterns were the time of the last dental visit, dental visit reason and the frequency of dental visiting. Also, how these mediation paths may be modified in different dental service provider sectors was tested by testing the effect modification of attending public or private sectors on the mediation paths of education and service utilisation patterns.

Methods

Baseline data collected from the Dental Care and Oral Health Study (DCOHS) were used. DCOHS was a state dental survey conducted from 2015 to 2019 in South Australia. Self-completed questionnaires were collected from randomly selected participants using the Australian Electoral Roll. Data were weighted by age and sex using the Australian Bureau of Statistics' 2015 population estimates to ensure estimates

were representative of the South Australian adult population. Out of 12,245 South Australians, with a response rate of 44.6%, 4,494 individuals participated in the survey by returning the questionnaire. More information on the DCOHS sampling method, size and power calculation is available in Song's PhD thesis (2020)[9]. Ethical approval was provided by the University of Adelaide Human Research Ethics Committee (H-288-2011), and the participants' identity and information were kept confidential.

Variables of interest

Figure 1 illustrates the thematic view of data analysis according to the research question. This Interaction Directed Acyclic Graph (IDAG) is a combination of two regular Directed Acyclic Graphs (DAG) in which one modifies the other[10]. IDAGs illustrate how interactions can modify causal mechanisms. To investigate how these mediated mechanisms of education (exposure) and oral health habits (mediators) on dental service utilisation (outcomes) differ in different service sectors (public versus private), the interaction of service sectors on these mediated paths (IDAG) was checked. The main DAG (i.e., mediation DAG) was drawn to test the direct and indirect effects of education level on dental service utilisation patterns (models 1, 2 and 3) through a mediation path. These mediators were tooth brushing habits, smoking and oral health status. In this mediation, it was hypothesised that the first two mediators influence the third (oral health status). How different service sectors modify these mediation effects (IDAG) was tested as well by measuring the effect modification of a baseline confounder (Service sector). According to Figure 1, we elaborate on the variables' definitions and ordering.

Education (Exposure)

The highest level of education was recorded. Categories were "*No schooling*", "*Completed primary school*", "*Some high school*", "*Completed High School*", "*Vocational training*", and "*University degree*" (including university degrees, diplomas and tertiary education). From a legal sense, it is compulsory to finish high school in South Australia unless approved in some circumstances (full-time work or starting vocational training, which is also captured in our study). Therefore, education was dichotomised into ≤12 Year/Certificate, including people with any level of high school or vocational training (Coded as 1) and >12 Year/Diploma (Coded as 0) for individuals with a diploma or university degrees.

Mediators

The mediation included three mediators as follows: Tooth Brushing (Mediator one), Smoking (Mediator two), and Oral Health Status (Mediator three). Information regarding tooth brushing habits was collected. Brushing at least once or more daily was coded as 1; if the daily brushing times were less than one, it was coded as 2. Participants were asked about their cigarette smoking status; participants who did not smoke were coded as 1, while those who did smoke were coded as 2. Participants were asked to rate their dental health and choose from each of these categories: *"Very poor", "Poor", "Good", "Very Good", and "Excellent"*. Self-reported oral health status of participants was dichotomised as poor when their responses were *"Very poor" or "Poor"* and coded as 2; otherwise, it was recorded as good and coded as 1.

Outcomes

Our models include three outcomes related to dental visiting patterns: Last dental visit (Outcome for model one), Reason for visit (Outcome for model two), and Frequency of dental care (Outcome for model three). Participants were asked about the last time they visited a dental professional (including dentist, dental specialist, oral health therapist, dental hygienist, dental therapist, dental technician, denturist or dental prosthetist). When it was less than 12 months ago, responses were coded as 0 and other times were coded as 1. If the main reason for the last dental visit was for an emergency or treatment, it was coded as 1; for examination or check-up, it was coded as 0. Participants were asked how often they seek care from a dental professional; at least once annually, responses were coded as 1 and otherwise coded as 0.

Confounders

The confounder variables included in the mediation models were the last dental service sector (private=0, public =1), Age (18-39 years old =0, 40-59 years old =1, and greater than or equal to 60 years old=2), Gender (male=0, female=1), Country of Birth (Australia=0, Other=1), Residential location (greater Adelaide area =0, other places=1), Hosehold untaxed income (≥$80,000 =0, <$80,000=1) and self-reported general health status (good=0, poor=1).

As education levels influence the households income, we have not adjusted our outcome models for income. However, to calculate the mediators' probability weights, two of the mediators' models, oral health status and smoking, were adjusted for income.

Statistical Analysis

The counterfactual analysis compares what happened and what would have happened at different levels of exposure. It measures what happened and what would have happened if we went back in time and gave the same person the same or different exposure. Counterfactual Meditation Analysis is one of the approaches that can be used to analyse the mechanisms between exposure and outcome through mediators. In these analyses, it is necessary to consider a series of cross-world assumptions. These assumptions are described below and are based on the fact that there should not be any unmeasured confounder violating the mediation pathways. In addition to this, when there are several mediators which affect each other (as in Figure 1), these assumptions are violated. Therefore, the flexible mediation method with multiple mediators approach[11,12], which is an extension of Counterfactual mediation analysis[13], was used to overcome this problem by not decomposing this as individual pathways but using the joint analogues effects. With this approach, the total effect is decomposed into direct and indirect effects. The direct effect is the change in the outcome when everyone in the population who had their exposure level switched from higher to lower education level, but the distribution of the mediators was set to those of higher educated individuals. In the same way, the indirect effect expresses the change in the dental service utilisation patterns when the exposure has been set to that of the lower educated group, but the distribution of the mediators changed to what it would be of the lower educated individuals[11,12,14].

Finally, the effect modification of different provider sectors as a baseline confounder in our different marginal structural models (*Geeglm* * Provider Sector) was measured.

This accounted for the impact of education levels on the mediation paths in the public and private sectors.

Dichotomising multicategory variables may cause homogeneity and loss of information. Although this study followed a robust methodology, most of the variables were dichotomised for various reasons. Several concepts are hard to visualise when using a c continuous-valued exposure with the potential outcome approach. On the other hand, a binary exposure has a clear and direct interpretation as it corresponds to the randomised trials exposed and control groups. For example, suppose that the exposure is a dichotomous variable that takes values 1 and 0; when the patient/individual in the observed data is exposed ($X = 1$), their counterfactual value which the exposure can take is the not exposed state, ($X = 0$). However, if the observed exposure is a continuous-valued variable, then the corresponding counterfactual values are a distribution compared to a single value. Using a whole distribution of potential outcomes can be challenging both in terms of interpretation as well as defining randomised trials corresponding to the distribution. Second, as we are using the mediator weights, these will be from the density functions, which can be unstable. Similar to exposure effect interpretation, the decomposition effect interpretation can be complex too.

Inference from the analysis and findings have no causal interpretation in the presence of unmeasured confounders. Therefore, this study was conducted under the assumption that there should be no unmeasured confounder between exposure-outcome, exposure-mediator, mediator-outcome, and no exposure-induced mediator outcome confounder. For this reason, sensitivity analysis was carried out to understand the nature of the

unmeasured confounders[15]. Hong et al. (2018) introduced weighting-based sensitivity analysis in causal mediation studies by calculating the propensity weights of mediators. In this approach, bias due to omitting currently adjusted confounders (i.e., observed pre-treatment confounders) can be an approximate prediction of probable unmeasured confounders[16]. This possible bias can be measured by step-by-step elimination of observed confounders and by calculating the difference in the new and previous mediators' distribution weights. They introduced two sensitivity parameters that estimate the bias size. By this bias estimate size, the new effect estimates affected by unmeasured confounders can be calculated. This bias size equals the multiplication of two sensitivity parameters, Sigma (σ: standard deviation of mediators' weights discrepancy) and Rho (ρ: correlation between the mediators' weights discrepancy and the outcome). The original approach and their R package are for models with one mediator. As mediation paths in this study included multiple mediators and interactions, Hong's codes were modified, and the mediators' weight discrepancy was calculated by multiplying each mediator's weight discrepancy and calculating the total mediators' weights.

All analyses were conducted using *RStudio* version 1.3.1056 and *R* version 4.0.4. To handle missingness, a multiple imputation technique was utilised using the *Mice* package. Mediation effects were measured by the *Geepack* package, and all three models were adjusted for confounders (service sector, age, gender, income, general health status, country of birth and residential location). Bootstrap assessment was done with 1000 repetitions and estimates were reported with 95% confidence intervals. R codes for mediation analysis are available in the supplement file.

Results

Findings are based on the imputed weighted sample. The mean age was 48.1 ± 18.2 years, with 49.0 % being male. Individuals with a higher education level (having a university degree) were 59.5 % of the population. People whose last dental visit was more than twelve months ago or having less than one dental visit in the last year were 41.5 % and 44.8 %, respectively (Models 1 & 3). Most participants (60.1 %) went for an examination or check-up, while 39.9 % visited because of an emergency or treatment during their last dental visit (Model 2). Further distribution of variables is given in Table A - supplementary file.

According to the crosstabulation results, delayed (more than twelve months) last dental visit (Model 1) was more prevalent (45.4%) in the group with low education compared to the highly-educated group (35.7%). Similarly, in Model 3, 49.8% of the low education group, compared to 37.3% of the highly-educated group, reported a dental visit less than once a year. Investigating the last dental visit frequency reason depicted that 66.6% of highly educated individuals visited a dentist for a dental check-up or an examination, and 33.4% of those visited their dentist because of an emergency or treatment. In comparison, 55.7% of people with low education visited their dentist for a check-up or an examination, and 44.2% visited for an emergency or treatment (Model 3). According to these findings, less educated individuals visited a dentist less frequently and mainly to receive emergency treatments rather than routine dental check-ups.

Table 1 depicts the results of the mediation models with the decomposition of the total indirect effect and are adjusted for confounder variables. In model 1, the direct effect

of education on the time of the last dental visit was 0.67 (95% CI 0.56, 0.78), which is interpreted as the odds of a favourable dental visit in the last 12 months would be 33 % less if changing the distribution of potential outcomes of individuals to their counterfactual exposure distribution (Changing education level from high to low) and keeping their mediators' distributions at the observed level (high educated individuals). Considering this interpretation, the odds of the direct effect were 1.23 (95% CI 1.05, 1.43) and 0.62 (95% CI 0.53, 0.74) for model 2 and model 3, respectively. The odds ratios of indirect effect for all models were close to one, and this could be interpreted as no more changes could be expected in favourable visiting patterns after a simultaneous change of the distribution of exposure in observed high-educated individuals to their counterfactual level and the mediators' distributions to their counterfactual mediators' distributions of low education individuals. In other words, lower levels of education, regardless of oral health status, smoking status and brushing, can affect the use of dental services.

In the lower section of Table 1, results show the effect modification of a baseline confounder (i.e., dental service providing sector). This shows how the direct and indirect effects would be in various dental service sectors. In other words, it shows the odds of outcomes for low education individuals who visited the public sector compared to their counterparts with different education and service sector. The odds ratio of indirect effect for all three models with no change kept at close to one, but the odds ratio for the direct effect changed to 1.30 (95% CI 0.77, 2.03) for Model 1, 1.24 (95% CI 0.78, 2.03) for Model 2 and 1.40 (95% CI 0.87, 2.35) for Model 3. In general individuals with low education didn't have proper dental service utilisation (models 1

and 3); however, those individuals with low education who visited a public sector had higher odds of proper dental service utilisation compared to the others.

According to the sensitivity analysis (Table B – Supplementary file), omitting currently adjusted confounders did not change the direct effect estimate. There are some negligible changes for the indirect effect, but new estimates in all models are still very close to one. Although results show no sensitivity to the omission of currently adjusted confounders, there is still a possibility of cumulative unmeasured confounders and measurement biases.

Discussion

This analysis sought to model how education affects dental service utilisation patterns in Australian adults and how these education effects were mediated by some measured health behaviours. The findings suggest that low-education individuals are less likely to have a dental visit in one year or to have received dental services at least once a year, respectively.

According to the findings, low education level was associated with a less favourable utilisation of dental services (Models 1 and 3). This inverse association between the use of dental services and low education has been reported in other studies. Listl (2012), in a study of socio-economic inequalities through the lifespan in thirteen European countries, reported that people with less education utilised dental services less than their counterparts with more education[4]. Also, Piotrowska et al. (2018) reported that the use of dental services in people with less education was almost half compared to people with more education[17]. Besides the association with dental visiting frequency, this study showed that low education was associated with more emergency and treatment visits compared to routine dental check-ups (Model 2).

Another notable finding was the results of the effect modification measurement, which indicated a relative improvement of the dental service patterns in the patients referred to the public sector. It can be interpreted that public services, to some extent, reduce this disparity in the use of dental services between people with different levels of education.

These findings provide new information on the impact of education on dental services utilisation patterns. Despite education having a direct effect on dental services utilisation, there was no indirect effect of education on dental utilisation through oral health status and behaviours. These findings support the policy idea that universal health coverage (UHC) and extension of public services may lead to an increase in dental service utilisation for low education individuals who suffers from low utilisation regardless of their oral health attitudes.

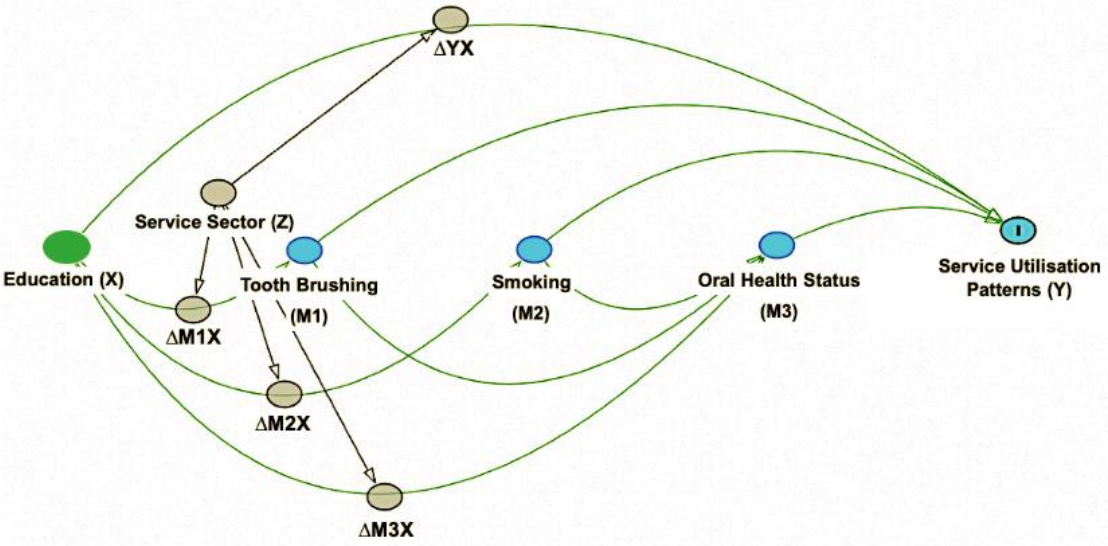
One of the strengths of this research was the use of robust counterfactual multiple mediation analysis. Due to the lack of software support, the statistical aspects of this study were performed independently by writing new codes. The large population and the use of weighted South Australian representative data were other strengths of this study.

These findings may not be completely free of bias, and there could be some biases due to cumulative unmeasured confounders and measurement errors, yet no method has been introduced for handling these. Most of the variables were self-reported, and as it is mentioned in the method section, by dichotomising the exposure, there is a chance of information loss. In addition, dichotomisation may lead to measurement error by coarsening the value into a broader category which could lead to an underestimation of the mediated effect and an overestimation of the direct effect[18]. However, to keep the analysis simple and to have a clear interpretation, we agreed to use dichotomised variables. Therefore, the results must be interpreted with caution as they can be sensitive to the cut point used in exposure dichotomisation. The DAG in this study illustrated the hypothesised ordering of the variables in a cross-sectional context.

However, the real ordering between confounding factors, exposure, mediators and outcomes is still unclear. Thus, longitudinal studies with clear temporal ordering are needed to validate the findings of this study.

Conclusion

In conclusion, low education reduces the odds of optimal dental service utilisation. The direct effect of low education regardless of mediation paths through smoking, tooth brushing, and oral health status reduces the odds of dental service utilisation, in terms of frequency of seeking dental care and times visiting a dentist annually. However, in terms of the reason for seeking dental care, lower education increases the odds of receiving emergency and treatment services. So, the key message is that if all persons with low education have their education like that of the high education level in the observed data, then the gaps in dental service utilisation may reduce.



X: Exposure **Y: Outcome**

M 1-3: Mediators **Z: Basline confounder which is tested for effect modification**

Δ: Used to illustrate this path modifed by the interaction of service sector (Z)

Confounders: Service Sector, Age, Gender, General Health Status, Country of Birth, Residential Location + [Income (for mediators 2 and 3 models)]

Figure 1- Directed Acyclic Graph illustrating the data analysis of the mediation analysis

Table 1- Direct effect of education and the total mediating effect of education through various mediators on dental service utilisation patterns

	Model 1	Model 2	Model 3
	OR (95% CI)		
(Intercept)	1.66 (1.29 - 2.09)	0.28 (0.22 – 0.36)	1.72 (1.37 - 2.18)
Direct effect of education (Reference: Diploma/Degree)	0.67 (0.56 - 0.78)	1.23 (1.05 – 1.43)	0.62 (0.53 - 0.74)
Total indirect effect of education through all mediators	1.01 (0.96 - 1.05)	0.99 (0.95 – 1.03)	1.00 (0.96 - 1.05)
Indirect effect of tooth brushing (Mediator1)	1.00 (0.96 - 1.03)	1.00 (0.97 – 1.03)	1.00 (0.97 - 1.04)
Indirect effect of smoking Status (Mediator 2)	1.00 (1.00 - 1.01)	1.00 (0.99 – 1.00)	1.00 (1.00 - 1.01)
Indirect effect of oral health status (Mediator 3)	1.01 (0.97 - 1.04)	0.99 (0.97 – 1.02)	1.00 (0.96 - 1.03)
Total Effect (direct + indirect effect)	0.67 (0.57 - 0.78)	1.22 (1.05 - 1.40)	0.63 (0.54 - 0.73)
Service Sector (Reference: Private)	0.28 (0.18 - 0.43)	1.70 (1.15 – 2.49)	0.21 (0.13 - 0.32)
Age 40 – 59 year (Reference: 18 – 39 year)	1.26 (1.02 - 1.54)	2.11 (1.72 – 2.67)	1.01 (0.82 - 1.24)
Age ≥60 year (Reference: 18 – 39 year)	2.08 (1.69 – 2.62)	2.34 (1.87 – 2.94)	1.73 (1.37 – 2.16)
Gender (Reference: Male)	1.17 (0.98 - 1.42)	0.83 (0.71 – 0.99)	1.35 (1.13 - 1.60)
General Health Status (Reference: Good Status)	0.56 (0.39 - 0.77)	2.04 (1.43 – 2.83)	0.51 (0.36 - 0.73)
Country of Birth (Reference: Australia)	1.10 (0.88 - 1.33)	1.22 (0.99 – 1.52)	0.97 (0.79 - 1.21)
Residential Location (Reference: Capital Area)	0.65 (0.52 - 0.79)	1.60 (1.33 – 1.95)	0.58 (0.47 - 0.70)
Mediation Effects after Effect Modification of a Baseline Confounder (i.e., Service Sector) (Reference: High-educated individuals who went to private sector)			
Direct Effect of Education: Sector	1.30 (0.78 - 2.15)	1.24 (0.78 – 2.03)	1.40 (0.87 - 2.35)
Indirect effect of tooth brushing (Mediator1) : Sector	0.99 (0.95 - 1.02)	1.00 (0.95 – 1.06)	0.99 (0.96 - 1.03)
Indirect effect of smoking status (Mediator 2) : Sector	0.99 (0.98 - 1.00)	1.00 (0.99 – 1.05)	0.99 (0.98 - 1.00)
Indirect effect of oral health status (Mediator 3) : Sector	0.99 (0.95 - 1.08)	1.00 (0.94 – 1.05)	1.00 (0.94 - 1.12)

Note: Model 1, Time of last dental visit (Reference: More than 12 Months ago); Model 2 (Reference: Examination or Check-up), Reason of the last dental visit; Model 3, Frequency of dental care (Reference: Less than once a year); OR, Odds Ratio; CI, Confidence Intervals.

Table A – Distributions of variables among the different sample population

	Response Sample (n=4494)		Weighted Sample (n=4494)		Imputed Weighted Sample (n=4494)
	All responses (n=4494)	Complete Cases (n=3657)	All responses (n=4494)	Complete Cases (n=3678)	
Age (years)					
18 - 39	946(21.0)	821(22.5)	1649(36.7)	1412(38.4)	1649(36.7)
40 - 59	1720(38.3)	1470(40.2)	1516(33.7)	1302(35.4)	1516(33.7)
≥60	1828(40.7)	1366(37.3)	1329(29.6)	964(26.2)	1329(29.6)
Gender					
Male	1976(44.0)	1610(44.0)	2203(49.0)	1818(49.4)	2204(49.0)
Female	2517(56.0)	2047(56.0)	2290(51.0)	1860(50.6)	2290(51.0)
Country of Birth					
Australia	3464(77.1)	2901(79.3)	3575(79.6)	3015(82.0)	3646(81.1)
Other Countries	936(20.8)	756(20.7)	827(18.4)	663(18.0)	848(18.9)
Missing	94(2.1)	---	92(2.0)	---	---
Income (AUD)					
≥80,000	1640(36.5)	1553(42.5)	1774(39.5)	1686(45.8)	1924(42.8)
<80,000	2420(53.8)	2104(57.5)	2291(51.0)	1992(54.2)	2570(57.2)
Missing	434(9.7)	---	429(9.5)	---	
Education (Exposure)					
Diploma/Degree	1713(38.1)	1539(42.1)	1784(39.7)	1616(43.9)	1819(40.5)
≤Year12/Certificate	2689(59.8)	2118(57.9)	2622(58.3)	2062(56.1)	2675(59.5)
Missing	92(2.0)	---	88(2.0)	---	---
Residential Location					
Capital area	3373(75.1)	2783 (76.1)	3474(77.3)	2880(78.3)	3474(77.3)
Non-capital area	1121(24.9)	874(23.9)	1020(22.7)	798(21.7)	1020(22.7)
General Health Status					
Poor	272 (6.1)	197(5.4)	248(5.5)	178(4.8)	252(5.6)
Good to Excellent	4154 (92.4)	3460(94.6)	4181(93.0)	3499(95.2)	4242(94.4)
Missing	68 (1.5)	---	65(1.5)	---	---
Dental Service Sector					
Private	3778(84.1)	3210(87.8)	3696(82.2)	3165(86.1)	3786(84.2)
Public	599(13.3)	447(12.2)	677(15.1)	512(13.9)	708(15.8)
Missing	117(2.6)	---	121(2.7)	---	---
Tooth Brushing (Mediator one)					
At least once daily	4057 (90.2)	3430(93.8)	4046(90.0)	3422(93.0)	4147(92.3)
Less than once daily	304 (6.8)	227(6.2)	329(7.3)	256(7.0)	347(7.7)
Missing	133 (3.0)	---	119(2.7)	---	---

Table 1 Continue	Response Sample (n=4494)		Weighted Sample (n=4494)		Imputed Weighted Sample (n=4494)
	All responses (n=4494)	Complete Cases (n=3657)	All responses (n=4494)	Complete Cases (n=3678)	
Smoking Status (Mediator two)					
No	3903 (86.8)	3251(88.9)	3876(86.2)	3238(88.1)	3938(87.6)
Yes	521 (11.6)	406(11.1)	546(12.2)	439(11.9)	556(12.4)
Missing	70 (1.6)	---	72(1.6)	---	---
Oral Health Status (Mediator three)					
Poor	534(11.9)	408(11.2)	511(11.3)	395(10.7)	515(11.5)
Good to Excellent	3924(87.3)	3249(88.8)	3953(88.0)	3283(89.3)	3979(88.5)
Missing	36(0.8)	---	30(0.7)	---	---
Last Dental Visit (Outcome: Model 1)					
More than 12 months ago	1743(38.7)	1354(37.0)	1858(41.4)	1456(39.6)	1865(41.5)
Less than 12 months ago	2735(60.9)	2303(63.0)	2622(58.3)	2221(60.4)	2629(58.5)
Missing	16(0.4)	---	14(0.3)	---	---
Reason for Last Dental Visit (Outcome: Model 2)					
Examination or Check-up	2491(55.4)	2124(58.1)	2650(59.0)	2257 (61.4)	2701(60.1)
Emergency or Treatment	1869(41.6)	1533(41.9)	1715(38.2)	1421(38.6)	1793(39.9)
Missing	134(3.0)	---	129(2.9)	---	---
Frequency of Dental Care (Outcome: Model 3)					
Less than once a year	1820(40.5)	1482(40.5)	1910(42.5)	1570(42.7)	2011(44.8)
At least once a year	2527(56.2)	2175(59.5)	2444(54.4)	2107(57.3)	2483(55.2)
Missing	147(3.3)	---	140(3.1)	---	---

Note: Data reported as the number of cases (Percent), Missing cases less than five have not been reported.

Table B. Sensitivity analysis of pre-treatment confounders.

	σ	Ƥ	Bias	Modified OR	Modified OR (95% CI)	Bias	Modified OR	Modified OR (95% CI)
Model 1								
Sector	0.024	-0.080	-0.002	1.01	[0.96, 1.05]	0.002	0.67	[0.56, 0.78]
Age	0.298	0.054	0.016	1.00	[0.94, 1.03]	-0.016	0.68	[0.57, 0.79]
Gender	0.011	-0.055	-0.001	1.01	[0.96, 1.05]	0.001	0.67	[0.56, 0.78]
Income	0.028	-0.026	-0.001	1.01	[0.96, 1.05]	0.001	0.67	[0.56, 0.78]
General Health	0.024	-0.039	-0.001	1.01	[0.96, 1.05]	0.001	0.67	[0.56, 0.78]
Country of Birth	0.003	0.036	0	1.01	[0.96, 1.05]	0	0.67	[0.56, 0.78]
Residential location	0.007	-0.027	0	1.01	[0.96, 1.05]	0	0.67	[0.56, 0.78]
Model 2								
Sector	0.024	-0.062	-0.001	0.99	[0.95, 1.04]	0.001	1.23	[1.05, 1.42]
Age	0.298	-0.088	-0.026	1.01	[0.97, 1.06]	0.026	1.20	[1.02, 1.39]
Gender	0.011	-0.038	0	0.99	[0.95, 1.03]	0	1.23	[1.05, 1.42]
Income	0.028	-0.088	-0.002	0.99	0.95, 1.04]	0.002	1.23	[1.05, 1.42]
General Health	0.024	-0.010	0	0.99	[0.95, 1.03]	0	1.23	[1.05, 1.42]
Country of Birth	0.004	0.065	0	0.99	[0.95, 1.03]	0	1.23	[1.05, 1.42]
Residential location	0.008	-0.039	0	0.99	[0.95, 1.03]	0	1.23	[1.05, 1.42]
Model 3								
Sector	0.024	-0.068	-0.002	1.01	[1.00, 1.01]	0.002	0.62	[0.53, 0.74]
Age	0.298	0.09	0.027	0.98	[0.98, 0.99]	-0.027	0.64	[0.54, 0.76]
Gender	0.011	-0.058	-0.001	1.00	[0.99, 1.01]	0.001	0.62	[0.53, 0.74]
Income	0.028	-0.008	0	1.01	[1.00, 1.01]	0	0.62	[0.53, 0.74]
General Health	0.024	-0.025	-0.001	1.00	[0.99, 1.01]	0.001	0.62	[0.53, 0.74]
Country of Birth	0.004	0	0	1.00	[0.99, 1.01]	0	0.62	[0.53, 0.74]
Residential location	0.008	-0.009	0	1.00	[0.99, 1.01]	0	0.62	[0.53, 0.74]

Note: Model 1, Time of last dental visit; Model 2, Reason of the last dental visit; Model 3, Frequency of dental care; OR, Odds Ratio; CI, Confidence Intervals; σ = standard deviation of weight discrepancy; Ƥ= correlation between the weight discrepancy and the outcome; Bias= σ ×Ƥ; *, The OR confidence interval's side changed; NIE, Natural Indirect Effect; NDE, Natural Direct Effect.

References

1. Petersen PE, Bourgeois D, Ogawa H, Estupinan-Day S, Ndiaye C. The global burden of oral diseases and risks to oral health. *Bulletin of the World Health Organization.* 2005;83:661-669.
2. Capurro DA, Davidsen M. Socioeconomic inequalities in dental health among middle-aged adults and the role of behavioral and psychosocial factors: evidence from the Spanish National Health Survey. *International journal for equity in health.* 2017;16(1):1-9.
3. Guiney H, Woods N, Whelton HP, Morgan K. Predictors of utilisation of dental care services in a nationally representative sample of adults. 2011.
4. Listl S. Inequalities in dental attendance throughout the life-course. *Journal of dental research.* 2012;91(7_suppl):S91-S97.
5. Liu Y, Li Z, Walker MP. Social disparities in dentition status among A merican adults. *International dental journal.* 2014;64(1):52-57.
6. Ghanbarzadegan A, Balasubramanian M, Luzzi L, Brennan D, Bastani P. Inequality in dental services: a scoping review on the role of access toward achieving universal health coverage in oral health. *BMC oral health.* 2021;21(1):1-11.
7. Ghanbarzadegan A, Bastani P, Luzzi L, Brennan D. Inequalities in utilization and provision of dental services: a scoping review. *Systematic reviews.* 2021;10(1):1-11.
8. Ju X, Jamieson LM, Mejia GC, Mittinty MN. Effect of oral health literacy on self-reported tooth loss: A multiple mediation analysis. *Community dentistry and oral epidemiology.* 2021.
9. Song Y. *Dentist-patient relationships and oral health-related quality of life* 2020.
10. Nilsson A, Bonander C, Strömberg U, Björk J. A directed acyclic graph for interactions. *International journal of epidemiology.* 2021;50(2):613-619.

11. Lange T, Rasmussen M, Thygesen LC. Assessing natural direct and indirect effects through multiple pathways. *American journal of epidemiology.* 2014;179(4):513-518.
12. Steen J, Loeys T, Moerkerke B, Vansteelandt S. Medflex: an R package for flexible mediation analysis using natural effect models. *Journal of Statistical Software.* 2017;76(11).
13. Greenland S, Robins JM. Identifiability, exchangeability, and epidemiological confounding. *International journal of epidemiology.* 1986;15(3):413-419.
14. Hong G, Deutsch J, Hill HD. Ratio-of-mediator-probability weighting for causal mediation analysis in the presence of treatment-by-mediator interaction. *Journal of Educational and Behavioral Statistics.* 2015;40(3):307-340.
15. Imai K, Keele L, Yamamoto T. Identification, inference and sensitivity analysis for causal mediation effects. *Statistical science.* 2010;25(1):51-71.
16. Hong G, Qin X, Yang F. Weighting-based sensitivity analysis in causal mediation studies. *Journal of Educational and Behavioral Statistics.* 2018;43(1):32-56.
17. Piotrowska DE, Pędziński B, Jankowska D, Huzarska D, Charkiewicz AE, Szpak AS. Socio-economic inequalities in the use of dental care in urban and rural areas in Poland. *Annals of Agricultural and Environmental Medicine.* 2018;25(3):512-516.
18. VanderWeele TJ, Valeri L, Ogburn EL. The role of measurement error and misclassification in mediation analysis: mediation and measurement error. Epidemiology. 2012 Jul;23(4):561-4.

Chapter 9 – Final Consideration

Chapter 9 - **Final Consideration**

In the early stages of designing this thesis, although I knew the focus of my thesis would be socioeconomic inequality, I was not sure what aspects of it to study. It could be specified from many angles such as the Australian Oral Health Care System structure, oral health professional distribution, Indigenous health, migrant and Culturally and Linguistically Diverse (CALD) communities. Inequality can be measured with different approaches, and therefore the choice of study method was my other concern. Finally, given that I was pursuing the goal that the results of this thesis be practical and not merely a report of inequality indicators, I decided to investigate the mechanisms that lead to inequality in dental services. Having a more accurate understanding of effective mechanisms would enable policymakers to address inequality much better. Therefore, mediation analysis was used to investigate the socioeconomic mechanisms of inequality. As mentioned in Chapter 6, these studies are suitable for answering the questions that one factor leads to a final effect through other variables.

Nevertheless, conducting studies with correct modelling requires appropriate background knowledge, so the literature was reviewed in the first phase. Within the systematic review methodologies, scoping reviews are a comprehensive methodology for answering policy questions by providing a concept map of determinants of the subject. Such a concept map provides an upstream perspective for policymakers and researchers to consider various influential factors.

Scoping reviews in the first and second chapters were done in the context of member countries of the Organisation for Economic Co-operation and Development (OECD). If it was limited to Australia, the content analysis might not be saturated due to the small number of included studies and, therefore, might be inaccurate. Thus, more comprehensive determinants were identified by considering the countries with a similar

context. Based on the number of included studies, these studies are the most comprehensive review studies on the issue of inequality in dental services to date, which led to the formation of the first conceptual model in this field. Therefore, the existing knowledge gap was partially resolved.

Following this step, the second phase began accordingly. In this phase, the cutting-edge flexible mediation analysis using the Ratio of Mediator Probability Weighting (RMPW) approach was utilised to investigate an Australian adult population representative at the South Australian level. This approach is superior to other methods as it is not model specific. Using the RMPW approach for sensitivity analysis was another strength of this PhD project. Few studies have utilised this methodology for their sensitivity analysis. Conducting this analysis having multiple mediators was one of the novelties of this project. R functions and codes used in chapters 7 and 8 modify existing methods to suit a multiple mediator mediation analysis. These codes can greatly facilitate future studies using the same method.

It is not always possible to conduct a perfect randomised clinical trial. For example, ethical considerations or particular variable measurements may be limiting. Time and cost may be other limitations. In such cases, other approaches may be considered accordingly.

Cross-sectional data were used in this thesis. Although DCOHS is a comprehensive survey that carefully studied the target population and collected multiple variables, there would inevitably be measurement and nonresponse biases. The education effect on various service utilisation patterns was investigated through behavioural mediators.

However, the variable that was not measured was health literacy, which may affect health behaviours regardless of academic education.

The counterfactual mediation analysis has advantages over simple regression models. It enables us to test the models in which each variable has its location. Models appropriately test the theories and confounders and mediators with their hypothesised relations. However, in regressions, variables, regardless of their locations in the proposed models and confounding mechanisms, are being put together. Another advantage of our approach was the sensitivity analysis which enabled us to test the sensitivity of our models' inferences for unmeasured confounders.

Although robust statistical methodology was used in this thesis, there were limitations in some statistical aspects due to the models' complexity. There is currently no statistical package that measures biases due to cumulative unmeasured confounders and measurement errors, so mediation results should be interpreted with caution. According to the explanations given in Chapter 6, the weighting of the binary mediator was more facilitated when we had several mediators. Because of this, the variables were dichotomised, accepting the fact that a considerable amount of information might be lost.

According to this PhD project, it is concluded that different intertwined factors lead to inequality in dental services. These factors may vary in different contexts and should be considered accordingly. These determinants form inequality structures in dentistry in the three main dimensions of access, utilisation and provision.

The results of empirical studies showed that household income level, regardless of insurance status, concession card status, and last dental visit, causes avoidance or delay in receiving dental services. These findings are important because, contrary to what was

initially expected, it has been shown that these facilitators do not help reduce the financial burden on dental services for low-income adult individuals in the current situation. Policymakers and researchers are encouraged to examine why these facilitators have not reduced the financial burden of receiving dental services and check whether these facilitators have adequately targeted the vulnerable groups.

In Chapter 8, it was found that low education increases the odds of receiving emergency and treatment services compared to routine dental check-ups and examinations. Regardless of smoking, tooth brushing and oral health status, a lower level of education can reduce the utilisation of dental services by around a third. This utilisation gap was somewhat improved in people who had access to public services.

These results show the importance of the underlying structural inequality determinants, such as income or education level. It is complicated and almost impossible to change such characteristics, but this emphasises the importance of assiduous policymaking in this field. For example, considering that the disparities in service utilisation improved in less-educated people referred to the public sector, it should be examined whether the extension of services, individuals or the number of public providers could improve service utilisation in the lower socioeconomic status groups. It should then be investigated whether such improvement in the utilisation of dental services can improve oral health outcomes. Another question that arises in the economic dimension is why the facilitators such as insurance, concession cards and public services did not reduce the financial burden in low-income individuals. Have these facilitators properly targeted vulnerable people? Is the coverage of dental services and expenses enough to reduce the financial burden? According to economic models, whom dental services

cover? Econometric modelling studies could well address such questions that would eventually lead to evidence-based oral health policies.

This thesis addressed the initial questions by redefining the concepts and investigating some of the mechanisms that led to inequality in dentistry and consequently clarified the importance of this issue from new perspectives. I believe that this is the essence of researching in general and hope that by examining such aspects, the final impact, which is the reduction of inequality in dental services, will eventually be reached.

"Since all things have causes, the knowledge of anything is not acquired or complete unless it is known by its causes."

~ Avicenna (973-1037) ~

Appendix I – Ethics Approval for Dental Care and Oral Health Study

Appendix I

THE UNIVERSITY of ADELAIDE

RESEARCH BRANCH
RESEARCH ETHICS AND COMPLIANCE UNIT

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17 November 2011

Associate Professor D Brennan
School of Dentistry

Dear Associate Professor Brennan

APPROVAL No.: **H-288-2011**
PROJECT TITLE: **Dental health services research for improved oral health outcomes**

I write to advise you that on behalf of the Human Research Ethics Committee I have approved the above project. Please refer to the enclosed endorsement sheet for further details and conditions that may be applicable to this approval.

The ethics expiry date for this project is: 30 November 2012

Participants taking part in the study are to be given a copy of the Information Sheet and the signed Consent Form to retain.

Please note that any changes to the project which might affect its continued ethical acceptability will invalidate the project's approval. In such cases an amended protocol must be submitted to the Committee for further approval.

It is a condition of approval that you **immediately report** anything which might warrant review of ethical approval including:

- serious or unexpected adverse effects on participants
- proposed changes in the protocol; and
- unforeseen events that might affect continued ethical acceptability of the project.

It is also a condition of approval that you inform the Committee, giving reasons, if the project is discontinued before the expected date of completion.

A reporting form is available from the website at http://www.adelaide.edu.au/ethics/human/guidelines/reporting. This may be used to renew ethical approval or report on project status including completion.

Yours sincerely

for **PROFESSOR GARRETT CULLITY**
Convenor
Human Research Ethics Committee

Appendix I

THE UNIVERSITY of ADELAIDE

RESEARCH BRANCH
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26 November 2012

Associate Professor D Brennan
School of Dentisrty, University of Adelaide

Dear Associate Professor Brennan

PROJECT NO: H-288-2011
Dental health services research for improved oral health outcomes

Thank you for your report on the above project. I write to advise you that I have endorsed renewal of ethical approval for the study on behalf of the Human Research Ethics Committee.

The expiry date for this project is: 30 November 2015

Where possible, participants taking part in the study should be given a copy of the Information Sheet and the signed Consent Form to retain.

Please note that any changes to the project which might affect its continued ethical acceptability will invalidate the project's approval. In such cases an amended protocol must be submitted to the Committee for further approval. It is a condition of approval that you immediately report anything which might warrant review of ethical approval including (a) serious or unexpected adverse effects on participants (b) proposed changes in the protocol; and (c) unforeseen events that might affect continued ethical acceptability of the project. It is also a condition of approval that you inform the Committee, giving reasons, if the project is discontinued before the expected date of completion.

A reporting form is available from the Committee's website. This may be used to renew ethical approval or report on project status including completion.

Yours sincerely

Dr John Semmler
Acting Convenor
Human Research Ethics Committee

Appendix I

Appendix II - Dental Care and Oral Health Study Baseline Questionnaire

THE UNIVERSITY of ADELAIDE

AUSTRALIAN RESEARCH CENTRE FOR POPULATION ORAL HEALTH
SCHOOL OF DENTISTRY

DENTAL CARE AND ORAL HEALTH STUDY

The purpose of this study is to answer fundamental questions on what works best in relation to the provision of dental care. The study involves collection of responses to a questionnaire from a sample of Australian adults aged over 18 years. The questionnaire will take about **20 minutes** to complete.

Why participate?

1. The study provides evidence to a National Strategic Plan Priority Area on health systems development.
2. This is a major study that tracks your health outcomes and dental care over time.
3. Results of the study will be available on a project website (more information provided at end of this survey).

How to complete the survey?

1. Please use a DARK pen to write your answers.
2. Please use BLOCK LETTERS.
3. Responses can be provided by:
   - Marking with a CROSS (eg. [x])
   - Circling a number (eg. (1))
   - Writing the response (eg. MOBILE DENTAL CLINIC)

Instructions are also provided at the beginning of each question.

4. There are three parts to the survey:

PART A asks questions about oral health.

PART B asks questions about general health.

PART C asks questions about your background, education and work.

5. Answer all questions, unless otherwise indicated.

Your feedback is strictly confidential

1. Results will be reported as group profiles only.
2. Individual identity will not be revealed.

Any queries

Dental care and oral health study
Health Services Research Unit
Contact: Madhan Balasubramanian
Tel: 08 83135027 Fax: 08 83133070
madhan.balasubramanian@adelaide.edu.au

Conducted by:

Health Services Research Unit
Australian Research Centre for Population Oral Health (ARCPOH)
School of Dentistry, The University of Adelaide

Please return the completed questionnaire as soon as possible in the reply paid envelope provided

Dental care and oral health study **PART A**

PART A contains questions about your oral health status, dental visits, dental insurance, financial burden due to dental care, impact of oral health on your daily life and issues related to your satisfaction with dental care and the dental system in Australia. Instructions on how to answer each question are provided at beginning of the question.

1 Tooth brushing habits [Please mark with a CROSS or WRITE your answer, where required]

A. In the last week, how many times did you brush your teeth? _____ (times) → **If NIL go to Question 1 D now**

B. If you said you brushed your teeth at least once a week, how long on average do you spend on brushing your teeth?

- ☐ Less than one minute
- ☐ About one minute
- ☐ About 1½ minutes
- ☐ About 2 minutes
- ☐ About 2½ minutes
- ☐ About 3 minutes
- ☐ More than 3 minutes

C. In the last week, how many times did you use an electric tooth brush? _____ (times)

D. In the last week, how many times did you use dental floss? _____ (times)

E. In the last week, how many times did you use a mouth rinse/wash? _____ (times)

F. If you used a mouth rinse or mouth wash, write the name of the product you used here: _____

2 Number of teeth [Please mark with a CROSS or WRITE your answer, where required]

A. Do you have any of your own natural teeth?

- ☐ Yes, I have some or all of my natural teeth
- ☐ No, I have none of my natural teeth → **If NO go to Question 3 now**

B. There are 16 teeth, including wisdom teeth, in the UPPER jaw. How many of these 16 teeth do you have in your upper jaw? *Do not count false teeth. If you have no teeth in your upper jaw write 'nil'.*

I have _____ (number) of teeth in my UPPER jaw.

C. There are 16 teeth, including wisdom teeth, in the LOWER jaw. How many of these 16 teeth do you have in your lower jaw? *Do not count false teeth. If you have no teeth in your lower jaw write 'nil'.*

I have _____ (number) of teeth in my LOWER jaw.

3 Dentures [Please mark with a CROSS]

Dentures are artificial teeth that can be removed.

A. Do you wear a denture in your UPPER jaw? ☐ Yes ☐ No

B. Do you wear a denture in your LOWER jaw? ☐ Yes ☐ No

4 Oral and general health [Please mark with a CROSS]

A. How would you rate your dental health? ☐ Excellent ☐ Very good ☐ Good ☐ Poor ☐ Very poor

B. How would you rate your general health? ☐ Excellent ☐ Very good ☐ Good ☐ Poor ☐ Very poor

Dental care and oral health study **PART A**

5 Dental visits [Please mark with a CROSS or WRITE your answer, where required]

A. When was your last visit to a dental professional?
(Includes dentist, dental specialist, oral health therapist, dental hygienist, dental therapist, dental technician, denturist or dental prosthetist)

- ☐ Less than 12 months ago
- ☐ One to less than two years ago
- ☐ Two to less than five years ago
- ☐ Five to less than ten years ago
- ☐ Ten years or more
- ☐ Never attended → Go to Question 6

B. What was the main reason for your last dental visit?

- ☐ Examination or check-up
- ☐ Treatment (not for relief or pain)
- ☐ Emergency/relief of pain

C. How often do you usually seek care from a dental professional?
(Includes dentist, dental specialist, oral health therapist, dental hygienist, dental therapist, dental technician, denturist or dental prosthetist)

- ☐ More than two times a year
- ☐ Two times a year
- ☐ Once a year
- ☐ Once every two years
- ☐ Less often than once every two years

D. Where did you go for your last dental visit?

- ☐ Private dental practice
- ☐ Public dental clinic (including dental hospital, community clinic)

E. Please write the name of the suburb or postcode of the clinic where you made your last dental visit ?

_____ suburb OR ☐☐☐☐ postcode

F. Overall, how many...

		In the last 12 months	One year to two years ago
1	...dental appointments have you attended.....		
2	...dental examinations have you had.....		
3	...clean and scale procedures have you had.....		
4	...fillings have you had.....		
5	...teeth have you had extracted (removed).....		

G. Have you had any other dental treatment in the last 12 months?
[Cross the relevant box(es)]

- ☐ No other treatment in the last 12 months
- ☐ Professional fluoride application
- ☐ New denture(s) prepared or fixed
- ☐ Oral surgery (besides extraction)
- ☐ Other treatment (please specify) _____
- ☐ Gum treatment (periodontal treatment)
- ☐ Adjustment, reline or rebase denture(s)
- ☐ Orthodontics
- ☐ Crown or bridge treatment

6 Future dental visits [Please mark with a CROSS]

A. Do you need to make a dental visit now? ☐ Yes ☐ No → If NO go to Question 7 now

B. What do you need the dental visit for? ☐ Check-up ☐ Treatment (not for relief of pain) ☐ Emergency/relief of pain

C. How soon do you think you need a check-up or treatment?

- ☐ In less than a week
- ☐ From one week to less than a month
- ☐ From one month to less than three months
- ☐ From three months to less than six months
- ☐ Six months or more

Dental care and oral health study **PART A**

7 Financial burden [Please mark with a CROSS or CIRCLE your answer, where required]

A. During the last 12 months, have you avoided or delayed visiting a dental professional because of cost? ☐ Yes ☐ No

B. Has cost prevented you from having any dental treatment that was recommended by a dental professional? ☐ Yes ☐ No

> Did you take up an alternative lower cost option for the treatment that was recommended? ☐ Yes ☐ No

> Which dental treatments were prevented by cost? (Please CROSS as many as applicable)

- ☐ Fillings
- ☐ Extractions
- ☐ Scale and clean
- ☐ Dental implants
- ☐ Gum treatments (periodontal)
- ☐ Dental crown or bridge
- ☐ Root canal
- ☐ Dentures made
- ☐ Orthodontic treatment
- ☐ Cosmetic treatment (eg. bleaching)
- ☐ Replace amalgams with white
- ☐ Others

C. In the last 12 months how much of a financial burden have dental visits been to you? ☐ None ☐ Hardly any ☐ A little ☐ A large burden

D. At most times of the year, how much difficulty would you have paying a **$150 bill** out of your own pocket? ☐ None ☐ Hardly any ☐ A little ☐ A lot

E. Overall, how satisfied are you with your current financial situation?

Totally dissatisfied										***Totally satisfied***
0	1	2	3	4	5	6	7	8	9	10

F. Overall, how satisfied are you with the material standards of your life?

Totally dissatisfied										***Totally satisfied***
0	1	2	3	4	5	6	7	8	9	10

G. Relative to others, how would you rate your financial position?

Worse than most										***Better than most***
0	1	2	3	4	5	6	7	8	9	10

H. Do you hold any of these concession cards?

- ☐ Health Care Card
- ☐ Pensioner Concession Card
- ☐ Commonwealth Seniors Card
- ☐ Other card
- ☐ None of the above
- ☐ Don't know

I. Do you have private health insurance (including hospital or ancillary/extras insurance, excluding Medicare)

☐ Yes, I have private health insurance ☐ No, I do not have private health insurance

> What best describes your private health insurance status?

- ☐ Combined hospital & ancillary/extras cover
- ☐ Hospital cover only
- ☐ Ancillary/extras only cover

Dental care and oral health study **PART A**

8 Impact of oral health on your daily life

HOW OFTEN during the **PAST YEAR**

	Never	Hardly ever	Occasionally	Fairly often	Very often
Please CIRCLE	1	2	3	(4)	5
1. Have you had **trouble pronouncing any words** because of problems with your teeth, mouth or dentures?	1	2	3	4	5
2. Have you felt that your **sense of taste has worsened** because of problems with your teeth, mouth or dentures?	1	2	3	4	5
3. Have you had **painful aching** in your mouth?	1	2	3	4	5
4. Have you found it **uncomfortable to eat any foods** because of problems with your teeth, mouth or dentures?	1	2	3	4	5
5. Have you been **self-conscious** because of your teeth, mouth or dentures?	1	2	3	4	5
6. Have you **felt tense** because of problems with your teeth, mouth or dentures?	1	2	3	4	5
7. Has your **diet been unsatisfactory** because of problems with your teeth, mouth or dentures?	1	2	3	4	5
8. Have you had to **interrupt meals** because of problems with your teeth, mouth or dentures?	1	2	3	4	5
9. Have you found it **difficult to relax** because of problems with your teeth, mouth or dentures?	1	2	3	4	5
10. Have you been **a bit embarrassed** because of problems with your teeth, mouth or dentures?	1	2	3	4	5
11. Have you been **a bit irritable** with other people because of problems with your teeth, mouth or dentures?	1	2	3	4	5
12. Have you had **difficulty doing your usual jobs** because of problems with your teeth, mouth or dentures?	1	2	3	4	5
13. Have you felt that **life in general was less satisfying** because of problems with your teeth, mouth and dentures?	1	2	3	4	5
14. Have you been **totally unable to function** because of problems with your teeth, mouth or dentures?	1	2	3	4	5
15. Have you had **pain** in the face, jaw, temple, in front of ear, or in the ear?	1	2	3	4	5
16. Have you **broken or chipped** a natural tooth?	1	2	3	4	5
17. Have you had **sensitive teeth**, for example due to hot or cold food or drinks?	1	2	3	4	5
18. Have you had any teeth that have become **loose** by themselves without some injury?	1	2	3	4	5
19. Have you had **sore gums**?	1	2	3	4	5

Dental care and oral health study **PART A**

9 Dental fear [Please CROSS the appropriate box]

Do you feel afraid or distressed when going to the dentist?	Not at all ☐	A little afraid or distressed ☐	Moderately afraid or distressed ☐	Very afraid or distressed ☐	Extremely afraid or distressed ☐

10 Dentist trust

These questions relate to Dentist Trust. In general... *Please CIRCLE a number for each statement*

	Strongly disagree				Strongly agree
1. Dentists care about their patients' health just as much or more as their patients do.	1	2	3	4	5
2. Sometimes dentists care more about what is best for them, than about patients dental needs.	1	2	3	4	5
3. Dentists are extremely thorough and careful.	1	2	3	4	5
4. You completely trust dentists decisions about which dental treatments are best.	1	2	3	4	5
5. Dentists think only about what is best for their patients.	1	2	3	4	5
6. Dentists are totally honest in telling their patients about all the different treatment options available for their conditions.	1	2	3	4	5
7. Sometimes dentists do not pay full attention to what patients are trying to tell them.	1	2	3	4	5
8. Dentists always use their very best skills and effort on behalf of their patients.	1	2	3	4	5
9. You have no worries about putting your oral health in the hands of the dentist.	1	2	3	4	5
10. A dentist would never mislead you about anything.	1	2	3	4	5
11. All in all, you trust dentists completely.	1	2	3	4	5

11 Dental care satisfaction

A. Have you ever visited a dentist before? ☐ Yes ☐ No → **If No, Go to Question 12 now**

B. These questions relate to your LAST DENTAL VISIT.

Please CIRCLE a number for each statement

	Strongly disagree				Strongly agree
1. I was satisfied with the dental care I received.	1	2	3	4	5
2. I would like to have had more explanation of my dental treatment options.	1	2	3	4	5
3. The dental surgery had everything needed to provide my dental care.	1	2	3	4	5
4. The dental care I received did not improve my dental health.	1	2	3	4	5
5. I was able to make the dental visit as promptly as I felt was necessary.	1	2	3	4	5
6. The dental professional explained whether there were any patient costs and how much, before beginning the treatment.	1	2	3	4	5
7. The dental professional I saw explained well what treatment was needed.	1	2	3	4	5
8. I am confident that I received good dental care at my last visit.	1	2	3	4	5
9. There are things about dental care I received that could have been better.	1	2	3	4	5

Dental care and oral health study **PART B**

PART B asks questions about your general health and impact of general health on your daily life. Instructions on how to answer each question are provided at beginning of each question.

12 General health information [Please mark with a CROSS or WRITE where required]

A. What is your current HEIGHT? _____ centimetres OR _____/_____ feet / inches

B. What is your current WEIGHT? _____ kilograms OR _____ pounds

C. Do you have any of these chronic medical conditions? [Please CROSS all that apply]

1. Asthma ☐	9. Cataracts ☐	17. Hypothyroidism ☐
2. Chronic bronchitis or emphysema ☐	10. Glaucoma ☐	18. Rheumatic fever ☐
3. Hypertension or high blood pressure ☐	11. Osteoporosis ☐	19. A bleeding problem ☐
4. A heart condition or heart attack ☐	12. Hip fracture ☐	20. Deafness ☐
5. High cholesterol ☐	13. A cancer or malignancy ☐	21. Diagnosed with dementia ☐
6. A stroke or "mini strokes" (TIA) ☐	14. A diagnosed depression ☐	22. Diagnosed with Alzheimer's disease ☐
7. Diabetes ☐	15. Parkinson's disease ☐	23. Artificial joints, heart valves or prosthesis ☐
8. Arthritis ☐	16. Epilepsy ☐	24. Other medical conditions (please specify) ☐ _____

D. **Which of these statements best describe your cigarette smoking status?**

- ☐ I smoke daily → A) On average, I smoke _____ (number) cigarettes per day.
- ☐ I smoke occasionally → A) On average, I smoke _____ (number) cigarettes per day.
- ☐ I do not smoke now but I used to → B) I used to smoke ____(number) cigarettes per day. C) I stopped smoking _____ years ago.
- ☐ I have never smoked

13 Your general health today [Please CROSS one box only for each question]

A. MOBILITY	I have no problems walking about. ☐	I have some problems walking about. ☐	I am confined to bed. ☐
B. SELF CARE (eg. Washing, dressing)	I have no problems with self care. ☐	I have some problems with washing and dressing myself. ☐	I am unable to wash or dress myself. ☐
C. USUAL ACTIVITIES (eg. household work, family, leisure)	I have no problems performing my usual activities. ☐	I have some problems performing my usual activities. ☐	I am unable to perform my usual activities. ☐
D. PAIN/DISCOMFORT	I have no pain or discomfort. ☐	I have moderate pain or discomfort. ☐	I have extreme pain or discomfort. ☐
E. ANXIETY/DEPRESSION	I am not anxious or depressed. ☐	I am moderately anxious or depressed. ☐	I am extremely anxious or depressed. ☐

Dental care and oral health study **PART B**

14 **Life satisfaction, social support and work** [Please CIRCLE a number that best represents your perspective]

A. The following statements seek views on levels of life satisfaction	Strongly disagree				Strongly agree
1. In most ways my life is close to my ideal.	1	2	3	4	5
2. The conditions of my life are excellent.	1	2	3	4	5
3. I am satisfied with my life.	1	2	3	4	5
4. So far I have acquired the important things I want in my life.	1	2	3	4	5
5. If I could live my life over, I would change almost nothing.	1	2	3	4	5

B. The following statements are about social support.	Strongly disagree				Strongly agree
1. There is a special person who is around when I am in need.	1	2	3	4	5
2. There is a special person with whom I can share joys and sorrows.	1	2	3	4	5
3. My family really tries to help me.	1	2	3	4	5
4. I get the emotional help and support I need from my family.	1	2	3	4	5
5. I have a special person who is a real source of comfort to me.	1	2	3	4	5
6. My friends really try to help me.	1	2	3	4	5
7. I can count on my friends when things go wrong.	1	2	3	4	5
8. I can talk about my problems with my family.	1	2	3	4	5
9. I have friends with whom I can share my joys and sorrows.	1	2	3	4	5
10. There is a special person in my life who cares about my feelings.	1	2	3	4	5
11. My family is willing to help me make decisions.	1	2	3	4	5
12. I can talk about my problems with my friends.	1	2	3	4	5

C. The following statements are about your work.
Paid work, study and volunteering are considered 'work'.

→ **IFYOU ARE NOT WORKING CURRENTLY GO TO QUESTION 15 NOW**

	Strongly disagree				Strongly agree
1. After work, I am too tired for leisure activities, family time or house chores.	1	2	3	4	5
2. I have so much work to do that it takes away from my personal interests.	1	2	3	4	5
3. My family/friends dislike how often I am preoccupied with work while I am at home.	1	2	3	4	5
4. Work takes up time that I'd like to spend with family or friends.	1	2	3	4	5
5. I am often too tired at work because of the things I have to do at home.	1	2	3	4	5
6. My superiors and peers dislike how often I am preoccupied with my personal life while at work.	1	2	3	4	5
7. My personal demands are so great that they interfere with my work.	1	2	3	4	5
8. My personal life takes up time that I'd like to spend at work.	1	2	3	4	5

Dental care and oral health study **PART B**

15 **General health** [Please CIRCLE a number that best represents your perspective]

A. The following statements are about your general health.

	Strongly disagree				Strongly agree
1. I take responsibility in caring for my health.	1	2	3	4	5
2. No matter how hard I try my health does not turn out the way I would like.	1	2	3	4	5
3. It is difficult for me to find effective solutions to health problems that come my way.	1	2	3	4	5
4. I succeed in the projects I undertake to improve my health.	1	2	3	4	5
5. I am generally able to achieve my goals with respect to health.	1	2	3	4	5
6. I am usually unsuccessful in making changes to things about my health that I don't like.	1	2	3	4	5
7. Generally, my plans for my health don't work out well.	1	2	3	4	5
8. I am able to do things for my health as well as most other people.	1	2	3	4	5

B. The following statements ask questions about stress. While answering Can you please consider " How often during the Past year..."

	Very often	Fairly often	Occasionally	Hardly ever	Never
Please CIRCLE	1	2	3	(4)	5
1. Have you felt upset because of something that happened unexpectedly?	1	2	3	4	5
2. Have you felt unable to control the important things in life?	1	2	3	4	5
3. Have you felt either nervous or stressed?	1	2	3	4	5
4. Have you dealt successfully with irritating life hassles?	1	2	3	4	5
5. Have you effectively coped with important changes in your life?	1	2	3	4	5
6. Have felt confident about your ability to handle your personal problems?	1	2	3	4	5
7. Have you felt things were not going your way?	1	2	3	4	5
8. Have you felt unable to cope with all things that you had to do?	1	2	3	4	5
9. Have you felt able to control irritations in your life?	1	2	3	4	5
10. Have you felt you were on the top of things?	1	2	3	4	5
11. Have you felt angered because of things that happened outside your control?	1	2	3	4	5
12. Have you found yourself thinking about all the things that you have to accomplish?	1	2	3	4	5
13. Have you felt able to control the way you spend your time?	1	2	3	4	5
14. Have you felt difficulties were piling up so high that you could not overcome them?	1	2	3	4	5

16 **Social and health system values** [Please CIRCLE a number that best represents your opinion]

	Strongly disagree				Strongly agree
1. The community is responsible for ensuring everyone is able to receive dental care.	1	2	3	4	5
2. People with similar dental problems should be provided with the same dental care.	1	2	3	4	5

Dental care and oral health study **PART B**

17 Personality traits [Please CIRCLE the number that best represents your answer]

Here are a number of personality traits that may or may not apply to you. Please indicate the extent to which you agree or disagree with each statement. You should rate the extent to which the pair of traits applies to you, even if one characteristic applies more strongly than the other.

I see myself as:	Disagree strongly	Disagree moderately	Disagree a little	Neither agree or disagree	Agree a little	Agree moderately	Agree strongly
1. Extraverted, enthusiastic	1	2	3	4	5	6	7
2. Critical, quarrelsome	1	2	3	4	5	6	7
3. Dependable, self-disciplined	1	2	3	4	5	6	7
4. Anxious, easily upset	1	2	3	4	5	6	7
5. Open to new experiences, complex	1	2	3	4	5	6	7
6. Reserved, quiet	1	2	3	4	5	6	7
7. Sympathetic, warm	1	2	3	4	5	6	7
8. Disorganised, careless	1	2	3	4	5	6	7
9. Calm, emotionally stable	1	2	3	4	5	6	7
10. Conventional, uncreative	1	2	3	4	5	6	7

18 Orientation to life [Please CIRCLE the number that best represents your answer]

Do you usually:	Yes, usually	Yes, sometimes	No
1. Feel that the things that happen to you in your life are hard to understand?	1	2	3
2. See a solution to problems and difficulties that other people find hopeless?	1	2	3
3. Feel that your daily life is a source of personal satisfaction?	1	2	3

19 Wellbeing [Please CIRCLE the number that best represents your answer]

HOW OFTEN during the **PAST MONTH:**	None of the time	A little of the time	Some of the time	Most of the time	All of the time
1. Did you feel tired out for no good reason?	1	2	3	4	5
2. Did you feel nervous?	1	2	3	4	5
3. Did you feel so nervous that nothing could calm you down?	1	2	3	4	5
4. Did you feel hopeless?	1	2	3	4	5
5. Did you feel restless or fidgety?	1	2	3	4	5
6. Did you feel so restless you could not sit still?	1	2	3	4	5
7. Did you feel depressed?	1	2	3	4	5
8. Did you feel that everything was an effort?	1	2	3	4	5
9. Did you feel so sad that nothing could cheer you up?	1	2	3	4	5
10. Did you feel worthless?	1	2	3	4	5

Dental care and oral health study **PART C**

PART C asks generic questions about your background, education, diet and work. Instructions on how to answer each question are provided at beginning of each question.

20 **Diet** [Please WRITE an appropriate number or choose from the options provided]

A1. My usual daily serves of fruit: _____(serves) (Number)

A2. My usual daily serves of vegetables: _____(serves) (Number)

B1. Since same time last year, my fruit consumption: ☐ Increased ☐ Decreased ☐ Stayed about the same

B2. Since same time last year, my vegetable consumption: ☐ Increased ☐ Decreased ☐ Stayed about the same

C1. How often is salt used in your household for cooking or preparing food? ☐ Very often ☐ Occasionally ☐ Rarely ☐ Not used

C2. How often is salt added to food at the table? ☐ Very often ☐ Occasionally ☐ Rarely ☐ Not used

21 **General information** [Please CROSS or WRITE your answer, where required]

A. Please write your YEAR OF BIRTH ☐☐☐☐

B. Please mark your GENDER ☐ Male ☐ Female

C. In which country were you born? ☐ Australia ☐ Other country (please specify) _____

Which year did you migrate to Australia? ☐☐☐☐

D. Are you of Aboriginal or Torres Strait Islander origin? ☐ No ☐ Yes, Torres Strait Islander ☐ Yes, Aboriginal ☐ Yes, Aboriginal & Torres Strait Islander

E. What is the main language you speak at home? ☐ English ☐ Other (please specify) _____

F. What is your current marital status? ☐ Single, never married ☐ Divorced ☐ Married or de facto partnership ☐ Separated ☐ Widowed

G. Do you have children? ☐ Yes ☐ No **If NO go to Question H now**

> Please provide the ages of your children starting with your oldest child (in years/months)

1. _____ 3. _____ 5. _____

2. _____ 4. _____ 6. _____

H. What is the HIGHEST level of education you have completed? ☐ No schooling completed ☐ Completed high school ☐ Completed primary school ☐ Vocational training ☐ Some high school ☐ University degree/Tertiary qualification

I. Where did you complete your highest education? ☐ In Australia ☐ In other country (please specify) _____

Dental care and oral health study **PART C**

22 Work related information

A. Are you currently employed? ☐ Yes, full time ☐ Yes, part-time ☐ No, not currently working

B. Please select an option that best describes the work you do?

- ☐ Managers
- ☐ Professionals
- ☐ Technicians and trade workers
- ☐ Community and personal service workers
- ☐ Clerical and administrative workers
- ☐ Sales workers
- ☐ Machinery operators and drivers
- ☐ Labourers

C. Which of the following best describes the position you hold within your business or organisation?

☐ Managerial

D1. How would you describe your management position?

- ☐ Top
- ☐ Upper
- ☐ Middle
- ☐ Lower

☐ Supervisory

D2. Do you participate in making policy decisions such as products or services delivered, people employed, budgets and so forth?

- ☐ Yes
- ☐ No

☐ Non-management/Non-supervisory

D3. As an official part of your job, do you supervise the work of other employees or tell other employees what work to do?

- ☐ Yes
- ☐ No

E. How many people contribute to your household income?

- ☐ Only ME
- ☐ Myself and my PARTNER
- ☐ Myself, my partner and OTHERS (including children, parents)

F. Which category does your total household income (before tax) fall into? Include any salaries, pensions, allowances, benefits etc. from all persons in the household. (Please CROSS one box only)

- ☐ Less than $20,000
- ☐ $20,001 to $40,000
- ☐ $40,001 to $60,000
- ☐ $60,001 to $80,000
- ☐ $80,001 to $100,000
- ☐ $100,001 to $120,000
- ☐ $120,001 to $140,000
- ☐ $140,001 to $160,000
- ☐ $160,001 to $180,000
- ☐ More than $180,000

Please feel free to write here if you have any suggestions/comments:

THE UNIVERSITY of ADELAIDE

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www.adelaide.edu.au/arcpoh/dentalcarestudy

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Appendix II

Appendix III – Supplementary Information of Paper 1

Appendix III

Paper 1 Search Strategies Syntax

TOTAL: 5546 Included 193

PubMed (2763 articles)

((("Dental Health Surveys"[Mesh]) OR ("Dental Care"[Mesh] OR ("Oral Health"[Mesh] OR "Dental Health Services"[Mesh])) AND (((("Socioeconomic Factors"[Mesh]) OR "Hierarchy, Social"[Mesh]) OR ("Healthcare Disparities"[Mesh] OR "Health Status Disparities"[Mesh])) OR "Social Determinants of Health"[Mesh]) OR "Social Class"[Mesh])) AND ((("dental services"[Title/Abstract]) OR ("dental visits"[Title/Abstract])) OR ("utilization" [Title/Abstract])) OR ("provision" [Title/Abstract])) OR ("use of services"[Title/Abstract]))

Scopus (2293 articles)

TITLE-ABS-KEY("oral health") OR TITLE-ABS-KEY("Dental Health Surveys") OR TITLE-ABS-KEY("Dental Health Services") OR TITLE-ABS-KEY("dental care") AND TITLE-ABS-KEY("Socioeconomic Factors") OR TITLE-ABS-KEY("Social Hierarchy") OR TITLE-ABS-KEY(Inequalities) OR TITLE-ABS-KEY("Social Disparities") OR TITLE-ABS-KEY("Social Gradient") OR TITLE-ABS-KEY("Health Status") OR TITLE-ABS-KEY("socioeconomic disadvantage") OR TITLE-ABS-KEY("socioeconomic inequalities") OR TITLE-ABS-KEY("Social Determinants") AND TITLE-ABS-KEY("dental services") OR TITLE-ABS-KEY("dental visits") OR TITLE-ABS-KEY("utilization") OR TITLE-ABS-KEY(provision) OR TITLE-ABS-KEY("use of services")

WOS (154 articles)

TS= ("Dental Health Surveys" OR "Dental Care" OR "Oral Health" OR "Dental Health Services")

AND

TS= ("Socioeconomic Factors" OR "Hierarchy, Social" OR "Healthcare Disparities" OR "Health Status Disparities" OR "Social Determinants of Health" OR "Social Class")

AND

TS= ("dental services" OR "dental visits" OR "utilization" OR "provision" OR "use of services")

ProQuest (336 articles)

noft(("Dental Health Surveys" OR "Dental Care" OR "Oral Health" OR "Dental Health Services")) AND noft(("Socioeconomic Factors" OR "Hierarchy, Social" OR "Healthcare Disparities" OR "Health Status Disparities" OR "Social Determinants of Health" OR "Social Class")) AND noft(("dental services" OR "dental visits" OR "utilization" OR "provision" OR "use of services"))

Table S1- Data extraction form of Paper 1

No	Author	Study Title/aim	Study population	Year	Study Design	Study place	Key Determinants of the study (in the scopes of utilization, access, provision, equality)
							• A • B • C • …

Table S2- Determinants of inequality in utilization and provision of dental services in OECD countries

Main themes	Sub-themes	Sub-sub themes	Count	References
Utilization of Services				
Individual determinants	**Demographic determinants**	Gender	18	(1-18)
		Race and ethnicity	25	(8, 9, 19-41)
		Nationality /Mother nationality	4	(3, 4, 42, 43)
		Age	42	(10, 11, 14, 15, 18, 22, 27-31, 33, 36, 38, 44-71)
		Marital status	3	(3, 38, 46)
	Self-rated health status	Functional abilities	4	(67, 72-74)
		Quality of life	3	(75-77)
		Special health needs/minorities	3	(31, 51, 78)
		Oral health status	10	(8, 9, 28, 31, 47, 57, 72, 79-81)
		Disease and health status	8	(5, 16, 24, 32, 37, 46, 77, 82)
Social determinants	**social status**	Residential location	20	(6, 14, 26, 27, 30, 36, 83-96)
		Vulnerable groups	9	(8, 26, 29, 30, 37, 64, 66, 97, 98)
		Population density	1	(94)
		Occupation /employment	5	(12, 99-102)
		Immigrant and refugees	11	(6, 8, 32, 41, 68, 71, 97, 103-106)
	Literacy	Education level	32	(1, 3, 5, 10, 13, 18, 20-22, 37-39, 43, 59, 65, 72, 78, 82, 86, 99-102, 107-115)
		Health literacy	4	(78, 112, 116, 117)
		Income	58	(1, 3, 5, 9-11, 14, 17, 20-23, 33, 36-38, 43,

Economic determinants	**Micro-economic**			46, 47, 51, 52, 58, 61, 66, 73, 79, 80, 85, 86, 88, 103, 106, 107, 109, 118-141)
		Wealth	7	(10, 73, 109, 124, 127, 140, 142)
		poverty	11	(13, 33, 49, 54, 82, 95, 97, 120, 124, 129, 143)
	Macro-economic	Macro-Economic crisis/condition	5	(100, 104, 144-146)
		Macroeconomic revenue collection	1	(147)
		Gini index	5	(7, 47, 79, 118, 136)
		GDP per capita/Country revenue	2	(147, 148)
		Economic disparities	4	(83, 84, 87, 108)
Cultural determinants	**Macro cultural factors**	Time and technology	9	(101, 135, 149-155)
		Environmental condition	1	(84)
	Micro cultural factors	Oral health behavior	6	(5, 30, 38, 57, 85, 156)
		Primary language spoken (Fluency)	5	(36, 41, 68, 71, 157)
		lifestyle	6	(5, 14, 57, 67, 114, 158)
		Attitude	8	(32, 42, 71, 76, 77, 85, 117, 139)
Provision of Services				
Health policy	**Policy implementation**	Appropriate policies	7	(63, 132-134, 143, 159, 160)
		Target population concentration	1	(87)
		National interventions	8	(63, 111, 141, 153, 159-163)
	Policy Formulation	Health basic insurance/public insurance	13	(11, 15, 18, 35, 38, 41, 66-69, 78, 89, 91, 106, 111, 114, 116, 119, 120, 135, 137, 138,

	(Insurance)			140, 143, 148, 155, 164-172)
		Supplementary insurance	35	(126, 134, 166, 173)
		Private insurance	5	(9, 18, 125, 174, 175)
		cardholder status	2	(91, 176)
Availability of services	**Type of available services**	Advice services /regular visiting pattern	10	(15, 36, 42, 91, 139, 155, 158, 165, 168, 177)
		Emergency visits	7	(68, 69, 90, 178-181)
		Service coverage	4	(28, 63, 80, 182)
		Specialized services	8	(7, 22, 44, 61, 84, 88, 102, 183)
		Preventive care	13	(3, 11, 31, 38, 98, 99, 113, 115, 121, 164, 171, 184, 185)
		Pharmacists Consultation	1	(180)
		School dental nurses and dental hygienists	1	(186)
	Distribution of services	Geographic location /dentist distribution	15	(11, 39, 88, 90, 93, 126, 137, 171, 172, 180, 185, 187-190)
		Distribution of dental schools	3	(148, 188, 191)
	Management of services	Inadequate private services	1	(182)
		Waiting time in public sector	2	(105, 161)
		Cost of service	11	(16, 60, 69, 91, 106, 140, 148, 157, 165, 192, 193)
		Service Satisfaction	1	(179)
		Dentists recall and follow up	2	(92, 130)

Appendix III

Included Articles in Paper 1

1. Guiney H, Woods N, Whelton HP, Morgan K. Predictors of utilisation of dental care services in a nationally representative sample of adults. 2011.
2. Anttila J, Tolvanen M, Kankaanpaa R, Lahti S. Social gradient in intermediary determinants of oral health at school level in Finland. Community dental health. 2018;35(2):75-80.
3. Christensen LB, Petersen PE, Steding-Jessen M. Consumption of dental services among adults in Denmark 1994–2003. European journal of oral sciences. 2007;115(3):174-9.
4. Christensen LB, Twetman S, Sundby A. Oral health in children and adolescents with different socio-cultural and socio-economic backgrounds. Acta odontologica Scandinavica. 2010;68(1):34-42.
5. Kengne Talla P, Gagnon MP, Dramaix M, Leveque A. Barriers to dental visits in Belgium: a secondary analysis of the 2004 National Health Interview Survey. Journal of public health dentistry. 2013;73(1):32-40.
6. Lee H, Seo S, Kang R, Kim Y, Hyun HK. Increasing access to oral healthcare for marriage-immigrant women in South Korea: programme design to policy recommendation. International dental journal. 2019;69(5):354-60.
7. Simon L, Choi SE, Ticku S, Fox K, Barrow J, Palmer N. Association of income inequality with orthodontic treatment use. Journal of the American Dental Association. 2020;151(3):190-6.
8. Hunter LP, Yount SM. Oral health and oral health care practices among low-income pregnant women. Journal of midwifery & women's health. 2011;56(2):103-9.

9. Akintobi TH, Hoffman LM, McAllister C, Goodin L, Hernandez ND, Rollins L, et al. Assessing the Oral Health Needs of African American Men in Low-Income, Urban Communities. American journal of men's health. 2018;12(2):326-37.
10. Allin S, Masseria C, Mossialos E. Equity in health care use among older people in the UK: an analysis of panel data. Applied Economics. 2011;43(18):2229-39.
11. Bailit H, D'Adamo J. State case studies: improving access to dental care for the underserved. J Public Health Dent. 2012;72(3):221-34.
12. Caban-Martinez AJ, Lee DJ, Fleming LE, Arheart KL, Leblanc WG, Chung-Bridges K, et al. Dental care access and unmet dental care needs among U.S. workers: the National Health Interview Survey, 1997 to 2003. J Am Dent Assoc. 2007;138(2):227-30.
13. Carrion IV, Castaneda H, Martinez-Tyson D, Kline N. Barriers impeding access to primary oral health care among farmworker families in Central Florida. Soc Work Health Care. 2011;50(10):828-44.
14. Crocombe LA, Stewart JF, Brennan DS, Slade GD, Spencer AJ. Is poor access to dental care why people outside capital cities have poor oral health? Aust Dent J. 2012;57(4):477-85.
15. Dounis G, Ditmyer MM, McCants R, Lee Y, Mobley C. Southern Nevada assisted living residents' perception of their oral health status and access to dental care. Gerodontology. 2012;29(2):e150-4.
16. Jones E, Shi L, Hayashi AS, Sharma R, Daly C, Ngo-Metzger Q. Access to oral health care: the role of federally qualified health centers in addressing disparities and expanding access. Am J Public Health. 2013;103(3):488-93.

17. Kiuchi S, Aida J, Kusama T, Yamamoto T, Hoshi M, Yamamoto T, et al. Does public transportation reduce inequalities in access to dental care among older adults? Japan Gerontological Evaluation Study. Community dentistry and oral epidemiology. 2020;48(2):109-18.
18. Roberts-Thomson K, Stewart J. Access to dental care by young South Australian adults. Australian Dental Journal. 2003;48(3):169-74.
19. Gilbert GH, Paul Duncan R, Shelton BJ. Social determinants of tooth loss. Health services research. 2003;38(6p2):1843-62.
20. Gupta N, Vujicic M, Yarbrough C, Harrison B. Disparities in untreated caries among children and adults in the U.S., 2011-2014. BMC oral health. 2018;18(1):30.
21. Liu Y, Li Z, Walker MP. Social disparities in dentition status among American adults. International dental journal. 2014;64(1):52-7.
22. Moeller JF, Chen H, Manski RJ. Diversity in the use of specialized dental services by older adults in the United States. Journal of public health dentistry. 2019;79(2):160-74.
23. Shi L, Lebrun LA, Tsai J. Access to medical care, dental care, and prescription drugs: the roles of race/ethnicity, health insurance, and income. Southern medical journal. 2010;103(6):509.
24. Smith DK, Castellanos EH, Murphy BA. Financial and socio-economic factors influencing pre- and post-cancer therapy oral care. Supportive care in cancer : official journal of the Multinational Association of Supportive Care in Cancer. 2018;26(7):2143-8.

25. Zhang W, Wu YY, Wu B. Racial/Ethnic Disparities in Dental Service Utilization for Foreign-Born and U.S.-Born Middle-Aged and Older Adults. Research on aging. 2019;41(9):845-67.
26. Martin-Kerry JM, Whelan M, Rogers J, Raichur A, Cole D, de Silva AM. Addressing disparities in oral disease in Aboriginal people in Victoria: where to focus preventive programs. Australian Journal of Primary Health. 2019;25(4):317-24.
27. Armfield JM. Socioeconomic inequalities in child oral health: a comparison of discrete and composite area-based measures. Journal of Public Health Dentistry. 2007;67(2):119-25.
28. Dehmoobadsharifabadi A, Singhal S, Quinonez CR. Impact of public dental care spending and insurance coverage on utilization disparities among Canadian jurisdictions. Journal of public health dentistry. 2018;78(4):346-51.
29. Ha DH, Xiangqun J, Cecilia MG, Jason A, Do LG, Jamieson LM. Social inequality in dental caries and changes over time among Indigenous and non-Indigenous Australian children. Australian and New Zealand journal of public health. 2016;40(6):542-7.
30. Kilpatrick NM, Neumann A, Lucas N, Chapman J, Nicholson JM. Oral health inequalities in a national sample of Australian children aged 2-3 and 6-7 years. Australian dental journal. 2012;57(1):38-44.
31. Bell JF, Huebner CE, Reed SC. Oral health need and access to dental services: evidence from the National Survey of Children's Health, 2007. Matern Child Health J. 2012;16 Suppl 1:S27-34.

32. DiMarco MA, Ludington SM, Menke EM. Access to and utilization of oral health care by homeless children/families. Journal of Health Care for the Poor and Underserved. 2010;21(2):67-81.
33. Edelstein BL, Chinn CH. Update on disparities in oral health and access to dental care for America's children. Academic pediatrics. 2009;9(6):415-9.
34. Flores G, Lin H. Trends in racial/ethnic disparities in medical and oral health, access to care, and use of services in US children: has anything changed over the years? International Journal for Equity in Health. 2013;12(1):10.
35. Flores G, Tomany-Korman SC. Racial and ethnic disparities in medical and dental health, access to care, and use of services in US children. Pediatrics. 2008;121(2):e286-98.
36. Fulkerson ND, Haff DR, Chino M. Health care access disparities among children entering kindergarten in Nevada. J Child Health Care. 2013;17(3):253-63.
37. Lebrun LA, Shi L. Nativity status and access to care in Canada and the U.S.: factoring in the roles of race/ethnicity and socioeconomic status. J Health Care Poor Underserved. 2011;22(3):1075-100.
38. Malecki K, Wisk LE, Walsh M, McWilliams C, Eggers S, Olson M. Oral health equity and unmet dental care needs in a population-based sample: findings from the Survey of the Health of Wisconsin. Am J Public Health. 2015;105 Suppl 3:S466-74.
39. Nash DA. Improving access to oral health care for children by expanding the dental workforce to include dental therapists. Dent Clin North Am. 2009;53(3):469-83.

40. Okunseri C, Bajorunaite R, Matthew R, Iacopino AM. Racial and ethnic variation in the provision of dental procedures. Journal of public health dentistry. 2007;67(1):20-7.
41. Shelley D, Russell S, Parikh NS, Fahs M. Ethnic disparities in self-reported oral health status and access to care among older adults in NYC. J Urban Health. 2011;88(4):651-62.
42. Nota A, Caruso S, Cantile T, Gatto R, Ingenito A, Tecco S, et al. Socioeconomic Factors and Oral Health-Related Behaviours Associated with Dental Caries in Preschool Children from Central Italy (Province of Ascoli Piceno). BioMed research international. 2019;2019:7981687.
43. Trohel G, Bertaud-Gounot V, Soler M, Chauvin P, Grimaud O. Socio-Economic Determinants of the Need for Dental Care in Adults. PloS one. 2016;11(7):e0158842.
44. Islas-Granillo H, Borges-Yañez S, Medina-Solis C, Márquez-Rodríguez S, Lucas-Rincón S, Fernández-Barrera M, et al. Dental prosthetic treatment needs in Mexican elders: Influence of socioeconomic position. Dental and Medical Problems. 2017;54(4):383-7.
45. Mariño R, Cueto A, Badenier O, Acevedo R, Moya R. Oral health status and inequalities among ambulant older adults living in central Chile. Community dental health. 2011;28(2):143.
46. Aarabi G, Valdez R, Spinler K, Walther C, Seedorf U, Heydecke G, et al. Determinants of Postponed Dental Visits Due to Costs: Evidence from the Survey of Health, Ageing, and Retirement in Germany. International journal of environmental research and public health. 2019;16(18).

47. Bernabe E, Marcenes W. Income inequality and tooth loss in the United States. Journal of dental research. 2011;90(6):724-9.
48. Brothwell DJ, Jay M, Schönwetter DJ. Dental service utilization by independently dwelling older adults in Manitoba, Canada. Journal of the Canadian Dental Association. 2008;74(2).
49. Costacurta M, Epis M, Docimo R. Evaluation of DMFT in paediatric patients with social vulnerability conditions. European journal of paediatric dentistry. 2020;21(1):70-3.
50. Kramarow EA. Dental care among adults aged 65 and over, 2017. 2019.
51. Edelstein BL. Disparities in oral health and access to care: findings of national surveys. Ambulatory pediatrics. 2002;2(2):141-7.
52. Grytten J, Holst D. Do young adults demand more dental services as their income increases? Community dentistry and oral epidemiology. 2002;30(6):463-9.
53. Hjern A, Grindefjord M, Sundberg H, Rosén M. Social inequality in oral health and use of dental care in Sweden. Community dentistry and oral epidemiology. 2001;29(3):167-74.
54. Jiménez-Gayosso SI, Medina-Solís CE, Lara-Carrillo E, Scougal-Vilchis RJ, de la Rosa-Santillana R, Márquez-Rodríguez S, et al. Socioeconomic inequalities in oral health service utilization any time in their lives for Mexican schoolchildren from 6 to 12 years old. Gac Med Mex. 2015;151:27-33.
55. Kim J, Choi Y, Park S, Kim JL, Lee TH, Cho KH, et al. Disparities in the experience and treatment of dental caries among children aged 9-18 years: the cross-sectional study of Korean National Health and Nutrition Examination Survey (2012-2013). International journal for equity in health. 2016;15:88.

56. Lambert MJ, Vanobbergen JSN, Martens LC, De Visschere LMJ. Socioeconomic inequalities in caries experience, care level and dental attendance in primary school children in Belgium: a cross-sectional survey. BMJ open. 2017;7(7):e015042.
57. Lee YS, Kim HG, Hur JY, Yang K. Oral Health in Low-Income Older Adults in Korea. Journal of community health nursing. 2016;33(2):98-106.
58. Listl S. Income-related inequalities in dental service utilization by Europeans aged 50+. Journal of dental research. 2011;90(6):717-23.
59. Listl S. Inequalities in dental attendance throughout the life-course. Journal of dental research. 2012;91(7 Suppl):91S-7S.
60. Manski RJ, Hyde JS, Chen H, Moeller JF. Differences Among Older Adults in the Types of Dental Services Used in the United States. Inquiry : a journal of medical care organization, provision and financing. 2016;53.
61. Matsuyama Y, Aida J, Takeuchi K, Tsakos G, Watt RG, Kondo K, et al. Inequalities of dental prosthesis use under universal healthcare insurance. Community dentistry and oral epidemiology. 2014;42(2):122-8.
62. Roberts-Thomson K, Brennan DS, Spencer AJ. Social inequality in the use and comprehensiveness of dental services. Australian journal of public health. 1995;19(1):80-5.
63. Shin BM, Jung SH, Kim MH, Ryu JI. Did the extended coverage policy contribute to alleviating socioeconomic inequality in untreated dental caries of both children and adolescents in South Korea? BMC oral health. 2020;20(1):124.
64. Verlinden DA, Reijneveld SA, Lanting CI, van Wouwe JP, Schuller AA. Socio-economic inequality in oral health in childhood to young adulthood, despite full dental coverage. European journal of oral sciences. 2019;127(3):248-53.

65. Vikum E, Krokstad S, Holst D, Westin S. Socioeconomic inequalities in dental services utilisation in a Norwegian county: the third Nord-Trondelag Health Survey. Scandinavian journal of public health. 2012;40(7):648-55.
66. Amin MS, Perez A, Nyachhyon P. Barriers to utilization of dental services for children among low-income families in Alberta. J Can Dent Assoc. 2014;80:e51.
67. Österberg T, Lundgren M, Emilson C-G, Sundh V, Birkhed D, Steen B. Utilization of dental services in relation to socioeconomic and health factors in the middle-aged and elderly Swedish population. Acta Odontologica Scandinavica. 1998;56(1):41-7.
68. Guendelman S, Angulo V, Wier M, Oman D. Overcoming the odds: access to care for immigrant children in working poor families in California. Matern Child Health J. 2005;9(4):351-62.
69. Jones K. An evaluation of the discriminant and predictive validity of relative social disadvantage as screening criteria for priority access to public general dental care, in Australia. BMC Health Services Research. 2014;14(1):1-9.
70. Wanyonyi KL, Radford DR, Gallagher JE. The relationship between access to and use of dental services following expansion of a primary care service to embrace dental team training. Public Health. 2013;127(11):1028-33.
71. Council on Access P, Interprofessional R, Robinson LA. Private sector response to improving oral health care access. Dent Clin North Am. 2009;53(3):523-35.
72. Listl S. Cost-related dental non-attendance in older adulthood: evidence from eleven European countries and Israel. Gerodontology. 2016;33(2):253-9.

73. Murakami K, Hashimoto H. Wealth-related versus income-related inequalities in dental care use under universal public coverage: a panel data analysis of the Japanese Study of Aging and Retirement. BMC public health. 2016;16:24.
74. Shin HS. Social gradients in oral health status in Korea population. Archives of oral biology. 2018;95:89-94.
75. Vásquez F, Paraje G, Estay M. Income-related inequality in health and health care utilization in Chile, 2000-2009. Revista Panamericana de Salud Pública. 2013;33:98-106.
76. Valdez R, Aarabi G, Spinler K, Walther C, Seedorf U, Heydecke G, et al. Association between Subjective Well-Being and Frequent Dental Visits in the German Ageing Survey. International journal of environmental research and public health. 2020;17(9).
77. Rocha-Buelvas A, Hidalgo-Troya A, Hidalgo-Eraso Á. Barriers of access to oral health care among university students in southern Colombia, 2011. A multivariate analysis. Revista de la Facultad de Medicina. 2014;62(4):521-8.
78. Sohn W, Ismail A, Amaya A, Lepkowski J. Determinants of dental care visits among low-income African-American children. Journal of the American Dental Association. 2007;138(3):309-18; quiz 95-96, 98.
79. Moeller J, Quinonez C. The Association Between Income Inequality and Oral Health in Canada: A Cross-Sectional Study. International journal of health services : planning, administration, evaluation. 2016;46(4):790-809.
80. Gundgaard J. Income-related inequality in utilization of health services in Denmark: evidence from Funen County. Scandinavian journal of public health. 2006;34(5):462-71.

81. Crete P, Boyd LD, Fitzgerald JK, LaSpina LM. Access to preventive oral health services for homebound populations: A pilot program. American Dental Hygienists' Association. 2018;92(6):24-32.
82. Stevens GD, Seid M, Tsai K-Y, West-Wright C, Cousineau MR. Improvements in access to care for vulnerable children in California between 2001 and 2005. Public Health Reports. 2009;124(5):682-91.
83. Salomon-Ibarra CC, Ravaghi V, Hill K, Jones CM, Landes DP, Morris AJ. Low rates of dental attendance by the age of one and inequality between local government administrative areas in England. Community dental health. 2019;36(1):22-6.
84. Morris E, Landes D. The equity of access to orthodontic dental care for children in the North East of England. Public health. 2006;120(4):359-63.
85. Piotrowska DE, Pedzinski B, Jankowska D, Huzarska D, Charkiewicz AE, Szpak AS. Socio-economic inequalities in the use of dental care in urban and rural areas in Poland. Annals of agricultural and environmental medicine : AAEM. 2018;25(3):512-6.
86. Piotrowska DE, Jankowska D, Huzarska D, Szpak AS, Pedzinski B. Socioeconomic inequalities in use and non-use of dental services in Poland. International journal of public health. 2020.
87. Tickle M, Moulding G, Milsom K, Blinkhorn A. Socioeconomic and geographical influences on primary dental care preferences in a population of young children. British dental journal. 2000;188(10):559-62.

88. Christensen LB, Rosing K, Lempert SM, Hede B. Patterns of dental services and factors that influence dental services among 64-65-year-old regular users of dental care in Denmark. Gerodontology. 2016;33(1):79-88.
89. Byck GR, Walton SM, Cooksey JA. Access to dental care services for Medicaid children: variations by urban/rural categories in Illinois. The Journal of Rural Health. 2002;18(4):512-20.
90. Dyer T, Skinner J, Canning D, Green J. A health equity methodology for auditing oral health and NHS General Dental Services in Sheffield, England. Community Dent Health. 2010;27(2):68-73.
91. Ellershaw A. Oral health and access to dental care in Australia—Comparisons by cardholder status and geographic region. Australian dental journal. 2005;50(4):282-5.
92. Friedman JW, Mathu-Muju KR. Dental therapists: improving access to oral health care for underserved children. American journal of public health. 2014;104(6):1005-9.
93. Jean G, Kruger E, Tennant M. Universal access to oral health care for Australian children: comparison of travel times to public dental services at consecutive census dates as an indicator of progressive realisation. Aust J Prim Health. 2020;26(2):109-16.
94. McKernan SC, Kuthy RA, Momany ET, McQuistan MR, Hanley PF, Jones MP, et al. Geographic accessibility and utilization of orthodontic services among Medicaid children and adolescents. J Public Health Dent. 2013;73(1):56-64.
95. Pinilla J, Gonzalez B. Equity in children's utilization of dental services: effect of a children's dental care programme. Community dental health. 2006;23(3):152.

96. Willie-Stephens J, Kruger E, Tennant M. Public and private dental services in NSW: a geographic information system analysis of access to care for 7 million Australians. New South Wales Public Health Bulletin. 2014;24(4):164-70.

97. Ferrazzano GF, Cantile T, Sangianantoni G, Ingenito A, Rengo S, Alcidi B, et al. Oral health status and Unmet Restorative Treatment Needs (UTN) in disadvantaged migrant and not migrant children in Italy. European journal of paediatric dentistry. 2019;20(1):10-4.

98. Batliner TS. American Indian and Alaska Native Access to Oral Health Care: A Potential Solution. Journal of Health Care for the Poor and Underserved. 2016;27(1A):1-10.

99. Cheema J, Sabbah W. Inequalities in preventive and restorative dental services in England, Wales and Northern Ireland. British dental journal. 2016;221(5):235-9.

100. Leinsalu M, Reile R, Vals K, Petkeviciene J, Tekkel M, Stickley A. Macroeconomic changes and trends in dental care utilization in Estonia and Lithuania in 2004-2012: a repeated cross-sectional study. BMC oral health. 2018;18(1):199.

101. Honkala E, Kuusela S, Rimpelä A, Rimpelä M, Jokela J. Dental services utilization between 1977 and 1995 by Finnish adolescents of different socioeconomic levels. Community dentistry and oral epidemiology. 1997;25(6):385-90.

102. Telford C, Murray L, Donaldson M, O'Neill C. An analysis examining socio-economic variations in the provision of NHS general dental practitioner care under a fee for service contract among adolescents: Northern Ireland Longitudinal Study. Community dentistry and oral epidemiology. 2012;40(1):70-9.

103. Rhee Kim YO, Telleen S. Predictors of the utilization of oral health services by children of low-income families in the United States: beliefs, cost, or provider? Journal of Korean Academy of Nursing. 2004;34(8):1460-7.

104. Rodriguez-Alvarez E, Lanborena N, Borrell LN. Place of Birth Inequalities in Dental Care Use before and after the Economic Crisis in Spain. International journal of environmental research and public health. 2019;16(10).

105. Davidson N, Skull S, Calache H, Chesters D, Chalmers J. Equitable access to dental care for an at-risk group: a review of services for Australian refugees. Australian and New Zealand journal of public health. 2007;31(1):73-80.

106. Howard JR, Ramirez J, Li Y, Gany F. Dental care access for low-income and immigrant cancer patients in New York City. J Community Health. 2015;40(1):110-5.

107. Abbas H, Aida J, Saito M, Tsakos G, Watt RG, Koyama S, et al. Income or education, which has a stronger association with dental implant use in elderly people in Japan? International dental journal. 2019;69(6):454-62.

108. Carta G, Cagetti M, Sale S, Congiu G, Strohmenger L, Oleari F, et al. Oral health inequalities in Italian schoolchildren-a cross-sectional evaluation. Community Dent Health. 2014;31(2):123-8.

109. Shen J, Listl S. Investigating social inequalities in older adults' dentition and the role of dental service use in 14 European countries. The European journal of health economics : HEPAC : health economics in prevention and care. 2018;19(1):45-57.

110. Tapias-Ledesma MA, Jimenez R, Garrido PC, Miguel AGd. Influence of sociodemographic variables on dental service utilization and oral health among the

children included in the year 2001 Spanish National Health Survey. Journal of public health dentistry. 2005;65(4):215-20.

111. Cornejo-Ovalle M, Paraje G, Vasquez-Lavin F, Perez G, Palencia L, Borrell C. Changes in socioeconomic inequalities in the use of dental care following major healthcare reform in Chile, 2004-2009. International journal of environmental research and public health. 2015;12(3):2823-36.

112. Gupta A, Feldman S, Perkins RB, Stokes A, Sankar V, Villa A. Predictors of dental care use, unmet dental care need, and barriers to unmet need among women: results from NHANES, 2011 to 2016. Journal of public health dentistry. 2019;79(4):324-33.

113. Kino S, Bernabe E, Sabbah W. Social Inequalities in Use of Preventive Dental and Medical Services among Adults in European Countries. International journal of environmental research and public health. 2019;16(23).

114. Ellershaw A. Oral health and access to dental care in Australia-comparisons by level of education. 2006.

115. Everaars B, Jerkovic-Cosic K, van der Putten GJ, Pretty IA, Brocklehurst P. Needs in Service Provision for Oral Health Care in Older People: A Comparison Between Greater Manchester (United Kingdom) and Utrecht (the Netherlands). Int J Health Serv. 2018;48(4):663-84.

116. Jones K, Parker E, Jamieson L. Access, literacy and behavioural correlates of poor self-rated oral health amongst an indigenous south Australian population. Community Dent Health. 2014;31(3):167-71.

117. Slack-Smith L, Lange A, Paley G, O'Grady M, French D, Short L. Oral health and access to dental care: a qualitative investigation among older people in the community. Gerodontology. 2010;27(2):104-13.

118. Aida J, Kondo K, Kondo N, Watt RG, Sheiham A, Tsakos G. Income inequality, social capital and self-rated health and dental status in older Japanese. Social science & medicine. 2011;73(10):1561-8.

119. Anikeeva O, Brennan DS, Teusner DN. Household income modifies the association of insurance and dental visiting. BMC health services research. 2013;13(1):432.

120. Duncan L, Bonner A. Effects of income and dental insurance coverage on need for dental care in Canada. J Can Dent Assoc. 2014;80:e6.

121. Grignon M, Hurley J, Wang L, Allin S. Inequity in a market-based health system: Evidence from Canada's dental sector. Health policy. 2010;98(1):81-90.

122. Grytten J, Holst D, Skau I. Demand for and utilization of dental services according to household income in the adult population in Norway. Community dentistry and oral epidemiology. 2012;40(4):297-305.

123. Guessous I, Theler J-M, Izart CD, Stringhini S, Bodenmann P, Gaspoz J-M, et al. Forgoing dental care for economic reasons in Switzerland: a six-year cross-sectional population-based study. BMC Oral Health. 2014;14(1):121.

124. Kailembo A, Quinonez C, Lopez Mitnik GV, Weintraub JA, Stewart Williams J, Preet R, et al. Income and wealth as correlates of socioeconomic disparity in dentist visits among adults aged 20 years and over in the United States, 2011-2014. BMC oral health. 2018;18(1):147.

125. Locker D, Maggirias J, Quinonez C. Income, dental insurance coverage, and financial barriers to dental care among Canadian adults. Journal of public health dentistry. 2011;71(4):327-34.

126. Lupi-Pegurier L, Clerc-Urmes I, Abu-Zaineh M, Paraponaris A, Ventelou B. Density of dental practitioners and access to dental care for the elderly: a multilevel analysis with a view on socio-economic inequality. Health policy. 2011;103(2-3):160-7.

127. Manski RJ, Moeller JF, Chen H, St Clair PA, Schimmel J, Pepper JV. Wealth effect and dental care utilization in the United States. Journal of public health dentistry. 2012;72(3):179-89.

128. Murakami K, Aida J, Ohkubo T, Hashimoto H. Income-related inequalities in preventive and curative dental care use among working-age Japanese adults in urban areas: a cross-sectional study. BMC Oral Health. 2014;14(1):117.

129. Nasseh K, Vujicic M. The effect of growing income disparities on U.S. adults' dental care utilization. Journal of the American Dental Association. 2014;145(5):435-42.

130. Nguyen L, Häkkinen U. Income-related inequality in the use of dental services in Finland. Applied health economics and health policy. 2004;3(4):251-62.

131. Nishide A, Fujita M, Sato Y, Nagashima K, Takahashi S, Hata A. Income-Related Inequalities in Access to Dental Care Services in Japan. International journal of environmental research and public health. 2017;14(5).

132. Raittio E, Aromaa A, Kiiskinen U, Helminen S, Suominen AL. Income-related inequality in perceived oral health among adult Finns before and after a major dental subsidization reform. Acta odontologica Scandinavica. 2016;74(5):348-54.

133. Raittio E, Kiiskinen U, Helminen S, Aromaa A, Suominen AL. Income-related inequality and inequity in the use of dental services in Finland after a major subsidization reform. Community dentistry and oral epidemiology. 2015;43(3):240-54.

134. Ramraj C, Sadeghi L, Lawrence HP, Dempster L, Quinonez C. Is accessing dental care becoming more difficult? Evidence from Canada's middle-income population. PloS one. 2013;8(2):e57377.

135. Ravaghi V, Farmer J, Quinonez C. Persistent but narrowing oral health care inequalities in Canada from 2001 through 2016. Journal of the American Dental Association. 2020;151(5):349-57 e1.

136. Singh A, Harford J, Antunes JLF, Peres MA. Area-level income inequality and oral health among Australian adults-A population-based multilevel study. PloS one. 2018;13(1):e0191438.

137. Biordi DL, Heitzer M, Mundy E, DiMarco M, Thacker S, Taylor E, et al. Improving access and provision of preventive oral health care for very young, poor, and low-income children through a new interdisciplinary partnership. Am J Public Health. 2015;105 Suppl 2:e23-9.

138. Felland LE, Felt-Lisk S, McHugh M. Health care access for low-income people: significant safety net gaps remain. Issue Brief Cent Stud Health Syst Change. 2004;84:1-4.

139. Telleen S, Rhee Kim YO, Chavez N, Barrett RE, Hall W, Gajendra S. Access to oral health services for urban low-income Latino children: social ecological influences. J Public Health Dent. 2012;72(1):8-18.

140. Thompson B, Cooney P, Lawrence H, Ravaghi V, Quinonez C. Cost as a barrier to accessing dental care: findings from a Canadian population-based study. Journal of public health dentistry. 2014;74(3):210-8.

141. Wang H, Norton EC, Rozier RG. Effects of the State Children's Health Insurance Program on access to dental care and use of dental services. Health Serv Res. 2007;42(4):1544-63.

142. Allin S, Masseria C, Mossialos E. Measuring socioeconomic differences in use of health care services by wealth versus by income. American journal of public health. 2009;99(10):1849-55.

143. Newacheck PW, Hung YY, Jane Park M, Brindis CD, Irwin Jr CE. Disparities in adolescent health and health care: does socioeconomic status matter? Health services research. 2003;38(5):1235-52.

144. Calzon Fernandez S, Fernandez Ajuria A, Martin JJ, Murphy MJ. The impact of the economic crisis on unmet dental care needs in Spain. J Epidemiol Community Health. 2015;69(9):880-5.

145. Elstad JI. Dental care coverage and income-related inequalities in foregone dental care in Europe during the great recession. Community dentistry and oral epidemiology. 2017;45(4):296-302.

146. Romaire MA, Bell JF, Grossman DC. Health care use and expenditures associated with access to the medical home for children and youth. Medical care. 2012:262-9.

147. Grytten J, Lund E, Rongen G. Equity in access to public dental services: the experience from Norway. Acta Odontologica Scandinavica. 2001;59(6):372-8.

148. Pegon-Machat E, Faulks D, Eaton KA, Widstrom E, Hugues P, Tubert-Jeannin S. The healthcare system and the provision of oral healthcare in EU Member States: France. Br Dent J. 2016;220(4):197-203.

149. Elani HW, Harper S, Allison PJ, Bedos C, Kaufman JS. Socio-economic inequalities and oral health in Canada and the United States. Journal of dental research. 2012;91(9):865-70.

150. FitzGerald EM, Cunich M, Clarke PM. Changes in inequalities of access to dental care in Australia 1977–2005. Australian Economic Review. 2011;44(2):153-66.

151. Habicht J, Kunst AE. Social inequalities in health care services utilisation after eight years of health care reforms: a cross-sectional study of Estonia, 1999. Social science & medicine. 2005;60(4):777-87.

152. Sengupta K, Christensen LB, Mortensen LH, Skovgaard LT, Andersen I. Trends in socioeconomic inequalities in oral health among 15-year-old Danish adolescents during 1995-2013: A nationwide, register-based, repeated cross-sectional study. Community dentistry and oral epidemiology. 2017;45(5):458-68.

153. Currie R, Pretty I, Tickle M, Maupomé G. Letter from America: UK and US state-funded dental provision. Community dental health. 2012;29(4):315.

154. Fricton J, Chen H. Using teledentistry to improve access to dental care for the underserved. Dent Clin North Am. 2009;53(3):537-48.

155. Smith BJ, Helgeson M, Prosa B, Finlayson TL, Orozco M, Asgari P, et al. Longitudinal analysis of cost and dental utilization patterns for older adults in outpatient and long-term care settings in Minnesota. PloS one. 2020;15(5):e0232898.

156. Hakeem FF, Sabbah W. Is there socioeconomic inequality in periodontal disease among adults with optimal behaviours. Acta odontologica Scandinavica. 2019;77(5):400-7.

157. Gross–Panico ML, Freeman WK. Identifying barriers to receiving preventive dental services: expanding access to preventive dental hygiene services through affiliated practice. American Dental Hygienists' Association. 2012;86(4):306-14.

158. Wamala S, Merlo J, Bostrom G. Inequity in access to dental care services explains current socioeconomic disparities in oral health: the Swedish National Surveys of Public Health 2004-2005. Journal of epidemiology and community health. 2006;60(12):1027-33.

159. Celeste RK, Nadanovsky P, Fritzell J. Trends in socioeconomic disparities in the utilization of dental care in Brazil and Sweden. Scandinavian journal of public health. 2011;39(6):640-8.

160. Leck V, Randall GE. The rise and fall of dental therapy in Canada: a policy analysis and assessment of equity of access to oral health care for Inuit and First Nations communities. Int J Equity Health. 2017;16(1):131.

161. Jang Y-E, Kim C-B, Kim N-H. Utilization of preventive dental services before and after health insurance covered dental scaling in Korea: 2009 to 2014 Community Health Survey. Asia Pacific Journal of Public Health. 2017;29(1):70-80.

162. Kim ES, Kim BI, Jung HI. Does the national dental scaling policy reduce inequalities in dental scaling usage? A population-based quasi-experimental study. BMC oral health. 2019;19(1):185.

163. Petersen PE, Kwan S. Equity, social determinants and public health programmes--the case of oral health. Community Dent Oral Epidemiol. 2011;39(6):481-7.

164. Abdus S, Decker SL. Association between Medicaid adult nonemergency dental benefits and dental services use and expenditures. Journal of the American Dental Association. 2019;150(1):24-33.

165. Lutfiyya MN, Gross AJ, Soffe B, Lipsky MS. Dental care utilization: examining the associations between health services deficits and not having a dental visit in past 12 months. BMC public health. 2019;19(1):265.

166. Srivastava P, Chen G, Harris A. Oral Health, Dental Insurance and Dental Service use in Australia. Health economics. 2017;26(1):35-53.

167. Teusner DN, Brennan DS, Spencer AJ. Associations between level of private dental insurance cover and favourable dental visiting by household income. Australian dental journal. 2015;60(4):479-89.

168. Tickle M, Williams M, Jenner T, Blinkhorn A. The effects of socioeconomic status and dental attendance on dental caries' experience, and treatment patterns in 5-year-old children. British dental journal. 1999;186(3):135-7.

169. Greenberg BJ, Kumar JV, Stevenson H. Dental case management: increasing access to oral health care for families and children with low incomes. J Am Dent Assoc. 2008;139(8):1114-21.

170. Kotagal M, Carle AC, Kessler LG, Flum DR. Limited impact on health and access to care for 19- to 25-year-olds following the Patient Protection and Affordable Care Act. JAMA Pediatr. 2014;168(11):1023-9.

171. Lin M, Sappenfield W, Hernandez L, Clark C, Liu J, Collins J, et al. Child- and state-level characteristics associated with preventive dental care access among U.S. children 5-17 years of age. Matern Child Health J. 2012;16 Suppl 2:320-9.

172. Schrimshaw EW, Siegel K, Wolfson NH, Mitchell DA, Kunzel C. Insurance-related barriers to accessing dental care among African American adults with oral health symptoms in Harlem, New York City. Am J Public Health. 2011;101(8):1420-8.

173. Garrido-Cumbrera M, Borrell C, Palencia L, Espelt A, Rodriguez-Sanz M, Pasarin MI, et al. Social class inequalities in the utilization of health care and preventive services in Spain, a country with a national health system. International journal of health services : planning, administration, evaluation. 2010;40(3):525-42.

174. Ku L. Medical and dental care utilization and expenditures under Medicaid and private health insurance. Medical care research and review. 2009;66(4):456-71.

175. Bisgaier J, Cutts DB, Edelstein BL, Rhodes KV. Disparities in child access to emergency care for acute oral injury. Pediatrics. 2011;127(6):e1428-35.

176. Schwarz E. Access to oral health care–an Australian perspective. Community Dentistry and Oral Epidemiology. 2006;34(3):225-31.

177. Ahmadi O, Machuca C, Sabbah W. Socioeconomic inequality in the provision of health advice in dental setting in England, Wales and Northern Ireland. Patient education and counseling. 2019;102(11):2068-72.

178. Kim PC, Zhou W, McCoy SJ, McDonough IK, Burston B, Ditmyer M, et al. Factors Associated with Preventable Emergency Department Visits for Nontraumatic Dental Conditions in the U.S. International journal of environmental research and public health. 2019;16(19).

179. Al-Haboubi M, Klass C, Jones K, Bernabe E, Gallagher JE. Inequalities in the use of dental services among adults in inner South East London. European journal of oral sciences. 2013;121(3 Pt 1):176-81.

180. Cohen LA. The role of non-dental health professionals in providing access to dental care for low-income and minority patients. Dent Clin North Am. 2009;53(3):451-68.

181. Truong A, Higgs P, Cogger S, Dietze P. Further research required to determine unique factors associated with dental care access among deprived populations. Public Health. 2014;128(12):1131-3.

182. Gallego F, Larroulet C, Palomer L, Repetto A, Verdugo D. Socioeconomic inequalities in self-perceived oral health among adults in Chile. International journal for equity in health. 2017;16(1):23.

183. Ravaghi V, Al-Hammadi Z, Landes D, Hill K, Morris AJ. Inequalities in orthodontic outcomes in England: treatment utilisation, subjective and normative need. Community dental health. 2019;36(3):198-202.

184. Shaban R, Kassim S, Sabbah W. Socioeconomic inequality in the provision of specific preventive dental interventions among children in the UK: Children's Dental Health Survey 2003. British dental journal. 2017;222(11):865-9.

185. Yoon H, Jang Y, Choi K, Kim H. Preventive Dental Care Utilization in Asian Americans in Austin, Texas: Does Neighborhood Matter? International journal of environmental research and public health. 2018;15(10).

186. Nash DA. Adding dental therapists to the health care team to improve access to oral health care for children. Academic pediatrics. 2009;9(6):446-51.

187. Jean G, Kruger E, Tennant M. The distribution of allied dental practitioners in australia: socio-economics and rurality as a driver of better health service accessibility. Australian dental journal. 2019;64(2):153-60.

188. Moles D, Frost C, Grundy C. Inequalities in availability of National Health Service general dental practitioners in England and Wales. British dental journal. 2001;190(10):548-53.

189. Jean G, Kruger E, Tennant M. The distribution of dentists in Australia Socio-economic profile as an indicator of access to services. Community Dent Health. 2020;37(1):5-11.

190. Landes DP, Holmes RD. Dental practice populations: the effect of distance on the most socially deprived communities accessing dental care in the North East of England. Public Health. 2012;126(5):424-6.

191. Wanchek T, Rephann T. Effects of a proposed rural dental school on regional dental workforce and access to care. 2013.

192. Molarius A, Engström S, Flink H, Simonsson B, Tegelberg Å. Socioeconomic differences in self-rated oral health and dental care utilisation after the dental care reform in 2008 in Sweden. BMC oral health. 2014;14(1):134.

193. Tubert-Jeannin S, Riordan PJ, Morel-Papernot A, Moulin R. Dental status and oral health quality of life in economically disadvantaged French adults. Special Care in Dentistry. 2004;24(5):264-9.

Appendix III

Appendix IV – Supplementary Information of Paper 2

Table S1- The final search strategy of the scoping review

Databases	PubMed, ProQuest, ISI Web of Science, Scopus	
Limitations	**Time limits**	01.01.2000 to 08.08.2020
	Language	English
General Search Strategy	(#1 AND #2 AND #3) [Title/Abstract]	
	#1	"Dental Health Surveys" OR "Oral Health Disparities" OR "Dental Health" OR "Oral Health"
	#2	"Socioeconomic Factors" OR "Social Hierarchy" OR "Inequalities" OR "Social Disparities" OR "Social Gradient*" OR "Health Status*" OR "socioeconomic disadvantage" OR "socioeconomic inequalities" OR "Social Determinants" OR "Socio Economic Status"
	#3	("Dental services" OR "Dental visits" OR "Access")
PubMed	((("Dental Health Surveys"[Mesh]) OR ("Oral Health"[Mesh] OR ("Dental Care"[Mesh] OR "Dental Health Services"[Mesh])) AND (((((("Socioeconomic Factors"[Mesh]) OR "Hierarchy, Social"[Mesh]) OR ("Healthcare Disparities"[Mesh] OR "Health Status Disparities"[Mesh])) OR "Social Determinants of Health"[Mesh]) OR "Social Class"[Mesh])) AND ((((("dental services"[Title/Abstract]) OR ("dental visits"[Title/Abstract])) OR ("access" [Title/Abstract]))	
Scopus	TITLE-ABS-KEY("oral health") OR TITLE-ABS-KEY("Dental Health Surveys") OR TITLE-ABS-KEY("Dental Health Services") OR TITLE-ABS-KEY("dental care") AND TITLE-ABS-KEY("Socioeconomic Factors") OR TITLE-ABS-KEY("Social Hierarchy") OR TITLE-ABS-KEY(Inequalities) OR TITLE-ABS-KEY("Social Disparities") OR TITLE-ABS-KEY("Social Gradient") OR TITLE-ABS-KEY("Health Status") OR TITLE-ABS-KEY("socioeconomic disadvantage") OR TITLE-ABS-KEY("socioeconomic inequalities") OR TITLE-ABS-KEY("Social Determinants") AND TITLE-ABS-KEY("dental services") OR TITLE-ABS-KEY("dental visits") OR TITLE-ABS-KEY("access")	
Web of Science	TS= ("Dental Health Surveys" OR "Dental Care" OR "Oral Health" OR "Dental Health Services") AND TS= ("Socioeconomic Factors" OR "Hierarchy, Social" OR "Healthcare Disparities" OR "Health Status Disparities" OR "Social Determinants of Health" OR "Social Class") AND TS= ("dental services" OR "dental visits" OR "access")	
ProQuest	noft(("Dental Health Surveys" OR "Dental Care" OR "Oral Health" OR "Dental Health Services")) AND noft(("Socioeconomic Factors" OR "Hierarchy, Social" OR "Healthcare Disparities" OR "Health Status Disparities" OR "Social Determinants of Health" OR "Social Class")) AND noft(("dental services" OR "dental visits" OR "Access"))	

Table S2- Data extraction form of the scoping review

No	Author	Study Title/aim	Study population	Year	Study Design	Study place	Key Determinants of the study (in the scopes of access equality)
							• A • B • C • …

Table S3- Determinants of access to dental services

Dimensions of access	Main determinants	Sub determinants	Number of articles	References
Acceptability	Family condition	Existence of an elderly member in the family	6	(1-6)
		Existence of a child in the family	10	(5, 7-15)
		Families living in poverty	1	(16)
		Race / ethnic minority /Aboriginality of the family	11	(6, 17-26)
		Occurring Pregnancy in the family	2	(27, 28)
		Member living alone	1	(2)
		Education level of the whole family	1	(20)
		Primary language spoken	2	(5, 19)
		Number of children at the shelter	1	(17)
	Culture	Fear of dental treatment or phobias	1	(5)
		Oral health beliefs	1	(17)
		Victimization	1	(17)
		Poor oral health behaviors	1	(2)
Financial	Health demands	Unmet oral healthcare needs	4	(21, 29-31)
		Health problems	1	(32)
		Poor oral condition	2	(2, 31)
	Affordability of services	Income	14	(1, 2, 10, 11, 15, 18, 20, 21, 32-37)
		Health insurance	13	(4, 11, 13, 16, 18, 21, 31, 33, 34, 36, 38-40)
		Cost of services (Out of pocket payment)	2	(33, 41)
		Medicaid and Medicare	1	(10)
		Federal government`s funding	2	(14, 42)
Physical	Availability of services	Oral health delivery system	5	(15, 30, 34, 43, 44)
		Public coverage of dental services	4	(31, 39, 44, 45)
		Dentists visits/Preventive care	6	(4, 23, 33, 38, 46, 47)
		Specialized treatment	1	(7)
		Virtual dental home	1	(10)
		Long waiting time	3	(15, 38, 48)
		High proportion of dentists	3	(11, 23, 49)
		Shelter based care	1	(17)
		Access to oral hygiene products	2	(4, 19)
		Pensioners	1	(15)
	Socio-environmental factors	Refugees	1	(48)
		Immigrants	2	(6, 21)
		Disadvantages people	2	(15, 23)
	Geographical distance	Geographic access	12	(21, 24, 25, 43, 50-57)
		Travelling time	1	(13)
		Using public transportation	1	(1)

		Rural populations	2	(19, 21)
		Living in census areas	1	(23)
		Living in the regions outside major cities	1	(1)

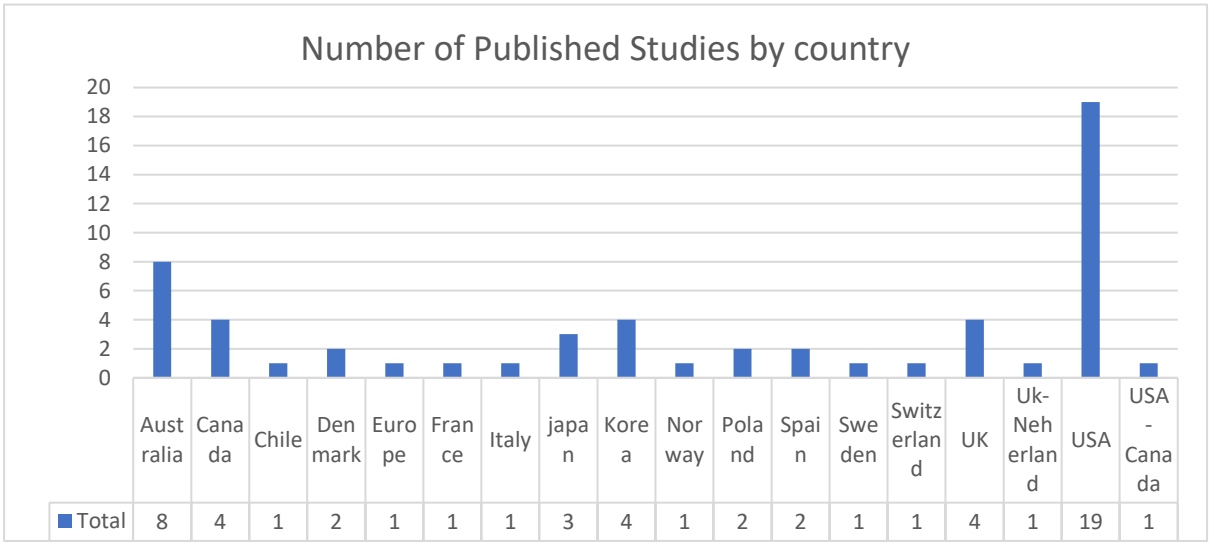

Figure S1- Number of Published Studies by country

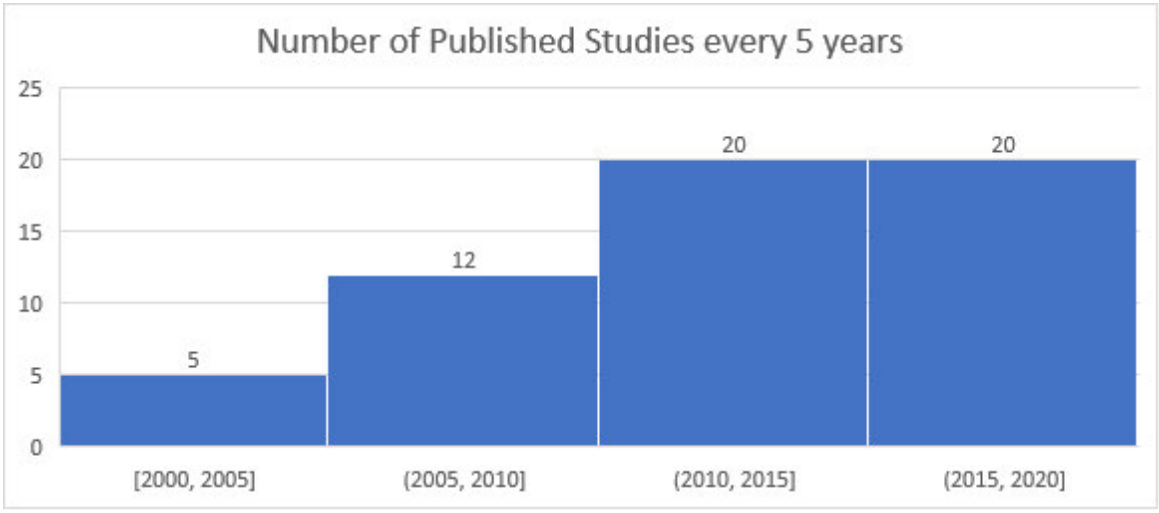

Figure S2- Number of Published Studies every 5 years

Included Articles in Paper 2

1. Kiuchi S, Aida J, Kusama T, Yamamoto T, Hoshi M, Yamamoto T, et al. Does public transportation reduce inequalities in access to dental care among older adults? Japan Gerontological Evaluation Study. Community Dent Oral Epidemiol. 2020;48(2):109-18.
2. Lee YS, Kim HG, Hur JY, Yang K. Oral Health in Low-Income Older Adults in Korea. J Community Health Nurs. 2016;33(2):98-106.
3. Listl S. Income-related inequalities in dental service utilization by Europeans aged 50+. J Dent Res. 2011;90(6):717-23.
4. Dounis G, Ditmyer MM, McCants R, Lee Y, Mobley C. Southern Nevada assisted living residents' perception of their oral health status and access to dental care. Gerodontology. 2012;29(2):e150-4.
5. Council on Access P, Interprofessional R, Robinson LA. Private sector response to improving oral health care access. Dent Clin North Am. 2009;53(3):523-35.
6. Shelley D, Russell S, Parikh NS, Fahs M. Ethnic disparities in self-reported oral health status and access to care among older adults in NYC. J Urban Health. 2011;88(4):651-62.
7. Morris E, Landes D. The equity of access to orthodontic dental care for children in the North East of England. Public Health. 2006;120(4):359-63.
8. Pinilla J, Negrin-Hernandez MA, Abasolo I. Time trends in socio-economic inequalities in the lack of access to dental services among children in Spain 1987-2011. Int J Equity Health. 2015;14:9.

9. Ravaghi V, Hargreaves DS, Morris AJ. Persistent Socioeconomic Inequality in Child Dental Caries in England despite Equal Attendance. JDR Clin Trans Res. 2020;5(2):185-94.
10. Bailit H, D'Adamo J. State case studies: improving access to dental care for the underserved. J Public Health Dent. 2012;72(3):221-34.
11. Biordi DL, Heitzer M, Mundy E, DiMarco M, Thacker S, Taylor E, et al. Improving access and provision of preventive oral health care for very young, poor, and low-income children through a new interdisciplinary partnership. Am J Public Health. 2015;105 Suppl 2:e23-9.
12. Caban-Martinez AJ, Lee DJ, Fleming LE, Arheart KL, Leblanc WG, Chung-Bridges K, et al. Dental care access and unmet dental care needs among U.S. workers: the National Health Interview Survey, 1997 to 2003. J Am Dent Assoc. 2007;138(2):227-30.
13. Jean G, Kruger E, Tennant M. Universal access to oral health care for Australian children: comparison of travel times to public dental services at consecutive census dates as an indicator of progressive realisation. Aust J Prim Health. 2020;26(2):109-16.
14. Leck V, Randall GE. The rise and fall of dental therapy in Canada: a policy analysis and assessment of equity of access to oral health care for Inuit and First Nations communities. Int J Equity Health. 2017;16(1):131.
15. Schwarz E. Access to oral health care–an Australian perspective. Community Dentistry and Oral Epidemiology. 2006;34(3):225-31.
16. Duncan L, Bonner A. Effects of income and dental insurance coverage on need for dental care in Canada. J Can Dent Assoc. 2014;80:e6.

17. DiMarco MA, Ludington SM, Menke EM. Access to and utilization of oral health care by homeless children/families. Journal of Health Care for the Poor and Underserved. 2010;21(2):67-81.
18. Edelstein BL. Disparities in oral health and access to care: findings of national surveys. Ambulatory pediatrics. 2002;2(2):141-7.
19. Fulkerson ND, Haff DR, Chino M. Health care access disparities among children entering kindergarten in Nevada. J Child Health Care. 2013;17(3):253-63.
20. Lebrun LA, Shi L. Nativity status and access to care in Canada and the U.S.: factoring in the roles of race/ethnicity and socioeconomic status. J Health Care Poor Underserved. 2011;22(3):1075-100.
21. Northridge ME, Kumar A, Kaur R. Disparities in Access to Oral Health Care. Annu Rev Public Health. 2020;41:513-35.
22. Shi L, Lebrun LA, Tsai J. Access to medical care, dental care, and prescription drugs: the roles of race/ethnicity, health insurance, and income. Southern medical journal. 2010;103(6):509.
23. Wamala S, Merlo J, Bostrom G. Inequity in access to dental care services explains current socioeconomic disparities in oral health: the Swedish National Surveys of Public Health 2004-2005. J Epidemiol Community Health. 2006;60(12):1027-33.
24. Jean G, Kruger E, Tennant M. The distribution of allied dental practitioners in australia: socio-economics and rurality as a driver of better health service accessibility. Aust Dent J. 2019;64(2):153-60.
25. Martin-Kerry JM, Whelan M, Rogers J, Raichur A, Cole D, de Silva AM. Addressing disparities in oral disease in Aboriginal people in Victoria: where to

focus preventive programs. Australian Journal of Primary Health. 2019;25(4):317-24.

26. Kilpatrick NM, Neumann A, Lucas N, Chapman J, Nicholson JM. Oral health inequalities in a national sample of Australian children aged 2-3 and 6-7 years. Aust Dent J. 2012;57(1):38-44.
27. Carrion IV, Castaneda H, Martinez-Tyson D, Kline N. Barriers impeding access to primary oral health care among farmworker families in Central Florida. Soc Work Health Care. 2011;50(10):828-44.
28. Hunter LP, Yount SM. Oral health and oral health care practices among low-income pregnant women. J Midwifery Womens Health. 2011;56(2):103-9.
29. Calzon Fernandez S, Fernandez Ajuria A, Martin JJ, Murphy MJ. The impact of the economic crisis on unmet dental care needs in Spain. J Epidemiol Community Health. 2015;69(9):880-5.
30. Crete P, Boyd LD, Fitzgerald JK, LaSpina LM. Access to preventive oral health services for homebound populations: A pilot program. American Dental Hygienists' Association. 2018;92(6):24-32.
31. Jones E, Shi L, Hayashi AS, Sharma R, Daly C, Ngo-Metzger Q. Access to oral health care: the role of federally qualified health centers in addressing disparities and expanding access. Am J Public Health. 2013;103(3):488-93.
32. Abbas H, Aida J, Saito M, Tsakos G, Watt RG, Koyama S, et al. Income or education, which has a stronger association with dental implant use in elderly people in Japan? Int Dent J. 2019;69(6):454-62.

33. Howard JR, Ramirez J, Li Y, Gany F. Dental care access for low-income and immigrant cancer patients in New York City. J Community Health. 2015;40(1):110-5.
34. Lupi-Pegurier L, Clerc-Urmes I, Abu-Zaineh M, Paraponaris A, Ventelou B. Density of dental practitioners and access to dental care for the elderly: a multilevel analysis with a view on socio-economic inequality. Health Policy. 2011;103(2-3):160-7.
35. Nishide A, Fujita M, Sato Y, Nagashima K, Takahashi S, Hata A. Income-Related Inequalities in Access to Dental Care Services in Japan. Int J Environ Res Public Health. 2017;14(5).
36. Ramraj C, Sadeghi L, Lawrence HP, Dempster L, Quinonez C. Is accessing dental care becoming more difficult? Evidence from Canada's middle-income population. PLoS One. 2013;8(2):e57377.
37. Guessous I, Theler J-M, Izart CD, Stringhini S, Bodenmann P, Gaspoz J-M, et al. Forgoing dental care for economic reasons in Switzerland: a six-year cross-sectional population-based study. BMC Oral Health. 2014;14(1):121.
38. Jang Y-E, Kim C-B, Kim N-H. Utilization of preventive dental services before and after health insurance covered dental scaling in Korea: 2009 to 2014 Community Health Survey. Asia Pacific Journal of Public Health. 2017;29(1):70-80.
39. Teusner DN, Brennan DS, Spencer AJ. Associations between level of private dental insurance cover and favourable dental visiting by household income. Aust Dent J. 2015;60(4):479-89.

40. Newacheck PW, Hung YY, Jane Park M, Brindis CD, Irwin Jr CE. Disparities in adolescent health and health care: does socioeconomic status matter? Health services research. 2003;38(5):1235-52.
41. Abdus S, Decker SL. Association between Medicaid adult nonemergency dental benefits and dental services use and expenditures. J Am Dent Assoc. 2019;150(1):24-33.
42. Grytten J, Lund E, Rongen G. Equity in access to public dental services: the experience from Norway. Acta Odontologica Scandinavica. 2001;59(6):372-8.
43. Christensen LB, Petersen PE, Steding-Jessen M. Consumption of dental services among adults in Denmark 1994–2003. European journal of oral sciences. 2007;115(3):174-9.
44. Gallego F, Larroulet C, Palomer L, Repetto A, Verdugo D. Socioeconomic inequalities in self-perceived oral health among adults in Chile. Int J Equity Health. 2017;16(1):23.
45. Kim ES, Kim BI, Jung HI. Does the national dental scaling policy reduce inequalities in dental scaling usage? A population-based quasi-experimental study. BMC Oral Health. 2019;19(1):185.
46. Everaars B, Jerkovic-Cosic K, van der Putten GJ, Pretty IA, Brocklehurst P. Needs in Service Provision for Oral Health Care in Older People: A Comparison Between Greater Manchester (United Kingdom) and Utrecht (the Netherlands). Int J Health Serv. 2018;48(4):663-84.
47. Grignon M, Hurley J, Wang L, Allin S. Inequity in a market-based health system: Evidence from Canada's dental sector. Health Policy. 2010;98(1):81-90.

48. Davidson N, Skull S, Calache H, Chesters D, Chalmers J. Equitable access to dental care for an at-risk group: a review of services for Australian refugees. Australian and New Zealand journal of public health. 2007;31(1):73-80.
49. Moles D, Frost C, Grundy C. Inequalities in availability of National Health Service general dental practitioners in England and Wales. British dental journal. 2001;190(10):548-53.
50. Armfield JM. Socioeconomic inequalities in child oral health: a comparison of discrete and composite area-based measures. Journal of Public Health Dentistry. 2007;67(2):119-25.
51. Carta G, Cagetti M, Sale S, Congiu G, Strohmenger L, Oleari F, et al. Oral health inequalities in Italian schoolchildren-a cross-sectional evaluation. Community Dent Health. 2014;31(2):123-8.
52. Chattopadhyay A. Oral health disparities in the United States. Dent Clin North Am. 2008;52(2):297-318, vi.
53. Christensen LB, Rosing K, Lempert SM, Hede B. Patterns of dental services and factors that influence dental services among 64-65-year-old regular users of dental care in Denmark. Gerodontology. 2016;33(1):79-88.
54. Lee H, Seo S, Kang R, Kim Y, Hyun HK. Increasing access to oral healthcare for marriage-immigrant women in South Korea: programme design to policy recommendation. Int Dent J. 2019;69(5):354-60.
55. Piotrowska DE, Jankowska D, Huzarska D, Szpak AS, Pedzinski B. Socioeconomic inequalities in use and non-use of dental services in Poland. Int J Public Health. 2020.

56. Piotrowska DE, Pedzinski B, Jankowska D, Huzarska D, Charkiewicz AE, Szpak AS. Socio-economic inequalities in the use of dental care in urban and rural areas in Poland. Ann Agric Environ Med. 2018;25(3):512-6.
57. Tickle M, Moulding G, Milsom K, Blinkhorn A. Socioeconomic and geographical influences on primary dental care preferences in a population of young children. British dental journal. 2000;188(10):559-62.

Appendix V – Supplementary tables and R Codes Used in Paper 4 and 5

Supplementary tables of paper 4

R Codes for Paper 4

Mediation

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#########################################################################
#
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#
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#
######Income Based Socio-economic Inequalities in Utilization of######
################Dental Services: A Mediation Analysis ################
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#
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#
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#
############################start of the COde#############################
#libraries
library(VGAM)
library(haven)
library(mice)
library(mitools)
library(geepack)
library(mitml)
library(pbapply)
library(ggplot2)
#########################################################################
#
#data set
MED2 <- read_sav("~/Desktop/phd/mediation/MED3.sav")
```

```
View(MED2)
#########################################################################
#
#Imputation
med2Imp <- mice(MED2, M=10, seed=123)
med2Imp <- complete(med2Imp)
med2Imp$agegroup_new <- as.factor(med2Imp$agegroup_new)
med2Imp$sex <- as.factor(med2Imp$sex)
med2Imp$Education_new <- as.factor(med2Imp$Education_new)
med2Imp$Income_di_X <- as.factor(med2Imp$Income_di_X)
med2Imp$Self_O_health_new <- as.factor(med2Imp$Self_O_health_new)
med2Imp$COB <- as.factor(med2Imp$COB)
med2Imp$Residential_locatip_new <- as.factor(med2Imp$Residential_locatip_new)

#################### Define the function for Bootstrap #################
effectSep1 <- function(med2Imp)
{
##########################start of the Function#########################
# fit Models for Mediators
# Fit a Model for M1 (PubPriv)
med2Imp$ATemp <- med2Imp$Income_di_X
FitM1 <- glm(factor(pubpriv_M) ~ factor(ATemp) + factor(insured_L1) +
factor(concard_new_L2) + agegroup_new + sex + Education_new +
Self_O_health_new + COB + Residential_locatip_new, data = med2Imp ,family =
"binomial")
# Fit a Model for M2 (insured)
med2Imp$ATemp <- med2Imp$Income_di_X
FitM2 <- glm(factor(insured_L1) ~ factor(ATemp) + agegroup_new + sex +
Education_new + Self_O_health_new + COB + Residential_locatip_new, data =
med2Imp, family = "binomial")
# Fit a Model for M3 (concard)
```

```
med2Imp$ATemp <- med2Imp$Income_di_X

FitM3 <- glm(factor(concard_new_L2) ~ factor(ATemp) + agegroup_new + sex + Education_new + Self_O_health_new + COB + Residential_locatip_new, data = med2Imp, family = "binomial")

# Assess intertwined casual pathways

#########################################################################
#

# Data Expansion

levelofincome <- unique(med2Imp$Income_di_X)

med2Imp$newID <- 1:nrow(med2Imp)

med2Imp1 <- med2Imp

med2Imp2 <- med2Imp

med2Imp1$Income_di_XStar1 <- levelofincome[1]

med2Imp2$Income_di_XStar1 <- levelofincome[2]

tempmed2imp <- rbind(med2Imp1,med2Imp2)

####

med2Imp1 <- tempmed2imp

med2Imp2 <- tempmed2imp

med2Imp1$Income_di_XStar2 <- levelofincome[1]

med2Imp2$Income_di_XStar2 <- levelofincome[2]

tempmed2imp <- rbind(med2Imp1, med2Imp2)

####

med2Imp1 <- tempmed2imp

med2Imp2 <- tempmed2imp

med2Imp1$Income_di_XStar3 <- levelofincome[1]

med2Imp2$Income_di_XStar3 <- levelofincome[2]

newmed2imp <- rbind(med2Imp1, med2Imp2)

#########################################################################
#

#Weighting
```

Appendix V

```
#M Weight
newmed2imp$ATemp <- newmed2imp$Income_di_X
temp <- predict(FitM1, type = "response", newdata = newmed2imp)
TempDirM1 <- ifelse(newmed2imp$pubpriv_M, temp, 1-temp)

newmed2imp$ATemp <- newmed2imp$Income_di_XStar1
temp <- predict(FitM1, type = "response", newdata = newmed2imp)
tempindirM1 <- ifelse(newmed2imp$pubpriv_M, temp, 1-temp)
newmed2imp$weightM1 <- tempindirM1/TempDirM1
#M2 Weight
newmed2imp$ATemp <- newmed2imp$Income_di_X
temp <- predict(FitM2, type = "response", newdata = newmed2imp)
TempDirM2 <- ifelse(newmed2imp$insured_L1, temp, 1-temp)

newmed2imp$ATemp <- newmed2imp$Income_di_XStar2
temp <- predict(FitM2, type = "response", newdata = newmed2imp)
tempindirM2 <- ifelse(newmed2imp$insured_L1, temp, 1-temp)
newmed2imp$weightM2 <- tempindirM2/TempDirM2
#M3 Weight
newmed2imp$ATemp <- newmed2imp$Income_di_X
temp <- predict(FitM3, type = "response", newdata = newmed2imp)
TempDirM3 <- ifelse(newmed2imp$concard_new_L2, temp, 1-temp)

newmed2imp$ATemp <- newmed2imp$Income_di_XStar3
temp <- predict(FitM3, type = "response", newdata = newmed2imp)
tempindirM3 <- ifelse(newmed2imp$concard_new_L2, temp, 1-temp)
newmed2imp$weightM3 <- tempindirM3/TempDirM3
# Total Mediators weights
```

```
newmed2imp$medweight <- newmed2imp$weightM1 * newmed2imp$weightM2 * newmed2imp$weightM3

# total Weight including survey weight

newmed2imp$totalweight <- newmed2imp$medweight * newmed2imp$weight

#########################################################################
#

# natural effect modelling

###################

#model1 Visit Avoidance

newmed2imp <- newmed2imp[order(newmed2imp$newID), ]

model1 <- geeglm(avoid_Y1 ~ factor(Income_di_X) + factor(Income_di_XStar1) + factor(Income_di_XStar2) + factor(Income_di_XStar3) + agegroup_new + sex + Education_new + COB + Residential_locatip_new, data = newmed2imp, family = "binomial", weights= totalweight, id=newmed2imp$newID)

###################

#Collect and return estimates

return(coef(model1)[1:10])

##########################End of the Function#########################

}

#######################For BootStrap Analysis#######################

#######################Run Function 5000 times#######################

#######################and Collect all Estimates#####################

bootstrapEffectEsts1 <- pbreplicate(10^3, effectSep1(med2Imp[sample(1:nrow(med2Imp),size=nrow(med2Imp),replace=T),]))

##########################Computing the table#########################

outputTabel1 <- matrix(NA, ncol=6, nrow=5)

boot1 <- t(apply(bootstrapEffectEsts1, 1, quantile, c(0.5,0.025,0.975)))

Ftablefullmodel1 <- exp(boot1)

TotalIndirecteffect1 <- exp(apply(boot1[c(3,4,5),],2,sum))

Totaleffect1 <- apply(bootstrapEffectEsts1[c(2,3,4,5),],2,sum)
```

```
temp <- rbind(bootstrapEffectEsts1, Totaleffect1, bootstrapEffectEsts1[c(2,3,4,5),]/rbind(Totaleffect1,Totaleffect1,Totaleffect1,Totaleffect1))

tempQuant <- t(apply(temp, 1, quantile, c(0.5,0.025,0.975)))

outputTabel1[,1:3] <- rbind(tempQuant[c(2,3,4,5,11),])

outputTabel1[1:4,4:6] <- tempQuant[12:15,]

#exp table

Ftable_oddsratio_model1 <- matrix(NA, ncol=6, nrow=5)

temptablel1<- exp(outputTabel1[,1:3])

Ftable_oddsratio_model1[,1:3] <- temptablel1[,1:3]

Ftable_oddsratio_model1[,4:6] <- outputTabel1[,4:6]

##########################Drawing  the Plot#########################

#plot

# Create labels

boxLabels = c("Direct Effect", "Indirect Effect through M1", "Indirect Effect through M2", "Indirect Effect through M3", "Total Effect")

df1 <- data.frame((yax = length(boxLabels):1), boxOdds = Ftable_oddsratio_model1[,1], boxCILow = Ftable_oddsratio_model1[,2], boxCIHigh = Ftable_oddsratio_model1[,3])

# Plot

(p1 <- ggplot(df1, aes(x = boxOdds, y = boxLabels)) +

      geom_vline(aes(xintercept = 1), size = .5, linetype = 'dashed') +

      geom_errorbarh(aes(xmax = boxCIHigh, xmin = boxCILow), size = 1.3, height =

                  .5, color = 'black') +

      geom_point(size = 3.5, color = 'blue') +

      theme_bw() +

      theme(panel.grid.minor = element_blank()) +

      scale_x_continuous(breaks = seq(0.1,2,0.1) ) +

      coord_trans(x = 'log10') +

      ylab('') +
```

```
xlab('Odds ratio (log scale)') + scale_y_discrete(limits = rev) + geom_hline(aes(yintercept = 1.5), size = 1, linetype = 'solid'))

##########################End of the Code##########################
```

Appendix V

Sensitivity Analyses

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#
######Income Based Socio-economic Inequalities in Utilization of######
################Dental Services: A Mediation Analysis ################
#########################################################################
#
#########################sensitivity analysis#########################
#########################################################################
#


#libraries
library(haven)
library(pbapply)
########################NOTE:                                write
ESTIMATES########################


#estimate and standard error for NDE
est.de = 0.754236198
CIL_NDE = 0.54009825
CIU_NDE = 0.95566755


#estimate and standard error for NIE
est.ie =  -0.061052363
CIL_NIE = -0.15995461
CIU_NIE = 0.05781965
```

```
##############################################################################
#

#data set

med2Imp <- read_sav("~/Desktop/phd/mediation/MED2Imp.sav")


#########################Weight full#########################

# fit Models for Mediators

# Fit a Model for M1 (PubPriv)

med2Imp$ATemp <- med2Imp$ex

FitM1 <- glm(factor(dm1) ~ factor(ATemp) * factor(dm2) * factor(dm3) + age + sex +
education + ohealth + cob + residency, data = med2Imp ,family = "binomial")

# Fit a Model for M2 (insured)

med2Imp$ATemp <- med2Imp$ex

FitM2 <- glm(factor(dm2) ~ factor(ATemp) + age + sex + education + ohealth + cob +
residency, data = med2Imp, family = "binomial")

# Fit a Model for M3 (concard)

med2Imp$ATemp <- med2Imp$ex

FitM3 <- glm(factor(dm3) ~ factor(ATemp) + age + sex + education + ohealth + cob +
residency, data = med2Imp, family = "binomial")

# Assess intertwined casual pathways

##############################################################################
#

# Data Expansion

levelofincome <- unique(med2Imp$ex)

med2Imp$newID <- 1:nrow(med2Imp)

med2Imp1 <- med2Imp

med2Imp2 <- med2Imp

med2Imp1$exStar1 <- levelofincome[1]

med2Imp2$exStar1 <- levelofincome[2]
```

```
tempmed2imp <- rbind(med2Imp1,med2Imp2)
####
med2Imp1 <- tempmed2imp
med2Imp2 <- tempmed2imp
med2Imp1$exStar2 <- levelofincome[1]
med2Imp2$exStar2 <- levelofincome[2]
tempmed2imp <- rbind(med2Imp1, med2Imp2)
####
med2Imp1 <- tempmed2imp
med2Imp2 <- tempmed2imp
med2Imp1$exStar3 <- levelofincome[1]
med2Imp2$exStar3 <- levelofincome[2]
newmed2imp <- rbind(med2Imp1, med2Imp2)
##########################################################################
#
#Weighting
#M Weight
newmed2imp$ATemp <- newmed2imp$ex
temp <- predict(FitM1, type = "response", newdata = newmed2imp)
TempDirM1 <- ifelse(newmed2imp$dm1, temp, 1-temp)

newmed2imp$ATemp <- newmed2imp$exStar1
temp <- predict(FitM1, type = "response", newdata = newmed2imp)
tempindirM1 <- ifelse(newmed2imp$dm1, temp, 1-temp)
newmed2imp$weightM1 <- tempindirM1/TempDirM1
#M2 Weight
newmed2imp$ATemp <- newmed2imp$ex
temp <- predict(FitM2, type = "response", newdata = newmed2imp)
TempDirM2 <- ifelse(newmed2imp$dm2, temp, 1-temp)
```

```
newmed2imp$ATemp <- newmed2imp$exStar2
temp <- predict(FitM2, type = "response", newdata = newmed2imp)
tempindirM2 <- ifelse(newmed2imp$dm2, temp, 1-temp)
newmed2imp$weightM2 <- tempindirM2/TempDirM2
#M3 Weight
newmed2imp$ATemp <- newmed2imp$ex
temp <- predict(FitM3, type = "response", newdata = newmed2imp)
TempDirM3 <- ifelse(newmed2imp$dm3, temp, 1-temp)

newmed2imp$ATemp <- newmed2imp$exStar3
temp <- predict(FitM3, type = "response", newdata = newmed2imp)
tempindirM3 <- ifelse(newmed2imp$dm3, temp, 1-temp)
newmed2imp$weightM3 <- tempindirM3/TempDirM3
# Total Mediators weights
newmed2imp$medweight <- newmed2imp$weightM1 * newmed2imp$weightM2 *
newmed2imp$weightM3
# total Weight including survey weight
newmed2imp$TW <- newmed2imp$medweight * newmed2imp$weight

#########################################################################
###############Sensitivity for pretreatment confounders#############
#########################################################################
#AGE=c1
# fit Models for Mediators
# Fit a Model for M1 (PubPriv)
med2Imp$ATemp <- med2Imp$ex
FitM1_c1 <- glm(factor(dm1) ~ factor(ATemp) * factor(dm2) * factor(dm3) + sex +
education + ohealth + cob + residency, data = med2Imp ,family = "binomial")
```

```
# Fit a Model for M2 (insured)

med2Imp$ATemp <- med2Imp$ex

FitM2_c1 <- glm(factor(dm2) ~ factor(ATemp) + sex + education + ohealth + cob +
residency, data = med2Imp, family = "binomial")

# Fit a Model for M3 (concard)

med2Imp$ATemp <- med2Imp$ex

FitM3_c1 <- glm(factor(dm3) ~ factor(ATemp) + sex + education + ohealth + cob +
residency, data = med2Imp, family = "binomial")

# Assess intertwined casual pathways

##########################################################################
#

#Weighting

#M Weight

newmed2imp$ATemp <- newmed2imp$ex

temp_c1 <- predict(FitM1_c1, type = "response", newdata = newmed2imp)

TempDirM1_c1 <- ifelse(newmed2imp$dm1, temp_c1, 1-temp)


newmed2imp$ATemp <- newmed2imp$exStar1

temp_c1 <- predict(FitM1_c1, type = "response", newdata = newmed2imp)

tempindirM1_c1 <- ifelse(newmed2imp$dm1, temp_c1, 1-temp_c1)

newmed2imp$weightM1_c1 <- tempindirM1_c1/TempDirM1_c1

#M2 Weight

newmed2imp$ATemp <- newmed2imp$ex

temp_c1 <- predict(FitM2_c1, type = "response", newdata = newmed2imp)

TempDirM2_c1 <- ifelse(newmed2imp$dm2, temp_c1, 1-temp_c1)


newmed2imp$ATemp <- newmed2imp$exStar2

temp_c1 <- predict(FitM2_c1, type = "response", newdata = newmed2imp)

tempindirM2_c1 <- ifelse(newmed2imp$dm2, temp, 1-temp)

newmed2imp$weightM2_c1 <- tempindirM2_c1/TempDirM2_c1
```

```
#M3 Weight

newmed2imp$ATemp <- newmed2imp$ex

temp_c1 <- predict(FitM3_c1, type = "response", newdata = newmed2imp)

TempDirM3_c1 <- ifelse(newmed2imp$dm3, temp_c1, 1-temp_c1)


newmed2imp$ATemp <- newmed2imp$exStar3

temp_c1 <- predict(FitM3_c1, type = "response", newdata = newmed2imp)

tempindirM3_c1 <- ifelse(newmed2imp$dm3, temp_c1, 1-temp_c1)

newmed2imp$weightM3_c1 <- tempindirM3_c1/TempDirM3_c1

# Total Mediators weights

newmed2imp$medweight_c1 <- newmed2imp$weightM1_c1 * newmed2imp$weightM2_c1 * newmed2imp$weightM3_c1

# total Weight including survey weight

newmed2imp$TW1 <- newmed2imp$medweight_c1 * newmed2imp$weight


#########################################################################
#

#sex=c2

# fit Models for Mediators

# Fit a Model for M1 (PubPriv)

med2Imp$ATemp <- med2Imp$ex

FitM1_c2 <- glm(factor(dm1) ~ factor(ATemp) * factor(dm2) * factor(dm3) + age + education + ohealth + cob + residency, data = med2Imp ,family = "binomial")

# Fit a Model for M2 (insured)

med2Imp$ATemp <- med2Imp$ex

FitM2_c2 <- glm(factor(dm2) ~ factor(ATemp) + age + education + ohealth + cob + residency, data = med2Imp, family = "binomial")

# Fit a Model for M3 (concard)

med2Imp$ATemp <- med2Imp$ex

FitM3_c2 <- glm(factor(dm3) ~ factor(ATemp) + age + education + ohealth + cob + residency, data = med2Imp, family = "binomial")
```

```
# Assess intertwined casual pathways
#########################################################################
#
#########################################################################
#
#Weighting
#M Weight
newmed2imp$ATemp <- newmed2imp$ex
temp <- predict(FitM1_c2, type = "response", newdata = newmed2imp)
TempDirM1 <- ifelse(newmed2imp$dm1, temp, 1-temp)

newmed2imp$ATemp <- newmed2imp$exStar1
temp <- predict(FitM1_c2, type = "response", newdata = newmed2imp)
tempindirM1 <- ifelse(newmed2imp$dm1, temp, 1-temp)
newmed2imp$weightM1_c2 <- tempindirM1/TempDirM1
#M2 Weight
newmed2imp$ATemp <- newmed2imp$ex
temp <- predict(FitM2_c2, type = "response", newdata = newmed2imp)
TempDirM2 <- ifelse(newmed2imp$dm2, temp, 1-temp)

newmed2imp$ATemp <- newmed2imp$exStar2
temp <- predict(FitM2_c2, type = "response", newdata = newmed2imp)
tempindirM2 <- ifelse(newmed2imp$dm2, temp, 1-temp)
newmed2imp$weightM2_c2 <- tempindirM2/TempDirM2
#M3 Weight
newmed2imp$ATemp <- newmed2imp$ex
temp <- predict(FitM3_c2, type = "response", newdata = newmed2imp)
TempDirM3 <- ifelse(newmed2imp$dm3, temp, 1-temp)
```

```
newmed2imp$ATemp <- newmed2imp$exStar3

temp <- predict(FitM3_c2, type = "response", newdata = newmed2imp)

tempindirM3 <- ifelse(newmed2imp$dm3, temp, 1-temp)

newmed2imp$weightM3_c2 <- tempindirM3/TempDirM3

# Total Mediators weights

newmed2imp$medweight_c2 <- newmed2imp$weightM1_c2 * newmed2imp$weightM2_c2 * newmed2imp$weightM3_c2

# total Weight including survey weight

newmed2imp$TW2 <- newmed2imp$medweight_c2 * newmed2imp$weight


#########################################################################
#

#########################################################################
#

#education= c3

# fit Models for Mediators

# Fit a Model for M1 (PubPriv)

med2Imp$ATemp <- med2Imp$ex

FitM1_c3 <- glm(factor(dm1) ~ factor(ATemp) * factor(dm2) * factor(dm3) + age + sex + ohealth + cob + residency, data = med2Imp ,family = "binomial")

# Fit a Model for M2 (insured)

med2Imp$ATemp <- med2Imp$ex

FitM2_c3 <- glm(factor(dm2) ~ factor(ATemp) + age + sex + ohealth + cob + residency, data = med2Imp, family = "binomial")

# Fit a Model for M3 (concard)

med2Imp$ATemp <- med2Imp$ex

FitM3_c3 <- glm(factor(dm3) ~ factor(ATemp) + age + sex + ohealth + cob + residency, data = med2Imp, family = "binomial")

# Assess intertwined casual pathways

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#
```

```
#########################################################################
#
#Weighting
#M Weight
newmed2imp$ATemp <- newmed2imp$ex
temp <- predict(FitM1_c3, type = "response", newdata = newmed2imp)
TempDirM1 <- ifelse(newmed2imp$dm1, temp, 1-temp)

newmed2imp$ATemp <- newmed2imp$exStar1
temp <- predict(FitM1_c3, type = "response", newdata = newmed2imp)
tempindirM1 <- ifelse(newmed2imp$dm1, temp, 1-temp)
newmed2imp$weightM1_c3 <- tempindirM1/TempDirM1
#M2 Weight
newmed2imp$ATemp <- newmed2imp$ex
temp <- predict(FitM2_c3, type = "response", newdata = newmed2imp)
TempDirM2 <- ifelse(newmed2imp$dm2, temp, 1-temp)

newmed2imp$ATemp <- newmed2imp$exStar2
temp <- predict(FitM2_c3, type = "response", newdata = newmed2imp)
tempindirM2 <- ifelse(newmed2imp$dm2, temp, 1-temp)
newmed2imp$weightM2_c3 <- tempindirM2/TempDirM2
#M3 Weight
newmed2imp$ATemp <- newmed2imp$ex
temp <- predict(FitM3_c3, type = "response", newdata = newmed2imp)
TempDirM3 <- ifelse(newmed2imp$dm3, temp, 1-temp)

newmed2imp$ATemp <- newmed2imp$exStar3
temp <- predict(FitM3_c3, type = "response", newdata = newmed2imp)
tempindirM3 <- ifelse(newmed2imp$dm3, temp, 1-temp)
```

```
newmed2imp$weightM3_c3 <- tempindirM3/TempDirM3

# Total Mediators weights

newmed2imp$medweight_c3 <- newmed2imp$weightM1_c3 * newmed2imp$weightM2_c3 * newmed2imp$weightM3_c3

# total Weight including survey weight

newmed2imp$TW3 <- newmed2imp$medweight_c3 * newmed2imp$weight

#########################################################################
#

#########################################################################
#

#ohealth=c4

# fit Models for Mediators

# Fit a Model for M1 (PubPriv)

med2Imp$ATemp <- med2Imp$ex

FitM1_c4 <- glm(factor(dm1) ~ factor(ATemp) * factor(dm2) * factor(dm3) + age + sex + education + cob + residency, data = med2Imp ,family = "binomial")

# Fit a Model for M2 (insured)

med2Imp$ATemp <- med2Imp$ex

FitM2_c4 <- glm(factor(dm2) ~ factor(ATemp) + age + sex + education + cob + residency, data = med2Imp, family = "binomial")

# Fit a Model for M3 (concard)

med2Imp$ATemp <- med2Imp$ex

FitM3_c4 <- glm(factor(dm3) ~ factor(ATemp) + age + sex + education + cob + residency, data = med2Imp, family = "binomial")

# Assess intertwined casual pathways

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#

#########################################################################
#

#Weighting

#M Weight

newmed2imp$ATemp <- newmed2imp$ex
```

```
temp <- predict(FitM1_c4, type = "response", newdata = newmed2imp)
TempDirM1 <- ifelse(newmed2imp$dm1, temp, 1-temp)

newmed2imp$ATemp <- newmed2imp$exStar1
temp <- predict(FitM1_c4, type = "response", newdata = newmed2imp)
tempindirM1 <- ifelse(newmed2imp$dm1, temp, 1-temp)
newmed2imp$weightM1_c4 <- tempindirM1/TempDirM1
#M2 Weight
newmed2imp$ATemp <- newmed2imp$ex
temp <- predict(FitM2_c4, type = "response", newdata = newmed2imp)
TempDirM2 <- ifelse(newmed2imp$dm2, temp, 1-temp)

newmed2imp$ATemp <- newmed2imp$exStar2
temp <- predict(FitM2_c4, type = "response", newdata = newmed2imp)
tempindirM2 <- ifelse(newmed2imp$dm2, temp, 1-temp)
newmed2imp$weightM2_c4 <- tempindirM2/TempDirM2
#M3 Weight
newmed2imp$ATemp <- newmed2imp$ex
temp <- predict(FitM3_c4, type = "response", newdata = newmed2imp)
TempDirM3 <- ifelse(newmed2imp$dm3, temp, 1-temp)

newmed2imp$ATemp <- newmed2imp$exStar3
temp <- predict(FitM3_c4, type = "response", newdata = newmed2imp)
tempindirM3 <- ifelse(newmed2imp$dm3, temp, 1-temp)
newmed2imp$weightM3_c4 <- tempindirM3/TempDirM3
# Total Mediators weights
newmed2imp$medweight_c4 <- newmed2imp$weightM1_c4 *
newmed2imp$weightM2_c4 * newmed2imp$weightM3_c4
# total Weight including survey weight
```

```
newmed2imp$TW4 <- newmed2imp$medweight_c4 * newmed2imp$weight

#########################################################################
#

#########################################################################
#

#cob=c5

# fit Models for Mediators

# Fit a Model for M1 (PubPriv)

med2Imp$ATemp <- med2Imp$ex

FitM1_c5 <- glm(factor(dm1) ~ factor(ATemp) * factor(dm2) * factor(dm3) + age +
sex + education + ohealth + residency, data = med2Imp ,family = "binomial")

# Fit a Model for M2 (insured)

med2Imp$ATemp <- med2Imp$ex

FitM2_c5 <- glm(factor(dm2) ~ factor(ATemp) + age + sex + education + ohealth +
residency, data = med2Imp, family = "binomial")

# Fit a Model for M3 (concard)

med2Imp$ATemp <- med2Imp$ex

FitM3_c5 <- glm(factor(dm3) ~ factor(ATemp) + age + sex + education + ohealth +
residency, data = med2Imp, family = "binomial")

# Assess intertwined casual pathways

#########################################################################
#

#########################################################################
#

#Weighting

#M Weight

newmed2imp$ATemp <- newmed2imp$ex

temp <- predict(FitM1_c5, type = "response", newdata = newmed2imp)

TempDirM1 <- ifelse(newmed2imp$dm1, temp, 1-temp)


newmed2imp$ATemp <- newmed2imp$exStar1
```

```
temp <- predict(FitM1_c5, type = "response", newdata = newmed2imp)
tempindirM1 <- ifelse(newmed2imp$dm1, temp, 1-temp)
newmed2imp$weightM1_c5 <- tempindirM1/TempDirM1
#M2 Weight
newmed2imp$ATemp <- newmed2imp$ex
temp <- predict(FitM2_c5, type = "response", newdata = newmed2imp)
TempDirM2 <- ifelse(newmed2imp$dm2, temp, 1-temp)

newmed2imp$ATemp <- newmed2imp$exStar2
temp <- predict(FitM2_c5, type = "response", newdata = newmed2imp)
tempindirM2 <- ifelse(newmed2imp$dm2, temp, 1-temp)
newmed2imp$weightM2_c5 <- tempindirM2/TempDirM2
#M3 Weight
newmed2imp$ATemp <- newmed2imp$ex
temp <- predict(FitM3_c5, type = "response", newdata = newmed2imp)
TempDirM3 <- ifelse(newmed2imp$dm3, temp, 1-temp)

newmed2imp$ATemp <- newmed2imp$exStar3
temp <- predict(FitM3_c5, type = "response", newdata = newmed2imp)
tempindirM3 <- ifelse(newmed2imp$dm3, temp, 1-temp)
newmed2imp$weightM3_c5 <- tempindirM3/TempDirM3
# Total Mediators weights
newmed2imp$medweight_c5 <- newmed2imp$weightM1_c5 *
newmed2imp$weightM2_c5 * newmed2imp$weightM3_c5
# total Weight including survey weight
newmed2imp$TW5 <- newmed2imp$medweight_c5 * newmed2imp$weight
#########################################################################
#
#########################################################################
#
```

```
#residency=c6

# fit Models for Mediators

# Fit a Model for M1 (PubPriv)

med2Imp$ATemp <- med2Imp$ex

FitM1_c6 <- glm(factor(dm1) ~ factor(ATemp) * factor(dm2) * factor(dm3) + age + sex + education + ohealth + cob, data = med2Imp ,family = "binomial")

# Fit a Model for M2 (insured)

med2Imp$ATemp <- med2Imp$ex

FitM2_c6 <- glm(factor(dm2) ~ factor(ATemp) + age + sex + education + ohealth + cob, data = med2Imp, family = "binomial")

# Fit a Model for M3 (concard)

med2Imp$ATemp <- med2Imp$ex

FitM3_c6 <- glm(factor(dm3) ~ factor(ATemp) + age + sex + education + ohealth + cob, data = med2Imp, family = "binomial")

# Assess intertwined casual pathways

#########################################################################
#

#########################################################################
#

#Weighting

#M Weight

newmed2imp$ATemp <- newmed2imp$ex

temp <- predict(FitM1_c6, type = "response", newdata = newmed2imp)

TempDirM1 <- ifelse(newmed2imp$dm1, temp, 1-temp)


newmed2imp$ATemp <- newmed2imp$exStar1

temp <- predict(FitM1_c6, type = "response", newdata = newmed2imp)

tempindirM1 <- ifelse(newmed2imp$dm1, temp, 1-temp)

newmed2imp$weightM1_c6 <- tempindirM1/TempDirM1

#M2 Weight

newmed2imp$ATemp <- newmed2imp$ex
```

```
temp <- predict(FitM2_c6, type = "response", newdata = newmed2imp)
TempDirM2 <- ifelse(newmed2imp$dm2, temp, 1-temp)

newmed2imp$ATemp <- newmed2imp$exStar2
temp <- predict(FitM2_c6, type = "response", newdata = newmed2imp)
tempindirM2 <- ifelse(newmed2imp$dm2, temp, 1-temp)
newmed2imp$weightM2_c6 <- tempindirM2/TempDirM2
#M3 Weight
newmed2imp$ATemp <- newmed2imp$ex
temp <- predict(FitM3_c6, type = "response", newdata = newmed2imp)
TempDirM3 <- ifelse(newmed2imp$dm3, temp, 1-temp)

newmed2imp$ATemp <- newmed2imp$exStar3
temp <- predict(FitM3_c6, type = "response", newdata = newmed2imp)
tempindirM3 <- ifelse(newmed2imp$dm3, temp, 1-temp)
newmed2imp$weightM3_c6 <- tempindirM3/TempDirM3
# Total Mediators weights
newmed2imp$medweight_c6 <- newmed2imp$weightM1_c6 * newmed2imp$weightM2_c6 * newmed2imp$weightM3_c6
# total Weight including survey weight
newmed2imp$TW6 <- newmed2imp$medweight_c6 * newmed2imp$weight
#########################################################################
#
#education-ohealth =c34
# fit Models for Mediators
# Fit a Model for M1 (PubPriv)
med2Imp$ATemp <- med2Imp$ex
FitM1_c34 <- glm(factor(dm1) ~ factor(ATemp) * factor(dm2) * factor(dm3) + age + sex + cob + residency, data = med2Imp ,family = "binomial")
# Fit a Model for M2 (insured)
```

```
med2Imp$ATemp <- med2Imp$ex

FitM2_c34 <- glm(factor(dm2) ~ factor(ATemp) + age + sex  + cob + residency, data = med2Imp, family = "binomial")

# Fit a Model for M3 (concard)

med2Imp$ATemp <- med2Imp$ex

FitM3_c34 <- glm(factor(dm3) ~ factor(ATemp) + age + sex + cob + residency, data = med2Imp, family = "binomial")

# Assess intertwined casual pathways

#########################################################################
#

#########################################################################
#

#Weighting

#M Weight

newmed2imp$ATemp <- newmed2imp$ex

temp <- predict(FitM1_c34, type = "response", newdata = newmed2imp)

TempDirM1 <- ifelse(newmed2imp$dm1, temp, 1-temp)


newmed2imp$ATemp <- newmed2imp$exStar1

temp <- predict(FitM1_c34, type = "response", newdata = newmed2imp)

tempindirM1 <- ifelse(newmed2imp$dm1, temp, 1-temp)

newmed2imp$weightM1_c34 <- tempindirM1/TempDirM1

#M2 Weight

newmed2imp$ATemp <- newmed2imp$ex

temp <- predict(FitM2_c34, type = "response", newdata = newmed2imp)

TempDirM2 <- ifelse(newmed2imp$dm2, temp, 1-temp)


newmed2imp$ATemp <- newmed2imp$exStar2

temp <- predict(FitM2_c34, type = "response", newdata = newmed2imp)

tempindirM2 <- ifelse(newmed2imp$dm2, temp, 1-temp)
```

```
newmed2imp$weightM2_c34 <- tempindirM2/TempDirM2

#M3 Weight

newmed2imp$ATemp <- newmed2imp$ex

temp <- predict(FitM3_c34, type = "response", newdata = newmed2imp)

TempDirM3 <- ifelse(newmed2imp$dm3, temp, 1-temp)


newmed2imp$ATemp <- newmed2imp$exStar3

temp <- predict(FitM3_c34, type = "response", newdata = newmed2imp)

tempindirM3 <- ifelse(newmed2imp$dm3, temp, 1-temp)

newmed2imp$weightM3_c34 <- tempindirM3/TempDirM3

# Total Mediators weights

newmed2imp$medweight_c34 <- newmed2imp$weightM1_c34 * newmed2imp$weightM2_c34 * newmed2imp$weightM3_c34

# total Weight including survey weight

newmed2imp$TW34 <- newmed2imp$medweight_c34 * newmed2imp$weight


#########################################################################
#

#########################################################################
#

################################## Sensitivity BIAS ######################

#c1

sigma1 = sd((-newmed2imp$TW1 + newmed2imp$TW)[newmed2imp$ex == 1])

rho1 = cor((-newmed2imp$TW1 + newmed2imp$TW)[newmed2imp$ex == 1], newmed2imp[newmed2imp$ex == 1, "y1"])

bias_NIE1 = sigma1 * rho1

bias_NDE1 = -bias_NIE1


#c2

sigma2 = sd((-newmed2imp$TW2 + newmed2imp$TW)[newmed2imp$ex == 1])
```

```
rho2 = cor((-newmed2imp$TW2 + newmed2imp$TW)[newmed2imp$ex == 1], newmed2imp[newmed2imp$ex == 1,"y1"])

bias_NIE2 = sigma2 * rho2

bias_NDE2 = -bias_NIE2

#c3

sigma3 = sd((-newmed2imp$TW3 + newmed2imp$TW)[newmed2imp$ex == 1])

rho3 = cor((-newmed2imp$TW3 + newmed2imp$TW)[newmed2imp$ex == 1], newmed2imp[newmed2imp$ex == 1, "y1"])

bias_NIE3 = sigma3 * rho3

bias_NDE3 = -bias_NIE3

#c4

sigma4 = sd((-newmed2imp$TW4 + newmed2imp$TW)[newmed2imp$ex == 1])

rho4 = cor((-newmed2imp$TW4 + newmed2imp$TW)[newmed2imp$ex == 1], newmed2imp[newmed2imp$ex == 1, "y1"])

bias_NIE4 = sigma4 * rho4

bias_NDE4 = -bias_NIE4

#c5

sigma5 = sd((-newmed2imp$TW5 + newmed2imp$TW)[newmed2imp$ex == 1])

rho5 = cor((-newmed2imp$TW5 + newmed2imp$TW)[newmed2imp$ex == 1], newmed2imp[newmed2imp$ex == 1, "y1"])

bias_NIE5 = sigma5 * rho5

bias_NDE5 = -bias_NIE5

#c6

sigma6 = sd((-newmed2imp$TW6 + newmed2imp$TW)[newmed2imp$ex == 1])

rho6 = cor((-newmed2imp$TW6 + newmed2imp$TW)[newmed2imp$ex == 1], newmed2imp[newmed2imp$ex == 1, "y1"])

bias_NIE6 = sigma6 * rho6

bias_NDE6 = -bias_NIE6

#c34

sigma34 = sd((-newmed2imp$TW34 + newmed2imp$TW)[newmed2imp$ex == 1])
```

```
rho34 = cor((-newmed2imp$TW34 + newmed2imp$TW)[newmed2imp$ex == 1],
newmed2imp[newmed2imp$ex == 1, "y1"])

bias_NIE34 = sigma34 * rho34

bias_NDE34 = -bias_NIE34


################################# Modified Estimates ####################


##########################SENS FUNCTION#########################
sens = function(est.ori, effect) {
 left = est.ori[paste0("CIL_", effect)]
 right = est.ori[paste0("CIU_", effect)]
 if (est.ori[paste0("CIL_", effect)] < 0 & est.ori[paste0("CIU_",
                                                  effect)] > 0) {
  if (get(paste0("bias_", effect)) < left | get(paste0("bias_",
                                                 effect)) > right) {
   sens = "*"
  }
  else {
   sens = ""
  }
 }
 if (est.ori[paste0("CIL_", effect)] > 0) {
  if (get(paste0("bias_", effect)) >= left) {
   sens = "*"
  }
  else {
   sens = ""
  }
```

```
  }
  if (est.ori[paste0("CIU_", effect)] < 0) {
    if (get(paste0("bias_", effect)) <= right) {
      sens = "*"
    }
    else {
      sens = ""
    }
  }
  return(sens)
}
################################## Modified Estimates ####################
est.ori = c(NIE1 = est.ie, CIL_NIE1 = CIL_NIE, CIU_NIE1 = CIU_NIE,
            NDE1 = est.de, CIL_NDE1 = CIL_NDE, CIU_NDE1 = CIU_NDE)
#c1= age
sensitivity_NIE1 = sens(est.ori, "NIE1")
sensitivity_NDE1 = sens(est.ori, "NDE1")

modified_NIE_c1 = est.ori["NIE1"] - bias_NIE1
modified_NDE_c1 = est.ori["NDE1"] - bias_NDE1
modifiedCIL_NIE_c1 = est.ori["CIL_NIE1"] - bias_NIE1
modifiedCIU_NIE_c1 = est.ori["CIU_NIE1"] - bias_NIE1
modifiedCIL_NDE_c1 = est.ori["CIL_NDE1"] - bias_NDE1
modifiedCIU_NDE_c1 = est.ori["CIU_NDE1"] - bias_NDE1
bias_c1 = c(round(sigma1, 3), round(rho1, 3), round(bias_NIE1,
                                    3), sensitivity_NIE1, round(modified_NIE_c1, 3),
paste0("[",

round(modifiedCIL_NIE_c1, 3), ",", round(modifiedCIU_NIE_c1,
```

```
3), "]"), round(bias_NDE1, 3), sensitivity_NDE1,
        round(modified_NDE_c1, 3), paste0("[", round(modifiedCIL_NDE_c1,
                                    3), ",", round(modifiedCIU_NDE_c1, 3), "]"))
#########################################################################
#
est.ori = c(NIE2 = est.ie, CIL_NIE2 = CIL_NIE, CIU_NIE2 = CIU_NIE,
        NDE2 = est.de, CIL_NDE2 = CIL_NDE, CIU_NDE2 = CIU_NDE)
#c2= sex
sensitivity_NIE2 = sens(est.ori, "NIE2")
sensitivity_NDE2 = sens(est.ori, "NDE2")
modified_NIE_c2 = est.ori["NIE2"] - bias_NIE2
modified_NDE_c2 = est.ori["NDE2"] - bias_NDE2
modifiedCIL_NIE_c2 = est.ori["CIL_NIE2"] - bias_NIE2
modifiedCIU_NIE_c2 = est.ori["CIU_NIE2"] - bias_NIE2
modifiedCIL_NDE_c2 = est.ori["CIL_NDE2"] - bias_NDE2
modifiedCIU_NDE_c2 = est.ori["CIU_NDE2"] - bias_NDE2
bias_c2 = c(round(sigma2, 3), round(rho2, 3), round(bias_NIE2,
                                    3), sensitivity_NIE2, round(modified_NIE_c2, 3),
paste0("[",

round(modifiedCIL_NIE_c2, 3), ",", round(modifiedCIU_NIE_c2,

3), "]"), round(bias_NDE2, 3), sensitivity_NDE2,
        round(modified_NDE_c2, 3), paste0("[", round(modifiedCIL_NDE_c2,
                                    3), ",", round(modifiedCIU_NDE_c2, 3), "]"))
#########################################################################
#
est.ori = c(NIE3 = est.ie, CIL_NIE3 = CIL_NIE, CIU_NIE3 = CIU_NIE,
        NDE3 = est.de, CIL_NDE3 = CIL_NDE, CIU_NDE3 = CIU_NDE)
#c3= education
```

```
sensitivity_NIE3 = sens(est.ori, "NIE3")
sensitivity_NDE3 = sens(est.ori, "NDE3")
modified_NIE_c3 = est.ori["NIE3"] - bias_NIE3
modified_NDE_c3 = est.ori["NDE3"] - bias_NDE3
modifiedCIL_NIE_c3 = est.ori["CIL_NIE3"] - bias_NIE3
modifiedCIU_NIE_c3 = est.ori["CIU_NIE3"] - bias_NIE3
modifiedCIL_NDE_c3 = est.ori["CIL_NDE3"] - bias_NDE3
modifiedCIU_NDE_c3 = est.ori["CIU_NDE3"] - bias_NDE3
bias_c3 = c(round(sigma3, 3), round(rho3, 3), round(bias_NIE3,
                                    3), sensitivity_NIE3, round(modified_NIE_c3, 3),
paste0("[",

round(modifiedCIL_NIE_c3, 3), ",", round(modifiedCIU_NIE_c3,

3), "]"), round(bias_NDE3, 3), sensitivity_NDE3,
        round(modified_NDE_c3, 3), paste0("[", round(modifiedCIL_NDE_c3,
                                        3), ",", round(modifiedCIU_NDE_c3, 3), "]"))
#########################################################################
#
est.ori = c(NIE4 = est.ie, CIL_NIE4 = CIL_NIE, CIU_NIE4 = CIU_NIE,
        NDE4 = est.de, CIL_NDE4 = CIL_NDE, CIU_NDE4 = CIU_NDE)
#c4= ohealth
sensitivity_NIE4 = sens(est.ori, "NIE4")
sensitivity_NDE4 = sens(est.ori, "NDE4")
modified_NIE_c4 = est.ori["NIE4"] - bias_NIE4
modified_NDE_c4 = est.ori["NDE4"] - bias_NDE4
modifiedCIL_NIE_c4 = est.ori["CIL_NIE4"] - bias_NIE4
modifiedCIU_NIE_c4 = est.ori["CIU_NIE4"] - bias_NIE4
modifiedCIL_NDE_c4 = est.ori["CIL_NDE4"] - bias_NDE4
modifiedCIU_NDE_c4 = est.ori["CIU_NDE4"] - bias_NDE4
```

```
bias_c4 = c(round(sigma4, 3), round(rho4, 3), round(bias_NIE4,
                                    3), sensitivity_NIE4, round(modified_NIE_c4, 3),
paste0("[",

round(modifiedCIL_NIE_c4, 3), ",", round(modifiedCIU_NIE_c4,

3), "]"), round(bias_NDE4, 3), sensitivity_NDE4,
        round(modified_NDE_c4, 3), paste0("[", round(modifiedCIL_NDE_c4,
                                    3), ",", round(modifiedCIU_NDE_c4, 3), "]"))
#########################################################################
#
est.ori = c(NIE5 = est.ie, CIL_NIE5 = CIL_NIE, CIU_NIE5 = CIU_NIE,
        NDE5 = est.de, CIL_NDE5 = CIL_NDE, CIU_NDE5 = CIU_NDE)
#c5= cob
sensitivity_NIE5 = sens(est.ori, "NIE5")
sensitivity_NDE5 = sens(est.ori, "NDE5")
modified_NIE_c5 = est.ori["NIE5"] - bias_NIE5
modified_NDE_c5 = est.ori["NDE5"] - bias_NDE5
modifiedCIL_NIE_c5 = est.ori["CIL_NIE5"] - bias_NIE5
modifiedCIU_NIE_c5 = est.ori["CIU_NIE5"] - bias_NIE5
modifiedCIL_NDE_c5 = est.ori["CIL_NDE5"] - bias_NDE5
modifiedCIU_NDE_c5 = est.ori["CIU_NDE5"] - bias_NDE5
bias_c5 = c(round(sigma5, 3), round(rho5, 3), round(bias_NIE5,
                                    3), sensitivity_NIE5, round(modified_NIE_c5, 3),
paste0("[",

round(modifiedCIL_NIE_c5, 3), ",", round(modifiedCIU_NIE_c5,

3), "]"), round(bias_NDE5, 3), sensitivity_NDE5,
        round(modified_NDE_c5, 3), paste0("[", round(modifiedCIL_NDE_c5,
                                    3), ",", round(modifiedCIU_NDE_c5, 3), "]"))
```

```
#########################################################################
#
est.ori = c(NIE6 = est.ie,  CIL_NIE6 = CIL_NIE, CIU_NIE6 = CIU_NIE,
        NDE6 = est.de, CIL_NDE6 = CIL_NDE, CIU_NDE6 = CIU_NDE)
#c6= residency
sensitivity_NIE6 = sens(est.ori, "NIE6")
sensitivity_NDE6 = sens(est.ori, "NDE6")
modified_NIE_c6 = est.ori["NIE6"] - bias_NIE6
modified_NDE_c6 = est.ori["NDE6"] - bias_NDE6
modifiedCIL_NIE_c6 = est.ori["CIL_NIE6"] - bias_NIE6
modifiedCIU_NIE_c6 = est.ori["CIU_NIE6"] - bias_NIE6
modifiedCIL_NDE_c6 = est.ori["CIL_NDE6"] - bias_NDE6
modifiedCIU_NDE_c6 = est.ori["CIU_NDE6"] - bias_NDE6
bias_c6 = c(round(sigma6, 3), round(rho6, 3), round(bias_NIE6,
                                    3),  sensitivity_NIE6,  round(modified_NIE_c6,  3),
paste0("[",

round(modifiedCIL_NIE_c6, 3), ",", round(modifiedCIU_NIE_c6,

3), "]"), round(bias_NDE6, 3), sensitivity_NDE6,
        round(modified_NDE_c6, 3), paste0("[", round(modifiedCIL_NDE_c6,
                                        3), ",", round(modifiedCIU_NDE_c6, 3), "]"))
#########################################################################
#
est.ori = c(NIE34 = est.ie,  CIL_NIE34 = CIL_NIE, CIU_NIE34 = CIU_NIE,
        NDE34 = est.de,  CIL_NDE34 = CIL_NDE, CIU_NDE34 = CIU_NDE)
#c34= education-ohealth
sensitivity_NIE34 = sens(est.ori, "NIE34")
sensitivity_NDE34 = sens(est.ori, "NDE34")
modified_NIE_c34 = est.ori["NIE34"] - bias_NIE34
modified_NDE_c34 = est.ori["NDE34"] - bias_NDE34
```

```
modifiedCIL_NIE_c34 = est.ori["CIL_NIE34"] - bias_NIE34
modifiedCIU_NIE_c34 = est.ori["CIU_NIE34"] - bias_NIE34
modifiedCIL_NDE_c34 = est.ori["CIL_NDE34"] - bias_NDE34
modifiedCIU_NDE_c34 = est.ori["CIU_NDE34"] - bias_NDE34
bias_c34 = c(round(sigma34, 3), round(rho34, 3), round(bias_NIE34,
                                    3), sensitivity_NIE34, round(modified_NIE_c34,
3), paste0("[",

round(modifiedCIL_NIE_c34, 3), ",", round(modifiedCIU_NIE_c34,

3), "]"), round(bias_NDE34, 3), sensitivity_NDE34,
        round(modified_NDE_c34, 3), paste0("[", round(modifiedCIL_NDE_c34,
                                    3), ",", round(modifiedCIU_NDE_c34, 3), "]"))

##########################################################################
####################

Sensitivity_Analysis <- matrix(NA, ncol=10, nrow=7)
Sensitivity_Analysis [1, 1:10] <- bias_c1[c(1,2,3,4,5,6,7,8,9,10)]
Sensitivity_Analysis [2, 1:10] <- bias_c2[c(1,2,3,4,5,6,7,8,9,10)]
Sensitivity_Analysis [3, 1:10] <- bias_c3[c(1,2,3,4,5,6,7,8,9,10)]
Sensitivity_Analysis [4, 1:10] <- bias_c4[c(1,2,3,4,5,6,7,8,9,10)]
Sensitivity_Analysis [5, 1:10] <- bias_c5[c(1,2,3,4,5,6,7,8,9,10)]
Sensitivity_Analysis [6, 1:10] <- bias_c6[c(1,2,3,4,5,6,7,8,9,10)]
Sensitivity_Analysis [7, 1:10] <- bias_c34[c(1,2,3,4,5,6,7,8,9,10)]
Sensitivity_Analysis <- as.data.frame(Sensitivity_Analysis)

colnames(Sensitivity_Analysis) = c("sigma", "rho", "bias_NIE",
                        "", "modified_NIE", "modifiedCI_NIE", "bias_NDE",
                        "", "modified_NDE", "modifiedCI_NDE")
```

R Codes for Paper 5

Mediation Analysis

```
#########################################################################
#
#########################################################################
#
######Income Based Socio-economic Inequalities in Utilization of######
################Dental Services: A Mediation Analysis ################
#################################Edication##############################
#########################################################################
#
#########################################################################
#
############################start of the COde############################
#libraries
library(VGAM)
library(haven)
library(dplyr)
library(mice)
library(mitools)
library(geepack)
library(mitml)
library(pbapply)
library(ggplot2)
#########################################################################
#
#data set
MED2 <- read_sav("/Volumes/users1/a1785821/Desktop/phd/education mediation/mednew21.sav")
View(MED2)
MED2 <- MED2%>%mutate_if(is.character, as.factor)
```

```
#########################################################################
#
#Imputation
med2Imp <- mice(MED2, M=10, seed=123)
med2Imp <- complete(med2Imp)
med2Imp$age <- as.factor(med2Imp$age)
med2Imp$Sex <- as.factor(med2Imp$Sex)
med2Imp$Education_X <- as.factor(med2Imp$Education_X)
med2Imp$Income <- as.factor(med2Imp$Income)
med2Imp$COB <- as.factor(med2Imp$COB)
med2Imp$Residential <- as.factor(med2Imp$Residential)
med2Imp$Ghealth <- as.factor(med2Imp$Ghealth)
################### Define the function for Bootstrap #################
effectSep1 <- function(med2Imp)
{
##########################start of the Function#########################
# fit Models for Mediators
# Fit a Model for M1 (Oral Health)
med2Imp$ATemp <- med2Imp$Education_X
FitM1 <- glm(factor(Ohealth_M1) ~ factor(ATemp) * factor(Smoke_M2) *
factor(Brush_M3) + Income + sector + age + Sex  + Ghealth + COB + Residential, data
= med2Imp ,family = "binomial")
# Fit a Model for M2 (Smoke)
FitM2 <- glm(factor(Smoke_M2) ~ factor(ATemp) + Income + sector + age + Sex +
Ghealth + COB + Residential, data = med2Imp, family = "binomial")
# Fit a Model for M3 (Brunshing)
FitM3 <- glm(factor(Brush_M3) ~ factor(ATemp) * factor(Smoke_M2) + sector+ age
+ Sex  + Ghealth + COB + Residential, data = med2Imp, family = "binomial")
#########################################################
################
# Data Expansion
```

```
levelofeducation <- unique(med2Imp$Education_X)
med2Imp$newID <- 1:nrow(med2Imp)
med2Imp1 <- med2Imp
med2Imp2 <- med2Imp
med2Imp1$Education_XStar1 <- levelofeducation[1]
med2Imp2$Education_XStar1 <- levelofeducation[2]
tempmed2imp <- rbind(med2Imp1,med2Imp2)
####
med2Imp1 <- tempmed2imp
med2Imp2 <- tempmed2imp
med2Imp1$Education_XStar2 <- levelofeducation[1]
med2Imp2$Education_XStar2 <- levelofeducation[2]
tempmed2imp <- rbind(med2Imp1, med2Imp2)
####
med2Imp1 <- tempmed2imp
med2Imp2 <- tempmed2imp
med2Imp1$Education_XStar3 <- levelofeducation[1]
med2Imp2$Education_XStar3 <- levelofeducation[2]
newmed2imp <- rbind(med2Imp1, med2Imp2)
##########################################################################
#
#Weighting
#M Weight
newmed2imp$ATemp <- newmed2imp$Education_X
temp <- predict(FitM1, type = "response", newdata = newmed2imp)
TempDirM1 <- ifelse(newmed2imp$Ohealth_M1, temp, 1-temp)
newmed2imp$ATemp <- newmed2imp$Education_XStar1
temp <- predict(FitM1, type = "response", newdata = newmed2imp)
tempindirM1 <- ifelse(newmed2imp$Ohealth_M1, temp, 1-temp)
```

```
newmed2imp$weightM1 <- tempindirM1/TempDirM1
#M2 Weight
newmed2imp$ATemp <- newmed2imp$Education_X
temp <- predict(FitM2, type = "response", newdata = newmed2imp)
TempDirM2 <- ifelse(newmed2imp$Smoke_M2, temp, 1-temp)
newmed2imp$ATemp <- newmed2imp$Education_XStar2
temp <- predict(FitM2, type = "response", newdata = newmed2imp)
tempindirM2 <- ifelse(newmed2imp$Smoke_M2, temp, 1-temp)
newmed2imp$weightM2 <- tempindirM2/TempDirM2
#M3 Weight
newmed2imp$ATemp <- newmed2imp$Education_X
temp <- predict(FitM3, type = "response", newdata = newmed2imp)
TempDirM3 <- ifelse(newmed2imp$Brush_M3, temp, 1-temp)
newmed2imp$ATemp <- newmed2imp$Education_XStar3
temp <- predict(FitM3, type = "response", newdata = newmed2imp)
tempindirM3 <- ifelse(newmed2imp$Brush_M3, temp, 1-temp)
newmed2imp$weightM3 <- tempindirM3/TempDirM3
# Total Mediators weights
newmed2imp$medweight <- newmed2imp$weightM1 * newmed2imp$weightM2 *
newmed2imp$weightM3
# total Weight including survey weight
newmed2imp$totalweight <- newmed2imp$medweight * newmed2imp$weight
#########################################################################
#
# natural effect modeling
###################
#model1 Visit Avoidance
newmed2imp <- newmed2imp[order(newmed2imp$newID), ]
model1 <- geeglm(Last_Y1 ~ (factor(Education_X) + factor(Education_XStar1) +
factor(Education_XStar2) + factor(Education_XStar3)) * sector + age + Sex + Ghealth
```

```
+ COB + Residential, data = newmed2imp, family = 'binomial', weights= totalweight, id=newmed2imp$newID)

###################

#Collect and return estimates

return(coef(model1)[1:16])

##########################End of the Function#########################

}

########################For BootStrap Analysis#######################

########################Run Function 5000 times######################

########################and Collect all Estimates####################

bootstrapEffectEsts1 <- pbreplicate(3, effectSep1(med2Imp[sample(1:nrow(med2Imp),size=nrow(med2Imp),replace=T),]))

##########################Computing the table#########################

outputTabel1 <- matrix(NA, ncol=6, nrow=5)

boot1 <- t(apply(bootstrapEffectEsts1, 1, quantile, c(0.5,0.025,0.975)))

Ftablefullmodel1 <- exp(boot1)

Totaleffect1 <- apply(bootstrapEffectEsts1[c(2,3,4,5),],2,sum)

Totalindirecteffect1 <- apply(bootstrapEffectEsts1[c(3,4,5),],2,sum)

temp <- rbind(bootstrapEffectEsts1, Totaleffect1, bootstrapEffectEsts1[c(2,3,4,5),]/rbind(Totaleffect1,Totaleffect1,Totaleffect1,Totaleffect1),Totalindirecteffect1)

tempQuant <- t(apply(temp, 1, quantile, c(0.5,0.025,0.975)))

outputTabel1[,1:3] <- rbind(tempQuant[c(2,3,4,5,17),])

outputTabel1[1:4,4:6] <- tempQuant[18:21,]

#exp table

Ftable_oddsratio_model1 <- matrix(NA, ncol=6, nrow=5)

temptablel1<- exp(outputTabel1[,1:3])

Ftable_oddsratio_model1[,1:3] <- temptablel1[,1:3]

Ftable_oddsratio_model1[,4:6] <- outputTabel1[,4:6]

##########################Drawing  the Plot#########################
```

```
#plot

# Create labels

boxLabels = c("Direct Effect", "Indirect through M1", "Indirect through M2", "Indirect through M3", "Total Effect")

df1 <- data.frame((yax = length(boxLabels):1), boxOdds = Ftable_oddsratio_model1[,1], boxCILow = Ftable_oddsratio_model1[,2], boxCIHigh = Ftable_oddsratio_model1[,3])

# Plot

(p1 <- ggplot(df1, aes(x = boxOdds, y = boxLabels)) +

geom_vline(aes(xintercept = 1), size = .5, linetype = 'dashed') +

geom_errorbarh(aes(xmax = boxCIHigh, xmin = boxCILow), size = 1.3, height =

.5, color = 'black') +

geom_point(size = 3.5, color = 'blue') +

theme_bw() +

theme(panel.grid.minor = element_blank()) +

scale_x_continuous(breaks = seq(0.1,1.8,0.1) ) +

coord_trans(x = 'log10') +

ylab('') +

xlab('Odds ratio (log scale)'))+ scale_y_discrete(limits = rev) + geom_hline(aes(yintercept = 1.5), size = 1, linetype = 'solid')

##########################End of the Code##########################
```

Appendix V

Sensitivity Analysis

```
#########################################################################
#
#########################################################################
#
#########################################################################
#
##Education effect on Dental Services Utilisation Patterns in Different Sectors: ####
################### A Multiple Mediation Analysis ######################
#########################################################################
#########################################################################
#########################sensitivity analysis#########################
#########################################################################
#


#libraries
library(haven)
library(pbapply)
#########################NOTE: write
ESTIMATES#########################


#estimate and standard error for NDE
est.de = -0.405340737
CIL_NDE = -0.57079726
CIU_NDE = -0.248848933


#estimate and standard error for NIE
est.ie =  0.012670171
CIL_NIE = -0.04331834
CIU_NIE = 0.050459304
```

```
#########################################################################
#

#data set

med2Imp <- read_sav("~/Desktop/education mediation/MED3Imp.sav")


#########################Weight full#########################

# fit Models for Mediators

# Fit a Model for M1 (Oral Health)

med2Imp$ATemp <- med2Imp$Education_X

FitM1 <- glm(factor(dm1) ~ factor(ATemp) * factor(dm2) * factor(dm3) + sector +
age + Sex + Income + Ghealth + COB + Residential, data = med2Imp ,family =
"binomial")

# Fit a Model for M2 (Smoke)

FitM2 <- glm(factor(dm2) ~ factor(ATemp) + sector + age + Sex + Income + Ghealth
+ COB + Residential, data = med2Imp, family = "binomial")

# Fit a Model for M3 (Brushing)

FitM3 <- glm(factor(dm3) ~ factor(ATemp)*factor(dm2) + sector + age + Sex +
Ghealth + COB + Residential, data = med2Imp, family = "binomial")

#########################################################################
#

# Data Expansion

levelofeducation <- unique(med2Imp$Education_X)

med2Imp$newID <- 1:nrow(med2Imp)

med2Imp1 <- med2Imp

med2Imp2 <- med2Imp

med2Imp1$Education_XStar1 <- levelofeducation[1]

med2Imp2$Education_XStar1 <- levelofeducation[2]

tempmed2imp <- rbind(med2Imp1,med2Imp2)

####
```

```
med2Imp1 <- tempmed2imp
med2Imp2 <- tempmed2imp
med2Imp1$Education_XStar2 <- levelofeducation[1]
med2Imp2$Education_XStar2 <- levelofeducation[2]
tempmed2imp <- rbind(med2Imp1, med2Imp2)
####
med2Imp1 <- tempmed2imp
med2Imp2 <- tempmed2imp
med2Imp1$Education_XStar3 <- levelofeducation[1]
med2Imp2$Education_XStar3 <- levelofeducation[2]
newmed2imp <- rbind(med2Imp1, med2Imp2)
#########################################################################
#
#Weighting
#M Weight
newmed2imp$ATemp <- newmed2imp$Education_X
temp <- predict(FitM1, type = "response", newdata = newmed2imp)
TempDirM1 <- ifelse(newmed2imp$dm1, temp, 1-temp)

newmed2imp$ATemp <- newmed2imp$Education_XStar1
temp <- predict(FitM1, type = "response", newdata = newmed2imp)
tempindirM1 <- ifelse(newmed2imp$dm1, temp, 1-temp)
newmed2imp$weightM1 <- tempindirM1/TempDirM1
#M2 Weight
newmed2imp$ATemp <- newmed2imp$Education_X
temp <- predict(FitM2, type = "response", newdata = newmed2imp)
TempDirM2 <- ifelse(newmed2imp$dm2, temp, 1-temp)

newmed2imp$ATemp <- newmed2imp$Education_XStar2
```

```
temp <- predict(FitM2, type = "response", newdata = newmed2imp)
tempindirM2 <- ifelse(newmed2imp$dm2, temp, 1-temp)
newmed2imp$weightM2 <- tempindirM2/TempDirM2
#M3 Weight
newmed2imp$ATemp <- newmed2imp$Education_X
temp <- predict(FitM3, type = "response", newdata = newmed2imp)
TempDirM3 <- ifelse(newmed2imp$dm3, temp, 1-temp)

newmed2imp$ATemp <- newmed2imp$Education_XStar3
temp <- predict(FitM3, type = "response", newdata = newmed2imp)
tempindirM3 <- ifelse(newmed2imp$dm3, temp, 1-temp)
newmed2imp$weightM3 <- tempindirM3/TempDirM3
# Total Mediators weights
newmed2imp$medweight <- newmed2imp$weightM1 * newmed2imp$weightM2 *
newmed2imp$weightM3
# total Weight including survey weight
newmed2imp$TW <- newmed2imp$medweight * newmed2imp$weight

#########################################################################
################Sensitivity for pretreatment confounders#############
#########################################################################
#AGE=c1
# fit Models for Mediators
# Fit a Model for M1 (PubPriv)
med2Imp$ATemp <- med2Imp$Education_X
FitM1_c1 <- glm(factor(dm1) ~ factor(ATemp) * factor(dm2) * factor(dm3) + sector
+ Sex + Income + Ghealth + COB + Residential, data = med2Imp ,family =
"binomial")
# Fit a Model for M2 (insured)
med2Imp$ATemp <- med2Imp$Education_X
```

```
FitM2_c1 <- glm(factor(dm2) ~ factor(ATemp) + sector + Sex + Income + Ghealth +
COB + Residential, data = med2Imp, family = "binomial")

# Fit a Model for M3 (concard)

med2Imp$ATemp <- med2Imp$Education_X

FitM3_c1 <- glm(factor(dm3) ~ factor(ATemp)*factor(dm2) + sector + Sex  +
Ghealth + COB + Residential, data = med2Imp, family = "binomial")

# Assess intertwined casual pathways

#########################################################################
#

#Weighting

#M Weight

newmed2imp$ATemp <- newmed2imp$Education_X

temp_c1 <- predict(FitM1_c1, type = "response", newdata = newmed2imp)

TempDirM1_c1 <- ifelse(newmed2imp$dm1, temp_c1, 1-temp)


newmed2imp$ATemp <- newmed2imp$Education_XStar1

temp_c1 <- predict(FitM1_c1, type = "response", newdata = newmed2imp)

tempindirM1_c1 <- ifelse(newmed2imp$dm1, temp_c1, 1-temp_c1)

newmed2imp$weightM1_c1 <- tempindirM1_c1/TempDirM1_c1

#M2 Weight

newmed2imp$ATemp <- newmed2imp$Education_X

temp_c1 <- predict(FitM2_c1, type = "response", newdata = newmed2imp)

TempDirM2_c1 <- ifelse(newmed2imp$dm2, temp_c1, 1-temp_c1)


newmed2imp$ATemp <- newmed2imp$Education_XStar2

temp_c1 <- predict(FitM2_c1, type = "response", newdata = newmed2imp)

tempindirM2_c1 <- ifelse(newmed2imp$dm2, temp, 1-temp)

newmed2imp$weightM2_c1 <- tempindirM2_c1/TempDirM2_c1

#M3 Weight

newmed2imp$ATemp <- newmed2imp$Education_X
```

```
temp_c1 <- predict(FitM3_c1, type = "response", newdata = newmed2imp)

TempDirM3_c1 <- ifelse(newmed2imp$dm3, temp_c1, 1-temp_c1)


newmed2imp$ATemp <- newmed2imp$Education_XStar3

temp_c1 <- predict(FitM3_c1, type = "response", newdata = newmed2imp)

tempindirM3_c1 <- ifelse(newmed2imp$dm3, temp_c1, 1-temp_c1)

newmed2imp$weightM3_c1 <- tempindirM3_c1/TempDirM3_c1

# Total Mediators weights

newmed2imp$medweight_c1 <- newmed2imp$weightM1_c1 *
newmed2imp$weightM2_c1 * newmed2imp$weightM3_c1

# total Weight including survey weight

newmed2imp$TW1 <- newmed2imp$medweight_c1 * newmed2imp$weight


#########################################################################
#

#sex=c2

# fit Models for Mediators

# Fit a Model for M1 (PubPriv)

med2Imp$ATemp <- med2Imp$Education_X

FitM1_c2 <- glm(factor(dm1) ~ factor(ATemp) * factor(dm2) * factor(dm3) + sector
+ age + Income + Ghealth + COB + Residential, data = med2Imp ,family =
"binomial")

# Fit a Model for M2 (insured)

med2Imp$ATemp <- med2Imp$Education_X

FitM2_c2 <- glm(factor(dm2) ~ factor(ATemp) + sector + age + Income + Ghealth +
COB + Residential, data = med2Imp, family = "binomial")

# Fit a Model for M3 (concard)

med2Imp$ATemp <- med2Imp$Education_X

FitM3_c2 <- glm(factor(dm3) ~ factor(ATemp)*factor(dm2) + sector + age  +
Ghealth + COB + Residential, data = med2Imp, family = "binomial")

# Assess intertwined casual pathways
```

```
#########################################################################
#
#########################################################################
#
#Weighting
#M Weight
newmed2imp$ATemp <- newmed2imp$Education_X
temp <- predict(FitM1_c2, type = "response", newdata = newmed2imp)
TempDirM1 <- ifelse(newmed2imp$dm1, temp, 1-temp)

newmed2imp$ATemp <- newmed2imp$Education_XStar1
temp <- predict(FitM1_c2, type = "response", newdata = newmed2imp)
tempindirM1 <- ifelse(newmed2imp$dm1, temp, 1-temp)
newmed2imp$weightM1_c2 <- tempindirM1/TempDirM1
#M2 Weight
newmed2imp$ATemp <- newmed2imp$Education_X
temp <- predict(FitM2_c2, type = "response", newdata = newmed2imp)
TempDirM2 <- ifelse(newmed2imp$dm2, temp, 1-temp)

newmed2imp$ATemp <- newmed2imp$Education_XStar2
temp <- predict(FitM2_c2, type = "response", newdata = newmed2imp)
tempindirM2 <- ifelse(newmed2imp$dm2, temp, 1-temp)
newmed2imp$weightM2_c2 <- tempindirM2/TempDirM2
#M3 Weight
newmed2imp$ATemp <- newmed2imp$Education_X
temp <- predict(FitM3_c2, type = "response", newdata = newmed2imp)
TempDirM3 <- ifelse(newmed2imp$dm3, temp, 1-temp)

newmed2imp$ATemp <- newmed2imp$Education_XStar3
```

```
temp <- predict(FitM3_c2, type = "response", newdata = newmed2imp)

tempindirM3 <- ifelse(newmed2imp$dm3, temp, 1-temp)

newmed2imp$weightM3_c2 <- tempindirM3/TempDirM3

# Total Mediators weights

newmed2imp$medweight_c2 <- newmed2imp$weightM1_c2 *
newmed2imp$weightM2_c2 * newmed2imp$weightM3_c2

# total Weight including survey weight

newmed2imp$TW2 <- newmed2imp$medweight_c2 * newmed2imp$weight


#########################################################################
#

#########################################################################
#

#income= c3

# fit Models for Mediators

# Fit a Model for M1 (PubPriv)

med2Imp$ATemp <- med2Imp$Education_X

FitM1_c3 <- glm(factor(dm1) ~ factor(ATemp) * factor(dm2) * factor(dm3) + sector
+ age + Sex + Ghealth + COB + Residential, data = med2Imp ,family = "binomial")

# Fit a Model for M2 (insured)

med2Imp$ATemp <- med2Imp$Education_X

FitM2_c3 <- glm(factor(dm2) ~ factor(ATemp) + sector + age + Sex + Ghealth +
COB + Residential, data = med2Imp, family = "binomial")

# Fit a Model for M3 (concard)

med2Imp$ATemp <- med2Imp$Education_X

FitM3_c3 <- glm(factor(dm3) ~ factor(ATemp)*factor(dm2) + sector + age + Sex +
Ghealth + COB + Residential, data = med2Imp, family = "binomial")

# Assess intertwined casual pathways

#########################################################################
#

#########################################################################
#
```

Appendix V

```
#Weighting
#M Weight
newmed2imp$ATemp <- newmed2imp$Education_X
temp <- predict(FitM1_c3, type = "response", newdata = newmed2imp)
TempDirM1 <- ifelse(newmed2imp$dm1, temp, 1-temp)

newmed2imp$ATemp <- newmed2imp$Education_XStar1
temp <- predict(FitM1_c3, type = "response", newdata = newmed2imp)
tempindirM1 <- ifelse(newmed2imp$dm1, temp, 1-temp)
newmed2imp$weightM1_c3 <- tempindirM1/TempDirM1
#M2 Weight
newmed2imp$ATemp <- newmed2imp$Education_X
temp <- predict(FitM2_c3, type = "response", newdata = newmed2imp)
TempDirM2 <- ifelse(newmed2imp$dm2, temp, 1-temp)

newmed2imp$ATemp <- newmed2imp$Education_XStar2
temp <- predict(FitM2_c3, type = "response", newdata = newmed2imp)
tempindirM2 <- ifelse(newmed2imp$dm2, temp, 1-temp)
newmed2imp$weightM2_c3 <- tempindirM2/TempDirM2
#M3 Weight
newmed2imp$ATemp <- newmed2imp$Education_X
temp <- predict(FitM3_c3, type = "response", newdata = newmed2imp)
TempDirM3 <- ifelse(newmed2imp$dm3, temp, 1-temp)

newmed2imp$ATemp <- newmed2imp$Education_XStar3
temp <- predict(FitM3_c3, type = "response", newdata = newmed2imp)
tempindirM3 <- ifelse(newmed2imp$dm3, temp, 1-temp)
newmed2imp$weightM3_c3 <- tempindirM3/TempDirM3
# Total Mediators weights
```

```
newmed2imp$medweight_c3 <- newmed2imp$weightM1_c3 *
newmed2imp$weightM2_c3 * newmed2imp$weightM3_c3

# total Weight including survey weight

newmed2imp$TW3 <- newmed2imp$medweight_c3 * newmed2imp$weight

#########################################################################
#

#########################################################################
#

#Ghealth=c4

# fit Models for Mediators

# Fit a Model for M1 (PubPriv)

med2Imp$ATemp <- med2Imp$Education_X

FitM1_c4 <- glm(factor(dm1) ~ factor(ATemp) * factor(dm2) * factor(dm3) + sector
+ age + Sex + Income + COB + Residential, data = med2Imp ,family = "binomial")

# Fit a Model for M2 (insured)

med2Imp$ATemp <- med2Imp$Education_X

FitM2_c4 <- glm(factor(dm2) ~ factor(ATemp) + sector + age + Sex + Income +
COB + Residential, data = med2Imp, family = "binomial")

# Fit a Model for M3 (concard)

med2Imp$ATemp <- med2Imp$Education_X

FitM3_c4 <- glm(factor(dm3) ~ factor(ATemp)*factor(dm2) + sector + age + Sex  +
COB + Residential, data = med2Imp, family = "binomial")

# Assess intertwined casual pathways

#########################################################################
#

#########################################################################
#

#Weighting

#M Weight

newmed2imp$ATemp <- newmed2imp$Education_X

temp <- predict(FitM1_c4, type = "response", newdata = newmed2imp)

TempDirM1 <- ifelse(newmed2imp$dm1, temp, 1-temp)
```

```
newmed2imp$ATemp <- newmed2imp$Education_XStar1
temp <- predict(FitM1_c4, type = "response", newdata = newmed2imp)
tempindirM1 <- ifelse(newmed2imp$dm1, temp, 1-temp)
newmed2imp$weightM1_c4 <- tempindirM1/TempDirM1
#M2 Weight
newmed2imp$ATemp <- newmed2imp$Education_X
temp <- predict(FitM2_c4, type = "response", newdata = newmed2imp)
TempDirM2 <- ifelse(newmed2imp$dm2, temp, 1-temp)

newmed2imp$ATemp <- newmed2imp$Education_XStar2
temp <- predict(FitM2_c4, type = "response", newdata = newmed2imp)
tempindirM2 <- ifelse(newmed2imp$dm2, temp, 1-temp)
newmed2imp$weightM2_c4 <- tempindirM2/TempDirM2
#M3 Weight
newmed2imp$ATemp <- newmed2imp$Education_X
temp <- predict(FitM3_c4, type = "response", newdata = newmed2imp)
TempDirM3 <- ifelse(newmed2imp$dm3, temp, 1-temp)

newmed2imp$ATemp <- newmed2imp$Education_XStar3
temp <- predict(FitM3_c4, type = "response", newdata = newmed2imp)
tempindirM3 <- ifelse(newmed2imp$dm3, temp, 1-temp)
newmed2imp$weightM3_c4 <- tempindirM3/TempDirM3
# Total Mediators weights
newmed2imp$medweight_c4 <- newmed2imp$weightM1_c4 *
newmed2imp$weightM2_c4 * newmed2imp$weightM3_c4
# total Weight including survey weight
newmed2imp$TW4 <- newmed2imp$medweight_c4 * newmed2imp$weight
```

```
#########################################################################
#

#########################################################################
#

#cob=c5

# fit Models for Mediators

# Fit a Model for M1 (PubPriv)

med2Imp$ATemp <- med2Imp$Education_X

FitM1_c5 <- glm(factor(dm1) ~ factor(ATemp) * factor(dm2) * factor(dm3) + sector
+ age + Sex + Income + Ghealth + Residential, data = med2Imp ,family = "binomial")

# Fit a Model for M2 (insured)

med2Imp$ATemp <- med2Imp$Education_X

FitM2_c5 <- glm(factor(dm2) ~ factor(ATemp) + sector + age + Sex + Income +
Ghealth + Residential, data = med2Imp, family = "binomial")

# Fit a Model for M3 (concard)

med2Imp$ATemp <- med2Imp$Education_X

FitM3_c5 <- glm(factor(dm3) ~ factor(ATemp)*factor(dm2) + sector + age + Sex +
Ghealth + Residential, data = med2Imp, family = "binomial")

# Assess intertwined casual pathways

#########################################################################
#

#########################################################################
#

#Weighting

#M Weight

newmed2imp$ATemp <- newmed2imp$Education_X

temp <- predict(FitM1_c5, type = "response", newdata = newmed2imp)

TempDirM1 <- ifelse(newmed2imp$dm1, temp, 1-temp)


newmed2imp$ATemp <- newmed2imp$Education_XStar1

temp <- predict(FitM1_c5, type = "response", newdata = newmed2imp)
```

```
tempindirM1 <- ifelse(newmed2imp$dm1, temp, 1-temp)
newmed2imp$weightM1_c5 <- tempindirM1/TempDirM1
#M2 Weight
newmed2imp$ATemp <- newmed2imp$Education_X
temp <- predict(FitM2_c5, type = "response", newdata = newmed2imp)
TempDirM2 <- ifelse(newmed2imp$dm2, temp, 1-temp)

newmed2imp$ATemp <- newmed2imp$Education_XStar2
temp <- predict(FitM2_c5, type = "response", newdata = newmed2imp)
tempindirM2 <- ifelse(newmed2imp$dm2, temp, 1-temp)
newmed2imp$weightM2_c5 <- tempindirM2/TempDirM2
#M3 Weight
newmed2imp$ATemp <- newmed2imp$Education_X
temp <- predict(FitM3_c5, type = "response", newdata = newmed2imp)
TempDirM3 <- ifelse(newmed2imp$dm3, temp, 1-temp)

newmed2imp$ATemp <- newmed2imp$Education_XStar3
temp <- predict(FitM3_c5, type = "response", newdata = newmed2imp)
tempindirM3 <- ifelse(newmed2imp$dm3, temp, 1-temp)
newmed2imp$weightM3_c5 <- tempindirM3/TempDirM3
# Total Mediators weights
newmed2imp$medweight_c5 <- newmed2imp$weightM1_c5 *
newmed2imp$weightM2_c5 * newmed2imp$weightM3_c5
# total Weight including survey weight
newmed2imp$TW5 <- newmed2imp$medweight_c5 * newmed2imp$weight
##########################################################################
#
##########################################################################
#
#residency=c6
```

```
# fit Models for Mediators

# Fit a Model for M1 (PubPriv)

med2Imp$ATemp <- med2Imp$Education_X

FitM1_c6 <- glm(factor(dm1) ~ factor(ATemp) * factor(dm2) * factor(dm3) + sector
+ age + Sex + Income + Ghealth + COB, data = med2Imp ,family = "binomial")

# Fit a Model for M2 (insured)

med2Imp$ATemp <- med2Imp$Education_X

FitM2_c6 <- glm(factor(dm2) ~ factor(ATemp) + sector + age + Sex + Income +
Ghealth + COB, data = med2Imp, family = "binomial")

# Fit a Model for M3 (concard)

med2Imp$ATemp <- med2Imp$Education_X

FitM3_c6 <- glm(factor(dm3) ~ factor(ATemp)*factor(dm2) + sector + age + Sex  +
Ghealth + COB, data = med2Imp, family = "binomial")

# Assess intertwined casual pathways

##########################################################################
#

##########################################################################
#

#Weighting

#M Weight

newmed2imp$ATemp <- newmed2imp$Education_X

temp <- predict(FitM1_c6, type = "response", newdata = newmed2imp)

TempDirM1 <- ifelse(newmed2imp$dm1, temp, 1-temp)


newmed2imp$ATemp <- newmed2imp$Education_XStar1

temp <- predict(FitM1_c6, type = "response", newdata = newmed2imp)

tempindirM1 <- ifelse(newmed2imp$dm1, temp, 1-temp)

newmed2imp$weightM1_c6 <- tempindirM1/TempDirM1

#M2 Weight

newmed2imp$ATemp <- newmed2imp$Education_X

temp <- predict(FitM2_c6, type = "response", newdata = newmed2imp)
```

```
TempDirM2 <- ifelse(newmed2imp$dm2, temp, 1-temp)

newmed2imp$ATemp <- newmed2imp$Education_XStar2
temp <- predict(FitM2_c6, type = "response", newdata = newmed2imp)
tempindirM2 <- ifelse(newmed2imp$dm2, temp, 1-temp)
newmed2imp$weightM2_c6 <- tempindirM2/TempDirM2
#M3 Weight
newmed2imp$ATemp <- newmed2imp$Education_X
temp <- predict(FitM3_c6, type = "response", newdata = newmed2imp)
TempDirM3 <- ifelse(newmed2imp$dm3, temp, 1-temp)

newmed2imp$ATemp <- newmed2imp$Education_XStar3
temp <- predict(FitM3_c6, type = "response", newdata = newmed2imp)
tempindirM3 <- ifelse(newmed2imp$dm3, temp, 1-temp)
newmed2imp$weightM3_c6 <- tempindirM3/TempDirM3
# Total Mediators weights
newmed2imp$medweight_c6 <- newmed2imp$weightM1_c6 *
newmed2imp$weightM2_c6 * newmed2imp$weightM3_c6
# total Weight including survey weight
newmed2imp$TW6 <- newmed2imp$medweight_c6 * newmed2imp$weight
##########################################################################
#
#sector =c34
# fit Models for Mediators
# Fit a Model for M1 (PubPriv)
med2Imp$ATemp <- med2Imp$Education_X
FitM1_c34 <- glm(factor(dm1) ~ factor(ATemp) * factor(dm2) * factor(dm3) + age +
Sex + Income + Ghealth + COB + Residential, data = med2Imp ,family = "binomial")
# Fit a Model for M2 (insured)
med2Imp$ATemp <- med2Imp$Education_X
```

```
FitM2_c34 <- glm(factor(dm2) ~ factor(ATemp) + age + Sex + Income + Ghealth +
COB + Residential, data = med2Imp, family = "binomial")

# Fit a Model for M3 (concard)

med2Imp$ATemp <- med2Imp$Education_X

FitM3_c34 <- glm(factor(dm3) ~ factor(ATemp)*factor(dm2) + age + Sex  + Ghealth
+ COB + Residential, data = med2Imp, family = "binomial")

# Assess intertwined casual pathways

##########################################################################
#

##########################################################################
#

#Weighting

#M Weight

newmed2imp$ATemp <- newmed2imp$Education_X

temp <- predict(FitM1_c34, type = "response", newdata = newmed2imp)

TempDirM1 <- ifelse(newmed2imp$dm1, temp, 1-temp)


newmed2imp$ATemp <- newmed2imp$Education_XStar1

temp <- predict(FitM1_c34, type = "response", newdata = newmed2imp)

tempindirM1 <- ifelse(newmed2imp$dm1, temp, 1-temp)

newmed2imp$weightM1_c34 <- tempindirM1/TempDirM1

#M2 Weight

newmed2imp$ATemp <- newmed2imp$Education_X

temp <- predict(FitM2_c34, type = "response", newdata = newmed2imp)

TempDirM2 <- ifelse(newmed2imp$dm2, temp, 1-temp)


newmed2imp$ATemp <- newmed2imp$Education_XStar2

temp <- predict(FitM2_c34, type = "response", newdata = newmed2imp)

tempindirM2 <- ifelse(newmed2imp$dm2, temp, 1-temp)

newmed2imp$weightM2_c34 <- tempindirM2/TempDirM2
```

Appendix V

```
#M3 Weight
newmed2imp$ATemp <- newmed2imp$Education_X
temp <- predict(FitM3_c34, type = "response", newdata = newmed2imp)
TempDirM3 <- ifelse(newmed2imp$dm3, temp, 1-temp)

newmed2imp$ATemp <- newmed2imp$Education_XStar3
temp <- predict(FitM3_c34, type = "response", newdata = newmed2imp)
tempindirM3 <- ifelse(newmed2imp$dm3, temp, 1-temp)
newmed2imp$weightM3_c34 <- tempindirM3/TempDirM3
# Total Mediators weights
newmed2imp$medweight_c34 <- newmed2imp$weightM1_c34 *
newmed2imp$weightM2_c34 * newmed2imp$weightM3_c34
# total Weight including survey weight
newmed2imp$TW34 <- newmed2imp$medweight_c34 * newmed2imp$weight

#########################################################################
#
#########################################################################
#
################################## Sensitivity BIAS ####################
#c1
sigma1 = sd((-newmed2imp$TW1 + newmed2imp$TW)[newmed2imp$Education_X
== 1])
rho1 = cor((-newmed2imp$TW1 + newmed2imp$TW)[newmed2imp$Education_X
== 1], newmed2imp[newmed2imp$Education_X == 1, "y1"])
bias_NIE1 = sigma1 * rho1
bias_NDE1 = -bias_NIE1

#c2
sigma2 = sd((-newmed2imp$TW2 + newmed2imp$TW)[newmed2imp$Education_X
== 1])
```

```
rho2 = cor((-newmed2imp$TW2 + newmed2imp$TW)[newmed2imp$Education_X
== 1], newmed2imp[newmed2imp$Education_X == 1,"y1"])

bias_NIE2 = sigma2 * rho2

bias_NDE2 = -bias_NIE2

#c3

sigma3 = sd((-newmed2imp$TW3 + newmed2imp$TW)[newmed2imp$Education_X
== 1])

rho3 = cor((-newmed2imp$TW3 + newmed2imp$TW)[newmed2imp$Education_X
== 1], newmed2imp[newmed2imp$Education_X == 1, "y1"])

bias_NIE3 = sigma3 * rho3

bias_NDE3 = -bias_NIE3

#c4

sigma4 = sd((-newmed2imp$TW4 + newmed2imp$TW)[newmed2imp$Education_X
== 1])

rho4 = cor((-newmed2imp$TW4 + newmed2imp$TW)[newmed2imp$Education_X
== 1], newmed2imp[newmed2imp$Education_X == 1, "y1"])

bias_NIE4 = sigma4 * rho4

bias_NDE4 = -bias_NIE4

#c5

sigma5 = sd((-newmed2imp$TW5 + newmed2imp$TW)[newmed2imp$Education_X
== 1])

rho5 = cor((-newmed2imp$TW5 + newmed2imp$TW)[newmed2imp$Education_X
== 1], newmed2imp[newmed2imp$Education_X == 1, "y1"])

bias_NIE5 = sigma5 * rho5

bias_NDE5 = -bias_NIE5

#c6

sigma6 = sd((-newmed2imp$TW6 + newmed2imp$TW)[newmed2imp$Education_X
== 1])

rho6 = cor((-newmed2imp$TW6 + newmed2imp$TW)[newmed2imp$Education_X
== 1], newmed2imp[newmed2imp$Education_X == 1, "y1"])

bias_NIE6 = sigma6 * rho6

bias_NDE6 = -bias_NIE6
```

```
#c34
sigma34 = sd((-newmed2imp$TW34 +
newmed2imp$TW)[newmed2imp$Education_X == 1])
rho34 = cor((-newmed2imp$TW34 +
newmed2imp$TW)[newmed2imp$Education_X == 1],
newmed2imp[newmed2imp$Education_X == 1, "y1"])
bias_NIE34 = sigma34 * rho34
bias_NDE34 = -bias_NIE34

################################## Modified Estimates ####################


#########################SENS FUNCTION#########################
sens = function(est.ori, effect) {
 left = est.ori[paste0("CIL_", effect)]
 right = est.ori[paste0("CIU_", effect)]
 if (est.ori[paste0("CIL_", effect)] < 0 & est.ori[paste0("CIU_",
                                                  effect)] > 0) {
  if (get(paste0("bias_", effect)) < left | get(paste0("bias_",
                                                  effect)) > right) {
   sens = "*"
  }
  else {
   sens = ""
  }
 }
 if (est.ori[paste0("CIL_", effect)] > 0) {
  if (get(paste0("bias_", effect)) >= left) {
   sens = "*"
  }
```

```
    else {
      sens = ""
    }
  }
  if (est.ori[paste0("CIU_", effect)] < 0) {
    if (get(paste0("bias_", effect)) <= right) {
      sens = "*"
    }
    else {
      sens = ""
    }
  }
  return(sens)
}
################################## Modified Estimates ####################
est.ori = c(NIE1 = est.ie, CIL_NIE1 = CIL_NIE, CIU_NIE1 = CIU_NIE,
            NDE1 = est.de, CIL_NDE1 = CIL_NDE, CIU_NDE1 = CIU_NDE)
#c1= age
sensitivity_NIE1 = sens(est.ori, "NIE1")
sensitivity_NDE1 = sens(est.ori, "NDE1")

modified_NIE_c1 = est.ori["NIE1"] - bias_NIE1
modified_NDE_c1 = est.ori["NDE1"] - bias_NDE1
modifiedCIL_NIE_c1 = est.ori["CIL_NIE1"] - bias_NIE1
modifiedCIU_NIE_c1 = est.ori["CIU_NIE1"] - bias_NIE1
modifiedCIL_NDE_c1 = est.ori["CIL_NDE1"] - bias_NDE1
modifiedCIU_NDE_c1 = est.ori["CIU_NDE1"] - bias_NDE1
bias_c1 = c(round(sigma1, 3), round(rho1, 3), round(bias_NIE1,
```

```
                                3), sensitivity_NIE1, round(modified_NIE_c1, 3),
paste0("[",

round(modifiedCIL_NIE_c1, 3), ",", round(modifiedCIU_NIE_c1,

3), "]"), round(bias_NDE1, 3), sensitivity_NDE1,
        round(modified_NDE_c1, 3), paste0("[", round(modifiedCIL_NDE_c1,
                                3), ",", round(modifiedCIU_NDE_c1, 3), "]"))
#########################################################################
#
est.ori = c(NIE2 = est.ie, CIL_NIE2 = CIL_NIE, CIU_NIE2 = CIU_NIE,
        NDE2 = est.de, CIL_NDE2 = CIL_NDE, CIU_NDE2 = CIU_NDE)
#c2= sex
sensitivity_NIE2 = sens(est.ori, "NIE2")
sensitivity_NDE2 = sens(est.ori, "NDE2")
modified_NIE_c2 = est.ori["NIE2"] - bias_NIE2
modified_NDE_c2 = est.ori["NDE2"] - bias_NDE2
modifiedCIL_NIE_c2 = est.ori["CIL_NIE2"] - bias_NIE2
modifiedCIU_NIE_c2 = est.ori["CIU_NIE2"] - bias_NIE2
modifiedCIL_NDE_c2 = est.ori["CIL_NDE2"] - bias_NDE2
modifiedCIU_NDE_c2 = est.ori["CIU_NDE2"] - bias_NDE2
bias_c2 = c(round(sigma2, 3), round(rho2, 3), round(bias_NIE2,
                                3), sensitivity_NIE2, round(modified_NIE_c2, 3),
paste0("[",

round(modifiedCIL_NIE_c2, 3), ",", round(modifiedCIU_NIE_c2,

3), "]"), round(bias_NDE2, 3), sensitivity_NDE2,
        round(modified_NDE_c2, 3), paste0("[", round(modifiedCIL_NDE_c2,
                                3), ",", round(modifiedCIU_NDE_c2, 3), "]"))
#########################################################################
#
```

```
est.ori = c(NIE3 = est.ie, CIL_NIE3 = CIL_NIE, CIU_NIE3 = CIU_NIE,
        NDE3 = est.de, CIL_NDE3 = CIL_NDE, CIU_NDE3 = CIU_NDE)
#c3= education
sensitivity_NIE3 = sens(est.ori, "NIE3")
sensitivity_NDE3 = sens(est.ori, "NDE3")
modified_NIE_c3 = est.ori["NIE3"] - bias_NIE3
modified_NDE_c3 = est.ori["NDE3"] - bias_NDE3
modifiedCIL_NIE_c3 = est.ori["CIL_NIE3"] - bias_NIE3
modifiedCIU_NIE_c3 = est.ori["CIU_NIE3"] - bias_NIE3
modifiedCIL_NDE_c3 = est.ori["CIL_NDE3"] - bias_NDE3
modifiedCIU_NDE_c3 = est.ori["CIU_NDE3"] - bias_NDE3
bias_c3 = c(round(sigma3, 3), round(rho3, 3), round(bias_NIE3,
                                    3), sensitivity_NIE3, round(modified_NIE_c3, 3),
paste0("[",

round(modifiedCIL_NIE_c3, 3), ",", round(modifiedCIU_NIE_c3,

3), "]"), round(bias_NDE3, 3), sensitivity_NDE3,
        round(modified_NDE_c3, 3), paste0("[", round(modifiedCIL_NDE_c3,
                                    3), ",", round(modifiedCIU_NDE_c3, 3), "]"))
#########################################################################
#
est.ori = c(NIE4 = est.ie, CIL_NIE4 = CIL_NIE, CIU_NIE4 = CIU_NIE,
        NDE4 = est.de, CIL_NDE4 = CIL_NDE, CIU_NDE4 = CIU_NDE)
#c4= ohealth
sensitivity_NIE4 = sens(est.ori, "NIE4")
sensitivity_NDE4 = sens(est.ori, "NDE4")
modified_NIE_c4 = est.ori["NIE4"] - bias_NIE4
modified_NDE_c4 = est.ori["NDE4"] - bias_NDE4
modifiedCIL_NIE_c4 = est.ori["CIL_NIE4"] - bias_NIE4
```

```
modifiedCIU_NIE_c4 = est.ori["CIU_NIE4"] - bias_NIE4
modifiedCIL_NDE_c4 = est.ori["CIL_NDE4"] - bias_NDE4
modifiedCIU_NDE_c4 = est.ori["CIU_NDE4"] - bias_NDE4
bias_c4 = c(round(sigma4, 3), round(rho4, 3), round(bias_NIE4,
                                    3), sensitivity_NIE4, round(modified_NIE_c4, 3),
paste0("[",

round(modifiedCIL_NIE_c4, 3), ",", round(modifiedCIU_NIE_c4,

3), "]"), round(bias_NDE4, 3), sensitivity_NDE4,
        round(modified_NDE_c4, 3), paste0("[", round(modifiedCIL_NDE_c4,
                                        3), ",", round(modifiedCIU_NDE_c4, 3), "]"))
########################################################################
#
est.ori = c(NIE5 = est.ie, CIL_NIE5 = CIL_NIE, CIU_NIE5 = CIU_NIE,
        NDE5 = est.de, CIL_NDE5 = CIL_NDE, CIU_NDE5 = CIU_NDE)
#c5= cob
sensitivity_NIE5 = sens(est.ori, "NIE5")
sensitivity_NDE5 = sens(est.ori, "NDE5")
modified_NIE_c5 = est.ori["NIE5"] - bias_NIE5
modified_NDE_c5 = est.ori["NDE5"] - bias_NDE5
modifiedCIL_NIE_c5 = est.ori["CIL_NIE5"] - bias_NIE5
modifiedCIU_NIE_c5 = est.ori["CIU_NIE5"] - bias_NIE5
modifiedCIL_NDE_c5 = est.ori["CIL_NDE5"] - bias_NDE5
modifiedCIU_NDE_c5 = est.ori["CIU_NDE5"] - bias_NDE5
bias_c5 = c(round(sigma5, 3), round(rho5, 3), round(bias_NIE5,
                                    3), sensitivity_NIE5, round(modified_NIE_c5, 3),
paste0("[",

round(modifiedCIL_NIE_c5, 3), ",", round(modifiedCIU_NIE_c5,
```

```
3), "]"), round(bias_NDE5, 3), sensitivity_NDE5,
        round(modified_NDE_c5, 3), paste0("[", round(modifiedCIL_NDE_c5,
                                    3), ",", round(modifiedCIU_NDE_c5, 3), "]"))
#########################################################################
#
est.ori = c(NIE6 = est.ie,  CIL_NIE6 = CIL_NIE, CIU_NIE6 = CIU_NIE,
        NDE6 = est.de, CIL_NDE6 = CIL_NDE, CIU_NDE6 = CIU_NDE)
#c6= residency
sensitivity_NIE6 = sens(est.ori, "NIE6")
sensitivity_NDE6 = sens(est.ori, "NDE6")
modified_NIE_c6 = est.ori["NIE6"] - bias_NIE6
modified_NDE_c6 = est.ori["NDE6"] - bias_NDE6
modifiedCIL_NIE_c6 = est.ori["CIL_NIE6"] - bias_NIE6
modifiedCIU_NIE_c6 = est.ori["CIU_NIE6"] - bias_NIE6
modifiedCIL_NDE_c6 = est.ori["CIL_NDE6"] - bias_NDE6
modifiedCIU_NDE_c6 = est.ori["CIU_NDE6"] - bias_NDE6
bias_c6 = c(round(sigma6, 3), round(rho6, 3), round(bias_NIE6,
                                    3), sensitivity_NIE6, round(modified_NIE_c6, 3),
paste0("[",

round(modifiedCIL_NIE_c6, 3), ",", round(modifiedCIU_NIE_c6,

3), "]"), round(bias_NDE6, 3), sensitivity_NDE6,
        round(modified_NDE_c6, 3), paste0("[", round(modifiedCIL_NDE_c6,
                                    3), ",", round(modifiedCIU_NDE_c6, 3), "]"))
#########################################################################
#
est.ori = c(NIE34 = est.ie,  CIL_NIE34 = CIL_NIE, CIU_NIE34 = CIU_NIE,
        NDE34 = est.de,  CIL_NDE34 = CIL_NDE, CIU_NDE34 = CIU_NDE)
#c34= education-ohealth
```

```
sensitivity_NIE34 = sens(est.ori, "NIE34")
sensitivity_NDE34 = sens(est.ori, "NDE34")
modified_NIE_c34 = est.ori["NIE34"] - bias_NIE34
modified_NDE_c34 = est.ori["NDE34"] - bias_NDE34
modifiedCIL_NIE_c34 = est.ori["CIL_NIE34"] - bias_NIE34
modifiedCIU_NIE_c34 = est.ori["CIU_NIE34"] - bias_NIE34
modifiedCIL_NDE_c34 = est.ori["CIL_NDE34"] - bias_NDE34
modifiedCIU_NDE_c34 = est.ori["CIU_NDE34"] - bias_NDE34
bias_c34 = c(round(sigma34, 3), round(rho34, 3), round(bias_NIE34,
                                        3), sensitivity_NIE34, round(modified_NIE_c34,
3), paste0("[",

round(modifiedCIL_NIE_c34, 3), ",", round(modifiedCIU_NIE_c34,

3), "]"), round(bias_NDE34, 3), sensitivity_NDE34,
          round(modified_NDE_c34, 3), paste0("[", round(modifiedCIL_NDE_c34,
                                          3), ",", round(modifiedCIU_NDE_c34, 3), "]"))

#########################################################################
####################

Sensitivity_Analysis <- matrix(NA, ncol=10, nrow=7)
Sensitivity_Analysis [1, 1:10] <- bias_c1[c(1,2,3,4,5,6,7,8,9,10)]
Sensitivity_Analysis [2, 1:10] <- bias_c2[c(1,2,3,4,5,6,7,8,9,10)]
Sensitivity_Analysis [3, 1:10] <- bias_c3[c(1,2,3,4,5,6,7,8,9,10)]
Sensitivity_Analysis [4, 1:10] <- bias_c4[c(1,2,3,4,5,6,7,8,9,10)]
Sensitivity_Analysis [5, 1:10] <- bias_c5[c(1,2,3,4,5,6,7,8,9,10)]
Sensitivity_Analysis [6, 1:10] <- bias_c6[c(1,2,3,4,5,6,7,8,9,10)]
Sensitivity_Analysis [7, 1:10] <- bias_c34[c(1,2,3,4,5,6,7,8,9,10)]
Sensitivity_Analysis <- as.data.frame(Sensitivity_Analysis)
```

```
colnames(Sensitivity_Analysis) = c("sigma", "rho", "bias_NIE",
                                   "", "modified_NIE", "modifiedCI_NIE", "bias_NDE",
                                   "", "modified_NDE", "modifiedCI_NDE")
```

```
##########################################################################
####################
```

Appendix V

Editor's comments

You provided a detailed and constructive response letter to the previous reviewer's comments. However, not all of the points made in that letter were included in the revised manuscript. Given that the reviewer made some extremely pertinent points (& was an eminent analytic methodologist and expert in causal inference), I feel you could include more of your responses within the manuscript discussion section in particular. Think carefully about this in your revision; it will act to strengthen your manuscript and add to important debates in this area.

Thank you so much. We have made the necessary changes as per request. Please see our response and the reference to the related lines the paper.

- Abstract: 'This article aimed to investigate how education level affects dental service utilisation patterns in the Australian adult population' should be 'The aim of the study was to investigate .....'

Corrected (Line 30)

- Please include keywords that use Medical Subject Headings (MeSH) as these help with indexing and searching in MEDLINE/PubMed and other databases (https://www.nlm.nih.gov/mesh/meshhome.html)

we have used MeSh terms. (line 51)

Education (MeSH Unique ID: D004493), Oral Health (MeSH Unique ID: D009909), Dentistry (MeSH Unique ID: D003813), Health literacy (MeSH Unique ID: D057220)

- The manuscript needs to be re-written in the 3rd (not 1st person) throughout (i.e. remove all 'we' and 'ours'. For example, 'Also, we tested how these mediation paths' would be 'How these mediation paths may be moderated....'

All sections are revised accordingly.

- Your 'variables of interest' and 'statistical analysis' sections are not reader-friendly at present. Have a think about the best way to present your analysis which will enable the readers of CDOE (who will not all be highly proficient in statistical methods) to take away the key message(s). For example, in the former, it is not necessary to have all of your variables listed one after the other which is too list-like. Think about re-structuring for example, into sub-sections for exposure, mediators, outcomes, confounders, and link to the DAG figure. Similarly, your analysis section needs to be re-structured around the objectives of the study (or study hypotheses/research questions).

All sections are revised accordingly.

- Please re-write your results around objectives (or research questions/hypotheses). Use these to structure the section. We usually advise one paragraph per table. Don't start of your results section referring to a table in the supplementary file. What are the key findings that you want your readers to take away from your work?

All sections are revised accordingly.

- In the discussion, please use full paragraphs that link from one to the next. For example, this is not a full paragraph and does not lead nicely into the next paragraph: 'While in our study, low education level was associated with a less favourable utilisation

of the dental services (Models 1 and 3), it led towards more emergency and treatment visits compared to routine dental check-ups (Model 2)'.

All sections are revised accordingly.

Reviewer(s)' Comments to Author:

Reviewer: 1

Comments to the Author

Overall, authors have responded to reviewers concerns in sufficient details. One of my main suggestions is to clearly specify that the temporal ordering between confounding factors, exposure, mediators and the outcomes is unclear; which is a key undisputed criterion for causal inference. Thus, longitudinal studies with clear temporal ordering are needed to validate the findings of this study.

It is added to the discussion. Line 285

Previous responses

Comments on CDOE-22-032

1- The authors sought to model how education affects dental service utilisation patterns in Australian adults, and how these education effects were mediated by some measured health behaviors. They estimated natural effects on the odds ratio scale.

- Response:

We agree with you. Even though the models are called vastly natural effect models in the literature and that is why we have used similar terminology. However, we are aware these effects are interventional analogous effects since we have multiple mediators. To

mitigate any risk of misunderstanding we used the general terms of direct and indirect effects and added this to the method:

“These assumptions are violated. Therefore, the flexible mediation method with multiple mediators approach11,12 which is an extension of Counterfactual mediation analysis 13 was used to overcome this problem by not decomposing this as individual pathways but using the joint analogues effects. With this approach, the total effect is decomposed into direct and indirect effects.” Lines 154-158

2- I found the hypothetical causal structure somewhat perplexing, because “oral health status” was defined as a mediator. Indeed, it seems plausible that education would affect oral heath status, which would in turn motivate service utilization. But the problem is that the outcome of service utilization also affects later oral health status, leading to reverse causation. This can be handled in a longitudinal setting in which each outcome affects subsequent mediator, but the authors did not model the data in this way, nor is this indicated in the DAG in Figure 1, suggesting a serious causal misspecification. People who do not see a dentist have worse oral health, which means that outcome affects mediator.

- Response:

We agree with you then in the sense that if we had longitudinal data we should have investigated this as the way you suggested but this is a one-off survey and we are not making any causal claims. This is the condensed DAG, if we had the longitudinal data then the extended version includes the longitudinal component. In re ality, what you are saying regarding the longitudinal analysis might be true however we should acknowledge that this is a cross-sectional analysis. Our current DAG is to show how

the data is generated and acknowledge what variables should come after each other. We mentioned this as one of the limitations and encouraged other researchers to investigate these mechanisms in a longitudinal context. On the other hand, it is not well evidenced and the long-term effect of dental visits on oral health is controversial. The possibility of a "healthy user effect" has been postulated (Thomson, 2010). Recent randomised trials found no effect on dental caries of those visiting the dentist more often (Clarkson et al. 2021, Wang et al. 1992). However, this is added as a limitation. Line 154-158

3- There is also a drawback that all mediators are self-reported, and subject to desirability bias (i.e. in a survey of oral health, brushing your teeth is a “better” answer than admitting to not brushing teeth). Moreover, the oral health status variable was a subjective categorization (very poor, poor, good, etc) and therefore it is not obvious that everyone has the same expectations of what constitutes “very good” oral health; this perception could easily be a function of educational level, which implies a misclassification that is dependent on exposure.

- Response:

We would like to draw your attention to the conclusion where we have mentioned that the results were conducted as if there was an absence of measurement error and we acknowledged that there might be measurement bias. So in presence of measurement error, the estimated effect may go in either direction. Thank you for highlighting this however in the medical literature where we can always conduct the clinical examination in large-scale surveys, self-reported measurements are a valid form of data gathering. However, this is added as a limitation. Line 279

4- I am concerned that participants could be as young as 18 years of age, but the educational exposure is dichotomized as university graduate or less than university graduate. Clearly, 18 year olds cannot yet be university graduates, even if they will eventually be university graduates, leading to a group that does not have the opportunity for exposure by virtue of their age.

- Response:

We agree with your points that well-defined exposures are needed and for this, we have re-labelled education as ≤ 12 years of study and > 12 years of study. From a legal sense, it is compulsory to finish high school in South Australia unless approves in some circumstances (full-time work or starting vocational training which is also captured in our study). Indigenous Australians also got the right to education since so back and by the time of this study, they had the chance and access to education. According to these, we assume that there is no violation of consistency assumption occurred.

It provides a clear conceptual cut point that is identifiable and meaningful, and it enables the testing of the idea that a higher level of education confers some degree of advantage in terms of oral health. If education is predictive of better oral health/utilisation then an understanding of the benefits of education could potentially be of policy relevance. For example, if literacy was the main issue, then efforts to ameliorate the disadvantage of lack of literacy could be attempted. Lines 111-113

5- On page 7 is a lengthy discussion to justify the loss of information from dichotomizing variables. It is clear, as the authors argue, that this is more convenient for them. But this convenience comes at the expense of tremendous loss of information, and the authors do not discuss this cost. For example, measurement error in the mediators (and dichotomization is a form of measurement error, by coarsening the value into a broader category) leads to underestimation of the mediated effect and overestimation of the direct effect, a consequence that is not discussed:

VanderWeele TJ, Valeri L, Ogburn EL. The role of measurement error and misclassification in mediation analysis: mediation and measurement error. Epidemiology. 2012 Jul;23(4):561-4.

• Response: we agree with these points you raised. However, for sure are aware that this was not for our convenience. This is not difficult to have multi-category exposure and this is possible to calculate the effect of the change from levels 1->2 and 1->3 of the exposure but yet this is not possible to estimate the change from levels 2->3 of an exposure with 3 levels. Although dichotomisation may lead to information loss but it assists researchers and policymakers have a better insight with a direct interpretation when we have potential outcomes. Also, if we have a continuous-valued variable, then the corresponding counterfactual values are a distribution that is less stable compared to a single value. Also, it would be more challenging in terms of defining randomised trials corresponding to the distribution. Even in a three-armed RCT defining potential outcomes is difficult. Similarly, the decomposition effect could be difficult to interpret. For these reasons we dichotomised most of the variables however the findings should be interpreted with caution as they may be sensitive to the

cut point used in exposure dichotomisation. We agree that is comes with a cost but at the same time, it comes with different kinds of benefits. To acknowledge your comment we have cited the paper you recommend and added this to the limitations:

“These findings may not be completely free of bias, and there could be some biases due to cumulative unmeasured confounders and measurement errors, yet no method has been introduced for handling these. Also, as it is mentioned in the method section, by dichotomising the exposure, there is a chance of information loss. In addition, dichotomisation may lead to measurement error, by coarsening the value into a broader category which could lead to underestimation of the mediated effect and overestimation of the direct effect. However, to keep the analysis simple and to have a clear interpretation we agreed to use dichotomised variables. Therefore, the results must be interpreted with caution as they can be sensitive to the cut point used in exposure dichotomisation.” Lines 277-284

6- On page 9 the outcome frequencies are described, and it is clear that many of the outcomes are common (i.e. >10% frequency). Under these circumstances, OR > RR, and the causal decomposition will fail due to non-collapsibility of the OR:

Vanderweele TJ, Vansteelandt S. Odds ratios for mediation analysis for a dichotomous outcome. Am J Epidemiol. 2010 Dec 15;172(12):1339-48.

- Response:

There are two different concepts that you are bringing together which are using OR and interpreting OR as RR anon-collapsibility of OR. We agree with you that OR should interpret similar to RR and we are not interpreting OR as RR. If we had captured RR and interpreted it as it is in a cross-sectional situation it was true because it was the

prevalence then. However, capturing OR does not create a problem (in decomposition or elsewhere) even if it is non-collapsible. We are not clear about what you are referring to as collapsibility; however, if you are referring to the collapsibility to the mediation then we would like to say that collapsibility has got nothing to do with mediation. Decomposition and the non-collapsibility of OR in Vanderweele and Vansteelandt's method are not relevant to the mediation effect. Let's see what collapsibility is. Let X denote the exposure, Y the outcome and C the confounder, then the coefficient of regression models in the presence of a confounder (e.g., stratification by gender) cannot be added up to create the total effect if we calculate OR. But with RR, we can calculate the total effect by having the decomposed coefficient of different levels of confounder. The mediated effect has a separate formula therefore it is not affected by this. Even at the end of the Vanderweele paper which you cited, it is mentioned that their method was described for a continuous outcome and for a binary mediator although the method could be similar no similar problem exists. On top of these, our approach is a different approach, They have used a product and difference approach we used a counterfactual approach using the marginal structure models

Please see:

Lange T, Rasmussen M, Thygesen LC. Assessing natural direct and indirect effects through multiple pathways. American journal of epidemiology. 2014;179(4):513-518.

Steen J, Loeys T, Moerkerke B, Vansteelandt S. Medflex: an R package for flexible mediation analysis using natural effect models. Journal of Statistical Software. 2017;76(11).

7- At the bottom of page 9, the authors interpret an NIE estimate close to the null as follows: “In other words, lower levels of education, regardless of oral health status, smoking status and brushing, can affect the use of dental services.” If you think about this, it is an impossible interpretation. The authors are claiming that use of dental services is affected only by education, and not in any way by the conditions inside someone’s mouth. By this logic, giving someone a toothache will not send them to the dentist, but giving them a university degree will. This is substantively impossible.

- Response:

First, it is clear that self-reported oral health is different from dental pain and there are lots of asymptomatic poor oral health situations which do not motivate patients to visit a dentist for example patients may keep remained roots for years. Even as you said when the intolerable pain exists, the levels of education don’t matter on whether to visit a dentist or not and these are what we capturaned also. Second, it should not interpret as the indirect effect is separate from the direct effect the correct interpretation is to define the change in indirect effect following a change in direct effect for example we should say by changing the level of education we can see this huge change in dental visits however after this counterfactual change we cannot see a significant change because education through oral health or tooth brushing status (mediators) on service utilisation. This does not imply the same interpretation as yours and just says that the indirect effect of education through oral health status on service utilisation was minimal. Also, education is currently taking a lot of effects and it is not showing effect as an average indirect effect. Even if it is not showing the individual indirect effect, the average is going to zero because there might be some positive and negative effects that

balanced each other towards zero effect. If we could somehow the individual effects then we might be able to see which is the true individual indirect effect is but with interventional analogous effects this is not possible. Even with one mediator, we might be able to test the causal null hypothesis (Yxm=Ȳxm) but having multiple we can not test the individual causal null hypothesis.

8- At the bottom of page 10, the authors write "Moreover, this is one finding and this needs to be substantiated repeatedly and with trials to establish any causal effects." But this is problematic because the authors have elected to report natural direct and indirect effects, and these cannot be estimated from trials:

Naimi AI, Kaufman JS, MacLehose RF. Mediation misgivings: ambiguous clinical and public health interpretations of natural direct and indirect effects. Int J Epidemiol. 2014 Oct;43(5):1656-61.

Briefly, the reason this can't be assigned in a trial is that there is no way in a trial to make someone be exposed but to have the mediator that they would have (counterfactually) if they were unexposed. It is possible in a trial to obtain the controlled direct effects, but not the natural effects.

• Response: Now, we believe with having a better definition of the mediation effects in the presence of multiple mediators as interventional analogous effects some of your comments are answered. In regards to this specific comment, we have removed this in the updated version of the manuscript.

9- It is also rather inexplicable that the authors write: “It is for these reasons, the estimates presented here do not have any causal interpretation, but are decomposed effects.” The mediation analysis is explicitly causal, and so to say that it has no causal interpretation raises the question of what interpretation it does have. This is especially perplexing because throughout the rest of the paper the authors say that it is causal, for example on page 11 in the discussion section: “One of the strengths of this research was the use of robust counterfactual multiple mediation analysis and decomposition of total casual effect into Natural Direct and Indirect Effects.” The authors seem to contradict themselves.

- Response: Thank you, we have removed that paragraph. As we said having multiple mediators these effects are interventional analogous effects and we have corrected this as well, although in the literature they have been vastly used as natural effects.

10- There is also a consistency assumption violation for the effect of university education because there is no mechanism conceivable by which every member of the population can be forced to receive a university education. Indeed, if a university degree were simply bestowed on every individual, it would not affect their oral health utilization. This is a difficult problem for this choice of exposure:

Kaufman JS. Commentary: Causal Inference for Social Exposures. Annu Rev Public Health. 2019 Apr 1;40:7-21.

- Response:

Please see the response to your comment #2.

11- In sum, this is an interesting effort, but has a number of substantive and methodological problems, and it would take some considerable work to remedy these problems. What I would recommend is to consider the mediation by these variables without considering an intervention on education, but simply by asking what proportion of the observed education disparity would be eliminated by controlling the intermediates:

Naimi AI, Schnitzer ME, Moodie EE, Bodnar LM. Mediation Analysis for Health Disparities Research. Am J Epidemiol. 2016 Aug 15;184(4):315-24.

It will also be necessary to conduct the modeling on the RR or RD scales, given the noncollapsibility problems of the OR. Finally, one needs longitudinal data for the effects of health service utilization on subsequent oral health status, or else removing oral health as a mediator, and instead making it one of the outcomes.

- Response:

We have tried to respond to your comments on longitudinal analysis (we have cross-sectional data and we acknowledged the measurement error and also this is not evidenced that oral health affects dental service utilisation), noncollapsibility of OR (these are interventional analogous effects and since we have not interpreted these as RR, it is no problem) and consistency assumption (a better definition of exposure is provided where individuals are not prevented by virtue of their age) there is no methodological problem. also as interventional analogous effects are themselves directly a controlled effect at the individual level there is no need to change the

methodology. We hope these responses were sufficient enough to make the utilised methodology limitations and benefits clear.

Appendix V

Appendix VI – Supplementary Papers and Collaborations

Appendix VI

Collaborated Paper 1: Challenges in the provision and utilization of oral health services among the Australian Indigenous population: a scoping review

Reprint permission received from Springer Nature (order number: 5175631176233, 24th Oct 2021):

Appendix VI

Journal of Public Health: From Theory to Practice
https://doi.org/10.1007/s10389-021-01661-4

ORIGINAL ARTICLE

Challenges in the provision and utilization of oral health services among the Australian Indigenous population: a scoping review

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Received: 2 April 2021 / Accepted: 28 September 2021

Abstract

Background Access to dental services are particularly important among Indigenous populations at a global level. This scoping review aimed to investigate challenges in the provision and utilization of oral health services among Indigenous Australians.

Methods This scoping review was conducted up to June 10, 2020. Five main databases were searched, including PUBMED, SCOPUS, ISI Web of Science, EMBASE and PROQUEST. Thematic analysis was used to analyse the data applying MAX QDA_{10} software. For a better understanding of the themes and subthemes, a thematic network was presented.

Results Results show that there are six main themes and 14 sub-themes affecting Indigenous Australians' utilization and provision of oral health services. Personal characteristics, socio-economic status and challenges regarding access were the main factors influencing utilization of oral health services. The findings suggest that challenges relating to public health, policymaking and service provision can affect Indigenous Australians' provision to oral health services.

Conclusion Benefits in Indigenous Australian access and utilization of oral health services may improve if policy makers at both national and local levels increase resourcing in this important public health sector. A deeper understanding of the social and cultural nuances driving Indigenous Australians' reluctance to attend for dental care is crucial.

Keywords Utilization · Provision · Oral health · Dental health · Indigenous Australian

Introduction

Oral health is an integral component of public health. Optimal oral health leads to an increase in quality of life and general health (Baiju et al. 2017). Limitations in dental public health systems, however, can lead to insufficient oral health (Mohammadpour et al. 2020). Various studies have focused on the effects of these challenges on vulnerable groups and minorities (Dahlan et al. 2019; Petersen et al. 2005).

One of the most vulnerable groups in Australia is the Indigenous community, which comprises approximately 3% of Australia's total population (Fredericks et al. 2020; Tiwari et al. 2018). Indigenous Australians have much poorer oral health, irrespective of indictor used, than their non-Indigenous counterparts (Irving et al. 2017). For example, Indigenous Australians have a higher rate of dental caries, more untreated teeth, more periodontal problems, lower levels of oral health literacy and lower reported quality of life compared to other people in the community (Irving et al. 2017; Parker and Jamieson 2010; Tynan et al. 2020).

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Published online: 16 October 2021

Various challenges have been posed in providing dental services to Indigenous Australians. These include fears of judgement, geographical access, higher costs of preventive and curative services, long waiting times and poor oral health literacy (Durey et al. 2016a; Durey et al. 2016b). There is some evidence that an under-utilization of dental services can worsen and intensify the oral health conditions of Indigenous Australians (Butten et al. 2020).

One of the key goals of the Australian Government is to provide adequate access to dental services and to reduce oral health inequality among Indigenous and non-Indigenous Australians (Donato and Segal 2013). Indigenous Australians (those identifying as Aboriginal and/or Torres Strait Islander) are prioritized in the oral health plans at both a national and state-level(Spencer and Harford 2001). However, access and utilization of dental public health services among Indigenous Australians remains low (Dyson et al. 2014; Irving et al. 2017; Nguyen 2008). This has many consequences, with dental problems leading to emotional, physical and financial impacts (Butten et al. 2020), as well as feelings of shame about personal appearance and self-esteem(Tynan et al. 2020).

Given the lack of empirical evidence on the challenges in the utilization and provision of oral health services for Indigenous Australians, it became apparent that a scoping study was needed. Therefore, this scoping review aimed to investigate the challenges in the provision and utilization of oral health services among Indigenous Australians to enable policymakers to make equitable and fair choices regarding funding for oral health services.

Method

This scoping review was conducted up to June 10, 2020. We implemented content analysis and thematic network answer the question: 'what are the main challenges in provision and utilization of the oral health services among Indigenous Australians. The scoping review instrument developed by Arksey and O'Malley (Arksey and O'Malley 2005) was applied to construct a comprehensive map of evidence on the research question (Munn et al. 2018). The following 6 steps were thus used (Arksey and O'Malley 2005):

- Identifying the research question
- Identifying relevant studies
- Study selection
- Charting the data
- Collating, summarizing and reporting the results
- Consultation exercise (optional)

Identifying the research question

The research question of a scoping review determines the scope of the study and provides the parameters for the initial search. At the same time, a scoping review question should include the population, content and context (PPC) of the study (Arksey and O'Malley 2005).

In this study, the population comprised Indigenous Australians. The content was the challenges and barriers in the provision and utilization of oral health services. The context was the historical, social, cultural and political nuances that have shaped Indigenous Australian health and wellbeing for the past 250 years.

The research question for this study was finalized as: 'what are the main challenges of oral health provision and utilization among Indigenous Australians'?

Identifying the relevant studies

Five scientific databases were searched systematically from January 1, 2000, to June 10, 2020. These included PUBMED, SCOPUS, PROQUEST, EMBASE and Web of Science. The search was conducted by applying the following keywords: oral health, dental health, oral care, oral hygiene and delivery, provision, providing, utilization, use, access and challenges, problems, barriers, obstacles, indigence, native, aboriginal, original Australian, Torres Strait Islander and Australia. The logical operator OR was used between the synonymous keywords, and the logical operator AND was applied to combine them. Table 1 shows details of the search strategy of the scoping review.

Study selection

Using the above search strategy, 187 articles were selected. This was reduced to 151 after exclusion of duplicates. The manuscripts were first scanned by their titles and abstracts by two of the researchers separately (YS and FO). The selected abstracts were saved in libraries applying EndNote X7.1, by Thomson Reuters. A PRISMA flowchart summarizes this process (Fig. 1). The full texts were then studied individually. In the event of a disagreement (about two of the articles), a third researcher (AG) read the paper to achieve consensus. Inclusion criteria included papers with full English text, qualitative or quantitative designs and original research articles or reviews. Three related reviews were included by the research team's consensus in order to improve the included data and enrich the synthesis. It is notable that these three reviews included relevant and rich data related to the present research question but their aims and research questions were not similar to our review. Exclusion criteria included only abstracts in English, letters, commentaries and editorials.

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Table 1 Search strategy of the scoping review

PUBMED	(((((‘Oral health’ [Title/Abstract] OR ‘Dental Health’ [Title/Abstract] OR ‘oral hygiene’ [Title/Abstract] OR ‘oral care’ [Title/Abstract] OR dental[Title/Abstract])) AND (delivery [Title/Abstract] OR provision [Title/Abstract] OR providing [Title/Abstract] OR utilization [Title/Abstract] OR use [Title/Abstract] OR usage [Title/Abstract] OR access [Title/Abstract] OR accessibility[Title/Abstract])) AND (challenges [Title/Abstract] OR problems [Title/Abstract] OR shortcomings [Title/Abstract] OR barriers [Title/Abstract] OR deficits [Title/Abstract] OR obstacles[Title/Abstract])) AND (Indigenous[Title/Abstract] OR Native[Title/Abstract] OR Aboriginal[Title/Abstract] OR original[Title/Abstract])) OR Torres Strait Islander[Title/Abstract])) AND (Australian[Title/Abstract] OR Australia[Title/Abstract])
SCOPUS	(TITLE-ABS-KEY (‘Oral health’ OR ‘Dental Health’ OR ‘oral hygiene’ OR ‘oral care’ OR dental) AND TITLE-ABS-KEY (*delivery* OR *provision* OR *providing* OR *utilization* OR *use* OR *usage* OR *access* OR *accessibility*) AND TITLE-ABS-KEY (*challenges* OR *problems* OR *shortcomings* OR *barriers* OR *deficits* OR *obstacles*) AND TITLE-ABS-KEY (*indigenous* OR *native* OR *aboriginal* OR *original* OR Torres Strait Islander) AND TITLE-ABS-KEY (*Australian* OR *Australia*))
EMBASE	TITLE, ABSTRACT, KEYWORDS: (‘oral health’ OR ‘dental health’ OR ‘oral hygiene’ OR ‘oral care’ OR dental AND (delivery OR provision OR providing OR utilization OR use OR usage OR access OR accessibility) AND (challenges OR problems OR shortcomings OR barriers OR deficits OR obstacles) AND (indigenous OR native OR aboriginal OR original OR Torres Strait Islander) AND (Australian OR Australia)
PROQUEST	TITLE: (‘Oral health’ OR ‘Dental Health’ OR ‘oral hygiene’ OR ‘oral care’ OR dental OR oral) AND (delivery OR provision OR providing OR utilization OR use OR usage OR access OR accessibility) AND ab(challenges OR problems OR shortcomings OR barriers OR deficits OR obstacles) AND ab(Indigenous OR Native OR Aboriginal OR original OR Torres Strait Islander AND ab(Australian OR Australia)
Web of Science	TITLE: (‘Oral health’ OR ‘Dental Health’ OR ‘oral hygiene’ OR ‘oral care’ OR dental) AND ALL FIELDS: (delivery OR provision OR providing OR utilization OR use OR usage OR access OR accessibility) AND ALL FIELDS: (challenges OR problems OR shortcomings OR barriers OR deficits OR obstacles) AND ALL FIELDS: (Indigenous OR Native OR Aboriginal OR original) OR Torres Strait Islander AND ALL FIELDS: (Australian OR Australia)

Charting the data

A data extraction form was applied according to the aim of the study. This form contained the author’s name, study title, study topic, study design, year and place of publication and key determinants of specialty selection. After all the included articles were extracted, a content-analysis approach was applied.

Collating, summarizing and reporting the results

Thematic analysis was used to summarize and categorize the data. Thematic analysis is an inductive approach for content analysis in order to make themes from the data content (Thomas and Harden 2008). Analysis was conducted via six steps as follows: In the first step, familiarization with data occurs through reading of the content several times. Then the initial codes were identified based on the research question and study aim. After reviewing these preliminary codes, the final codes were created. The final codes were merged and categorized to create sub-themes. In the fifth step, the main themes were refined and labelled. Finally, for a better understanding of the themes and subthemes, the results were both tabulated and a thematic network was presented applying MAX QDA_{10} software for qualitative data analysis.

Results

As indicated in Fig. 1, of the 187 initially included articles, 24 were selected for the scoping review. All 24 manuscripts except one was published between 2007 and 2020. Thirteen articles (54.2%) involved quantitative data and six (25%) followed a qualitative approach. One study (4.1%) adopted a mix method approach, with the remaining four manuscripts being review articles (12.5%) or discussion papers (4.1%) (Table 2).

There were six main themes and 14 sub-themes identified that indicated the challenges of oral health provision and utilization in the Indigenous Australian context (Table 3).

The first theme was identified as ‘personal characteristics’, with five sub-themes, including age, sex, physiological status, psychological status and health literacy status (Table 3). These themes demonstrated how oral health utilization can be influenced and shaped by the personal characteristics of Indigenous Australians. Among the personal characteristics,

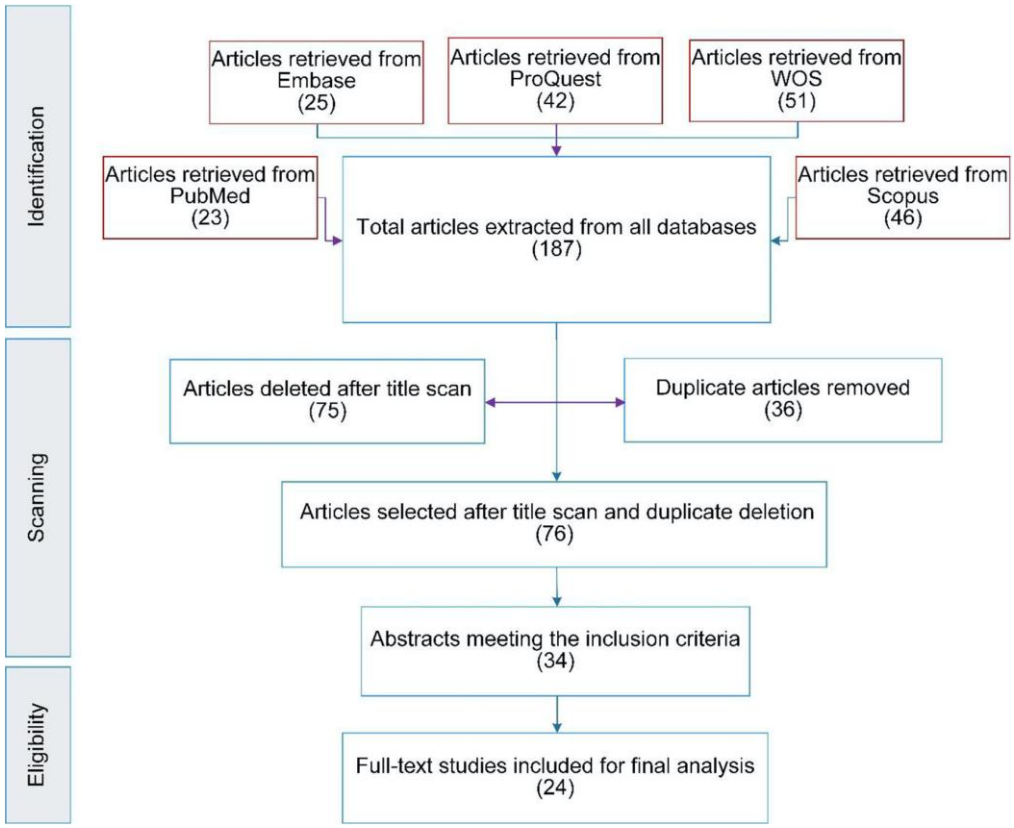

Fig. 1 The PRISMA flowchart of the scoping review

age is considered as a determinant criterion. Children (Jamieson et al. 2006; Patel et al. 2017), teenagers (Butten et al. 2020) and elders (Amarasena et al. 2015) are supposed as the important age groups. Moreover, women (Amarasena et al. 2015; Butten et al. 2020; Jamieson et al. 2014) are more vulnerable to lack of access and utilization to oral health services. Oral health literacy was considered as a risk indicator for poor self-reported oral health outcomes among the indigenous groups (Parker and Jamieson 2010). Low levels of oral health literacy may contribute to lack of attention to oral health and late and emergency dental referrals (Irving et al. 2017); therefore, it will be important for the policy makers to identify more vulnerable groups and help them to become informed.

The second theme identified was socio-economic status. This theme comprised economic status and social and cultural status of the Indigenous Australian population that poses many challenges in the utilization of oral health services. Financial concerns of the families (Butten et al. 2019; Jones et al. 2014), transportation problems (Jones et al. 2016; Tynan et al. 2020) and living in remote areas (Kruger et al. 2008) were among some of the economic challenges of oral health utilization. Cultural barriers included difficulty in communication (Parker et al. 2012), language barriers (Jones et al. 2016) and low self-efficiency(Jamieson et al. 2014).

Public health limitations are among other challenges that restrict provision of optimal oral health services among Indigenous Australians. Public health issues in this regard are divided into public health behaviours and public health facilities. The main concept among the Indigenous population according to our findings include beliefs (Tynan et al. 2020) and perceptions (Amarasena et al. 2014) that affect oral health-related behaviours. These behaviours range from daily tooth brushing and fluoride toothpaste use to consumption of sugary foods and carbonated beverages (Dimitropoulos et al. 2018). Along with public behaviours, public facilities can affect a population's provision to oral health services. Our findings indicated that the communities which have inadequate levels of natural fluoride in the drinking water and high levels of dental caries need greater access to dental public health facilities (Ehsani and Bailie 2007). Water fluoridation units in the more populated remote Indigenous communities (i.e. more than 500 people) (Ehsani and Bailie 2007) is a good example of an equitable and cost-saving dental public health intervention.

Appendix VI

Table 2 Main characteristics of the included studies

Author	Year	Study topic	Study sample	Study design
Amarasena [21]	2015	Studying the relationship among scocil and psychological factors and oral health	289 participants via convenience sampling	Quantitative
Amarasena [22]	2014	Investigating the behaviours and perceptions related to oral health	181 participants (>22 years)	Quantitative
Butten [12]	2020	Exploring the impact of oral health among children	A purposefull sample of women with a child	Qualitative
Butten [23]	2019	Exploring the families' experiences about oral health	20 parents	Qualitative
Campbell [24]	2015	Investigating the activities done by ACCHS	Online survey on 50 providers and interview with a purposeful sample	Mixed-method
Dimitropoulos [25]	2018	Determination of the children's oral health needs and barriers and fasilitators of access to these services	94 children between 5 to 12 yers	Quantitative
Durey [10]	2016	The experience of inequality in oral health related to the context and structure	Related literature	Critical review
Durey [26]	2017	Exploring the barriers and fasilitatos of access to oral services	52 participants including patents and carers	Qualitative
Ehsani [27]	2007	Assessing the feasibility and estimating the costs of water fluoridation	2 small plans of fluoridation	Quantitative
Green [28]	2010	Highlighting the problems and their causes and the improving actions	–	Discussion paper
Irving [7]	2017	Identifying the factors that lead to the oral health attitides and behaviours	Children higher that 14 years old	Quantitative
Jones [29]	2016	Exploring the causes for attending the oral health services or none	49 participants via purposeful sampling	Qualitative
Parker [9]	2010	Examining the relationship among health literacy in the scope of oral health and the related outcomes	468 people in the ages of 17 to 72.	Quantitative
Patel [30]	2017	Examining the interventions' outcomes with the aim of reducing differences and inequalities in oral services	Related literature	Narrative Review
Schluter [31]	2017	Reporting the status of oral health, oral behaviours and satisfaction of the appearance	Adults with the age of upper 20	Quantitative
Slater [32]	2001	Investigating the association between socio-economic status and preventive treatment oral services	521,016 cases referred to oral health centres	Quantitative
Smith [33]	2007	A survey on the people's status of oral health and their oral health behaviours	999 participants during 2 years	Quantitative
Tynan [8]	2020	Exploring the community's viewpoints towards oral health and the ways of improvement in rural areas	Focus groups discussion	Qualitative
Jamieson [34]	2014	Investigating the relationship between self-efficacy and the staus of oral health and the QOL as well	446 women that were pregnant	Quantitative
Jones [35]	2014	The association among oral health access and oral health literacy and social and economical and behavioural status	310 participants	Quantitative
Parker [36]	2012	Presenting a framefork for oral health services according to the children's need	Adult participants	Qualitative
Williams [37]	2011	Synthesizing the barriers to oral health appling a holistic approach	Related literature	Review
Jamieson [38]	2006	Assessing the effect of location on necessary needs in the field of oral health	326,099 children between 4 to 14 years	Quantitative
Kruger [39]	2008	Investigating the status of oral health and the related needs in adults	177 Aborginal workers in health field	Quantitative

Policy making challenges, including resource allocation and the governments' actions and interventions, are considered as the fourth challenges of provision to oral health services (Table 3). Allocating adequate funding to the oral health needs of Indigenous Australians (Ehsani and Bailie 2007; Green and Blinkhorn 2010) was the strongest sub-theme. Including programs that aimed to reduce early childhood caries, increasing services to remote communities, developing the role of Aboriginal health workers, improving oral health literacy, establishing water fluoridation and providing periodontal therapy are some effective interventions that can be compounded by the complex interplay between psychosocial and cultural determinants of both Indigenous Australians and oral health professionals. Public health behaviour and public health facilities were two of the sub-themes in this regard.

Service provision challenges were identified as the fifth theme influencing oral health provision among Indigenous Australians. The emphasis on surgeries as opposed to

Appendix VI

Table 3 Challenges of provision and utilization of oral health services among the Australian Indigenous population

Main themes	Sub-themes	Final codes
Personal characteristics	Age	Older ages
		The teenage years
		Early childhood
	Sex	Being female
	Physiological status	Pregnancy
		Perceived severity and pain
		Dental history
	Psychological status	High levels of psychological distress
		Low self-efficacy
		Fear
	Health literacy status	Parents' limited oral health knowledge
		Low health literacy and wrong perceptions
		Lack of information
		Brushing and utilizing fluoride toothpaste
		Oral health awareness
Socio-economic status	Economic challenges	Financial concerns and shortage of resources
		Transportation problems
		Worrying about the future
		Juggling multiple priorities
		Living in a rural locations
		Remote communities' poor status of oral health /high treatment needs
	Social and cultural challenges	Urban Indigenous families
		Rural dwellers' poorer status towards oral health
		Lack of access to safe environment with no cultural barriers
		Availability and access to appropriate services
		Problem-based visit of the dentist (pain existed, emergency services)
		Language barriers
		Difficulty communicating with clients
Public health challenges	Public health behaviours	Health beliefs
		Limitted access to the personal toothbrush
		Minimum use of toothpaste with fluoride
		Restricted permanent tooth brushing
		Diets full of sugary foods and soft drinks
		Non-optimal oral health behaviours and perceptions
	Public health facilities	Water fluoridation
		Living conditions
		Oral hygiene
Policy making challenges	Recourse generation and allocation	Considerable approval from the public dental services
		Competing demands on limited budgets/adequate funding
	Actions and interventions	Policy and organizational practices
		Lack of effective interventions
		Effective policies, management and funding responsibility
		Integration strategies designed for Aboriginal oral health
Service providing challenges	Preventive services	Prevention of risk indicators
		Integrating health care system with dental services
		Lack of comprehensive primary health care models
		Diagnoses and treatments ended to oral surgery
	Oral health providers	Ignoring prevention, restricting cost of services, increasing sugary products' marketing

Table 3 (continued)

Main themes	Sub-themes	Final codes
		Unfairness and differentiation from health care providers
		Oral health services' providers lack of knowledge
		Access to reliable manufacturers and suppliers of equipment
Access challenges	Financial access	Contacting's difficulty with patients
		Appointments' high rate of failure and cancelation
		Problems in patterns of attendance
		Cost of services (specially in women).
	Non-financial access	Consent issues
		Geographic barriers in accessing oral health services
		Individuals challenges the same as access to dental services

preventive services was noted (Slater 2001), together with lack of integration between preventive primary health care systems and dental services (Schluter et al. 2017; Smith et al. 2007). A lack of an existing comprehensive primary health care model (Campbell et al. 2015) can lead to a decrease in provision of oral health services. It was apparent that many Indigenous Australians were unaware of how to make an emergency dental visit and had limited understanding of the prevention of dental disease (Jones et al. 2014).

Finally, access challenges, including financial and non-financial access, were among other identified challenges that reduce Indigenous Australian utilization of dental services. Difficulties in contacting patients (Parker et al. 2012), geographic barriers in accessing oral health services (Williams et al. 2011) and high rates of failure to attend appointments (Parker et al. 2012) contribute to this. Cost of dental services (Durey et al. 2017; Schluter et al. 2017) was a significant barrier restricting many Indigenous Australians' access to oral health services.

For a better understanding of the challenges impacting the utilization and provision of oral health services among Indigenous Australians, Fig. 2 clarifies the conceptual map of the present scoping review through a thematic network.

Discussion

Our findings indicate that many Indigenous Australians encounter challenges and barriers in the utilization and provision of oral health services. Our findings are corroborated by El-Yousfi et al. (2019), who identified three categories of determinants as the barrier to oral health services among vulnerable groups. These three determinants include individual, organizational and policy level barriers (El-Yousfi et al. 2019) that can be matched to the present results to some extent.

The present results have shown that age (children, teenagers, elderly), sex, physiological status, psychological status and oral health literacy status can decrease oral health utilization among Indigenous Australians. Hernández-Palacios et al. (2015) identified that sex, low income and low educational level have a significant influence on the self-perceived oral health status of elderly Mexicans (Hernández-Palacios et al. 2015). Lee et al. (2014) described how sex, marital status, income level and educational levels influenced oral health utilization among residents of Ohio in the United States (Lee et al. 2014).

Similar to our findings regarding socio-economic status, El-Yousfi et al. (2019) described how 'cultural differences in

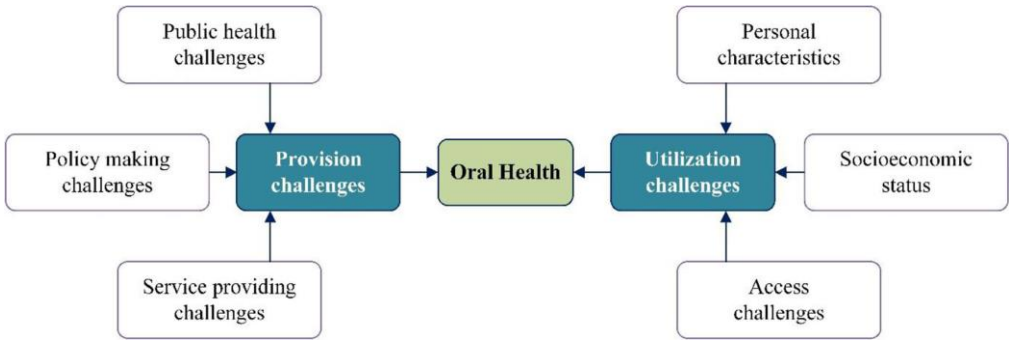

Figure 2 The conceptual framework and the thematic map of the scoping review.

oral healthcare seeking behaviour' was one cultural barrier and the 'limited ability to express need for dental treatment' as the main economic challenge (El-Yousfi et al. 2019). Watt et al. (2019) provided evidence that Indigenous populations at a global level are vulnerable adult population groups in utilizing oral health services. They described how a population's social class, income, education, psychosocial factors and social relationships are considered as the intermediate determinants that affect the utilization of oral health services (Watt et al. 2019). Biordi et al. (2015) also emphasized how barriers to utilize oral health care remain significant in low-income children (Biordi et al. 2015). In the Indigenous Australian context, access to social supportive packages may help overcome the economic barriers of oral health care utilization.

Watt et al. described how resources were an enabler to access oral health services (Watt et al. 2019), with Dahlan et al. (2019) also referring to social support as a determinant of access to oral health care among immigrants and ethnic minorities (Dahlan et al. 2019). A study among the Canadian population emphasized how cost is a huge barrier to accessing oral health care along with the clients' oral health literacy, fear and anxiety (Zangiabadi et al. 2017). Tour findings identify public health challenges as one of the barriers to provision of oral health services among Indigenous Australians. This is supported by Levesque et al. (2013) who emphasized that ability to perceive health care needs containing health beliefs, expectations and literacy can lead to access to health care services (Levesque et al. 2013). Similarly, Göstemeyer et al. (2019) indicated that lack of oral health knowledge, beliefs and behaviours can act as barriers to access oral health care. They described how oral hygiene of patients was a determinant barrier in provision of oral and dental treatment (Göstemeyer et al. 2019). Regular dental visits together with access to water fluoridation and other public health interventions are both beneficial and cost-effective in this regard.

Policy makers have a multi-disciplinary role in improving provision of the oral health services. They can set the agenda to include wider discussion around provision of oral services, advocate stakeholders and allocate more resources to this area. Designing and managing of effective population-level interventions can be considered by national and local policy makers to support the oral health needs of all socially excluded populations, Indigenous Australians among them.

Balasubramanian et al. (2019) have shown that some problems in dental service utilization arise from narrow approaches to dental education and imbalances among the skills, jobs and competencies of oral service providers. Macro challenges of the health care system exist, including imbalanced geographic distribution and an increasing divide between the 'professions' interests and needs of the population (Balasubramanian et al. 2019). These problems can restrict both access and utilization of oral health services.

Limitations

Study limitations include: a quantitative approach for analysing oral health indicators among Indigenous Australians would have provided useful information in conjunction with the scoping review. That would have enabled the present results to be triangulated with the face to face interviews from Indigenous participants to better explore other probable reasons of challenges in the utilization of oral health services. Moreover, similar to any other systematic review, the present scoping review should be considered along with other sources to minimize the probability of bias in data iclusion and data synthesis.

Conclusion

Our findings indicate that the utilization and provision of oral health services for Indigenous Australians can be restricted via personal and socioeconomic factors. Challenges relating to policy making, service providing, public health and access can affect their utilization and provision. Policy makers at a national and local level can plan to decrease these limitations although most need long-term, multidisciplinary interventions.

Author's contributions PB designed the study and finalized the data analysis. YS, AG, MS and FO collected the data and extracted the data. LJ technically edited and finalized the article.

Availability of data and materials All data generated or analysed during this study are included in this published article and the appendix. The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Code availability MAX QDA_{10} software for qualitative data analysis.

Declarations

Ethical statement There were no ethical considerations in collecting, analysing and publishing the data as a scoping review.

Conflict of interest The authors declare that they have no conflict of interest regarding the study.

Ethics approval Not applicable.

Consent to participate Not applicable.

Consent for publication Not applicable.

References

Amarasena N, Kapellas K, Brown A et al (2015) Psychological distress and self-rated oral health among a convenience sample of indigenous Australians. J Public Health Dent 75:126–133. https://doi.org/10.1111/jphd.12080

Amarasena N, Kapellas K, Skilton M et al (2014) Oral health behaviours and perceptions reported by indigenous Australians living in Darwin, Northern Territory. Community Dent Health 31:57–61. https://doi.org/10.1922/CDH_3276Jamieson05

Arksey H, O'Malley L (2005) Scoping studies: towards a methodological framework. Int J Soc Res Methodol 8:19–32. https://doi.org/10.1080/1364557032000119616

Baiju R, Peter E, Varghese N et al (2017) Oral health and quality of life: current concepts. J Clin Diagn Res 11:ZE21–ZE26. https://doi.org/10.7860/JCDR/2017/25866.10110

Balasubramanian M, Brennan DS, Short SD et al (2019) A strife of interests: a qualitative study on the challenges facing oral health workforce policy and planning. Health Policy 123:1068–1075. https://doi.org/10.1016/j.healthpol.2019.07.010

Biordi DL, Heitzer M, Mundy E et al (2015) Improving access and provision of preventive oral health care for very young, poor, and low-income children through a new interdisciplinary partnership. Am J Public Health 105:e23–e29. https://doi.org/10.2105/AJPH.2014.302486

Butten K, Johnson NW, Hall KK et al (2019) Impact of oral health on Australian urban aboriginal and Torres Strait islander families: a qualitative study. Int J Equity Health 18:1–10. https://doi.org/10.1186/s12939-019-0937-y

Butten K, Johnson NW, Hall KK et al (2020) Yarning about oral health: perceptions of urban Australian aboriginal and Torres Strait islander women. BMC Oral Health 20:35. https://doi.org/10.1186/s12903-020-1024-x

Campbell MA, Hunt J, Walker D et al (2015) The oral health care experiences of NSW aboriginal community controlled health services. Aust N Z J Public Health 39:21–25. https://doi.org/10.1111/1753-6405.12294

Dahlan R, Ghazal E, Saltaji H et al (2019) Impact of social support on oral health among immigrants and ethnic minorities: a systematic review. PLoS One 14:e0218678. https://doi.org/10.1371/journal.pone.0218678

Dimitropoulos Y, Gunasekera H, Blinkhorn A et al (2018) A collaboration with local aboriginal communities in rural New South Wales, Australia to determine the oral health needs of their children and develop a community-owned oral health promotion program. Rural Remote Health 18:4453. https://doi.org/10.22605/RRH4453

Donato R, Segal L (2013) Does Australia have the appropriate health reform agenda to close the gap in indigenous health? Aust Health Rev 37:232–238. https://doi.org/10.1071/AH12186

Durey A, Bessarab D, Slack-Smith L (2016a) The mouth as a site of structural inequalities; the experience of aboriginal Australians. Community Dent Health 33:161–163. https://doi.org/10.1922/CDH_3717Durey03

Durey A, McAullay D, Gibson B et al (2016b) Aboriginal health worker perceptions of oral health: a qualitative study in Perth, Western Australia. Int J Equity Health 15:4. https://doi.org/10.1186/s12939-016-0299-7

Durey A, McAullay D, Gibson B et al (2017) Oral health in young Australian aboriginal children: qualitative research on parents' perspectives. JDR Clin Trans Res 2:38–47. https://doi.org/10.1177/2380084416667244

Dyson K, Kruger E, Tennant M (2014) A decade of experience evolving visiting dental services in partnership with rural remote aboriginal communities. Aust Dent J 59:187–192. https://doi.org/10.1111/adj.12162

Ehsani JP, Bailie R (2007) Feasibility and costs of water fluoridation in remote Australian aboriginal communities. BMC Public Health 7:1–8. https://doi.org/10.1186/1471-2458-7-100

El-Yousfi S, Jones K, White S et al (2019) A rapid review of barriers to oral healthcare for vulnerable people. Br Dent J 227:143–151. https://doi.org/10.1038/s41415-019-0529-7

Fredericks B, Lee V, Adams M et al (2020) Aboriginal and Torres Strait islander health. In: Professional nursing and midwifery practice, 3rd edn. Elsevier, Melbourne, pp 264–277

Göstemeyer G, Baker SR, Schwendicke F (2019) Barriers and facilitators for provision of oral health care in dependent older people: a systematic review. Clin Oral Investig 23:979–993. https://doi.org/10.1007/s00784-019-02812-4

Green J, Blinkhorn A (2010) How can inequalities in the Oral health of Australian aboriginal people be addressed? Int J Health Promot Educ 48:107–110. https://doi.org/10.1080/14635240.2010.10708192

Hernández-Palacios RD, Ramírez-Amador V, Jarillo-Soto EC et al (2015) Relationship between gender, income and education and self-perceived oral health among elderly Mexicans. An exploratory study. Cien Saude Colet 20:997–1004. https://doi.org/10.1590/1413-81232015204.00702014

Irving M, Gwynne K, Angell B et al (2017) Client perspectives on an aboriginal community led oral health service in rural Australia. Aust J Rural Health 25:163–168. https://doi.org/10.1111/ajr.12307

Jamieson LM, Armfield JM, Roberts-Thomson KF (2006) The role of location in indigenous and non-indigenous child oral health. J Public Health Dent 66:123–130. https://doi.org/10.1111/j.1752-7325.2006.tb02567.x

Jamieson LM, Parker EJ, Roberts-Thomson KF et al (2014)Self-efficacy and self-rated oral health among pregnant aboriginal Australian women. BMC oral health 14:29. https://doi.org/10.1186/1472-6831-14-29

Jones K, Keeler N, Morris C et al (2016) Factors relating to access to dental care for Indigenous South Australians. J Health Care Poor Underserved 27:148–160. https://doi.org/10.1353/hpu.2016.0042

Jones K, Parker E, Jamieson L (2014) Access, literacy and behavioural correlates of poor self-rated oral health amongst an indigenous south Australian population. Community Dent Health 31:167–171. https://doi.org/10.1922/CDH_3316Jones05

Kruger E, Smith K, Atkinson D et al (2008) The oral health status and treatment needs of indigenous adults in the Kimberley region of Western Australia. Aust J Rural Health 16:283–289. https://doi.org/10.1111/j.1440-1584.2008.00985.x

Lee W, Kim S-J, Albert JM et al (2014) Community factors predicting dental care utilization among older adults. J Am Dent Assoc 145:150–158. https://doi.org/10.14219/jada.2013.22

Levesque J-F, Harris MF, Russell G (2013)Patient-centred access to health care: conceptualising access at the interface of health systems and populations. Int J Equity Health 12:18. https://doi.org/10.1186/1475-9276-12-18

Mohammadpour M, Bastani P, Brennan D et al (2020) Oral health policymaking challenges in Iran: a qualitative approach. BMC Oral Health 20:158. https://doi.org/10.1186/s12903-020-01148-w

Munn Z, Peters MD, Stern C et al (2018) Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. BMC Med Res Methodol 18:143. https://doi.org/10.1186/s12874-018-0611-x

Nguyen H (2008) Patient centred care: cultural safety in indigenous health. Aust Fam Physician 37:990–994 https://search.informit.org/doi/10.3316/informit.351890330015262

Parker E, Misan G, Shearer M et al (2012) Planning, implementing, and evaluating a program to address the oral health needs of aboriginal children in Port Augusta, Australia. Int J Pediatr 2012:496236. https://doi.org/10.1155/2012/496236

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Parker EJ, Jamieson LM (2010) Associations between indigenous Australian oral health literacy and self-reported oral health outcomes. BMC Oral Health 10:3. https://doi.org/10.1186/1472-6831-10-3

Patel J, Durey A, Hearn L et al (2017) Oral health interventions in Australian aboriginal communities: a review of the literature. Aust Dent J 62:283–294. https://doi.org/10.1111/adj.12495

Petersen PE, Bourgeois D, Ogawa H et al (2005) The global burden of oral diseases and risks to oral health. Bull World Health Organ 83: 661–669

Schluter PJ, Askew DA, Spurling GK et al (2017) Aboriginal and Torres Strait islander oral health and its impact among adults: a cross-sectional study. Aust Dent J 62:84–94. https://doi.org/10.1111/adj.12439

Slater PJ (2001) Patterns of access to public oral health care in Queensland by gender, indigenous status and rurality. Aust Dent J 46:122–133. https://doi.org/10.1111/j.1834-7819.2001.tb00567.x

Smith K, Kruger E, Dyson K et al (2007) Oral health in rural and remote Western Australian indigenous communities: a two-year retrospective analysis of 999 people. Int Dent J 57:93–99. https://doi.org/10.1111/j.1875-595x.2007.tb00444.x

Spencer AJ, Harford JE (2001) Oral health of Australians: national planning for oral health improvement. South Australian Department of Human Services, Adelaide

Thomas J, Harden A (2008) Methods for the thematic synthesis of qualitative research in systematic reviews. BMC Med Res Methodol 8: 45. https://doi.org/10.1186/1471-2288-8-45

Tiwari T, Jamieson L, Broughton J et al (2018) Reducing indigenous oral health inequalities: a review from 5 nations. J Dent Res 97:869–877. https://doi.org/10.1177/0022034518763605

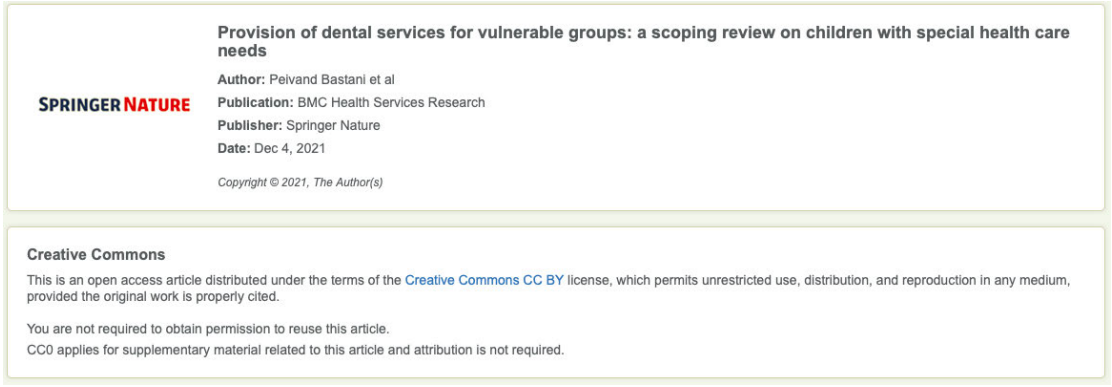
Tynan A, Walker D, Tucker T et al (2020) Factors influencing the perceived importance of oral health within a rural aboriginal and Torres Strait islander community in Australia. BMC Public Health 20:514. https://doi.org/10.1186/s12889-020-08673-x

Watt RG, Venturelli R, Daly B (2019) Understanding and tackling oral health inequalities in vulnerable adult populations: from the margins to the mainstream. Br Dent J 227:49–54. https://doi.org/10.1038/s41415-019-0472-7

Williams S, Jamieson L, MacRae A et al (2011) Review of indigenous oral health. Australian Indigenous HealthBulletin 11:1–18

Zangiabadi S, Costanian C, Tamim H (2017) Dental care use in Ontario: the Canadian community health survey (CCHS). BMC Oral Health 17:165. https://doi.org/10.1186/s12903-017-0453-7

Collaborated Paper 2: Provision of dental services for vulnerable groups: a scoping review on children with special health care needs



Provision of dental services for vulnerable groups: a scoping review on children with special health care needs

Author: Peivand Bastani et al
Publication: BMC Health Services Research
Publisher: Springer Nature
Date: Dec 4, 2021

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Bastani *et al. BMC Health Services Research* (2021) 21:1302
https://doi.org/10.1186/s12913-021-07293-4

BMC Health Services Research

RESEARCH ARTICLE Open Access

Provision of dental services for vulnerable groups: a scoping review on children with special health care needs

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Abstract

Background: The provision of dental services for children with special health care needs (CSHCN) needs to be considered by policymakers. This study is aimed to explore the determinant factors affecting dental and oral services provision for this vulnerable group.

Methods: A review was conducted applying the 9-steps approach. Five scientific databases of PUBMED, SCOPUS, Web of Science and PROQUEST and EMBASE were searched up to 10.07.2021, applying appropriate keywords. Thematic analysis was used to analyse the extracted data, and a conceptual map was developed according to JBI manual for evidence synthesis.

Results: From the abstracts of the 136 articles that fulfilled the inclusion criteria, 56 articles were included. Five main themes were identified as determinants affecting the provision of dentistry services for CSHCN, including needs assessment, policy advice, oral health interventions, providers' perception and access barriers. According to the developed conceptual map, assessing the needs of CSHCN can lead to particular policy advice. Regarding the policies, appropriate oral health interventions can be presented. These interventions, along with providers' perception about service delivery to CSHCN and the barriers to access them, determine the provision of dentistry services for CSHCN.

Conclusions: An effective needs assessment of CSHCN and their parents/carers can lead to evidence-informed policymaking and applicable policy advice according to the needs. Then policymakers should develop interventions to improve the community's health literacy, as well as support the seeking behaviours for appropriate services. Policymakers should also consider how to limit the barriers to accessing oral and dental health by CSHCN to decrease disparities.

Keywords: Dentistry service, Provision, Children with special health care needs, Dental health, Oral health, Disparity

Introduction

People with special health care needs (SHCN) are defined as those having long-term physical, behavioural, emotional and developmental conditions that require attention and health care [1]. Different causes have been identified, such as congenital, developmental, traumatic or environmental associated reasons for these conditions, which lead to a limitation in daily activities [2]. These conditions affect a wide range of the world's population at

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all ages and social classes, but its prevalence varies from region to region. Based on the World Health Organization's report on disability, the estimated population of Children with Special Health Care Needs (CSHCN) among 14-year-old and younger individuals with "moderate or severe disability" and "severe disability" were 93 million and 13 million, respectively as the prevalence of disability for them were 5.1 and 0.7% in 2004 [3]. This prevalence was reported by the U.S. Department of Health and Human Services in 2009–2010. According to this report, 15.1% of American children (about 11.2 million children) had special health care needs [4]. This can directly cause a financial burden for those families with CSHCN because of their healthcare expenditures [5].

People with special needs are considered as high-risk and vulnerable groups, not only because of the problems caused by disability but also because of the limitations that society imposes on them. In some societies, people with special needs are usually kept out of society and have limited access to educational and health facilities [6]. These conditions directly affect general health and, consequently their oral health [7, 8]. In general, CSHCN is at higher risk for health problems. They have less access to oral health services, and their underlying conditions can affect their oral health status [9]. Many of them have sensory and motor disabilities, which makes attending a routine dental appointment difficult [10, 11]. It was reported that 62.5% of the children's parents/carers admitted that their children had difficulty brushing their teeth [12]. Also, the parents/carers of these children often delay dental treatment due to anxiety [13]. On the other hand, dentists are less likely to treat people with special needs for various reasons [14]. Numerous other factors, such as the economic status, parental information levels, drug therapies, and systemic conditions, are related to the oral health status of these children [15–18].

While many potential barriers are reported for the provision of dental services to the general population, these issues become more considerable for CSHCN. For instance, the nonavailability of dentists is reported as a major barrier to access dental care services [19]. Other barriers of providing dental services include lack of appropriate government policies and dental benefit schemes [20]. These barriers can be intensified for people with any kind of disability, particularly children. Some of these barriers are related to physical, structural, geographical, professional, or behavioural determinants that can simply restrict their access to the oral and dental health services [21], and the others are related to the governments and health policymakers to provide more comprehensive and accessible packages for them.

More than what was stated, it is important to notice that according to the reports, the prevalence of caries in CSHCN is higher than in other children [9]. The most common oral diseases in this group are the higher prevalence of dental caries and periodontal disease [22, 23]. Considering all the above, the issue becomes more highlighted, and various ways are applied to reduce the problems of people with special needs to receive dental services such as creating ramps for the disabled, proper restroom, dental chairs suitable for wheelchairs, increasing various courses for parents/carers and dental students, etc. All these interventions greatly depend on the provision of the appropriate services according to CSHCN` needs. In this regard, many universities also offer courses for undergraduate students to increase the willingness of graduate dentists to treat people with special health needs by treating in their clinical hours [24, 25].

Therefore, according to evidence and to the best of our knowledge, it is obvious that CSHCN as a vulnerable group requires to be mentioned from all the aspects of their health as well as dental and oral health and providing dental services along with preventive oral interventions should be considered for them, but the question is that what are the main determinant factors affecting on dental and oral services provision in children with special health care needs.

In order to answer this question and because of the lack of a comprehensive systematic framework for updated studies in this area, this scoping review aimed to review and update the literature and develop the conceptual boundaries of the topic for the provision of dental and oral services in children with special health care needs.

Method

Scoping reviews are generally conducted to indicate the nature and extent of the research evidence [26]. The present scoping review has adopted the 9-step approach proposed by Peters et al. (2015) according to the JBI manual of evidence synthesis [27].

I. ***Defining and arranging the objective and question of the scoping review***

At the first step, the research team defined the objective of the review, which was achieving a conceptual map for dental services provision of CSHCN. With this purpose, the review question was aligned as follows: "what are the main determinants of dental services' provision in CSHCN"?

II. ***Developing and aligning the inclusion criteria with the objective and question***

First, the PCC that stands for participants, concept and context was developed as follows: the population is defined as the dental services provided for

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CSHCN, the concept includes the provision of dental services in CSHCN. Context also includes the social, cultural, political, financial and technological aspects that surround the content. According to this, the inclusion criteria were all the articles having the English full-text in any qualitative or quantitative designs, mix-methods, commentaries, viewpoints and editorials with the aim of dentistry services provision for CSHCN. The conference proceedings, policy papers, reviews, guidelines and instructions were excluded.

III. ***Describing the planned approach to evidence searching and selecting***

In this step, the search strategy was designed applying the related keywords the same as dental health, oral health, dentistry, oral hygiene, special health care needs, disability, special needs, unmet needs, child and children and other synonymous words or phrases. To achieve more sensitivity, the Boolean operator OR was used between all the synonyms, and the operator AND was applied to combine them. The search limitations were the English language and the time limit between 01.01.2000, up to 10.07.2021. Table A-Supplement reports the search strategy syntax.

IV. ***Searching for the evidence***

Five scientific databases of PUBMED, SCOPUS, ISI Web of Science and PROQUEST and EMBASE were searched systematically, applying the search strategy's keywords (Table A-Supplement). Google Scholar was also searched at the last stage for searching according to the titles.

V. ***Selecting the evidence***

The following systematic search was conducted step by step according to the PRISMA [28] flowchart for clarifying the results from the search of the databases, removing the duplications, reviewing the articles via their titles and abstracts and selecting the related articles according to the objective of the review, retrieving the full texts and finally going through the reference lists for a hand-search through Google Scholar. The PRISMA flowchart shows the details in Fig. 1.

VI. ***Extracting the evidence***

A data extraction form was designed according to the study's objective. This form contains some information such as the name of the author, the year of publishing the study, study place, aim of the study, study design, study setting and the main results as the determinants of the provision of dental services in CSHCN.

VII. ***Charting the evidence***

In this step, the data is charted and summarized descriptively and with the logic of achieving the objective of the study. This chart distinctly shows the characteristics of the included studies according to the data of the extraction form (Table B-Supplement).

Summarizing the evidence in accordance with the objective and question.

In order to categorize and summarize the data, the thematic analysis was used via six following steps: First, the extracted data from the full-text of the articles were reviewed several times and compared with the original text, then the coding process was started, and the appropriate labels were assigned to the initial codes, in another word, in an open coding process, the meaningful units of the extracted data which better answer to the review's research question were highlighted and labeled as the initial codes. Then, in the third step, the initial codes were reviewed and integrated to achieve the final codes. The finalized codes became integrated, refined and categorized one more time, to reach the sub-themes according to the study's objective. In the fifth step, the main themes were appeared by categorizing the sub-themes according to their main concepts, these main themes finally were reviewed and labelled, and at the last step, the main themes and sub-themes were tabulated for better illustration and comprehension. MAXQDA software version 10 was used to analyze the data.

VIII. ***Consultation of experts***

This step (consultation of experts) is recommended throughout the scoping review according to the JBI manual for evidence synthesis [27]. As the final aim of the scoping review is to develop the conceptual boundaries of the topic and achieve a final map to show the graphic logical relationships between the main themes and sub-themes. In this step, a thematic network was illustrated applying VISIO plan software, and the final map was consulted with 3 of the experts in the scope of health policymaking and oral health. These three experts have a related academic education as well as scientific reputation in the area of oral and dental health policymaking. For this purpose, after.

finalyzing the "data charting" and tabulating the results of main and sub-themes, a virtual mini-expert panel was conducted with three aforementioned experts and two of the researchers who are experts in the area of oral and dental health policymaking. The main results were presented and discussed via

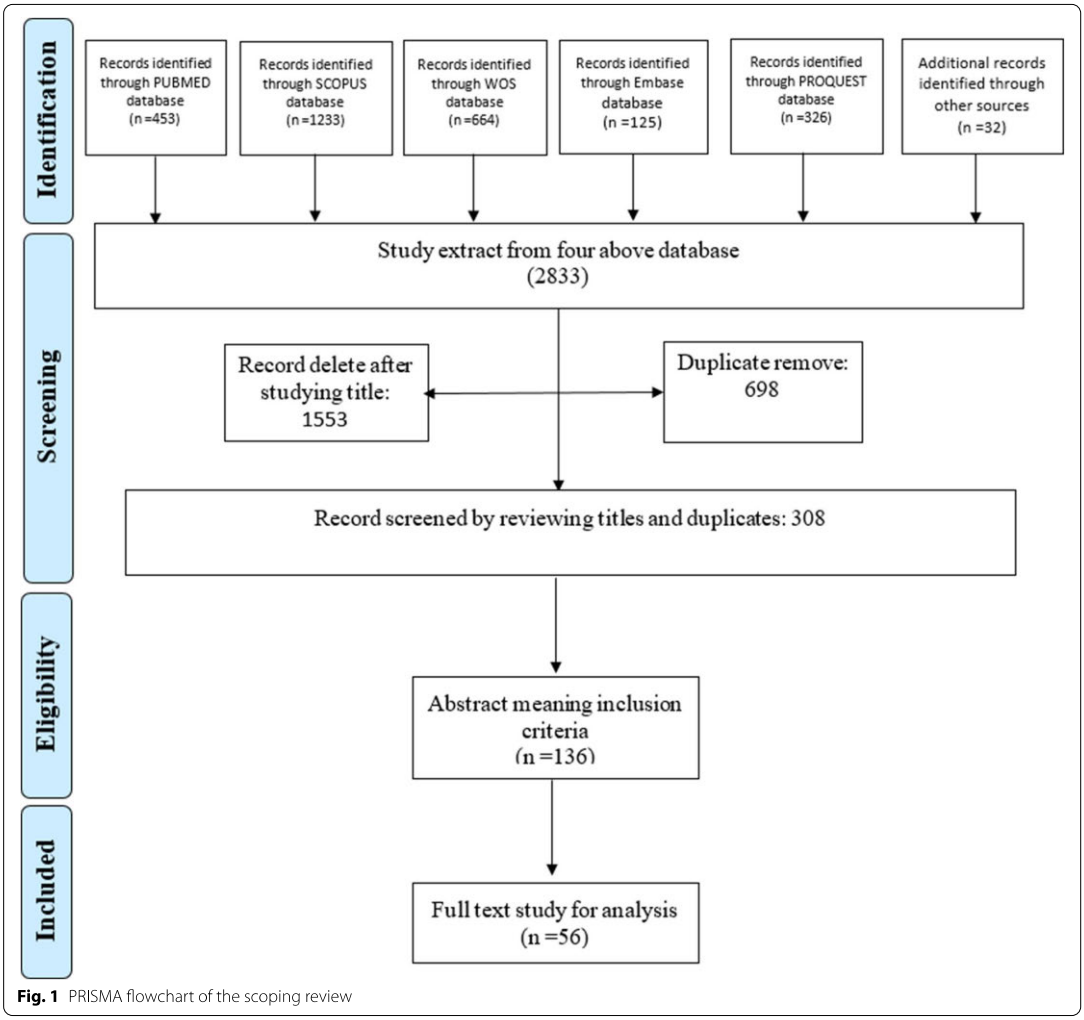

Fig. 1 PRISMA flowchart of the scoping review

the virtual panel, and the viewpoints of the experts were achieved to become sure of the comprehensiveness and robustness of the results and the appropriatness of the suggested map.

Results

Results show that among 136 articles' abstracts that fulfilled the inclusion criteria, 56 full texts were included to be analysed (Fig. 1). Table B-Supplement shows the characteristics of these articles. According to Fig. 2, most of the included articles were conducted in the USA (45%).

Considering the type of study, Fig. 3 shows that most of the included articles have a cross-sectional design (69%), qualitative studies were in the second order (12%).

Finally, other descriptive results demonstrated that most of the articles were published in 2020 that can indicate the highlighted significance of the issue among the researchers (Fig. 4).

The thematic analysis of the data has summarized in Table 1. Five main themes and 47 related sub-themes are created according to Table 1. The main themes include providers` perception, need assessment, access barriers, policy advice and interventions for oral health improvement, determining the main dimensions of the dental

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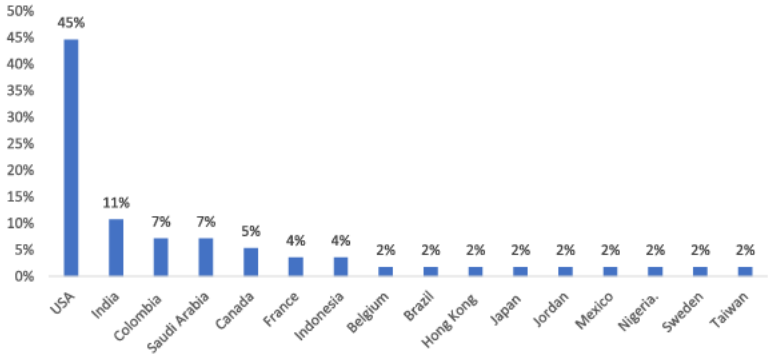

Fig. 2 Distribution of the included articles according to their place

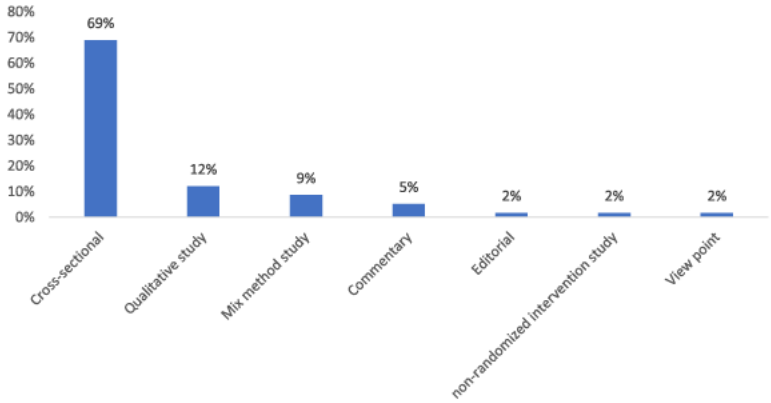

Fig. 3 Distribution of the included articles according to their study type

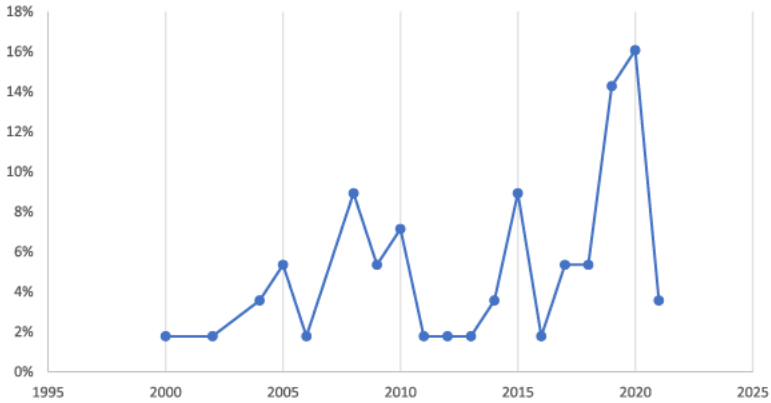

Fig. 4 Distribution of the included articles according to the year of publication

Appendix VI

Table 1 Dimensions to be considered for children with special needs` dentistry service

Main dimensions	Sub-dimensions	References
Need assessment	Caries-risk assessment	[29]
	Improving the health literacy (children, parents and caregivers)	[29–33]
	Quality of care of caregivers and caregivers burden	[34, 35]
	Poor oral hygiene status	[9]
	Utilize preventive dental care	[36, 37]
	Dentist visit/Timely referral to the dentists	[35, 37–39]
	Difficulty in performing proper tooth brushing	[31]
	Level of intellectual disability	[8]
Providers perception	Dentists` feelings and perceptions	[40]
	Paediatricians`/dentists` knowledge and experience	[35, 39, 41, 42]
	Dentists` specialized training like empathy training	[15, 35, 38]
	Preparedness and willingness of dental care providers	[24]
	Communication skills	[42]
	Complexity of the child's medical condition	[43]
	Oral hygiene challenges	[43]
	Inadequately motivation	[35]
	Fear of the dentist and health care providers	[44]
Access barriers	Challenging behaviours	[25, 32, 43, 45]
	Inadequate insurance coverage	[8, 25, 46, 47]
	Low demand from parents	[48]
	Community disagreement regarding fluoride	[48]
	Social-economic status and lower-income	[9, 49–51]
	Dissatisfaction with dental treatments	[44]
	Costs and financial burden	[49]
	Familial and cultural influences on oral care habits	[49]
	Location and equipment of the dental offices	[41]
	Physical barriers inaccessibility to a dental office	[41]
	Limited agency resources	[49]
	Lack of training program for undergraduate and Curricular changes	[44, 52]
	Affordability	[8, 43]
Policy advice	Engaging non-dental providers	[53]
	Restrictive administrative and system-level policies	[53]
	Coordination between community-based organizations, health providers, and advocates	[54, 55]
	Increased experience for general dentists through residency training	[44]
	Improving special care dentistry training	[44, 54]
	Increasing the number of general dentists	[54]
	Dental community in coordination with early intervention providers.	[55]
	Engagement of multidisciplinary professionals in CSHCN's checkups	[56]
	Proposing health-care delivery services that increase coordination and access	[57]
	Development of effective oral health programs	[30, 57]
Oral health improvement interventions	Training to brush the teeth with the help of pictures	[32, 44, 58]
	Basic training of dental professionals in sign language	[44]
	Additional training and education dentist	[40, 44, 59]
	The increasing role of teacher towards dental health care children with special needs	[60, 61]
	Community-based and preventive interventions	[36, 62, 63]
	Improve all caregivers' oral hygiene skills	[63]57
	Incorporate oral health education into nursing curricula	[59]

and oral services` provision that are needed to be considered. More descriptions of each of these dimensions are as follows:

Providers' perception

Providers' perception toward service providing for CSHCN includes nine sub-themes. This theme is really important and easily can influence the quantity and quality of the service provision to CSHCN. The providers` negative feelings and perception [40], along with their inadequate knowledge and experience in communicating with these children [41], can affect the access and tendency of the CSHCN and their families to utilize dental services. Furthermore, other emotional reactions by the providers, the same as fear [44] or lack of motivation [35] can intensify this problem.

In this regard, according to DeLucia et al. [24] and Adyanthaya et al. [41], the dentistry students with more experience of working with children with special needs, had a greater tendency and satisfaction of providing services to CSHCN. Improving the educational curriculums and changing their direction toward experimental learning of these patients were among those recommendations that would affect the dentists' perception [44]. At the same time, more comprehensive knowledge of dentists may cause better perception. So, focusing on training and empowering dentists and their teams with the special skills and knowledge of working with CSHCN can improve their perception and performance [29].

Intervention for oral health improvement

This theme includes seven sub-themes that all present effective interventions in a wide range of those interventions with the aim of empowering the children with special health care needs, their parents and caregivers and those interventions with the target of enabling dentists, nurses, paediatricians and other healthcare providers to provide more effective services or offer more timeliness referral for dental cares.

Different studies have pointed to various interventions in this regard. For instance, integrating oral and dental health education in the nursing curriculum was among one of the interventions for reaching a better oral in children with special health needs [52]. According to the evidence, improving the attitudes of dentists and other care providers lead to an effective understanding of CSHCN's needs and consequently hone the quality of the services [59]. Another suggested intervention was training and enabling the dental service providers in the scope of using sign language, particularly for working among hearing-impaired patients [60]. Other interventions proposed a reimbursement system providing additional payments to those practitioners who work with CSHCN [15, 43]. Such interventions, along with those suggested creating a calm and peaceful environment in dental clinics for decreasing the sense of fear and anxiety [44] of the children with special needs, may lead to improving their oral health status.

Need assessment

Need assessment, as the other theme of provision of dental services in children with special needs, includes eight sub-themes. Summarizing and synthesizing all, this theme shows the different and complex needs of CSHCN in the area of oral and dental services. Although some of their needs are obvious and evidence-based, the same as their poorer status of oral hygiene [9] and their physical or intellectual problems in performing tooth brushing and other routine care [31], the others may be considered as unmet needs and should be regarded by the oral health policymakers as well. Preventive dental services are among the latter one. These kinds of services are more considerable compared the specialized treatments. Thus regarding the preference of preventive dental health services, the need assessment should pay attention to these needs and the other risk factors together with poverty and restrictions related to disabilities in CSHCN [8]. Medical unmet needs can also be considered as an intensive predictor of unmet dentistry needs [49]. So it can be used as an indicator for population need assessment, and the later policies and plans can be implicated based on this. At the same time, oral health promotional behaviours such as routine dental visits and tooth brushing can have a strong relationship with the status of decayed teeth in CSHCN [61].

Policy advice

Policy advice consists of ten sub-themes. This advice and directions are mainly to try to increase the intra-sectoral coordination as well as multidiciplinary team-based activities and improve the community-based service delivery based on the children's needs. In this regard, one of the main effective policies is health care providers' collaboration. This policy can significantly improve the access of children with special needs to dental services [53]. At the same time, policies which aimed at the provision of comprehensive preventive and treatment services for CSHCN can be much more effective than those concentrated only on one separate service [49]. It would be clear that policies directed to reducing the barriers of access to services for CSHCN can be much effective [53].

Access barriers

Access barriers consist of 13 sub-themes in three classifications of geographical and physical access, cultural and behavioural access and finally the financial access.

Among the factors related to financial access, inappropriate insurance coverage is considered as one of the main barriers that can greatly affect the CSHCN's access. In this regard, evidence confirms that insured children with special needs have a better status of oral health along with having fewer problems in dental visits and fewer unmet needs [46, 47]. Another access barrier is the socioeconomic status of families with children with special health needs. This can lead to poor oral health in CSHCN [49, 53]. More than economic barriers, other restrictions in resources, administrative limitations and referral system problems along with high costs of the services also can affect the families' demand for dental services [44, 48]. Among other considerable barriers, we can point to the lack of eager and skilful dentists in some regions for working with CSHCN [51, 54].

Finally, at the last step of the scoping review, a mini expert panel was conducted, including two of the researchers (PB and AG) and three other experts in the fields of health policymaking and oral health. Via this mini panel session, the pre-stated dimensions that affected the dentistry services' provision for children with special needs were presented, and open discussions were conducted about the main themes and sub-themes, and their relations and the final conceptual map of the study was formed. According to this developed conceptual map, oral and dental health need assessment of CSHCN's services is considered as a starting and fundamental point. According to this need assessment containing both the obvious and declared needs and the unmet needs of CSHCN, the policymakers can set new agendas for policymaking, and in this regard, new policy advice can be formulated. According to these policies, appropriate oral health interventions can be presented. These interventions can be targeted at the CSHCN, their parents or caregivers or the dentists, nurses, paediatricians and other healthcare providers. At the same time, the perceptions of the providers, including their motivations, fears, experiences, knowledge and feeling toward providing services to the CSHCN, can greatly affect the quantity and quality of the provision of oral and dental services to CSHCN. More than these determinants, the geographical and physical access to the provided services along with the cultural and behavioural access and, of course, the financial access to the service that is provided for CSHCN can intensively affect the utilization of these services and the children's oral and dental health (Fig. 5).

Discussion

Findings show that the critical oral health need assessment of the children with special needs can be considered as a start point of the conceptual map of providing dental services. This need assessment should distinctly cover a vast range of oral health services, from the unmet needs of the children to their preventive and treatment needs. Oral hygiene improvement is an area of consideration

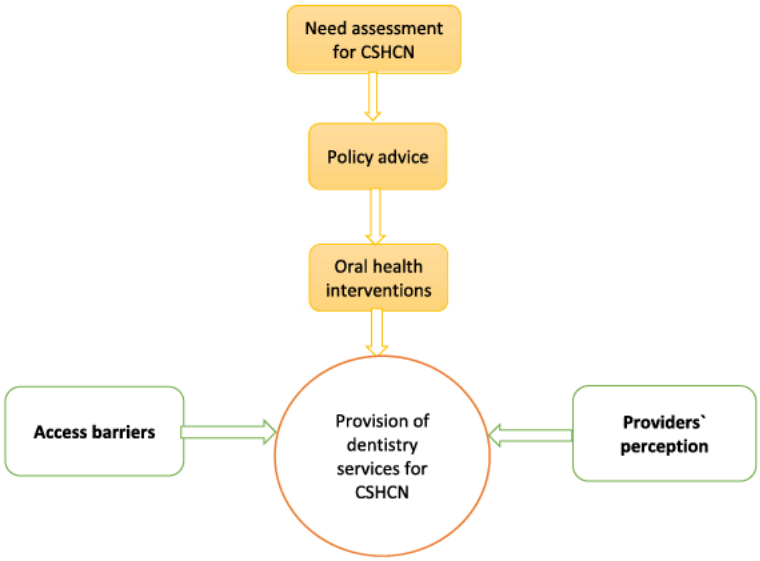

Fig. 5 The conceptual map achieved from the scoping review

in this regard. Alkhabuli et al. (2019) have emphasized that oral hygiene among Emiratis children with special needs was recorded as good, fair, or poor according to the Simplified Oral Hygiene Index [60]. Another important requirement is educating CSHCN's parents about their children oral health needs, which can widely affect the reduction of unmet needs [31]. So, considering different perspectives to achieve a comprehensive need assessment can help policymakers move toward more applicable plans and valuable interventions.

According to the present results, review findings, need assessment is an important input for policy advice. Evidence shows that those countries that suffer apparent and need-based policies in the area of oral and dental health, specialy for the high-risk groups can not achieve the oral health goals for the whole community in general and the high-risk groups in a particular perspective [64]. Ghanbarzadegan et al., (2021) have mentioned policy formulation and policy implementation as two determinants of inequality in the provision of dental services. It means that lack of evidence-informed policies based on a comprehensive need assessment can lead to inappropriate policymaking and inequality [65]. For this purpose, these policies should be integrated the assessed needs to the provision of services via making collaboration with health care providers. In other words, dental services can lead to better oral health in children with special health care needs only if policymakers move toward an integrated health care system focused on preventive oral care. According to Hashmi et al. (2019), receiving preventive oral health among CSHCN was reported low. In particular, children registered in managed care programs that had preventive cares coverage also had a better oral health condition compared to those unregistered [60]. This evidence can clarify the role of policies such as health services integration in CSHCN. Other policies which aim for the access of CSHCN to dental services can be considered as well. These policies vary from increasing the CSHCN's insurance coverage to increasing geographical access to the dental clinics and also improving the cultural access, for instance, improving the children and their parents/carers' health literacy. So, it is critical for the policymakers to formulate and implement applied policies according to their local condition with the aim of increasing the CSHCN's oral health access and utilization.

According to the current map, the policy advice based on the primary need assessment have led to appropriate interventions to improve oral health among CSHCN. In this regard, health care systems can implement appropriate and effective interventions according to their resources, social and cultural context. For instance, Krishnan et al., (2019) suggested some ergonomic and psychological interventions such as allocating separated soundproof rooms, playing relaxing music and decreasing the dental instruments' extra noises in clinics for CSHCN [44]. Other interventions for decreasing the sense of fear or anxiety of CSHCN can be reached according to the health system's facilities and resources. Other interventions can focus on preventive and oral hygiene practices such as tooth brushing training by using educational videos or posters and with the assistance of trained teachers and social media. Considering the mutual relationship among the CHSCN's needs, the evidence-informed policies, and the applied interventions is a critical and significant issue for the policymakers. In this regard, Bastani et al. (2021) have also emphasized that lack of effective and practical interventions, policies and practices can be considered as a challenge for the provision and utilization of oral health services [66].

According to the present results, these interventions based on policies advice and previous need assessment can affect the provision of dental services positively in CSHCN. At the same time, providers' perceptions can widely influence service provision. Adyanthaya et al., (2017) claimed that the most significant barriers as perceived by the practitioners were their level of training and motivation [41]. The importance of perception will intensify knowing that the oral health practitioners' knowledge, attitudes and perceptions can greatly affect their practices and performances. Altman et al. (2018) claimed that negative perception of health care providers associated with lack of adequate capacity and skills could cause difficulties in service utilization in CSHCN [67]. Another aspect of the importance of providers' perception in providing care to CSHCN is the comprehensive interaction of CSHCN, their families and the health care system with the health care providers' capacities and perceptions. So it is recommended to reinforce dental practitioners' practical skills and positive attitudes toward working for CSHCN.

Finally, the present results indicate that although the need assessment, policies advice, oral health interventions, and the providers' perception can highly affect the provision of dental services to CSHCN, barriers to access these services can directly restrict the provision process and outcomes. These barriers in any kind of geographical, social, cultural or financial can restrict the children and their families access and affect the provision of oral health services in its intermediate or final indexes such as the DMFT index. Bahadori et al., (2013) emphasized that the cost of services, inconvenience, fear, organization, and patient-dentist relationship are counted as barriers to access to dental services [68]. At the same time, the World's report on disability (2011) has divided access barriers into health cares in three main dimensions of

financial and affordability, barriers to service delivery and human resources barriers [69]. All these access barriers can widely influence the receiving of routine services like dental visits. It is obvious that any change or reduction in access and utilization of dental services by CSHCN can threaten their oral health status as well hamper the performance of the health care system in service provision.

According to what was discussed, the present framework could be applied in different settings. A comprehensive and multi-perspective approach of need assessment can be applied as a basis for evidence-informed policymaking. For this porpuse, both determined and unmet needs of the CSHCN should be considered. Such policies can be accompanied by practical interventions and practices that cover the aimed group's needs of oral and dental health. It would be obvious that considering different aspects of access to oral and dental health services such as cultural, geographical and financial access can facilitate and develop provision and utilization of the services by all the population as well as the CSHCN. As similarly Ghanbarzadegan et al., (2022) have pointed to the acceptability of oral and dental services by the population and physical and financial aspects as the main determinants of access to dental health [70]. Thus, it can be concluded that for developing such a framework, the policymakers not should pay sufficient attention to the CSHCN's needs and formulate the policies and design the interventions according to their special needs but also, they should thouroghly consider both the providers` perception and the aspects of access to the services by the consumers.

Limitations

Although the scoping reviews give a comprehensive conceptual map on the effective determinants on a specific scope, the result of this study can be enriched by applying face to face interviews with some of the children with special health care needs, their parents/carers, oral health practitioners and the health care providers to achieve a broad view. Another limitation of the study can be related to including only published papers in English.

Strengths

The main strength of the study is presenting not only the main and sub-dimensions of dentistry services` provision for children with special health care needs but also trying to illustrate the relations among these dimensions through a conceptual map. Such a map can shed the light for policymakers for better provision of dentistry services for this vulnerable group. To the best of our knowledge, such a comprehensive scoping review that can shed the light for policymakers to identify the main determinants and design the applied intervention has not been presented before.

Conclusion

The present findings illustrate a conceptual map of the provision of dental services in children with special health care needs. According to this map, an effective need assessment from this community, including the children and their parents/carers may lead to evidence-informed policymaking and applicable policy advice according to the needs. Such a comprehensive need assessment can be useful in setting new agendas of policymaking or opening the windows in formulating or implementing new policies to improve dentistry services` provision for CSHCN. Then, the policymakers and oral health providers should seek suitable interventions to improve the community's health literacy, as well as support behaviours of seeking appropriate services by CSHCN. Such interventions can fade the unmet dentistry needs of these children and finally achieve a better status of their oral health. It is also achieved by the results that the policymakers should pay enough attention to restricting the barriers of access to dental services in children with special health care needs. Developing insurance coverage as well as decreasing financial, geographical and social barriers are among some strategies for improving more access to dentistry services by the CSHCN and reducing inequality and disparities.

Abbreviations

CSHCN: Children with special health care needs; SHCN: Special health care needs.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12913-021-07293-4.

Additional file 1.

Acknowledgements

Not applicable.

Authors' contributions

PB has designed the study and prepared the manuscript draft, AG and MM have collected the data and initial coding. They have both collaborated in data analysis, synthesizing and data interpretations. GR has finalized the analysis and MAP has supervised the study and finalized the manuscript draft. All the authors have read and confirmed the final version of the manuscript.

Funding

There was no funding for this piece of article.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Not applicable.

Appendix VI

Consent for publication
Not applicable.

Competing interests
All the authors declare that there was no conflict of interest.

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Received: 21 November 2020 Accepted: 15 November 2021
Published online: 04 December 2021

References

1. Bethell CD, Read D, Stein RE, Blumberg SJ, Wells N, Newacheck PW. Identifying children with special health care needs: development and evaluation of a short screening instrument. Ambul Pediatr. 2002;2(1):38–48.
2. American Academy of Paediatric Dentistry. Definition of special health care needs. Pediatr Dent. 2016;38(speical issue):16.
3. Krahn GL. WHO world report on disability: a review. Disabil Health J. 2011;4(3):141–2.
4. Smalley LP, Kenney MK, Denboba D, Strickland BJM. Family perceptions of shared decision-making with health care providers: results of the National Survey of Children with Special Health Care Needs, 2009–2010. Matern Child Health J. 2014;18(6):1316–27.
5. Caicedo CJ. Families with special needs children: family health, functioning, and care burden. J Am Psychiatr Nurs Assoc. 2014;20(6):398–407.
6. Sabbagh-Haddad A, Gare R. Mental disability. Dentistry for Patients with Special Needs Sao Paulo. 2007:145–61.
7. van Schrojenstein Lantman-de HM, Walsh PN. Managing health problems in people with intellectual disabilities. Bmj. 2008;337:a2507.
8. Lewis C, Robertson AS, Phelps S. Unmet dental care needs among children with special health care needs: implications for the medical home. Pediatrics. 2005;116(3):e426–e31.
9. Zhou N, Wong HM, McGrath C. Oral health and associated factors among preschool children with special healthcare needs. Oral Dis. 2019;25(4):1221–8.
10. Cermak SA, Duker LIS, Williams ME, Dawson ME, Lane CJ, Polido JC. Sensory adapted dental environments to enhance oral care for children with autism spectrum disorders: a randomized controlled pilot study. J Autism Dev Disord. 2015;45(9):2876–88.
11. Stein LI, Polido JC, Cermak SA. Oral care and sensory over-responsivity in children with autism spectrum disorders. Pediatr Dent. 2013;35(3):230–5.
12. Zhou N, Wong H, McGrath C. A multifactorial analysis of tooth-brushing barriers among mentally challenged children. J Dent Res. 2018;97(n. Spec Iss B, no. 0273).
13. Bell RA, Dean J, McDonald R, Avery D. Management of the developing occlusion. McDonald and Avery's dentistry for the child and adolescent. 9th ed. Maryland Heights: Mosby Elsevier; 2011. p. 550–613.
14. Nelson LP, Getzin A, Graham D, Zhou J, Wagle EM, McQuiston J, et al. Unmet dental needs and barriers to care for children with significant special health care needs. Pediatr Dent. 2011;33(1):29–36.
15. DE AA, Roseman J, MA P, JB T, LS C. Access to dental care in Alabama for children with special needs: Parents' perspectives. J Am Dent Assoc. 2004;135(4):490–5.
16. Christensen GJ. Special oral hygiene and preventive care for special needs. J Am Dent Assoc. 2005;136(8):1141–3.
17. Desai M, Messer LB, Calache H. A study of the dental treatment needs of children with disabilities in Melbourne, Australia. Aust Dent J. 2001;46(1):41–50.
18. da Silva Júnior IF, Stüermer VM, Hartwig AD, Scharsdosim LR, Azevedo MS. Use of dental care services and related factors in students with special health care needs in a rehabilitation and education center. RSBO. 2018;15(1):5–11.
19. Asthana G, Arora SA, Kalsi R, Saurav K, Rana N. Barriers To Seeking Dental Treatments. Natl J Integr Res Med. 2021;12(3):87–91.
20. Masoe AV, Blinkhom A, Taylor J, Blinkhorn FJJDOH. Factors influencing provision of preventive oral health care to adolescents attending public oral health services in New South Wales, Australia. 2014;2(204):1–8.
21. da Rosa SV, Moysés SJ, Theis LC, Soares RC, Moysés ST, Werneck RI, et al. Barriers in access to dental services hindering the treatment of people with disabilities: a systematic Review. 2020;2020.
22. Jain M, Mathur A, Kumar S, Dagli RJ, Duraiswamy P, Kulkarni S. Dentition status and treatment needs among children with impaired hearing attending a special school for the deaf and mute in Udaipur India. J Oral Sci. 2008;50(2):161–5.
23. Scott A, March L, Stokes ML. A survey of oral health in a population of adults with developmental disabilities: comparison with a national oral health survey of the general population. Aust Dent J. 1998;43(4):257–61.
24. DeLucia LM, Davis EL. Dental students' attitudes toward the care of individuals with intellectual disabilities: relationship between instruction and experience. J Dent Educ. 2009;73(4):445–53.
25. Ocanto R, Levi-Minzi MA, Chung J, Sheehan T, Padilla O, Brimlow D. The development and implementation of a training program for pediatric dentistry residents working with patients diagnosed with ASD in a special needs dental clinic. J Dent Educ. 2020;84(4):397–408.
26. Grant MJ, Booth AJ. A typology of reviews: an analysis of 14 review types and associated methodologies. Health Inf Libr J. 2009;26(2):91–108.
27. Peters MD, Godfrey C, McInerney P, Munn Z, Tricco AC, Khalil HJ Jmfes, JBI. Chapter 11: scoping reviews (2020 version). 2020;2020.
28. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. Ann Intern Med. 2018;169(7):467–73.
29. Ningrum V, Wang W-C, Liao H-E, Bakar A, Shih Y-HJ. A special needs dentistry study of institutionalized individuals with intellectual disability in West Sumatra Indonesia. Sci Rep. 2020;10(1):1–8.
30. Salles PS, Tannure PN, Rosa Oliveira CA, de Souza IPR, Portela MB, GFBJ C. Dental needs and management of children with special health care needs according to type of disability. J Dent Child. 2012;79(3):165–9.
31. Hegde AM, Babu AA, Mohammed A, John A, Singh K, Shetty SJ, et al. Special needs of special children-parental view. J Health Allied Sci NU. 2015;5(02):038–44.
32. Hsiao S-Y, Chen P-H, Huang S-S, Yen C-W, Huang S-T, Yin S-Y, et al. Dental treatment needs and related risk factors among school children with special needs in Taiwan. J Pers Med. 2021;11(6):452.
33. Hassona Y, Aljafari A, AA A, Abdalfattah L, Hosey MT. Failure on all fronts: Qualitative analysis of the oral health care experience in individuals with intellectual disability. Spec Care Dent. 2021;41(2):235–43.
34. Chi DL, McManus BM, Carle AC. Caregiver burden and preventive dental care use for US children with special health care needs: a stratified analysis based on functional limitation. Matern Child Health J. 2014;18(4):882–90.
35. Gadiyar A, Gaunkar R, Kamat AK, Tiwari A, Kumar A. Impact of oral health-related behaviors on dental caries among children with special health-care needs in Goa: A cross-sectional study. J Indian Soc Pedod Prev Dent. 2018;36(1):33.
36. Craig MH, Scott JM, Slayton RL, Walker AL, Chi DL. Preventive dental care use for children with special health care needs in Washington's Access to Baby and Child Dentistry program. J Am Dent Assoc. 2019;150(1):42–8.
37. Van Cleave J, Davis MM. Preventive care utilization among children with and without special health care needs: associations with unmet need. Ambul Pediatr. 2008;8(5):305–11.
38. Camoin A, Tardieu C, Dany L, Saliba-Serre B, Faulks D, Coz PL. Inequalities in treatment planning for children with intellectual disabilities: A questionnaire study of dentists in Europe. Spec Care Dent. 2020;40(4):356–63.
39. Goyal A, Nishant RM, Gauba K, Jaiswal M. Awareness among pediatricians regarding oral health care in children including those with special health care needs: A cross-sectional survey. J Fam Med Prim Care. 2020;9(8):4151.
40. Descamps I, Fernandez C, Van Cleynenbreugel D, Van Hoecke Y, Marks L. Dental care in children with Down syndrome: A questionnaire for Belgian dentists, Med Oral Patol Oral Cir Bucal. 2019;24(3):e385.

Appendix VI

41. Adyanthaya A, Sreelakshmi N, Ismail S, Raheema M. Barriers to dental care for children with special needs: General dentists' perception in Kerala, India. J Indian Soc Pedod Prev Dent. 2017;35(3):216.
42. Al-Harbi FS, Al-Daiji DH. The Influence of dentist's knowledge on the quality of oral health care giving to disabled patients in Saudi Arabia (AL-Qassim Province as a Pilot Study). Int J 2018;6(6):148–154.
43. Vertel N, Harrison RL, Campbell KMJJCDA. Access to dental Services for Children with special health care needs: a pilot study at the dental department of BC Children's. Hospital. 2017;83(h6):1488–2159.
44. Krishnan L, Iyer K, Madan Kumar PDJD, CBR, Development I. Barriers in dental care delivery for children with special needs in Chennai, India: a mixed method. Research. 2018;29(4).
45. Lee JN, Scott JM, Chi DL. Oral health behaviours and dental caries in low-income children with special healthcare needs: A prospective observational study. Int J Paediatr Dent. 2020;30(6):749–57.
46. Sarkar M, Earley ER, Asti L, Chisolm DJ. Differences in health care needs, health care utilization, and health care outcomes among children with special health care needs in Ohio: a comparative analysis between Medicaid and private insurance. J Public Health Manage Pract. 2017;23(1):e1–9.
47. Zickafoose JS, Smith KV, Dye C. Children with special health care needs in CHIP: access, use, and child and family outcomes. Acad Pediatr. 2015;15(3):S85–92.
48. Cruz S, Chi DL, Huebner CE. Oral health services within community-based organizations for young children with special health care needs. Spec Care Dent. 2016;36(5):243–53.
49. Kane D, Mosca N, Zotti M, Schwalberg R. Factors associated with access to dental care for children with special health care needs. J Am Dent Assoc. 2008;139(3):326–33.
50. Newacheck PW, Kim SE. A national profile of health care utilization and expenditures for children with special health care needs. Arch Pediatr Adolesc Med. 2005;159(1):10–7.
51. Waldman HB, Perlman SP, Rader R. Hardships of raising children with special health care needs (a commentary). Soc Work Health Care. 2010;49(7):618–29.
52. Krause M, Vainio L, Zwetchkenbaum S, Inglehart MR. Dental education about patients with special needs: a survey of US and Canadian dental schools. J Dent Educ. 2010;74(11):1179–89.
53. Kranz AM, Ross R, Sorbero M, Kofner A, Stein BD, Dick AW. Impact of a Medicaid policy on preventive oral health services for children with intellectual disabilities, developmental disabilities, or both. J Am Dent Assoc. 2020;151(4):255–64. e3.
54. Williams JJ, Spangler CC, Yusaf NK. Barriers to dental care access for patients with special needs in an affluent metropolitan community. Spec Care Dent. 2015;35(4):190–6.
55. Huebner CE, Chi DL, Masterson E, Milgrom P. Preventive dental health care experiences of preschool-age children with special health care needs. Spec Care Dent. 2015;35(2):68–77.
56. Ide-Okochi A, Funayama H, Asada Y. Pediatric dentists' perspectives of children with special health care needs in Japan: developmental disabilities, phobia, maltreatment, and multidisciplinary collaboration. BMC Pediatr. 2021;21(1):1–11.
57. Song PH, White BA, Chisolm DJ, Berney S, Domino ME. The effect of an accountable care organization on dental care for children with disabilities. J Public Health Dent. 2020;80(3):244–9.
58. Shenoy R, Jodalli P, Sonde L, Pasha I. Assessment of Oral health status and comparative evaluation of different methods of Oral health education in Children with Special Health Care Needs. Indian J Public Health Res Dev. 2019;10(9).
59. Parish CL, Singer R, Abel S, Metsch LR. Addressing the oral healthcare needs of special needs children: pediatric nurses' self-perceived effectiveness. Spec Care Dent. 2014;34(2):88–95.
60. Hashmi S, Mohanty VR, Balappanavar AY, Yadav V, Kapoor S, Rijhwani K. Effectiveness of dental health education on oral hygiene among hearing impaired adolescents in India: A randomized control trial. Spec Care Dent. 2019;39(3):274–80.
61. Chairanna I, Kusuma Astuti IG. The increasing role of teacher towards dental health care of special need student in first and second grade. Indian J Forensic Med Toxicol. 2019;13(4):1760–4.
62. AH S, Wyne AH, Asiri FY, Gulzar S, Sheehan SA, Alghmlas AS, et al. Effectiveness of preventive Oral health measures among special care school children (boys) in Al-Kharj, Saudi Arabia. 2020;14(8):36–40.
63. Campanaro M, Huebner CE, Davis BE. Facilitators and barriers to twice daily tooth brushing among children with special health care needs. Spec Care Dent. 2014;34(4):185–92.
64. Mohammadpour M, Bastani P, Brennan D, Ghanbarzadegan A, Bahmaei J. Oral health policymaking challenges in Iran: a qualitative approach. BMC Oral Health. 2020;20:1–12.
65. Ghanbarzadegan A, Bastani P, Luzzi L, Brennan D. Inequalities in utilization and provision of dental services: a scoping review. Syst Rev. 2021;10(1):1–11.
66. Bastani P, Sarikhani Y, Ghanbarzadegan A, Ostovar F, Samadbeik M, Jamieson L. Challenges in the provision and utilization of oral health services among the Australian Indigenous population: a scoping review. J Public Health. 2021 [In Press].
67. Altman L, Zurynski Y, Breen C, Hoffmann T, Woolfenden S. A qualitative study of health care providers' perceptions and experiences of working together to care for children with medical complexity (CMC). BMC Health Serv Res. 2018;18(1):1–11.
68. Bahadori M, Ravangard R, Asghari B. Perceived barriers affecting access to preventive dental services: Application of DEMATEL method. Iran Red Crescent Med J. 2013;15(8):655.
69. Organization WH. World report on disability 2011: World Health Organization 2011.
70. Ghanbarzadegan A, Balasubramanian M, Luzzi L, Brennan D, Bastani P. Inequality in dental services: a scoping review on the role of access toward achieving universal health coverage in oral health. BMC Oral Health. 2021;21(1):1–11.

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