Assessing Nutrition as a Mediator between Oral and General Health

by

Saima Islam

This thesis is submitted in fulfilment of the requirement for the degree of Doctor of Philosophy

Adelaide Dental School, the University of Adelaide

May 2018

Supervised by Professor David S Brennan
Co-supervised by Professor Kaye Roberts-Thomson
Adelaide Dental School, the University of Adelaide

Table of Contents

List of Tables

List of Table from Article 1

List of Table from Article 2

List of Table from Article 3

List of Figures

List of Figure from Article 1

List of Figure from Article 2

List of Figure from Article 3

Abstract

Objective: To evaluate the association of oral health on general health and whether food intake mediates the relationship.

Method: Data were collected in 2004–06 in a representative sample of Australian adults from NSW and Queensland, using a three-stage, stratified clustered sample, involving a computer-assisted telephone interview (CATI), followed by an oral examination, mailed questionnaire and a food frequency questionnaire (FFQ).

Self-rated general health was the outcome, and self-rated oral health, periodontal status, oral health impact (OHIP) and missing-teeth were explanatory variables, and food groups (dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed-vegetables, vegetables and fruits) were mediators. Age, gender, smoking-status, brushing-habits, diabetes, alcohol-consumption and social-support were the control variables.

For mediation analysis Baron and Kenny's mediation analysis was initially performed, followed by Sobel's test. Lastly bootstrapping for standard-error and Structural Equation Modelling (SEM) were conducted to assess the consistency of the mediation model.

Result: A total of n =14,123 adults responded to the CATI (49% response rate), and n =5505 were examined. In the nutrition sub-study, a total of n = 1218 persons were approached, with n =1129 responding (92.7% response rate). Among them, there were 752 respondents who were aged 45 years or more.

From multivariate linear regression analysis, It has been found that adults with better self-rated dental health rated their general health better (β=0.408, $p<0.001$). Worse oral health was associated with worse general health (for OHIP and missing-teeth, β= -0.027 and -0.01, $p<0.001$). Adults with none/mild and moderate periodontal problems compared to severe problems rated their general health better (β_1=0.13, $p<0.001$ and β_2=0.09, $p<0.001$).

Baron and Kenny, and Sobel tests showed the associations between oral health (OHIP and missing-teeth) were partially mediated by food intake (Sobel test: for all mediators, $p<0.001$). The associations between periodontal status and self- rated general health were partially mediated by food intake (Sobel test: for all mediators, $p<0.05$). The association between self-rated dental health and general health was partially mediated by food intake (Sobel test: for all mediators, $p<0.01$).

For all four explanatory variables, periodontitis, number of missing-teeth, OHIP-score and self-rated dental health, Bootstrap results showed zero in the bias-corrected confidence intervals for mediators, indicative of no mediation.

SEM analysis for mediation between periodontal status and general health showed p= 0.76, p=0.045, p=0.050, p=0.015, p=0.73, p=0.42 and p= 0.30 for dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed-vegetables, vegetables and fruits.

SEM analysis for mediation showed p= 0.95, p=0.34, p=0.44, p=0.40; p= 0.04 and p=0.58 for dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed-vegetables, vegetables and fruits respectively for OHIP and p>0.05 for dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed-vegetables, vegetables and fruits for missing-teeth.

SEM analysis for mediation between self-rated dental and general health showed p>0.05 for dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed-vegetables, vegetables and fruits.

Conclusion: SEM indicated the association between periodontitis and self-rated general health was partially mediated by bread-cereal, meat-fish-eggs and sweet-snacks. But the association between self-rated dental health, OHIP-Score or number of missing-teeth and self- rated general health was not mediated by any of these food items.

Number of words: 495/500 words

Notes

References

References in this thesis follow a generic style that provides author-date citation where the author(s) and date of publication is listed in the parentheses. In the text, to differentiate work by the same authors in the same year, a letter after the year is included. In this APA 6th UofA (University of Adelaide) Copy author-date referencing system, where there are three or more authors, the first author is listed followed by "et al." in the text. All authors are listed in the bibliography.

List of Abbreviations

ABS	Australian Bureau of Statistics
BMI	Body Mass Index
CAL	Clinical Attachment Level
CATI	Computer-Assisted Telephone Interview
CDC-AAP	Centre for Disease Control and Prevention and the American Academy of Periodontology
CEJ	Cemento-Enamel Junction
CFI	Comparative Fit Index
DMFT	Decayed, Missing, and Filled teeth
EWP	Electronic White Pages
FFQ	Food Frequency Questionnaire
KS	Kolmogorov-Smirnov
MNA	Mini Nutritional Assessment
NDNS	National Diet and Nutrition Survey
NHANES	National Health and Nutrition Examination Survey
NSAOH	Australian National Survey of Adult Oral Health
NSW	New South Wales
OHIP	Oral Health Impact Profile
PAL	Physical Activity Level

PD	Probing Depth
PPD	Probing Pocket Depth
QoL	Quality of Life
REC	Gingival Recession
RMSEA	Root Mean Square Error of Approximation
SEM	Structural Equation Modelling
SES	Socio Economic Status
SPSS	Statistical Package for the Social Science
SRDH	Self-Rated Dental Health
SRGH	Self-Rated General Health
VAF	Variance Accounted For
WHO	World Health Organization
WIMP	Winnifred's Mediation Program

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.

I give consent to this copy of my thesis when deposited in the University Library, being made available for loan and photocopying, subject to the provisions of the Copyright Act 1968.

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

I also give permission for the digital version of my thesis to be made available on the web, via the University's digital research repository, the Library Search and also through web search engine, unless permission has been granted by the University to restrict access for a period of time.

Signed _____

Saima Islam

Dated:

Acknowledgements

I would like to thanks my supervisors Professor David S Brennan and Professor Kaye Roberts-Thomson for accepting me as a student and guiding me all through this PhD journey.

In particular, my greatest debt of gratitude is to Professor David S Brennan for his insights and encouragement on this project over the years. Professor Brennan, with whom I had the privilege to work, who always had time for me and whose frank and honest comments inspired me to work harder and harder. I have no words to express the generosity and kindness he has shown me during my study.

I acknowledge the support provided by the following scholarship:

1. APHCRI Centre of Research Excellence in Primary Oral Health Care Scholarship for three years.
2. Full Tuition Fee Remission Scholarship for PhD from the University of Adelaide
3. Oliver Rutherford-Turner Award 2017 from Adelaide Dental School

I would like to thank Mrs Valerie Williams from Valerie Williams professional writing services to assist me in preparing the thesis.

I would like to thank my husband Dr. Al Riyadh for his support and considerable patience throughout this project. I also thank to my joy of life, my daughters Nysha and Neemat for scarifying their quality time with their mum and for constant love and support. I wish to thank my parents, sister and brothers for their constant love and encouragement. Lastly, I thank all my friends and colleagues who have contributed directly or indirectly towards this study.

Presentations arising from the thesis

Conference Presentations

1. Islam S*, Brennan DS, Roberts-Thomson K (2017). Assessing Nutrition as a Mediator between Oral and General Health. In International Association for Dental Research. San Francisco, USA. Poster Presentation. March 2017. (See Appendix for Abstract and Poster)
2. Islam S*, Brennan DS, Roberts-Thomson K (2017). Nutritional intake mediates the relationship between periodontal status and self-rated general health in adults. In International Association for Dental Research ANZ division. Adelaide, Australia. Oral presentation. [10+5 minutes]. 26th September, 2017. (See Appendix for Acceptance letter and Abstract)

University Presentations and Internal presentation

1. Islam S*, Brennan DS, Roberts-Thomson K (2017). Nutritional intake mediates the relationship between periodontal status and self-rated general health in adults. Adelaide Dental School Research Day Presentation, 2017.Oral Presentation. [10+5 minutes].The University of Adelaide. Adelaide. July 2017. (See Appendix for Abstract)
2. Islam S*, Brennan DS, Roberts-Thomson K (2016). Assessing nutrition as a mediator of the association between oral health and general health Adelaide Dental School Research Day Presentation, 2016.Oral Presentation. [10+5 minutes].The University of Adelaide. Adelaide. July 2016. (See Appendix for Abstract)

Internal Seminars

1. Islam S*. Nutritional intake mediates the relationship between periodontal status and self-rated general health in adults. Australian Research Centre for Population Oral Health, Adelaide Dental School. Oral Presentation. [45+15 minutes]. July 2017.
2. Islam S*. Impact of Oral Health on Nutrition Intake and General Health of Older People – Preliminary findings. Australian Research Centre for Population Oral Health, Adelaide Dental School. Oral Presentation. [45+15 minutes]. August 2015.
3. Islam S*. Impact of Oral Health on Nutrition Intake and General Health of Older People - A Longitudinal Study. Australian Research Centre for Population Oral Health, Adelaide Dental School. Oral Presentation. [45+15 minutes]. April 2014

*Presenter Author

Chapter 1: Introduction

"Oral health"– the health of the teeth and mouth- is the reflection of a person's health and well-being throughout life. The permanent natural teeth are meant to last for life. However, over a lifetime a person's physiological ageing, diseases, and other causes may result in changes in dental appearance, morphology and function later in life (Müller et al., 2017).

The prevalence of oral health-related diseases within the Australian adult population is - very high. In all 6.5% of adults have complete tooth loss, and 11.4% of adults have fewer than 21 teeth (Slade et al., 2007). After controling for age, in Australia adults fewer than 21 natural teeths scored worst (highest) oral health impacts and quality of life (Steele et al., 2004). In 2017, Jamieson et al., also indicated that fewer than 21 teeth associated with poorer general health. One in four adults have untreated dental decay, a similar proportion of adults have severe periodontal disease and one in five suffer from dental pain (Slade et al., 2007).

Oral health is one of the domains of health that can affect functioning and hence the overall feeling of health (Benyamini et al., 2004) The importance of oral health for each individual varies, but it has a major impact on quality of life and on self-confidence by impacting on both physical and mental health (Einarson et al., 2009). Individuals with good oral health have been found to age with improved quality of life and fewer illnesses compared to people with poor oral health (Ghezzi & Ship, 2000; Loesche et al., 1995).

General health is the functional ability of an individual. Many aspects of general health and quality of life can be impacted upon by oral health. Bad breath and dental deterioration may restrict involvement in social gatherings, limit participation in social activity, and influence judgments made by one person about another person's personality. On the other

hand, healthy natural teeth allow for unrestricted psycho-social well-being (Müller et al., 2017). Therefore, healthy natural dentition and a pleasant dental appearance contribute to a persons' quality of life.

Oral health and general health share common risk factors. As the risk of chronic conditions increases with age, a relationship exists between oral disease and an individual's health and also has a combined impact on adults' overall health (Griffin et al., 2012). Oral health is also closely interrelated with systemic health. Tooth loss share the common risk factor with non-communicable diseases, such as cardiovascular diseases and gastrointestinal disorders (Hung et al., 2005; Osterberg et al., 2010), noninsulin-dependent diabetes mellitus (Cleary & Hutton, 1995; Medina-Solis et al., 2006) and chronic kidney disease (Fisher et al., 2008). Periodontitis is also associated with several systemic diseases and is a risk factor for coronary heart disease, diabetes, and adverse changes in blood pressure and serum cholesterol level (D'Aiuto et al., 2006). No strong evidence has been found of a relationship between root caries and specific chronic disease, but Loesche and Lopatin (1998) stated that root caries is part of the Total Dental Index, which is a good risk predictor of cardiovascular disease.

Therefore, maintaining good oral health can contribute to better general health and, thus, doubtlessly to the quality of life (QoL). On the other hand poor oral hygiene, missing teeth and tooth loss can have a negative influence on people's quality of life. (Sáez-Prado et al., 2016).

Good oral health status is important for chewing ability, taste perception, swallowing, phonetics and comfort when wearing a removable denture (Dormenval et al., 1995). Thus adults with deficits in oral health are likely to avoid or modify foods that are problematic to eat due to difficulties in chewing and swallowing, pain or fear of causing further harm to

fragile dentitions with these factors in turn, possibly affecting a person's nutritional status (Quandt et al., 2010).

Chewing disability is related with the decrease of the number of natural teeth (Bortoluzzi et al., 2012). Lexomboon et al., stated that tooth loss in later life is strongly associated with difficulty chewing hard food. Tooth loss, even of a small number of functional tooth units is often associated with chewing difficulties and has a negative influence on diet quality due to the limited food choices (Samnieng et al., 2011). In Daly et al.'s (2003) study, one quarter of participants reported changing their dietary habits due to a dental problem, more than half reported difficulty in chewing and one third reported having to interrupt meals due to their dental problem. Decreased chewing ability is associated with less likelihood of meeting nutritional recommendations for total vegetables, dark green and orange vegetables, and legumes and being more likely to consume calories from solid fats, alcohol, and added sugar (Margaret et al., 2010). On the other hand, sugar-sweetened beverages are dietary sources of sugar that are factors in caries development and leading to tooth loss (Wiener et al., 2017).

Another study found that patients with chronic periodontitis consumed too few fruits and vegetables (Javid et al., 2014). In the systematic review O'Connor et al., (2019) found a relationship between poor dietary intake and increased risk of periodontal disease. However the possible direction of effect was unavailable due to a lack of studies. But an inverse associations were found between fatty acids, vitamin C, vitamin E, beta-carotene, fibre, calcium, dairy, fruits, and vegetables and risk of periodontal disease.

The prevalence of periodontitis increased with larger body mass groups (Saito et al., 1998). In the systematic review and meta-analysis Chafee et al., (2010) stated that, one consequence of obesity might be an increased risk for periodontal disease, on the other

hand, periodontitis might increase the risk of weight gain. But in clinical practice it founds that, a higher prevalence of periodontal disease should be expected among obese adults. Later on, Kumar et al., (2013) agreed with the statement that obesity is one of the risk indicators for periodontal disease and reported that obesity increases production of reactive oxygen species and an increase in inflammatory cytokines and progression of periodontitis.

To maintain a healthy life at any age, sensible/healthier food consumption is necessary. Some reports (Callen & Wells, 2003; Laugero et al., 2011) have stated that poor dietary habits in older age increase the rate of developing chronic health problems. Laugero et al. (2011) found that a lower intake of protein, fruits, vegetables, fibre and omega-3 fatty acids and a higher intake of carbohydrate and food groups, characterized by salty snacks, sweet foods, and high Glycaemic Index (GI) foods along with physical activity patterns affect the development of chronic health diseases in older age. Fruits, vegetables, whole-grains, low-fat dairy products, poultry, fish and nut consumption have also been recommended for preventing heart disease and stroke for the at-risk population (Nielsen et al., 2016).

From the above discussion, it can therefore be stated that poor oral health can be a major risk factor for poor nutrition and, ultimately, for compromised health in general, with this also supported by Palmer and Stanski (2015). In 2002, Ritchie et al. reviewed and summarised the research studies from 1966-2001 highlighting associations between oral health and nutrition and stated that nutrition has an important potential mediation role in the oral health systemic disease relationship.

1.1. Statement of the Problem/Research Gap

While the impact of oral health on general health is well established, oral health and nutritional status are also associated in various ways, with the relationship between

nutritional status and general health in older age documented in the literature. However a lack of research is evident that has explained the combined association between oral health, nutrition and general health.

Some studies (Adiatman et al., 2013; Brennan & Singh, 2012; Dormenval et al., 1995; Jung & Shin, 2008; Palmer & Stanski, 2015; Ritchie et al., 2002; Saarela et al., 2014; U.S. Department of Health and Human Services, 2000) have focused on oral health, nutrition and general health in one study. However most studies (Adiatman et al., 2013; Brennan & Singh, 2012; Jung & Shin, 2008; Saarela et al., 2014) have not stated any association occurring at the same time between these three variables, while others have discussed mediation effects. Consequently, a gap is apparent in research studies using mediation analysis as a method to discuss these relationship.

Most research associated with oral health, nutrition or general health is age specific for older/very old people, a lack of research on a wider age group, and specifically in Australia, is apparent.

1.2. Aims

The main aim of this study is to evaluate the impact of oral health on general health and to test whether the intake of different food groups mediates this relationship among Australian adults. Other supporting aims to assist this study to reach to the main aim are as follows:

- to evaluate the impact of oral health on different kinds of food consumption;
- to evaluate the impact of consumption of different kind of food on general health;
- to evaluate the impact of oral health on general health.

1.3. Research Contribution

This research articulates the impact of oral health on consumption of different food group and, consequently, on general health in Australia. This study is measuring perceived general health. Although prior to this study, a few studies have been conducted by researchers in Australia and in other developed countries, this study's findings provide new evidence in the context of a different sample, a different country, and a different methodology. The following contributions to practice and the literature are expected.

1.3.1. Contribution to Practice

The relationship between oral health, nutrition and systemic health are complex and multidirectional. This research will help all healthcare professionals to understand the potential relationships between nutrition, oral health and general health and to adopt an interdisciplinary approach to providing optimal care to adults. An understanding of these relationships and the finding of this research, related to appropriately targeted dietary messages for dental patients/adults, might also be helpful to nutritionists in developing dietary guidelines which will assist health professionals to design oral health policy and, consequently, general health policy.

1.3.2. Contribution to Literature

The current study extends and fills the gap in the previous research as it introduces dietary data, uses a large sample size and assesses a range of oral health measures. This research extends the previous research as it measures the impact of oral health on dietary status and general health within the same study and tests the effect of mediation, thus providing a complete assessment of this area of research.

1.4. Thesis structure

This thesis has been structured in a publication format. Papers submitted for publication have been included in different section of Chapter 4, all three are original research articles. To provide a clear description of the research work, additional chapters, namely, 'Introduction', 'Literature Review', 'Methodology' and Discussion and Conclusion are presented. An overall outline of the thesis structure is as follows:

Chapter 1 sets the background of oral health, nutrition and general health and the importance of the association between them.

Chapter 2 focuses the literature review on the definition and measurement of oral health, nutrition and general health in studies on oral health and also on the associations between them.

Chapter 3 describes the methods adopted in the current study to analyse the data, which follows a description of the study design and data collection.

Chapter 4 presents the three research articles in different sections.

Chapter 5 discusses of the research findings and the study's, strengths, limitations and, implications as well as the research conclusions.

Chapter 2: Literature Review

This chapter presents a detailed review of the literature on the definition and measurement of oral health, nutrition and general health in studies of oral health and also on the associations between them. The chapter develops a conceptual model from the existing literature, with this followed by the current study's aim and hypotheses.

2.1. How Oral Health is Defined and Measured

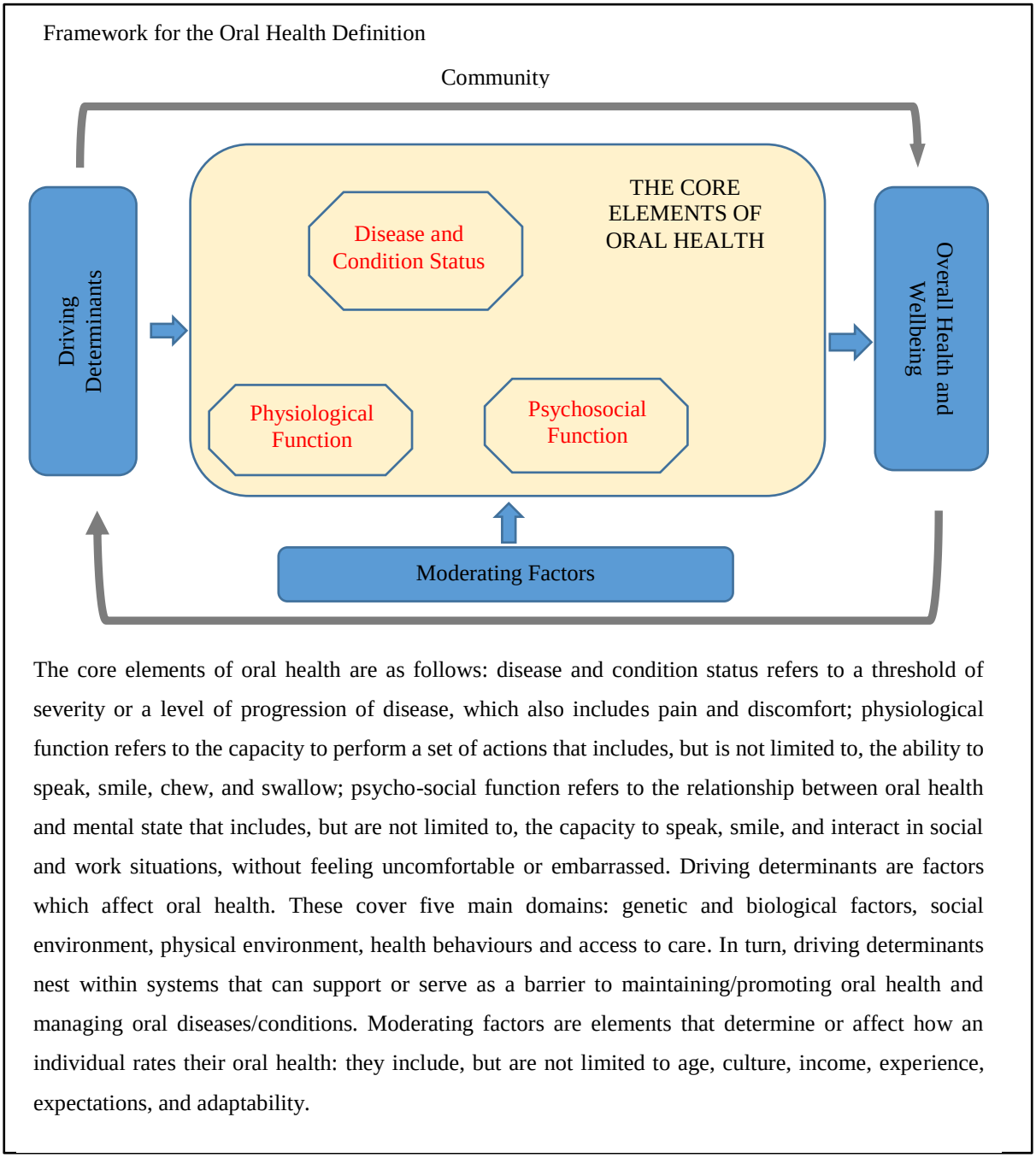
Researchers have defined and measured 'oral health' from different angles - some have used clinical measures, some have used perception-based measures, and some have measured oral health by its function and social role.

According to Glick et al. (2016), the definition of oral health is, "oral health is multi-faceted and includes the ability to speak, smile, taste, touch, chew, swallow and convey a range of emotions through facial expressions with confidence and without pain, discomfort and disease of the craniofacial complex". Further attributes of oral health include:

- It is a fundamental component of health and physical and mental well-being. It exists along a continuum influenced by the values and attitudes of individuals and communities.
- It reflects the physiological, social and psychological attributes that are essential to the individual's quality of life.
- It is influenced by the individual's changing experiences, perceptions and ability to adapt to circumstances.

Figure 2.1 below presents a theoretical framework for the definition of oral health which explains the complex interactions between the three core components of oral health (disease and condition status, physiological function and psycho-social function): a range

of driving determinants (elements which influence and determine oral health): and moderating factors (factors which determine or affect how an individual rates their oral health): as well as, finally, overall health and well-being.



The core elements of oral health are as follows: disease and condition status refers to a threshold of severity or a level of progression of disease, which also includes pain and discomfort; physiological function refers to the capacity to perform a set of actions that includes, but is not limited to, the ability to speak, smile, chew, and swallow; psycho-social function refers to the relationship between oral health and mental state that includes, but are not limited to, the capacity to speak, smile, and interact in social and work situations, without feeling uncomfortable or embarrassed. Driving determinants are factors which affect oral health. These cover five main domains: genetic and biological factors, social environment, physical environment, health behaviours and access to care. In turn, driving determinants nest within systems that can support or serve as a barrier to maintaining/promoting oral health and managing oral diseases/conditions. Moderating factors are elements that determine or affect how an individual rates their oral health: they include, but are not limited to age, culture, income, experience, expectations, and adaptability.

Figure 2.1: Framework for oral health definition
Source: (Glick et al., 2016)

In the literature, oral health is assessed by clinical measures such as dental plaque, calculus, gingival or periodontal infection, infection under the denture, xerostomia and/or hypo salivation as typically measured by clinical oral examination (Kaija et al., 2013; Renato et al., 2008; Ulinski et al., 2013).

As a measure of oral health, self-perception of oral health is a powerful tool which includes both 'global self-rated oral health' and 'satisfaction with dentures'. If we examine the literature, some research has focused on the number of teeth and, global self-rated oral health (Jung & Shin, 2008; Renato et al., 2008; Ulinski et al., 2013) while other research has had a focus on satisfaction with dentures (Margaret et al., 2010; Roberto & Borges-Yanez, 2012).

Dental visits and self-care are a measure of oral health as health behaviours which include tooth-brushing frequency, frequency of dental visits, the reason for the most recent dental visit and the type of dental practice. A few research studies (Ulinski et al., 2013) include dental care aspects such as regular visits to dental service, last dental appointment and the reason for seeking that appointment to assess the state of oral health problems related to access to care. Other researchers were concerned with the use of dental services, that is, the frequency of visits (Avlund et al., 2001; Roberto & Borges-Yanez, 2012) and the time since the individual was last seen by a dental professional (Saarela et al., 2014), but tooth brushing was absent in that study.

To develop comprehensive measures of oral health, oral health impact (e.g., chewing problems, avoiding laughing/smiling, interrupted meals, difficulty in relaxing, needing a dental visit) and health behaviour, such as tooth brushing, also need to be considered. In the oral health impact measures, some researchers (Avlund et al., 2001; Brennan & Singh, 2012; Jung & Shin, 2008; Makhija et al., 2007; Roberto & Borges-Yanez, 2012; Saarela et

al., 2014) have focused on chewing problems or pain in the mouth while chewing, while others have included the perceived need for dental care (Jung & Shin, 2008) and interrupted meals or cooking food differently due to problems with the individuals' teeth, mouth or dentures (Makhija et al., 2007). However the other facets of oral health impact such as avoiding laughing/smiling and difficulty in relaxing or sleeping are mostly ignored in the extant literature except when included as items in a scale score.

2.2. How Nutrition Status is Defined and Measured

Assessment of nutritional status includes measuring food and nutrition intake (dietary assessment), body composition and, body level of nutrients, and investigating the functional markers of nutritional status (Bates et al., 2005). Food and nutrition intake includes the intake of individual foods, food groups and actual nutrients. When measuring dietary intake, it is important to select an appropriate and robust methodology suitable for meeting the aims of the study, with this largely missing in the extant literature (Moynihan et al., 2009). It is also important to include objective measures to validate the dietary information collected, for example, calculation of the Physical Activity Level (PAL). Measurement of body composition includes anthropometric measures which include weight, height and other indices of body composition. Body Mass Index (BMI) score can be calculated by using body weight and height. Biochemical assessment of the levels of antioxidant vitamins A, C and , E, carotenoids, B vitamins, vitamin D, dietary minerals and protein status, measure the concentrations of nutrients in the body. Functional biomarkers may be used as an index of disease risk or disease progression and provide a measure of intermediate disease status (Moynihan et al., 2009).

Table 2.1 below explains the different dietary methods that assess nutritional status, their application and limitations to their use in oral health studies.

Table 2.1: Summary of dietary assessment methods and their application to the study of oral health

Dietary method	Brief description	Applications	Limitations	Example of application to study of oral health
24 hour recall	Subject recalls all food consumed in previous 24 hours in an interview.	Suitable for obtaining average intake of populations.	Relies on memory. Takes no account of daily variation in food intake. Unsuitable for obtaining reliable data on the individual dietary intake.	Unsuitable.
Repeat 24 hour recall	24 hour recall repeated on several occasions.	Suitable for obtaining average intakes and range of intake of populations. Reliability increases with increased number of recalls.	Relies on memory. Unsuitable for assessing individual nutrient intakes unless repeated several times.	NHANES survey used 2 ×24 hour recall which is suited to investigating averages and range of populations, but not suited to investigating individuals' intakes or for ranking individuals within a population.
Food frequency questionnaire (FFQ)	Self-administered questionnaire in which subject indicates the frequency of consumption of a set list of foods from a range of frequency options.	Suitable for classifying subjects into bands of intake and for relative ranking of individuals within the study population. Easy to apply to large surveys.	Relies on memory. Unsuitable for assessing absolute intakes of nutrients or for comparing levels of intake to dietary recommendations.	Joshipura et al. (1996) used data collected by the FFQ from almost 50,000 subjects and compared the intakes of foods and nutrients according to dental status. Absolute nutrient values were reported, but this was justified by cross-validating data against a 2-week food record in a sub-sample of the population.
Dietary history	Detailed one to one dietary interview with a skilled dietician on present or past dietary intake.	Suited to measuring normal habitual intake of individuals and for comparing intake with dietary recommendations	Relies on memory. Takes at least one hour and requires skilled dietician.	Nelson (1991) used this method to assess the usual past dietary intake in a group of non-elderly people who were edentulous (without teeth).
Precise weighing method	All ingredients, foods served, and leftover food are weighed and an aliquot is chemically analysed	Provides accurate information on nutrient intake and overcomes systematic error of using food tables	Requires much subject cooperation. Only suited to small studies as chemical analysis of food is costly in terms of time and resources.	This level of accuracy in nutrient intake is not usually required in studies of diet and dental status

Dietary method	Brief description	Applications	Limitations	Example of application to study of oral health
	for nutrient composition.			
Weighed food diary	The subject weighs and records all food consumed over a period of time e.g. one week.	Provides an accurate assessment of food and nutrient intake and may be applied to a collection of all types of dietary data, e.g. assessment of individuals' intake.	Subject may change usual food intake due to the requirement to weigh food. Eating out is problematic requires literacy. Requires high level of subject cooperation that may introduce selection bias.	The UK NDNS of persons aged 65 years and over used a 4 day weighed food intake diary to assess diet (Steele et al., 1998).
Estimated food diary	Subject records all foods and drinks consumed over a set number of days in a purpose designed diary using household measures to estimate portion size.	Suitable for assessing individuals' intake of nutrients and looking for changes in diet over time. Requires less subject cooperation compared to the weighed intake.	Researcher assigns portion weight, and so this method takes more researcher time. Accuracy is decreased due to the estimation of portion size. Requires literacy of subject.	Bradbury et al. (2006) used this method to measure the dietary intake of full denture wearers before and following contemporaneous dietary and dental intervention

Note: NHANES=National Health and Nutrition Examination Survey (US); NDNS=National Diet and Nutrition Survey (UK).
* Source: Moynihan et al. (2009).

Many studies have used the Mini Nutritional Assessment (MNA) tool to measure nutritional status (Adiatman et al., 2013; Farre et al., 2013; Gil-Montoya et al., 2013; Iwasaki et al., 2014; Renato et al., 2008; Saarela et al., 2014). The MNA tool has 18 brief questions grouped into four blocks. The first block refers to anthropometric measurements; the second is an overall assessment of the patient; the third contains nutritional assessment questions, such as a number of meals, fluid intake and ability to feed oneself: and the fourth is a subjective assessment of nutritional status and self-evaluation. Depending on the score (maximum 30 points), nutrition status is defined by three categories: satisfactory nutritional status (> 24 points); the risk of malnutrition (23.5-17 points); and malnutrition (<17 points) (Guigoz et al., 1994). When measuring diet, it is preferable to have an objective measure of a biomarker, for example, antioxidant vitamin concentrations for an index of fruit and vegetable intake. It is also important to observe over a minimum of three days or more for micronutrients which the MNA does not do.

In another study (Margaret et al., 2010), the block food frequency questionnaire, along with the BMI was used to assess dietary intake. This assessed the usual intake of 110 foods measured in g (cup)/1000 kcals and converted to the Healthy Eating Index (HEI)-2005 component score. The block food frequency questionnaire is a 24-hour recall method, thus, it does not take account of daily variation in food intake.

Jung and Shin (2008) measured nutritional status using the 'Determine Your Nutritional Health' tool developed by the Nutrition Screening Initiative (Kennedy-Malone et al., 2004). The tool consists of 10 items and has a possible total score of 21. A higher score indicates a poorer nutritional status with nutritional risk. In this method, nutritional status is measured using a self-rated scale.

2.3. How General Health is Defined and Measured

General health has been defined as a multidimensional construct by the World Health Organization (WHO) as "a state of complete physical, psychological, and social well-being and not merely the absence of disease or infirmity" (WHO, 2011). That is, health is a combination of individuals' ability to function and perceive well-being in physical, mental, and social domains. This follows the same concept and principles of the Whitehead definition in 1992 and, in recent years, also of Gil-Montoya et al. (2013).

In the study of oral health, general health should be defined by analysing the major dimensions of health, That is, physical symptoms and functional capacity, social functioning and perception of well-being (Emami et al., 2013). Laugero et al. (2011) defined general health by medical health history, cognitive functioning, self-rated health status, smoking and alcohol history, anthropometric measures, blood pressure, and physical performance. The BMI score was calculated, with physical activity determined by using a modified Paffenbarger questionnaire from the Harvard Alumni Activity Survey. Blood, saliva, and urine were collected, serum insulin was measured, and urinary cortisol was determined. Some studies (Avlund et al., 2001; Brennan & Singh, 2012; Roberto & Borges-Yanez, 2012) have assessed general health by people's functional ability or frailty or by their quality of life which measures their mobility, activity, self-care etc. In 2007, Makhija et al. defined and assessed general health through the BMI score, physical activity level, independent life-space score, mental health and comorbidity score on a specific list of chronic conditions.

Self-rated general health is a very important tool used to define and measure general health, with this being a global self-rating summary measure of people's general health that has been used extensively in research to measure people's general health status (Benyamini

et al., 2004; Brennan & Singh, 2011; Krause & Jay, 1995). It has also been found to predict future health outcomes (Benyamini et al., 2004). In 2015, Inkrot et al., considered self-rated general health as a reflection of clinically meaningful measures and concluded that patients with stable chronic heart failure, poor self-rated general health can predict mortality in long term follow-up. Self-rated general health can determine the physical function, the presence of disease, the existence of disabilities and functional limitations, so it has also been a predictive variable for hospitalization, development of falls, and functional impairment in the physical daily basic activity for elderly people (Ocampo, JM, 2010).

Some more recent studies (Farre et al., 2013; Saarela et al., 2014) have measured general health using medical conditions and independency status along with quality of life.

2.4. Relationship between Oral Health and Nutritional Status

Oral health and nutritional status are associated in various ways. Some studies have observed that the number of food items eaten by adult people is significantly associated with the number of teeth they have, leading to a limited choice of foods and, consequently, a reduction in the intake of fruits, vegetables, and fibre, thus increasing the risk of malnutrition (low BMI and MNA score) (Marcenes et al., 2003; Mojon et al., 1999; N'Gom & Woda, 2002; Samnieng et al., 2011). Again, tooth loss, poorly fitting dentures, and loss of taste and smell can eventually alter the food intake and put individuals at risk of malnutrition (lower intake of nutrient) (Tsakos et al., 2010). Good oral health influences nutritional status, physical health, and social functioning in older adults (Jung & Shin, 2008).

Renato et al. (2008) found that those who expressed dissatisfaction with their own gingival health and worse oral status had a higher risk of malnutrition. Having even a few natural

teeth was protective against the risk of malnutrition. Renato et al. (2008) used the Mini Nutritional Assessment (MNA) tool to measure nutritional status. Margaret et al. (2010) stated that those with 0-10 teeth were less likely to meet nutritional recommendations compared to those with 11+ teeth for total vegetables, dark green and orange vegetables and legumes and calories from solid fat, alcohol, and added sugar.

In a recent study, Saarela et al. (2014) found that those elders who were edentulous and had no dentures were at particular risk of malnutrition (Lower MNA score). Other studies have said that patients with chronic periodontitis consumed too few fruits and vegetables (Javid et al., 2014).

In a systematic review accompanied by meta-analysis Toniazzo and colleagues (2017) showed that “remaining teeth”, “edentulous individuals”, “functional teeth units”, “Decayed, Missing and Filled Teeth (DMFT) Index”, “dental plaque” “periodontal disease” and “self-reported oral status” were used in a review of the literature on oral health outcomes regarding the relationship between nutritional status and oral health. The systematic review demonstrated that individuals with malnutrition/ at risk of malnutrition had lower numbers of teeth and used a dental prosthesis.

In Renato et al.’s (2008) study, sociodemographic and behavioural information including age, family income, schooling, ethnicity, gender, marital status, geographical localization and smoking status along with medical history were used as control variables. Demographic measures of age, sex, ethnicity, income, household size and education were included in the Margaret et al. (2010) study. Saarela et al. (2014) included demographic measures (age, gender, education) and medical history as control variables.

2.5. Relationship between Nutrition Status and General Health

The relationship between the nutritional status and general health of adults has been documented in the literature. Some studies (Callen & Wells, 2003; Laugero et al., 2011) have reported that poor dietary habits in older age increase the rate of developing chronic health problems. Other studies (Farre et al., 2013; Rissanen et al., 1996) have also shown that people with higher comorbidity are at risk of being undernourished.

Laugero et al. (2011) found that a lower intake of protein, fruits, vegetables, fibre and omega-3 fatty acids and a higher intake of carbohydrate and food groups, characterized by salty snacks, sweet foods, and high Glycaemic Index (GI) foods along with physical activity patterns affect the development of chronic health diseases in older age. Gender, age, education, income to poverty ratio and type 2 diabetes were used as confounders in this study.

A diet with less fat, saturated fat, and cholesterol and with more carbohydrate, fibre, vitamins (especially folate, vitamins C and E, and β-carotenes), and minerals (iron and zinc) may be advisable not only to improve people's general health but also to improve cognitive function (Rosa et al., 1997). Gender, age, educational background, profession, income and characteristics of the individual's homes were taken into account as control variables.

According to the joint WHO/FAO Expert Consultation on diet, nutrition and the prevention of chronic diseases (Nishida et al., 2004), to reduce risk for cardiovascular health a diet should provide very low (<1% of daily energy intake) intake of trans fatty acids, adequate intake (6-10% of daily energy intake) of Polyunsaturated fatty acids and lowering intake for sodium chloride (less than 5g/d). The joint consultation report of WHO/FAO (2003) states that adequate intake of non-starch polysaccharides fibre such as

whole-grain cereals and legumes (> 20 g/d) and fruits and vegetables (≥400g/d) have potential health benefits in preventing obesity, diabetes, cardiovascular disease and various cancers. The restriction of free sugar intake (< 10% of total energy) also contribute to reducing the risk of unhealthy weight gain (Nishida et al., 2004).

Insufficient nutrition is frequent in elderly individuals, also aging is associated with both a loss of muscle mass and strength and an increase in body fat (Kinney, 2004). Van Asselt et al., (2013) stated that frailty, sarcopenia and undernutrition are the three geriatric conditions with common health related risk factors like cardiovascular disease, stroke, and type 2 diabetes. Specifically, sarcopenia is present in frail or undernourished elderly. An inadequate nutritional status i.e., insufficient protein, energy or micronutrient intake are associated with an increased risk of frailty, while a dietary pattern rich in fruit and vegetable sources of antioxidants would be an effective way to battle against the emergence of frailty (Feart, C 2019) and optimal nutrition may contribute to the prevention of frailty by decreasing the incidence of CHD, stroke, and type 2 diabetes (Bischoff et al 2006).

The systematic review and meta-analysis (Hosseini et al 2018) suggested that a diet high in fruit and vegetables may lead to reduction in inflammation, (where inflammation is one of the major cause of a range of chronic diseases) and enhanced immune cell profile.

In 2013, Farre et al. stated that the risk of being undernourished is higher in women and in those with dementia, with higher comorbidity, with a higher number of prescription medicines, having a lower score for instrumental activity, and taking prescription drugs for cardiovascular disease. The confounders used in that study were gender, education, being a caregiver, eyesight and hearing status, chronic diseases, number of drugs, and quality of life.

2.6. Relationship between Oral Health and General Health

The impact of oral health conditions on general health has been established in many studies (Mack et al., 2005; Makhija et al., 2007; Roberto & Borges-Yanez, 2012; Saarela et al., 2014; Ulinski et al., 2013). When establishing the relationship between oral health and general health, the remaining number of teeth or the extent of tooth loss were mostly used to assess oral health (Brennan & Singh, 2012; Kaija et al., 2013; Saarela et al., 2014; Ulinski et al., 2013).

According to the literature, tooth loss (e.g., oral health status) can affect general health in several ways with these indicated as follows:

- lower intake of fruits and vegetables, fibre, and carotene and increased intake of cholesterol and saturated fats, in addition to a higher prevalence of obesity, can increase the risk of cardiovascular diseases and gastrointestinal disorders (Hung et al., 2005; Osterberg et al., 2010);
- increased rates of chronic inflammatory changes of the gastric mucosa and in the upper gastrointestinal tract and of pancreatic cancer, and higher rates of peptic or duodenal ulcers (Abnet et al., 2005; Sierpinska et al., 2007);
- increased risk of noninsulin-dependent diabetes mellitus (Cleary & Hutton, 1995; Medina-Solis et al., 2006);
- increased risk of electrocardiographic (ECG) abnormalities, hypertension, heart failure, ischaemic heart disease, stroke, and aortic valve sclerosis (Abnet et al., 2005; Okoro et al., 2005; Volzke et al., 2005). A study also demonstrated a possible association between complete edentulism and an increased risk of coronary heart disease (Pablo et al., 2008). Furthermore, another large prospective

study concluded that an individual's number of teeth was a dose-dependent predictor of cardiovascular mortality (Holmlund et al., 2010);

- decreased daily function, physical activity, and physical domains of health-related quality of life (Mack et al., 2005; Mollaoglu & Alpar, 2005);
- increased risk of chronic kidney disease (Fisher et al., 2008);

In the late 1980's Mattila et al. (1989) reported the association between dental health and acute myocardial infarction and related the significance of periodontal disease to general health. Since then, evidence of the relationship between periodontal disease and several systemic diseases has been growing periodontitis is now associated with an increased risk of coronary heart disease, diabetes, and adverse changes in blood pressure and in serum cholesterol level (D'Aiuto et al., 2006)

In 2001, Avlund et al. found that people with fewer teeth and greater chewing difficulty and those who used dental services less regularly had poor functional ability that is they feel tired or need help with mobility. A similar pattern was also found in Roberto and Borges-Yanez (2012) study with low utilization of dental services and poor self-perception of oral health considered as possible risk markers for frailty syndrome, that is, unintentional weight loss, poor endurance and energy, low physical activity, slowness and weakness. Following the previous researcher, Saarela et al. (2014) found that totally edentulous people with no dentures often require assistance in personal care more than others.

In the relationship between oral health and general health, the following factors were the main ones adjusted for analysis in the literature: age, gender (Avlund et al., 2001; Brennan & Singh, 2012; D'Aiuto et al., 2006; Mack et al., 2005; Makhija et al., 2007; Osterberg et al., 2010; Roberto & Borges-Yanez, 2012; Saarela et al., 2014; Ulinski et al., 2013), birth

place (Brennan & Singh, 2012; Osterberg et al., 2010; Saarela et al., 2014), comorbidity (Makhija et al., 2007; Roberto & Borges-Yanez, 2012; Saarela et al., 2014), education (Mack et al., 2005; Makhija et al., 2007; Osterberg et al., 2010; Roberto & Borges-Yanez, 2012; Ulinski et al., 2013), economic status (Mack et al., 2005; Makhija et al., 2007; Ulinski et al., 2013), ethnicity (D'Aiuto et al., 2006; Makhija et al., 2007; Ulinski et al., 2013), companionship (Avlund et al., 2001; Ulinski et al., 2013), physical activity level (Makhija et al., 2007; Osterberg et al., 2010), smoking status (D'Aiuto et al., 2006; Osterberg et al., 2010; Roberto & Borges-Yanez, 2012) and social status (Avlund et al., 2001; Brennan & Singh, 2012; Osterberg et al., 2010).

2.7. Relationship between Oral Health, Nutrition and General Health

The interaction between oral health, nutrition and general health is complex and multidirectional. Oral health is an important determinant of overall health and can be impacted upon by dietary and/or nutritional factors (Palmer & Stanski, 2015). According to the US Department of Health and Human Services (2000) oral problems can result in reduced appetite and changes in the ability to chew, taste and swallow. This in turn influences food and beverage choice, and the frequency of eating occasions. Reduced oral functioning or tooth loss, is linked to a qualitatively poorer diet, probably as many nutritious whole foods, such as meats, fruits beans, vegetables and grains, may also be difficult to chew. Thus, poor oral health can be a major risk factor for poor nutrition and ultimately, for compromised health in general (Palmer & Stanski, 2015).

In 1995 Dormenval et al. stated that good oral health is important for chewing ability, taste perception, swallowing, phonetic ability and comfort when wearing removable denture thus, a poor oral health status might have a negative effect on general health. In 1998 Papas et al. later reported that, as the number of teeth declined, the levels of vitamin A, fibre and

calcium also declined, those who wore dentures consumed more refined carbohydrates and sugar and, in both cases, the level of cholesterol increased which has significant consequences for general health. They also stated that the edentulous population may be at risk of having a diet low in fibre, with this, associated with a high prevalence of many chronic diseases and conditions such as diverticular disease, bowel cancer, appendicitis and constipation.

In 2002, Ritchie et al. reviewed and summarised the research studies from 1966- 2001, highlighting associations between oral health and nutrition and stating the important potential mediation role of nutrition in the oral health-systemic disease relationship. More specifically they stated that oral pain can occur as a result of caries, periodontal disease, soft-tissue lesions, and temporomandibular joint disease. Both dental caries and periodontal disease can lead to tooth loss, and tooth loss may contribute to the intake of calorie-dense, nutrient-poor diets, decreased intake of anti-oxidants and increased intake of foods that foster obesity.

Other studies (Adiatman et al., 2013; Brennan & Singh, 2012; Jung & Shin, 2008; Saarela et al., 2014) focused on oral health, nutrition and general health the in one analysis. Saarela et al. (2014) concluded that edentulous people and those with no denture were at particular risk of malnutrition, and that dentition status was associated with mortality. However they did not state any association between these three factors at the same time. Jung and Shin (2008) concluded in the same way as Saarela et al. (2014) that oral health influences nutritional status, physical health and social functioning in older adults. In Brennan and Singh's (2012) study, they revealed that lower compliance with dietary guidelines was associated with poorer general health, orofacial pain, sore gums and lower social status. Adiatman et al. (2013) concluded that a significant relationship was found only between the number of functional tooth units and nutritional status.

2.8. Conceptual Model

From the literature, the concept of the relationship between oral health and general health is found to have become an integral part of health research, with these two areas of health substantially connected. Oral health and nutritional status are also associated in various ways, the relationship between nutritional status and general health is documented in the literature and a connection is found between oral health, nutrition and general health. Therefore, this has raised the vital question of how nutrition affects the relationship between oral health and general health. This also assume that nutrition may be postulated as a mediator of the relationship between oral health and general health.

Based on the literature review, the conceptual model in Figure 2.2 can be formulated for testing.

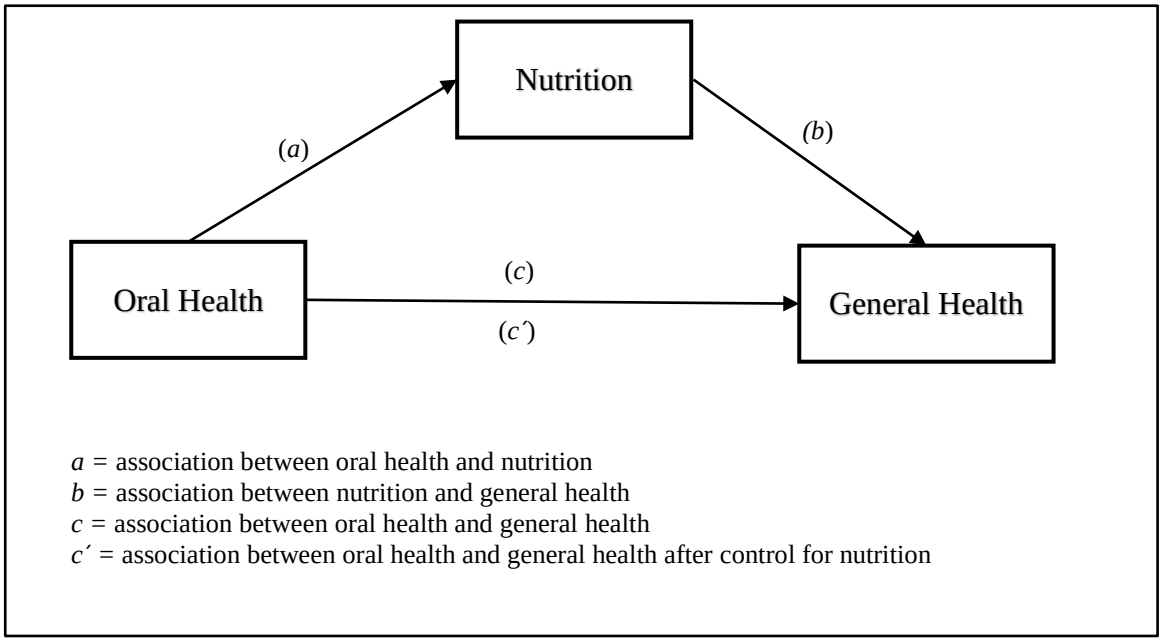


Figure 2. 2: Conceptual model for hypotheses development

To test this conceptual model in the current study mediation analysis, was introduced. This explores the role of intervening variables (mediators) in an observed relationship between an exposure variable and an outcome variable, rather than hypothesizing only a direct

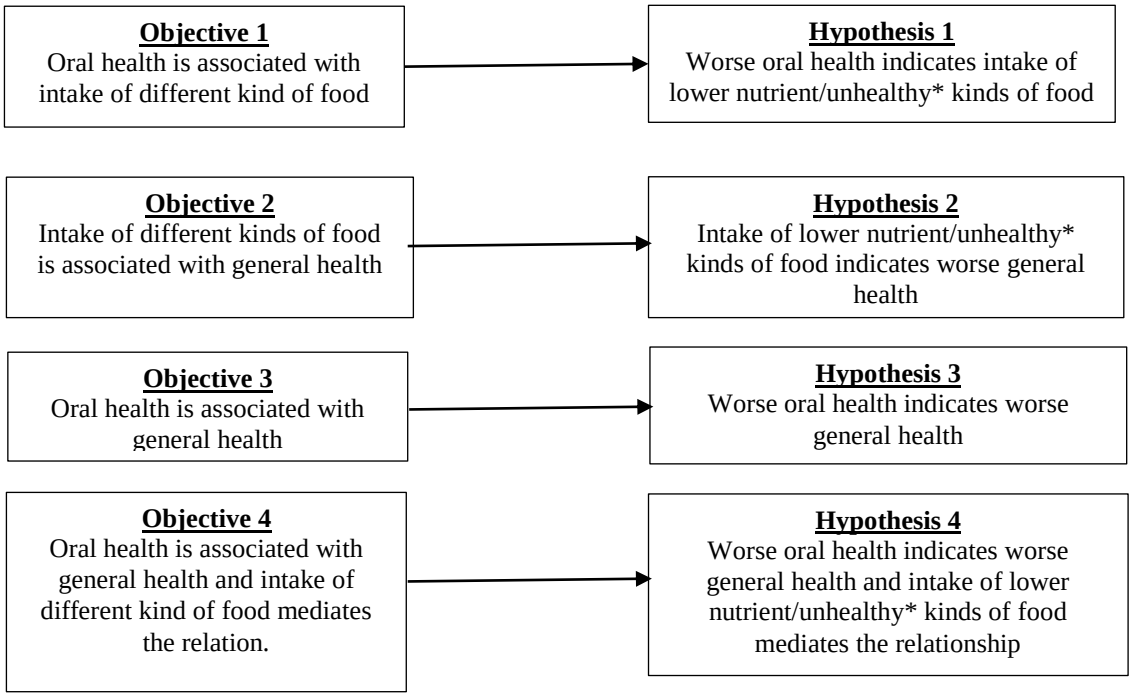
relationship between the exposure variable and the outcome variable. Testing this conceptual mediation model explores the role of nutrition in the relationship between oral health and general health, that is, oral health affects nutritional status was introduced. This in turn, affects general health.

2.9. Hypotheses

Based on the literature review, the conceptual model and the study's research interest, the study's main objective is to evaluate the "association of oral health and general health and test to whether the intake of different food groups mediates the relationship". Specifically, this research addresses the following research objectives:

- Determine the association between oral health and the different types of food consumption of adult people in Australia.
- Determine the association between the different types of food consumption and the general health of adults in Australia.
- Determine the association between oral health and the general health of adults in Australia.
- Test whether the intake of different food groups mediates the relationship between oral health and general health of adults in Australia.

The flow chart below in Figure 2.3 connects each hypothesis to its corresponding objective.



*Lower nutrient/unhealthy food refers to food with high free sugar, trans fatty acids sodium chloride and starchy carbohydrates and also low in non-starch polysaccharides fibre (such as whole-grain cereals, legumes, fruits and vegetables.

Figure 2.3: Hypotheses and their corresponding objectives

Chapter 3: Methodology

This chapter describes in detail the methodology followed in relation to study design and data collection and the data analysis methods employed for data management and statistical analysis in the papers submitted for publication, as presented in Chapter 4 (sections 4.3, 4.4, and 4.5), with the methodology addressing the particular aims of each paper of the current study. In addition, this chapter describes the aspects of sample size and power, data weighting and study variables.

3.1. Study design and data collection

Data for this study were derived from the 2004–2006 Australian National Survey of Adult Oral Health (NSAOH) (Slade et al., 2007). Study participants were selected at random using a three-stage, stratified clustered sampling design as show in Figure 3.1. The sampling frame was households compiled from listed telephone numbers in the Electronic White Pages (EWP) database (Slade et al., 2007). The first stage selected postcode for six states and two territories, postcodes were first stratified into two groups based on the Australian Bureau of Statistics (ABS) postcode geographical classification: 'metropolitan' and 'ex-metropolitan' strata. The Australian Capital Territory (ATC) was defined as a single metropolitan stratum. Postcodes represented the geographic clustering in the design and were selected with probability proportional to size, where size was defined as the number of households listed in the 'electronic white pages' in each postcode. The second stage of sampling selected a systematic sample of households listed in the 'electronic white pages' for each sampled postcode. The third and final stage involved random selection of one person aged 15 years or more per household. In households where only one person was aged 15 years or more, that person was selected. If households comprised more than one

person aged 15 years or more, a computer algorithm was then used to select one of those people at random.

Information was collected by a computer-assisted telephone interview (CATI) (full details of the CATI has been reported in Slade et al., 2007) followed by an oral epidemiological examination and a mailed questionnaire, then a food frequency questionnaire. A primary approach letter explaining the purpose of the survey was mailed to the participants selected from sampled telephone numbers, approximately 10 days prior to dialling them. The telephone interview collected information on dental status, socio demographic characteristics and a number of health-related factors from 79 questions, several with multiple responses. People who reported they were dentate (i.e., that they had teeth) were invited to participate in an oral epidemiological examination and first asked to complete a consent form and a questionnaire regarding their medical history. Trained examining dentists followed a standardised protocol to record level of tooth loss, dental decay experience, tooth wear, periodontal and signs of gum disease assessment. Following the epidemiological examination, a questionnaire was mailed to all examined people containing information such as psycho-social variables. In the nutrition sub-study, a subsequent food frequency questionnaire (FFQ) was sent to the participants in the Australian states of New South Wales and Queensland. The FFQ collected data on consumption of specific food items that included nine types of dairy, nine types of bread and cereal, 21 types of meat, fish and eggs, 15 types of sweet foods and snacks, four types of mixed vegetables, 25 types of vegetables and eight types of fruits based on the items used in the National Nutrition Survey (ABS, 1995). The food groups reflect the dietary guidelines for Australian and the Recommended Dietary Intake for use in Australia reviewed by the National Health and Medical Research Council (NHMRC) (ABS, 1998).Adult participants aged 45 years or more were selected for this current study.

These are the most recent national data on adults in Australia at present. An updated NSAOH (Australian National Survey of Adult Oral Health) is being collected and analysed but it is not yet available.

Oral problems like tooth loss (Åstrøm et al., 2006), or periodontal disease (Yoshihara et al., 2009) are age related and increase with age, also the risk of chronic conditions

increases with age (Griffin et al., 2012) As chronic health problems take time to develop and may not be noticeable among younger ages, in this study older adults aged 45 years and more were considered.

The data from the 2004-2006 Australian National Survey of Adult Oral Health has been used for different studies. For example, Slade et al., (2013) compared the effect of pre-fluoridation cohort and population lifetime exposed to fluoridated water on dental caries. Others used this survey data for oral health, dental insurance and dental service (Srivastava et al., 2017), impact of smoking on periodontitis (Loc et al., 2008), root carries experience (Ninuk et al., 2017). But very few research has done using the Food Frequency Questionnaire; Brennan et al., (2010) investigated only the consumption of different kind of fruits and vegetables by tooth loss and social-status. For the current study, all food groups were used from the Food Frequency Questionnaire. Food frequency data were cleaned and merged with computer-assisted telephone interview (CATI) data, oral epidemiological examination and a mailed questionnaire data and created a new set of data for the analysis of this current study.

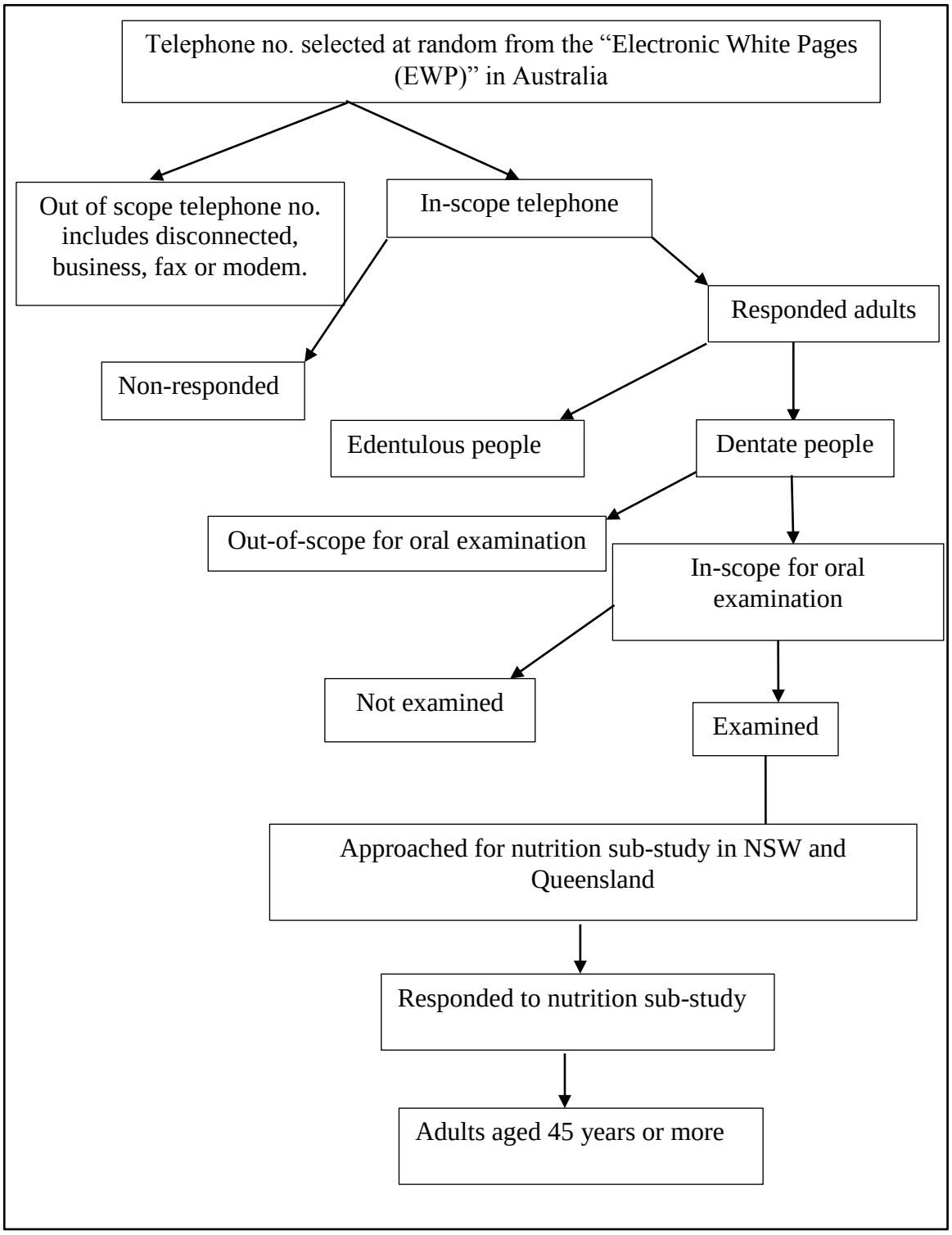


Figure 3. 1: Selection procedure for s participating in the survey

3.2. Estimate of Sample Size and Power

The determination of sample size was based on two-group comparisons of proportions using PC-Size software version 2.0 (Dallal, 1986) using an alpha level of 0.05 and a beta

of 0.80. Data on the consumption of food from the National Nutrition Survey (ABS, 1999) were used as a population estimate, and a range of sample sizes were calculated for hypothesised levels of difference. A sample size per group of n=583 would enable differences as low as 7% to be detected for the consumption of meat with the sample size of n=429 enabling the same for the consumption of vegetables. This level of difference is comparable to reported observed differences in nutrient intake by dentition status observed among dentate adults (Krall et al., 1998). Taking the higher number of n=583 per group would require 1,166 responses in total from a sample of 2,046 (assuming 95% could be contacted and a 60% response rate).

The current study considered participants aged 45 years and over. According to Census 2005, the proportion of those aged 45+ years in the estimated residential dented population compare to 15+ years estimated residential dented population in New South Wales and Queensland is 0.47. Depending upon the population proportion a sample size of 548 (minimum) is determined.

3.3. Study Variables

The outcome variable was self-rated general health (SRGH) collected from the computer-assistant telephone interview (CATI). The explanatory variables self-rated dental Health (SRDH) and number of missing teeth (derived from two variables “number of remaining teeth in your upper jaw” and “number of remaining teeth in your lower jaw”) were also collected during the CATI. The explanatory variable, “periodontal status” was assessed at the clinical examination, and the “Oral Health Impact Profile (OHIP) score” was collected from answers to the mailed questionnaire. The mediator variables “dairy”, “bread-cereal”, “meat-fish-eggs”, “sweet foods-snacks”, “mixed vegetables”, “vegetables” and “fruits” were collected from the subsequent food frequency questionnaire (FFQ) based on the

National Nutrition Survey (ABS, 1998). The food groups reflect the dietary guidelines for Australian and the Recommended Dietary Intake for use in Australia reviewed by the National Health and Medical Research Council (NHMRC) (ABS, 1998).

Age, gender, smoking status, tooth-brushing habits, diabetes, alcohol consumption and social support were the control variables. Control variables were selected initially from a literature review of associations between oral health and nutrition, nutrition and general health, and oral health and general health. The critical level of $p \leq 0.20$ (Del Duca et al., 2013) was then used to select the control variables in this study.

Some control variables ”gender”, “age”, “diabetic status”, and “smoking status” were collected during the CATI while, others, such as “tooth-brushing status”, “social support” and “alcohol consumption” were derived from answers to the mailed questionnaire.

3.3.1. Self-rated general health

As mentioned above, the outcome variable was “self-rated general health (SRGH)”. Self-ratings of health were assessed using single-item global ratings measured on 5-point Likert scales (Krause & Jay, 1995), which include the question “how would you rate your general health?” Conceptually, this is considered as a general health perception in Wilson and Cleary’s model (Baker et al., 2008). The responses comprised the ordinal categories of ‘poor’, ‘fair’, ‘good’, ‘very good’ and ‘excellent’.

3.3.2. Self-rated dental health

The explanatory variable, “self-rated dental health (SRDH)” is a single-item global rating of oral health often used in research (Jones et al., 2001; Locker et al., 2002; Matthias et al., 1993) and was based on those used in previous population oral health surveys conducted by the Australian Research Centre for Population Oral Health (Carter & Stewart, 1999,

2002; Carter et al., 1994). It was assessed by the question "how would you rate your own dental health?", with responses that comprised the ordinal categories of 'poor', 'fair', 'good', 'very good' and 'excellent'.

3.3.3. Periodontal status

The explanatory variable periodontal status was evaluated at the clinical examination using a method modified from the examination manual of the 2001 US National Health and Nutrition Examination Survey (NHANES) (Center for Disease Control [CDC], 2001). The periodontal pocket depth and gingival recession (REC) were measured using the National Institute of Dental and Craniofacial Research periodontal probe that has two-millimetre (mm) markings. Probing pocket depth (PPD) was defined as the distance from the free gingival margin to the bottom of the periodontal crevice/ pocket. Gingival recession (REC) was defined as the distance from the cemento-enamel junction (CEJ) to the free gingival margin. All fractional millimetre (mm) measurements were rounded down to the nearest whole millimetre (mm). The clinical attachment level (CAL) was calculated as the sum of PPD and REC for each site during the data management stage. Measurements were made at the mesio-buccal, mid-buccal and disto-buccal sides of all teeth. Three mutually exclusive categories of periodontal status were computed using the following definitions from the Centres for Disease Control and Prevention and the American Academy of Periodontology: severe periodontitis = two or more interproximal sites (not on the same tooth) with ≥6 mm CAL and at least one interproximal site with PD ≥5 mm; moderate periodontitis = at least two interproximal sites with ≥4 mm CAL (not on the same tooth) or at least two interproximal sites with ≥5mmPD (not on the same tooth); and no/mild periodontitis = neither moderate nor severe (Page & Eke, 2007).

3.3.4. Number of missing teeth

The explanatory variable “number of missing teeth” was derived from the variable “number of teeth present”, calculated by adding together two variables “number of remaining teeth in your upper jaw” and “number of176 remaining teeth in your lower jaw”. Then, by using the formula “32 - number of teeth present”, the “number of missing teeth” was derived.

3.3.5. OHIP-14 questionnaire

The instrument used in the current study to measure the impact of oral health on the quality of life of elderly people was the Oral Health Impact Profile (OHIP)-14 (Slade, 1998). The questionnaire comprises of 14 questions, corresponding to seven dimensions: functional limitation, pain, psychological discomfort, physical disability, psychological disability, social disability, and handicap. Five answers were possible for each question, based on the Likert-type scale: “never”, “hardly ever”, “occasionally”, “fairly often” and “very often” (Ulinski et al., 2013).

The severity of the impact on oral health could be calculated by the sum of ordinal responses where “never” was coded as 0, “hardy ever” as 1, “occasionally” as 2, “fairly often” as 3 and, “very often” as 4.This meant that a subject could have an OHIP-14 severity value ranging from 0-56 (Slade, 1998). Higher OHIP-14 scores indicate a greater impact from the dental problem (Brennan & Singh, 2011).

3.3.6. Dairy

The nine types of dairy product comprised: flavoured milk; milk as a drink; milk on breakfast cereals; milk in hot beverages; cream or sour cream; ice-cream; yoghurt; cottage or ricotta cheese and cheddar and other cheeses with the FFQ used to collect these data.

For each item, the average consumption frequency was recorded for the previous 12 months. The data for these items were collected on a 9-point scale ranging from ‘never, or less than once a month’ to ‘6+ times per day’, coded 0-8. The total was the sum of all nine items with a possible range of 0-72, with a higher score indicating higher consumption.

3.3.7. Bread-cereal

White bread or rolls, wholemeal/mixed grain bread or rolls, English muffin, bagel or crumpet, dry or savoury biscuits and crispbread, muesli, cooked porridge, breakfast cereal, rice (white or brown) and pasta-noodles, were the nine types of food items that were considered in the bread-cereal food group . For each item, the average consumption frequency was recorded for the consumption on average in the past 12 months. The data for these items were collected on a 9-point scale ranging from ‘never, or less than once a month’ to ‘6+ times per day’, coded 0-8. The total was the sum of all nine items with a possible range of 0-72, with a higher score indicating more consumption.

3.3.8. Meat-fish-eggs

In this food group, data were collected on the consumption of 16 different kinds of meat food items; four kinds of fish items including canned fish (tuna, salmon and sardines); cooked fish (steamed, baked and grilled); fried fish and other seafood; and egg. For each item, the average consumption frequency was recorded for the previous 12 months. The data for these items were collected on a 9-point scale ranging from ‘never, or less than once a month’ to ‘6+ times per day’, coded 0-8. The total was the sum of all 21 items with possible range of 0-168, with a higher score indicates more consumption.

3.3.9. Sweet foods-snacks

In the category of sweet foods-snacks, the varieties of sweet and baked goods and snacks included s 15 items that comprised muffins, scones, and pikelets, sweet pies or sweet pastries, other puddings or desserts, plain sweet biscuits, cream/chocolate biscuits, meat pie, sausage roll or savoury pasty, pizza, hamburger, chocolate (including chocolate bars), other confectionery, jam-marmalade-syrup-honey**,** peanut butter and other nut spreads, vegemite, marmite and promite, nuts and potato chips, corn chips, twisties, etc. For each item, the average consumption frequency was recorded for the previous 12 months. The data for these items were collected on a 9-point scale ranging from 'never, or less than once a month' to '6+ times per day', coded 0-8. The total was the sum of all 15 items with a possible range of 0-120, with a higher score indicating more consumption.

3.3.10. Mixed vegetables

Data were collected on four kinds of mixed vegetables comprising a green/mixed salad in a sandwich, a side salad/with a main meal, stir-fried or mixed vegetables and vegetable casserole were collected. For each item, the average consumption frequency was recorded for the previous 12 months. These items were collected on a 9-point scale ranging from 'never, or less than once a month' to '6+ times per day', coded 0-8. The total was the sum of all four items with a possible range 0-32, with a higher score indicating more consumption.

3.3.11. Vegetables

Excluding the mixed vegetables items, 22 different kinds of vegetables were included in this item. The frequency of consumption was collected for the following: potato (boiled, mashed or baked); hot chips; pumpkin; sweet potato; peas; green beans; silverbeet/spinach;

broccoli; cauliflower; brussels sprouts/cabbage/coleslaw; carrots; zucchini/eggplant/ squash; capsicum; sweetcorn or corn on the cob; mushrooms; tomatoes; lettuce; celery/cucumber; onions or leeks; soybeans or tofu; baked beans; and other beans/lentils. For each item, the average consumption frequency was recorded for the previous 12 months. The data for these items were collected on a 9-point scale ranging from 'never, or less than once a month' to '6+ times per day', coded 0–8. The total was the sum of all 22 items with a possible range of 0–176, with a higher score indicating more consumption.

3.3.12. Fruits

Ten (10) different kinds of fruits (including dried, frozen and tinned) were included in this FFQ, with these comprising: apple/pear; orange/mandarin/grapefruit; banana; stone fruits (peach, nectarine, plum, apricot); mango or pawpaw; pineapple; grapes or berries; melon (water-, rock-, honeydew-); lemon juice; and other fruit juices or fruit drinks. The data on these items were collected on a 9-point scale ranging from 'never, or less than once a month' to '6+ times per day', coded 0–8. The total was the sum of all 10 items with a possible range of 0–80, with a higher score indicating more consumption.

3.3.13. Age

Age was used in this study as a continuous variable, with a range of 45-90.

3.3.14. Gender

Gender was classified as male or female.

3.3.15. Smoking status

Smoking status was collected and used as a categorical variable in three categories "currently smoke", "former smoker" and "never smoked".

3.3.16. Tooth brushing habit

For the variable “tooth-brushing habit”, participants estimated the average number of tooth-brushing times per day, with this used to calculate the variable “number of times brushed teeth last week”.

3.3.17. Diabetes

Diabetes information was collected by asking participants whether or not a doctor had told them they had diabetes.

3.3.18. Alcohol consumption

The variable “alcohol consumption” was estimated as the average number of standard alcohol drinks per day calculated from two collected variables “days per week of alcohol drinking” and “number of standard drinks per day’.

3.3.19. Social support

Social support was used as a continuous variable with a range of 12–60, using the Multidimensional Scale of Perceived Social Support Assessment, a 12-item scale of perceived social support from family and friends (Zimet et al., 1988). Participants responded to the items on a 5-point Likert-type scale (ranging from ‘strongly disagree’ to ‘strongly agree’), with scores ranging from 1–5. The total was the sum of all 12 items with a possible range of 12–60.

3.4. Conceptual Mediation Model

The study developed the model in Figure 3.2 below to test for mediation. Seven (7) types of food groups were considered as possible mediators between oral health and general

health. Different oral health measures such as “periodontal status”, “self-rated dental health (SRDH)”, “number of missing teeth” and “OHIP score” were considered as exposure variables, with “self-rated general health (SRGH)” the outcome variable. For each exposure, a model was tested with each individual mediator

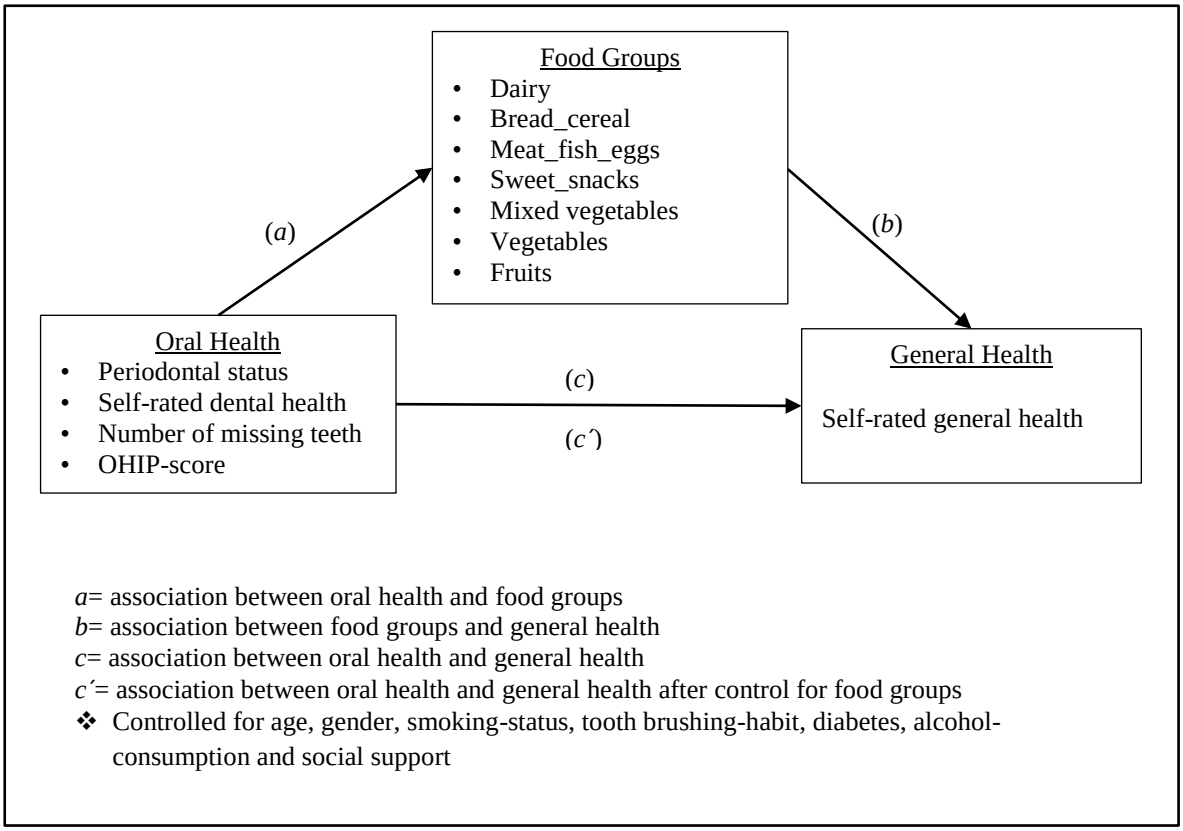


Figure 3. 2: Conceptual mediation model

3.5. Data Analysis Method

3.5.1. Descriptive statistics

Descriptive statistics including proportions/frequencies, means, standard deviations (SDs) and 95% confidence intervals (CIs) were used to summarise oral health, food frequency, general health and socio-demographic characteristics. Correlations were also used to assess correlations between oral health, general health and food frequency measures.

3.5.2. Normality test

To assess the variable distribution, skewness and kurtosis were checked. The study also conducted the Kolmogorov–Smirnov test to test the assumption that data were drawn from a normally distributed population.

3.5.3. Skewness and Kurtosis

Skewness is a measure of the asymmetry of the distribution of a variable. The skew value of a normal distribution is zero, usually implying symmetric distribution. A positive skew value indicates that the tail on the right side of the distribution is longer than the left side and the bulk of the values lie to the left of the mean. In contrast, a negative skew value indicates that the tail on the left side of the distribution is longer than the right side and the bulk of the values lie to the right of the mean. West et al. (1996) proposed a reference of substantial departure from normality as an absolute skew value > 2.

Kurtosis is a measure of the peakiness of a distribution. The original kurtosis value is sometimes called kurtosis (proper) and West et al. (1996) proposed a reference of substantial departure from normality as an absolute kurtosis (proper) value > 7. For some practical reasons, most statistical packages such as SPSS provide ‘excess’ kurtosis obtained by subtracting 3 from the kurtosis (proper). The excess kurtosis should be zero for a perfectly normal distribution.

A z-test is applied for normality test using skewness and kurtosis. A z-score could be obtained by dividing the skew values or excess kurtosis by their standard errors.

$$Z = \frac{Skew\ value}{SE_{skewness}} \quad ; \qquad Z = \frac{Excess\ kurtosis}{SE_{excess\ kurtosis}}$$

According to different sample size, the critical values for normality is as follows;

1) For small samples ($n < 50$), if absolute z-scores for either skewness or kurtosis are larger than 1.96, which corresponds with an alpha level 0.05, then reject the null hypothesis and conclude the distribution of the sample is non-normal.
2) For medium-sized samples ($50 < n < 300$), reject the null hypothesis at absolute z-value over 3.29, which corresponds with an alpha level 0.05, and conclude the distribution of the sample is non-normal.
3) For sample sizes greater than 300, depend on the histograms and the absolute values of skewness and kurtosis without considering z-values. Either an absolute skew value larger than 2 or an absolute kurtosis (proper) larger than 7 may be used as reference values for determining substantial non-normality (Hae-Young, 2013).

3.5.4. Kolmogorov-Smirnov test

The Kolmogorov-Smirnov (KS) test is arguably the most well-known test for normality. In its original form, the KS test is used to decide whether a sample comes from a population with a completely specified continuous distribution. In practice, however, researchers often need to estimate one or more of the parameters of the hypothesised distribution (e.g., the normal distribution) from the sample, in which case the critical values of the KS test may no longer be valid. In the case of normality testing, Massey (1951) suggested using sample means and sample variances, and this is the norm in the current use of the KS test. Lilliefors (1967) and Dallal and Wilkinson (1986) provided a table of approximate critical values of KS statistics that are based on sample means and sample variances.

This is also available in most widely used statistical software packages. The current study conducted the Kolmogorov–Smirnov test using the SPSS 24 software package. If the *p*-value was more than 0.05, in other words, if the test statistics were not significant, then the observations can be said to be normally distributed.

3.5.5. Multivariate linear regression

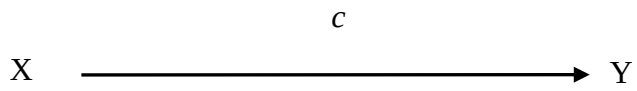
Linear regression is a basic and commonly used type of predictive analysis. The overall idea of regression is to identify the strength of the effect that the independent variable(s) have on a dependent variable and to examine which variables in particular are significant predictors of the outcome variable.

The current study conducted multivariate regression analysis using the SPSS 24 software package. Firstly, the study assessed the relationship of self-rated oral health to the consumption of different types of food. The study then assessed the effects of the consumption of different types of food on general health and, lastly, an analysis of the association of oral health with general health was undertaken.

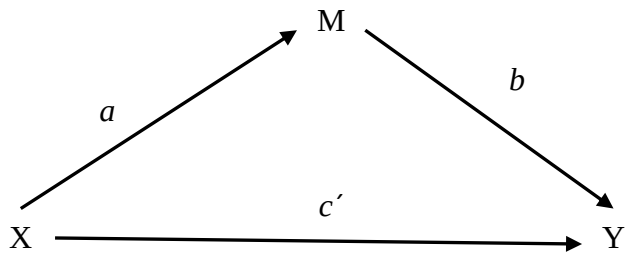
3.5.6. Mediation analysis

If when utilising an intervening variable model, the explanatory variable X is assumed to exert an effect on an outcome variable Y through one or more intervening variables, then the intervening variable(s) are called the mediator/s (M/s) (Lyytinen & Gaskin, 2012).

Consider a variable X that is assumed to exert an effect on another variable Y. The variable X is called the explanatory variable and the variable on which it exerts an effect is called the outcome variable Y. Below is the diagrammatic form of the unmediated model:



The effect of X on Y may be mediated by a process or mediating variable M, and the variable X may still exert an effect on Y. Below is the diagrammatic form of the mediated model:



The direct effect is the pathway from the explanatory variable to the outcome while controlling for the mediator. Here c´ could also be called a direct effect. The coefficient for the indirect effect represents the change in Y for every unit change in X that is mediated by M. Judd and Kenny (1981) suggested computing the difference between the regression coefficients to calculate the indirect effect. The approach involves subtracting the partial coefficient (coefficient of X in path *c´*) from the simple regression coefficient of X in path *c*. Finally, the total effect is the sum of the direct and indirect effects of an explanatory variable on the outcome.

3.5.6.1. *Baron and Kenny Method*

Baron and Kenny (1986) proposed a four-step approach in which several regression analyses are conducted, and the significance of the coefficients is examined at each step.

If the mediational model is correctly specified, the paths of c, *a*, *b*, and c´ can be estimated by linear regression. In some cases, other methods of estimation (e.g., logistic regression, multilevel regression modelling) must be used instead of multiple regression. Regardless of which analytic data method is used, the steps necessary for testing mediation are the same.

Baron and Kenny (1986) recommended the following steps for mediation analysis:

Step 1: Show that the explanatory variable affects the outcome. Use Y as the criterion variable in a regression equation and X as a predictor, which estimates and tests path c in the above diagram. This step establishes that there is an effect that may be mediated.

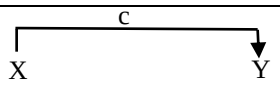
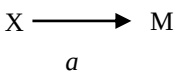
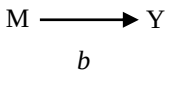
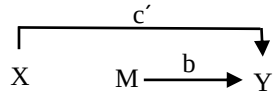
Step 2: Show that the explanatory variable affects the mediator. Use M as the criterion variable in a regression equation and X as a predictor, which estimates and tests path *a*.

Step 3: Show that the mediator affects the outcome variable. Use Y as the criterion variable in a regression equation and M as a predictor, which estimates and tests path *b*.

If Steps 1-3 have established the significant relationship, then proceed to step 4. If one or more of these relationships are insignificant, researchers usually conclude that mediation is not possible or likely.

Step 4: To show that M completely mediates the X-Y relationship, the effect of X on Y controlling for M (path c´) should be insignificant. If X is still significant (i.e., both X and M significantly predict Y) the finding supports partial mediation (see also Table 3.1).

Table 3.1: Mediation analysis steps

	Analysis	Visual depiction
Step 1	Conduct a simple regression analysis with X predicting Y to test for path *c* alone $Y=B_0 +B_1 X +e$	
Step 2	Conduct a simple regression analysis with X predicting M to test for path *a*, $M=B_0 +B_1 X +e$	
Step 3	Conduct a simple regression analysis with M predicting Y to test the significance of path *b* alone, $Y=B_0 +B_1 M +e$	
Step 4	Conduct a multiple regression analysis with X and M predicting Y, $Y=B_0 +B_1 X + B_2 M +e$	

Source: web.pdx.edu/~newsomj/da2/ho_**mediation**.pdf

3.5.6.2. *Sobel test*

The Sobel (1982) test evaluates the significance of the mediator by the product of the coefficients ($a \times b$). It also requires the standard error (SE) of a or s_a and the SE of b or s_b, both of which can easily be found from simple regression analysis. The standard error of ab is then estimated which equals the square root of $b^2s_a^2 + a^2s_b^2$. The test of the indirect effect is then done by the Z test as follows:

$$z = \frac{a \times b}{\sqrt{b^2 s_a^2 + a^2 s_b^2}}$$

The absolute value of Z is larger than 1.96 with this being significant at the 0.05 level.

In the current research, the Sobel test was performed for an indirect effect using Winnifred's Mediation Program (WIMP), which is accessed on Kris Preacher's website, <http://www.unc.edu/~preacher/sobel/sobel.htm>.

3.5.6.3. *Bootstrapping for standard errors*

Bootstrapping, developed by Preacher and Hayes (2004, 2008), is a non-parametric method based on resampling with a replacement which is done many times (e.g., 5000 times). The main feature of this test is that it does not rely on the assumption of normality and thus, it is also a fit for smaller sample sizes (Hair et al., 2014; Pardo & Román, 2013). The indirect effect is computed from each sample, and a sampling distribution can then be empirically generated. As the mean of the bootstrapped distribution will not exactly equal the indirect effect, a corrected estimate for bias can be made. With the distribution, a confidence interval (CI), a p-value or a standard error (SE) can be determined. Very typically, a confidence interval (CI) is computed and then checked to determine if zero (0) is in the interval. If zero (0) is not in the interval, then the researcher can be confident that the

indirect effect is different from zero (0). In the current research, the bootstrapping for standard error (SE) procedure was performed with 2000 resampling events, and was conducted using Mediation Macro for SPSS (Preacher &Hayes, 2008).

3.5.6.4. *Structural equation modelling (SEM) for mediation analysis*

Structural equation modelling (SEM) is a very general, powerful multivariate technique. It uses a conceptual model, path diagram and system of linked regression-style equations to capture complex and dynamic relationships within a web of the observed and unobserved variables (Douglas et al., 2013). In mediation analysis, SEM is a popular method. It involves the examination of the process of an independent variable X that is thought to exert an effect on a dependent variable, directly, as X→Y (path *c*), or indirectly through a mediator, X→M→Y (path *c´*). Traditionally, researchers have fit a series of regressions to estimate this relationship; however, , statistical researchers have shown the superiority of SEM in simultaneously and more efficiently estimating these relationships (Iacobucci, 2008). In the SEM mediation analysis, all paths are fit at the same time in a single model. The significance of the path coefficients can be tested and, if desired compared in magnitude (Iacobucci, 2010).

The maximum likelihood method was conducted for the SEM mediation analysis with the IBM SPSS AMOS 24 program used. Three types of effect were collected from the results: direct, indirect and total effect. The direct effects were represented by regression coefficients, either standardised (β weights) or unstandardised (B weights), and were interpreted in the usual manner. The indirect effects were estimated by the sums of the products of direct effects through the intervening variables in the model. The total effects were simply the sum of the direct and indirect effects. The relative influence of variables

within an equation was determined by comparing the standardised coefficients and the statistical significance test using a *p*-value.

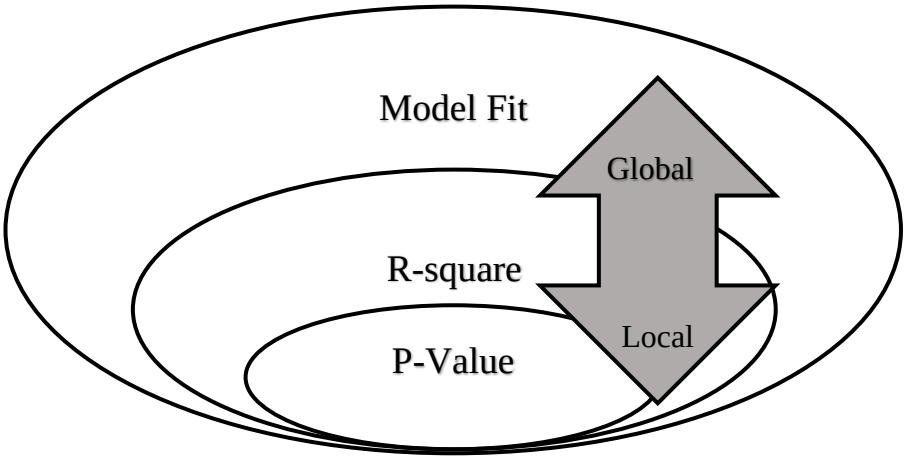
If the direct path was significant, the study included the mediating variable and used the procedure again. If the indirect path was not significant, no mediation was found; if the indirect path was significant, the study calculated the variance accounted for (VAF) with the following equation:

$$VAF = \frac{indirect\ effect}{total\ effect} \times 100$$

According to Hair et al. (2014) a VAF value of greater than 80% is full mediation: a value between 20% and 80% indicates partial mediation, and a value less than 20% means no mediation is present.

3.5.6.4.1. Fit Indices

In order for a hypothesis to be supported the mediation model for SEM, many criteria must be met. These criteria can be classified as global or local tests. In order for a hypothesis to be supported, the local test must be met; in order for a local test to have meaning, all global tests must be met. If a hypothesised relationship has a significant p-value, the global test of variance is next explained by R-squared (R^2) (Statwiki). The model that best represents the data and reflects the underlying theory is known as the best model fit. Figure 3.3 below illustrates the precedence of global and local tests.



Source: Statwiki, 2018. (http://statwiki.kolobkreations.com/index.php?title=Structural_Equation_Modeling#Statistical_Support_for_Hypotheses_through_global_and_local_tests)

A variety of fit indices can provide the most fundamental indication of how well the proposed theory fits the data (Hooper et al., 2008).

3.5.6.4.2. R-squared

The coefficient of determination (R^2) is a common measure based on which the structural model is evaluated. This coefficient represents the combined effects of all independent variables on dependent variables (Hadi et al., 2016). The evaluation of goodness-of-fit using R^2 is somewhat subjective, with R^2 having no fixed guidelines (Iacobucci, 2010).

3.5.6.4.3. f^2 effect size

The effect size of the mediator in the SEM model is denoted by f^2 and calculated by the equation

$$f^2 = \frac{R^2_{include} - R^2_{exclude}}{1 - R^2_{include}}$$

According to Hadi,et al. (2016), $f^2 \geq 0.02$, $f^2 \geq 0.15$, and $f^2 \geq 0.35$, represent small, medium, and large effects respectively.

3.5.6.4.4. CFI (Comparative fit index)

The Comparative Fit Index (CFI), first introduced by Bentler (1990), was subsequently included as part of the fit indices in his EQS program (Kline, 2005). This statistic assumes that all latent variables are uncorrelated (null/independence model) and compares the sample covariance matrix with this null model. The values for this statistic range between 0.0 and 1.0 with values closer to 1.0 indicating good fit. A cut-off criterion of CFI $\geq$ 0.90 was initially advanced; later on other studies have shown that a value greater than 0.90 is needed to ensure that misspecified models are not accepted (Hu & Bentler, 1999). Thus, a value of CFI $\geq$ 0.95 is presently recognised as being indicative of a good fit (Hu & Bentler, 1999). This index is today included in all SEM programs and is one of the most popularly reported fit indices as it is one of the measures least affected by sample size (Fan et al., 1999).

The current study has not reported χ^2 or the root mean square error of approximation (RMSEA) because χ^2 is sensitive to a large sample size (n > 250), almost always indicating a poor fit (Iacobucci, 2010), while the RMSEA worsens as the number of variables in the model increase (Fan & Sivo, 2005; Kenny & McCoach, 2003). Overall, in view of power and robustness, Hu and Bentler (1998) have demonstrated the strong performance of the Comparative Fit Index (CFI).

3.6. Weighting

Unit record weights for this study's survey were calculated to reflect the probabilities of selection and to adjust for different participation rates across postcodes and among age and

gender categories. For the telephone interview survey, weights were adjusted to ensure that survey estimates were consistent with the 2005 ABS Estimated Residential Population data. For the oral examination survey, which was restricted to dentate people aged 15 years and over, estimates of the dentate population were derived from the telephone interview survey and used to derive the examination weights (Slade et al., 2007).

3.7. Ethic Approval

The nutrition sub-study was approved by the University of Adelaide Human Research Ethics Committee (H-029-2005)

Chapter 4: Results

This chapter outlines the response, descriptive statistics of the study variables and three research articles that were produced from this study.

4.1. Responses

In the Australian National Survey of Adult Oral Health (NSAOH), 36,931 telephone numbers were selected at random from the EWP sampling frame, of which 8,119 telephone numbers were out-of-scope numbers (see Figure 4.1 below). Of the 28,812 in-scope telephone numbers, a total of 14,123 adults responded to the CATI (49% response rate). In total, 12,861 dentate adults responded to the telephone interview and a total of 5,505 adults were examined (44% of the interviewed people who were invited to the oral examination). In the nutrition sub-study, a total of 1,218 persons were approached in NSW and Queensland, with 1,129 responding (92.7% response rate). Among them, 752 respondents to the nutrition sub-study were aged 45 years and over.

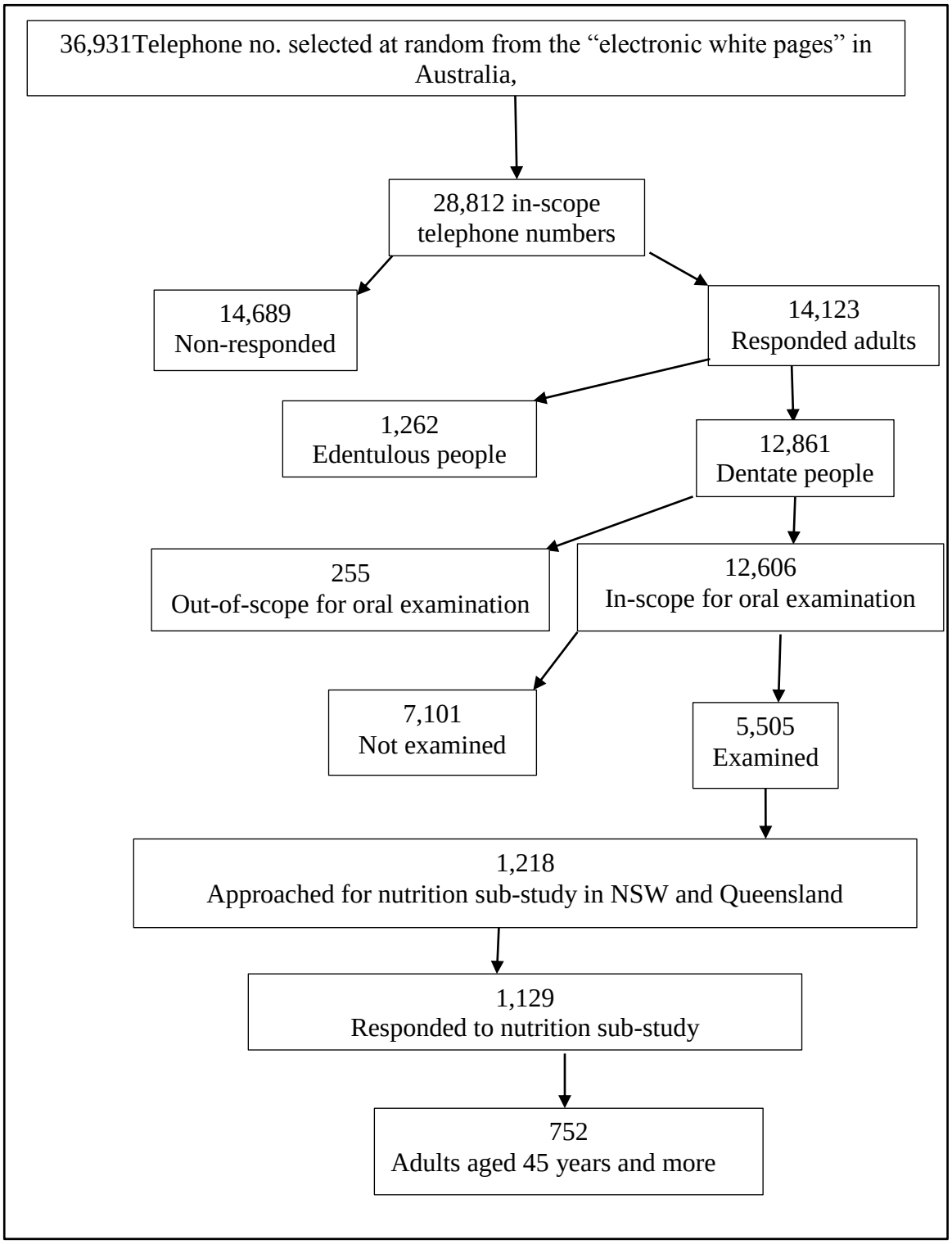


Figure 4. 1: Number of people selected and participating in the survey

4.2. Descriptive Statistics

Table 4.1 shows the variables analysed in this study and their descriptive statistics. The four oral health measures, seven different groups of food items, one general health measure and seven control variables are described in Table 4.1 below.

Table 4. 1: Descriptive statistics of the variables.

Variables		Kind of variable		%/Mean (SD)
Oral Health	Periodontitis	Categorical	None/Mild	66.1%
			Moderate	30.4%
			Severe	3.5%
	Self-rated dental health	Continuous (range 1-5)		3.3 (0.9)
	OHIP Score	Continuous (range 0-51)		7.3 (7.93)
	Number of missing teeth	Continuous (range 0-28)		7.7 (6.9)
Food groups	Dairy	Continuous (range 0-51)		25.6 (6.4)
	Bread-cereal	Continuous (range 0-45)		25.6 (5.5)
	Meat-fish-eggs	Continuous (range 0-72)		42.4 (8.6)
	Sweet foods-snacks	Continuous (range 0-64)		32.5 (8.5)
	Mixed vegetables	Continuous (range 1-15)		12.4 (3.8)
	Vegetables	Continuous (range 1-107)		61.9 (12.1)
	Fruits	Continuous (range 1-64)		28.4 (8.5)
Self-rated general health		Continuous (range 1-5)		3.6 (0.9)
Control variables	Age	Continuous (range 45-90)		60.5(10.1)
	Average number of brushing	Continuous (range 0-5)		1.9 (0.7)
	Average alcohol consumption	Continuous (range 0 to 12)		1.1(1.6)
	Social support score	Continuous (range 12-60)		46.7(7.6)
	Gender	Categorical	Male	49.6%
			Female	50.4%
	Smoking Status	Categorical	Currently smoke	13.1%
			Former smoker	35.2%
			Never smoke	51.6%
	Doctor said have diabetes	Categorical	Yes	7.7%
			No	92.3%

4.3. Research Article 1

Islam S, Brennan DS, Roberts-Thomson K. Nutritional intake partially mediates the relationship between periodontal status and self-rated general health in adults. Community Dentistry and Oral Epidemiology. [Submitted 8 May 2018]

Highlights:

- This article shows the mediation effects of food consumption in the relationship between periodontal status and self-rated general health in Australian adults.
- Based on the research, we provide suggestions for all healthcare professionals to understand the potential relationships among food consumption, periodontal status and self-rated general health and for nutritionists to develop dietary guidelines for adults with periodontitis to maintain a healthy life
- Article has been submitted to *Community Dentistry and Oral Epidemiology* (see Appendix)

4.3.1. Statement of Authorship

Statement of Authorship

Title of Paper	Nutritional intake partially mediates the relationship between periodontal status and self-rated general health in adults.
Publication Status	☐ Published ☐ Accepted for Publication ☑ Submitted for Publication ☐ Unpublished and Unsubmitted w ork w ritten in manuscript style
Publication Details	Islam S, Brennan DS, Roberts-Thomson K. Nutritional intake partially mediates the relationship between periodontal status and self-rated general health in adults. [Community Dentistry and Oral Epidemiology] submitted 8 May 2018.

Principal Author

Name of Principal Author (Candidate)	Saima Islam		
Contribution to the Paper	Designed the analytic plan and objective for the paper. Performed literature search, planned overall analysis, performed analysis and interpreted the findings. Wrote the manuscript.		
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	10 May 2018

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	David S Brennan		
Contribution to the Paper	Supervised the development and progress of the study. Contributed to the study design, and overall analysis strategy. Provided intellectual content and revised the manuscript		
Signature		Date	10 May 2018

Name of Co-Author	Kaye Roberts-Thomson		
Contribution to the Paper	Supervised the development of the study and revised the manuscript.		
Signature		Date	10 May 2018

Please cut and paste additional co-author panels here as required.

4.3.2. Submitted article

The article presented on pp 57-85 shows the mediation effects of food consumption in relation between periodontal status and self-rated general health in Australian adults. This article has been submitted to *Community Dentistry and Oral Epidemiology*, and is provided in the form as submitted to the journal.

Nutritional intake partially mediates the relationship between periodontal status and self-rated general health in adults

Author

Saima Islam [1]

David S Brennan[1]

Kaye Roberts-Thomson[1]

[1]Australian Research Centre for Population Oral Health, Adelaide Dental School,

The University of Adelaide, South Australia, Australia.

Correspondence:

[1]Adelaide Health & Medical Sciences (AHMS) building, Level 9, 57 North Terrace, Adelaide SA 5000

Tel +61 8 8313 4048 Fax: +61 8 8313 3070

Email: Saima.islam@adelaide.edu.au

Running Head: Periodontal status and general health.

Acknowledgments: The research reported in this paper is a study of the Australian Primary Health Care Research Institute (APHCRI), which is supported under the Australian Government's Primary Health Care Research, Evaluation and Development Strategy. The information and opinions contained in it do not necessarily reflect the views or policy of the Australian Primary Health Care Research Institute or the Department of Health

Key words: Nutrition Intake, Periodontal Status, Self-rated general health, Mediation.

No Conflict of interest to declare

Abstract

Objective: Periodontitis is a chronic inflammatory disease affecting the supporting structures of the teeth and playing a significant role in the systemic health of adults. Our aim is to investigate the association of periodontal status and general health and to test whether the intake of different food groups mediates this relationship. **Method**: Data were collected in 2004–06, using a computer-assisted telephone interview, followed by an oral examination, mailed questionnaire and a food frequency questionnaire (FFQ) in two states of Australia, New South Wales and Queensland. Multivariate linear regression was conducted to assess relationships between the variables. Self-rated general health and periodontal status were used as the outcome and explanatory variables, food groups (dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables and fruits) were the mediators. Age, gender, smoking status, tooth-brushing habits, diabetes, alcohol consumption and social support were the control variables. Baron and Kenny's mediation analysis was initially performed, followed by Sobel's test for mediation. Lastly, bootstrapping for standard error and structural equation modelling (SEM) were conducted to assess the consistency of the mediation model to the data. If SEM indicated the presence of mediation, the variance accounted for (VAF) was calculated to ascertain the strength of mediation. **Result**: A total of 1129 persons responded to the FFQ (92.7% response rate), with 62.6% aged 45+ years. Adults with none/mild and moderate periodontitis compared to severe periodontal problems rated their general health better (β_1=-0.13 with p<0.001 and β_2=-0.09 with p<0.001). The Baron and Kenny and Sobel tests showed the associations between periodontal status and self-rated general health were partially mediated by food intake (Sobel test: for all mediators: dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables and fruits, p<0.05). Multiple mediation bootstrap results showed bias-corrected confidence intervals (-0.0091, 0, 0052) for the mediators: dairy (-0.0012, 0.0347); bread-cereal (-0.0017, 0.0303); fish-meat-eggs (-0.0028, 0.0287); sweet foods-snacks (-0.0036, 0.0126); mixed vegetables (-0.0064, 0.0132); vegetables and (-0.00205, 0.0022) fruits with this indicative of no mediation. The SEM analysis for mediation showed p=0.76, p=0.045, p=0.050, p=0.015, p=0.73, p=0.42 and p=0.30 for dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables and fruits. The VAF for bread-cereal was 35.7%; for meat-fish-eggs 35.7%; and for sweet foods-snacks was 39.3%. **Conclusion:** Less severe periodontal problems predicted better general health. Structural equation modelling (SEM) and VAF indicated that the

association between periodontal status and self-rated general health (SRGH) was partially mediated by the consumption of bread-cereal, meat-fish-eggs and sweet foods-snacks.

Nutritional intake partially mediates the relationship between periodontal status and self-rated general health in adults

1. Introduction

In Australia, the burden of periodontitis is significant. Periodontal disease affects 22.9% of the adult population, and varies from 7.5% for those aged 15–34 to 52.0% at age 65 years and over.[1] Periodontitis is a common chronic inflammatory disease that affects the supporting structure of the teeth[2] and the effect of periodontal disease increases with age.[3] Periodontitis has been reported to have negative impacts on aspects of daily living and health-related quality of life[4,5] and may adversely increase the risk of systemic health outcomes.[6] Periodontal disease can lead to oral pain, teeth becoming loose and even being lost, then can result in chewing difficulty which can affect both body composition and nutritional status.[7] Sensible/healthier food consumption is essential for general health.[8]

In the late 1980s, Mattila et al. reported the association between dental health and acute myocardial infarction and related the significance of periodontal disease to general health.[9] Since then, evidence of the link between periodontal disease and several systemic diseases is growing, and periodontitis is associated with an increased risk of coronary heart disease, diabetes, and adverse changes in blood pressure and serum cholesterol level.[10]
The impact of oral conditions on nutrition status may relate importantly to nutrient or food intake. Some studies found no difference in nutrient intake between patients with periodontal disease and the general population[11], but others reported an increasing prevalence of periodontitis with larger body mass groups [12]. Most recent studies say that patients with chronic periodontitis consumed too few fruits and vegetables.[13]

To maintain a healthy life at any age, sensible/healthier food consumption is necessary. Some reports[14,15] state that poor dietary habits in older age increase the rate of developing chronic health problems. Laugero et al. found that a lower intake of protein, fruits, vegetables, fibre and omega-3 fatty acids and a higher intake of carbohydrate and food groups, characterized by salty snacks, sweet foods, and high Glycaemic Index (GI) foods along with physical activity patterns affect the development of chronic health diseases in older age [15] Fruits, vegetables, whole-grains, low-fat dairy products, poultry, fish and nut

consumption were recommended for preventing heart disease and stroke in the at-risk population.[16]

A diet with very low (<1% of daily energy intake) intake of trans fatty acids, adequate intake (6-10% of daily energy intake) of Polyunsaturated fatty acids and low intake of sodium chloride (less than 5g/d) can reduce the risk for cardiovascular health and restriction of free sugar intake (< 10% of total energy) can contribute to reduce the risk of unhealthy weight gain (Nishida et al., 2004). The joint consultation report of WHO/FAO (2003) states that adequate intake of non-starch polysaccharides fibre such as whole-grain cereals and legumes (> 20 g/d) and fruits and vegetables (≥400g/d) have potential health benefits in preventing obesity, diabetes, cardiovascular disease and various cancers.

Hosseini et al (2018) suggested from the systematic review and meta-analysis, a diet high in fruit and vegetables may lead to reduction in inflammation, (where inflammation is one of the major cause of a range of chronic diseases) and enhanced immune cell profile.

From the literature review, we can see associations between periodontitis and general health, periodontitis and nutrition, and nutrition and general health. Nutrition may be postulated as a mediator of the relationship between periodontitis and general health. Therefore, the purpose of the current study is to investigate the potential association of periodontal status and general health and to test whether the intake of different food groups mediates this relationship for adults.

Mediation analysis explores the role of intervening variables (mediators) in an observed relationship between an exposure variable and an outcome variable, rather than hypothesising only a direct relationship between the exposure variable and the outcome variable. A mediational model (also called a 'mediation model') hypothesises that the exposure variable affects the mediator variable which, in turn, affects the outcome variable.[17]

We believe that elucidating this relationship might be helpful in making appropriate/sensible food choice for adults with periodontitis so they can maintain a healthy life.

2. Method

2.1. Participants and data collection

Data for this study were derived from the 2004–2006 Australian National Survey of Adult Oral Health (NSAOH).[18] Study participants were selected at random using a multistage, stratified clustered sample selection procedure with a sampling frame compiled from listed telephone numbers in the Electronic White Pages (EWP) database.[18] Information was collected by a computer-assisted telephone interview (CATI) followed by an oral epidemiological examination, and completion of a mailed questionnaire, and then a food frequency questionnaire (FFQ). An initial letter explaining the purpose of the survey was mailed to the participants selected from sampled telephone numbers, approximately 10 days prior to dialling them. The telephone interview collected information on socio-demographic characteristics and several health-related factors including smoking status. People who reported they were dentate were invited to participate in an oral epidemiological examination that included periodontal assessment. Following the epidemiological examination, a questionnaire was mailed to all examined people containing information such as psycho-social variables. The subsequent FFQ collected data on the consumption of specific food items that included nine types of dairy; nine types of bread and cereal; 21 types of meat, fish and eggs; 15 types of sweet foods and snacks; four types of mixed vegetables; 25 types of vegetables; and eight types of fruits based on the items used in the National Nutrition Survey.[19] Periodontal disease is age related and increases with age.[3] The risk of chronic conditions also increases with age.[20] As chronic health problems take time to develop and may not be noticeable among those of younger ages, we considered older adults aged 45 years and older as participants in this study. Full details of participation in the study, together with descriptive findings, have been reported elsewhere.[18]

2.2. Study variables

The outcome variable was self-rated general health (SRGH). Self-ratings of health were assessed using single item global ratings measured on 5-point Likert scales[21], which

included the question “how would you rate your general health?” Conceptually, this is considered as a general health perception in Wilson and Cleary’s model.[22] The responses comprised the ordinal categories of ‘poor,’ ‘fair,’ ‘good’, ‘very good’ and ‘excellent’.

The main exposure periodontal status was evaluated at the clinical examination using a method modified from the examination manual used in the US National Health and Nutrition Examination Survey (NHANES) (2001).[23] The periodontal pocket depth and gingival recession were measured using the National Institute of Dental and Craniofacial Research periodontal probe that has 2-mm markings. Probing pocket depth (PPD) was defined as the distance from the free gingival margin to the bottom of the periodontal crevice/pocket. Gingival recession (REC) was defined as the distance from the cemento-enamel junction (CEJ) to the free gingival margin. All fractional millimetre measurements were rounded down to the nearest whole millimetre. The clinical attachment level (CAL) was calculated as the sum of PPD and REC for each site during the data management stage. Measurements were made at the mesio-buccal, mid-buccal and disto-buccal sides of all teeth. Three mutually exclusive categories of periodontal status were computed using the following definitions from the Centers for Disease Control and Prevention and the American Academy of Periodontology (CDC–AAP): severe periodontitis = two or more interproximal sites (not on the same tooth) with ≥ 6 mm CAL and at least one interproximal site with PD ≥ 5 mm; moderate periodontitis = at least two interproximal sites with ≥ 4 mm CAL (not on the same tooth) or at least two interproximal sites with ≥ 5mm PD (not on the same tooth); and no/mild periodontitis = neither moderate nor severe.

Seven mediators of food items (dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables and fruits) from the subsequent FFQ based on the National Nutrition Survey[19] were considered as mediators. For each food item, the average consumption frequency was recorded for the past 12 months. These items were collected on a 9-point scale ranging from ‘never, or less than once a month’ to ‘6+ times per day’.

Age, gender, smoking status, tooth-brushing habits, diabetes, alcohol consumption and social support were the control variables. Control variables were selected initially from a literature review of associations between periodontal status and nutrition, nutrition and self-rated general health, and periodontal status and general health. The critical level of $p \leq 0.20$[24] was then used to select the control variables in this study.

Age, tooth-brushing habits and alcohol consumption were used as a continuous variable with a range of 45–90 years, the average number of tooth-brushing times per day and the average number of standard alcohol drinks per day, respectively. Social support was also used as a continuous variable with a range of 12–60, using the Multidimensional Scale of Perceived Social Support Assessment, a 12-item scale of perceived social support from family and friends.[25] Respondents answered items on a 5-point Likert-type scale ('strongly disagree' to 'strongly agree'), scored 1–5. The total is the sum of all 12 items, and the possible range for the total is 12–60. Gender was dichotomised between male and female, diabetic status was coded based on whether or not a doctor had told them they had diabetes and smoking status was categorised as "currently smoke", "former smoker" and "never smoked".

2.3. Statistical analyses

Initially, the distribution of the outcome and mediator variables was assessed using the Kolmogorov–Smirnov test, and kurtosis and skewness were checked.

We then used multivariable regression analysis in three stages. First, we assessed the relationship of periodontal status to consumption of a different type of food. Then the effect of consumption of different types of food on general health was assessed, followed by the association of periodontal status to general health.

The hypothesis that periodontal status is associated with self-rated general health (SRGH) through the consumption of food (seven different types of food group) was tested in the mediation analysis, in accordance with recommendations by Baron and Kenny.[26] The analyses was performed as follows: first, we checked in the regression analysis if a direct effect (path *c*) between the independent variable (periodontal status) and the dependent variable (self-rated general health [SRGH]) was significant (see Fig. 1). Second, we checked if the independent variable predicted the proposed mediator (M) (path *a*). Third, the mediator was used as a predictor of the dependent variable (Y) (path *b*). Lastly, if non-zero relationships between paths *a*, *b* and *c* existed, we then checked the association of the independent variable to the dependent variable after controlling for mediators (path c′).

Full mediation exists when the effect of the independent variable on the dependent variable is no longer significant after including the mediator in the model. Partial mediation occurs when the relationship between the independent variable and dependent variable is

significantly reduced, but still significant when the mediator is included in the model. In order to test the significance of mediation, the Sobel test was performed for an indirect effect using Winnifred's Mediation Program (WIMP), which is based on Kris Preacher's website, <http://www.unc.edu/~preacher/sobel/sobel.htm>.

A non-parametric resampling procedure, bootstrapping for standard errors, was also conducted to test mediation, with this procedure not imposing the assumption of the normality of the sampling distribution. The bootstrapping for standard errors with 2000 resampling iterations was conducted using Mediation Macro for SPSS by Preacher and Hayes (2008).[27] Lastly, structural equation modelling (SEM) for mediation analysis was conducted using AMOS graphics, in which all three paths (paths *a*, *b* and *c* from Fig. 1) fit in a single model. The significance of the path coefficient was tested and compared in magnitude. If the indirect path was not significant, no mediation was found; if it was significant, we calculated the variance accounted for (VAF) to test the strength of the mediator. According to Hair et al. (2014), a VAF value greater than 80% is full mediation, a value 20%–80% is partial mediation, and a value less than 20%, although the indirect effect is significant, means that no mediation occurs.[28]. All analysis was performed using SPSS version 24.0.

3. Result

3.1. Response

In the NSAOH, a total of 14,123 adults responded to the CATI (49% response rate), and 5,505 were examined (44% of interviewed people who were invited to the examination). In the nutrition sub-study, a total of 1,218 persons were approached in New South Wales and Queensland, with 1,129 responding (92.7% response rate). Among them, 752 respondents to the nutrition sub-study were aged 45 years or over.

3.2. Sampling distribution

This study shows that around 34% of adult participants aged 45 years and over suffer from moderate to severe periodontitis. The Kolmogorov–Smirnov test indicated that several variables deviated from normal distributions ($p<0.05$). However, the skewness and kurtosis were between -1 to 1 and -3 to 3 (see Table 1). As also found from the graphical presentation, for all continuous variables, the histograms had the approximate shape of a

normal curve. The mean, standard deviation and correlations of main study variables are shown in Table 1.

3.3. Relations between Periodontitis, food items and self-rated general health

The multivariate linear regression model (see Table 2) showed that adults with severe periodontal status compared to those with moderate or less periodontal status consumed less frequently bread-cereal, sweet foods-snacks, mixed vegetables, vegetables, vegetables and fruits and more frequent consumption of dairy products and meat-fish-eggs

Those adults who consumed more dairy, bread-cereal, meat-fish-eggs and sweet foods-snacks again rated their general health as poor. Those who vegetables, fruits and mixed vegetables consumed more frequently rated their general health higher.

Lastly, adults with none/mild and moderate periodontal problems compared to those with severe periodontal problems rated their general health higher.

3.4. Mediation analysis

From Baron and Kenny's mediation analysis (see Table 2), a significant (p<0.005) relationship between periodontitis and all kinds of food groups is shown by model *a*. For model *b*, all food groups were significantly (p<0.001) associated with self-rated general health (SRGH). Moreover, for model *c*, periodontitis is significantly (p<0.001) associated with self-rated general health (SRGH). In model *c′*, we see that, after introducing food groups, both periodontitis and all food groups (except dairy) significantly (p<0.001) predicted self-rated general health (SRGH). However, from the Sobel test, it can be concluded that the association between periodontitis and SRGH was partially mediated by dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables and fruits (p<0.005).

From the bootstrapping test for standard errors, as implemented by Preacher and Hayes (2008), the bias correction confidence intervals (CIs) for all food groups included "0"; that is, they indicated that the indirect effect was not significant and that no mediation was established.[27]

From the SEM analysis (Table 3), a significant indirect association was found for mediators of bread-cereal, meat-fish-eggs and sweet foods-snacks. This indicated that the association between periodontitis and SRGH was partially mediated by bread-cereal, meat-fish-eggs and sweet foods-snacks.

From VAF, it was found that 35.7% of the effect of periodontitis on SRGH was explained by the consumption of bread-cereal. Again 35.7% of the effect of periodontitis on SRGH was explained by the consumption of meat-fish- eggs. Also, 39.3% of the effect of periodontitis on SRGH was explained by the consumption of sweet foods-snacks.

4. Discussion

This study showed that higher self-rated general health (SRGH) has positive correlations with the consumption of mixed vegetables, vegetables and fruits, and negative correlations with the consumption of dairy, bread-cereal, meat-fish-eggs and sweet foods-snacks.

In this study, an indirect effect of periodontitis was found on SRGH which is partially mediated by the consumption of the different kinds of food groups of bread-cereal, meat-fish-eggs and sweet foods-snacks, which was confirmed by both SEM and path analysis. That is, periodontal status has both direct and indirect effects on SRGH, but the direct effect was not mediated, whereas the indirect effect was transmitted through bread-cereal, meat-fish-eggs or sweet foods-snacks. Note that, with complete mediation, the independent variable had no direct effect on the dependent variable; its entire effect was indirect, (i.e., the entire effect was transmitted through the mediator variable). Therefore, 35.7% of the effect of periodontitis on SRGH was explained by the consumption of bread and cereal. The consumption of meat, fish and eggs also had the same effect of periodontitis on self-rated general health (SRGH). However, consumption of sweet foods-snacks (39.3%) had slightly more effect of periodontitis on self-rated general health (SRGH).

On the other hand, consumption of dairy products, mixed vegetables, vegetables or fruits did not mediate the relationship between periodontitis and SRGH; that is, the consumption of these food items (dairy products, mixed vegetables, vegetables or fruits) had no effect on the relationship between periodontitis and self-rated general health (SRGH). However, increasing the consumption of mixed vegetables, vegetables and fruits had a positive impact on general health. Having more periodontal problems may also be considered as a

risk factor as these respondents had a higher consumption of dairy which is associated with worse general health.

To explore the mediation effect, several different approaches (classical and modern) were tested in this study. Initially, the most classical approach of Baron and Kenny (1986)[26] was conducted, with this having been used by many researchers.[29-32] The main criticism of this method is that mediation may work out even when no statistical significance of the dependent and independent variables is found.[33] In addition, in Baron and Kenny's (1986) approach, after inclusion of the mediator, if the relationship stays significant, mediation may be partial or absent, which is not specified.[26] To identify the appropriate specifications of mediation, the Sobel test was popularised, with this test measuring whether an intermediation effect is significant.[33] The problem with Sobel's test is its dependence on distribution assumptions which may have an effect on the estimation of true *p*-values in smaller sample sizes. Researchers[27,34] suggested using bootstrapping for standard errors to address this problem, with this method appearing to have higher power in a small sample. In modern mediation analysis, SEM is one of the prominent methods that can fulfil the requirements of mediation analysis if it is considered necessary.[35] Structural equation modelling (SEM) uses a conceptual model, a path diagram and a system of linked equations (regression style) to capture complex and dynamic relationships within a web of observed and unobserved variables. It also provides a more appropriate inference framework for mediation analysis in a single analysis. Therefore, this study focused on the result from the SEM mediation model using the AMOS technique.

For the goodness-of-fit model, we have reported the Comparative Fit Index (CFI) values. Ideally, for a model that fits the data, the CFI would be close to 0.95 or higher.[36] We have not reported χ^2 or the root mean square error of approximation (RMSEA) because χ^2 is sensitive to a large sample size (n>250) for which it almost always indicates a poor fit[37] and the RMSEA worsens as the number of variables in the model increase.[38,39] Overall, given power and robustness, Hu and Bentler (1998) have demonstrated the CFI's strong performance.[40] The coefficient of determination (R^2) value for each model in this study is not strong, but these R^2 values are for the overall model, while this study is interested in the effect of the mediators in our predictive model. The goodness-of-fit evaluation using R^2 is somewhat subjective, with R^2 having no fixed guidelines [37]. The effect size (f^2) of the mediators (dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables,

vegetables and fruits) in the relationship between periodontitis and self-rated general health (SRGH) is small.

The strength of this study is its large and representative sample derived from the Australian National Survey of Adult Oral Health (NSAOH). We have used both classical and modern methods to analyse mediation.

Very few studies[41] have examined the role of nutrition as a mediator in the relationship between oral health and general health. These studies have only reviewed the literature in relation to oral conditions with nutrition or have only linked various nutrition variables and systemic disease, but relatively little work has been done on the hypothesised mediation model.

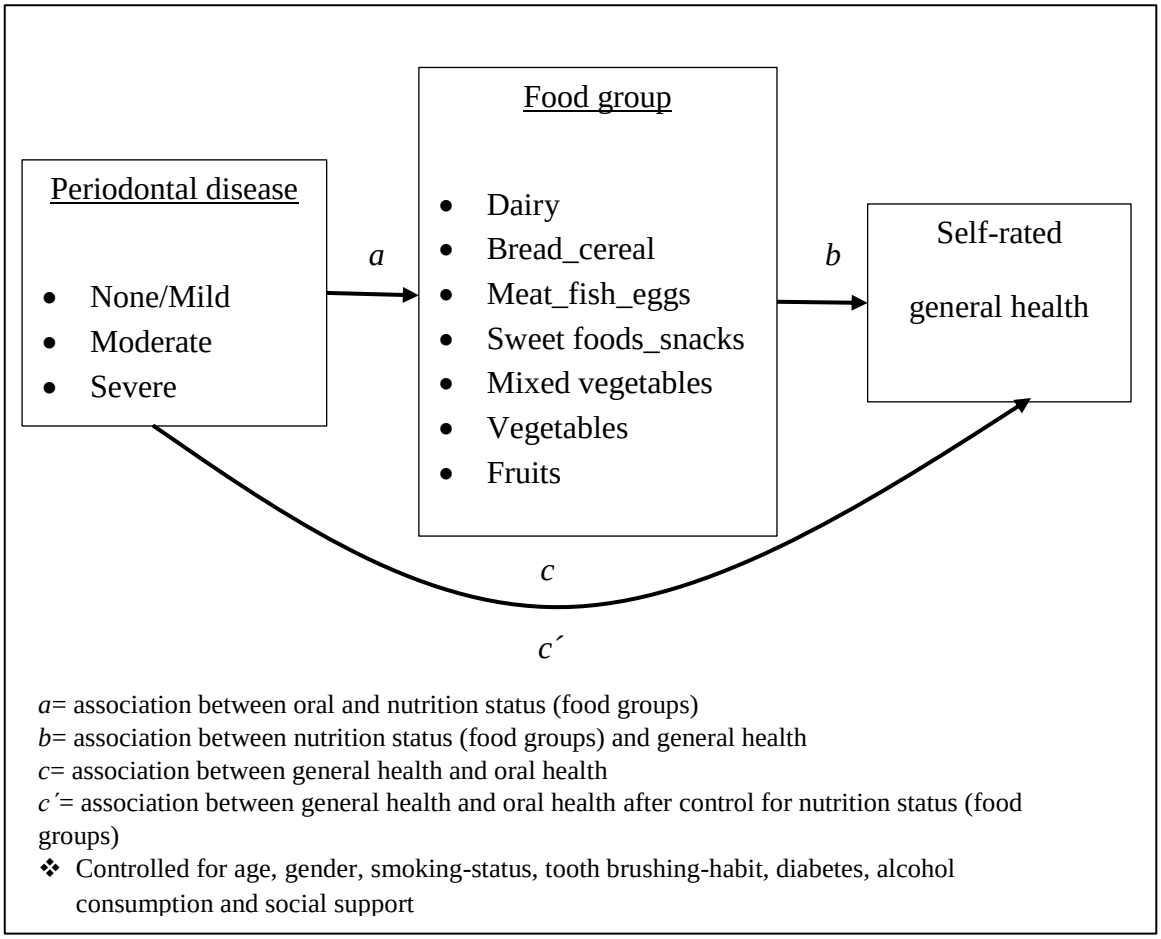
One limitation of this study is its cross-sectional design which makes it impossible to draw the causal relationships between periodontal status, different kinds of food groups and general health. While consideration of cause is an essential aspect of mediation, the aim of this study was not to investigate the causal relationship. Instead, the focus was on establishing whether mediation is supported when statistical associations are examined. In the current study, a less healthy and healthy food items were considered in the same food group. For example, all kind of dairy such as low fat and full fat dairy were considered as a "dairy" Sugary fruits, fruit juice and other all kind of fruits considered as a "fruits". Starchy vegetables, fried vegetables, oiled/mashed/baked vegetables, raw vegetables and cooked vegetables considered as 'vegetables'. Even good protein (fish), protein with saturated fat (red meat) and eggs considered in a same food group. However, according to initial research interest, overall food group was considered, further research could focus on less healthy and healthy food groups or consider nutrient variables, such as saturated fat, poly- or mono-fats, protein, carbohydrate, sugar, fibre, calcium, cholesterol, iron, folate, etc., from consumed food. In addition, the study had a lack of socio-economic status (SES)-related control variables. In the selection procedure for the control variables, the SES variables were insignificant; this study also focused more on the biological relationship between periodontal status and general health. An additional limitation of this study was that individual models were conducted for each mediator which may violate the overall assessment of direct and indirect effects. However, according to our interest, we could consider the mediators one at a time if the mediators did not have an effect on one another.[42] In this study, we have been initially interested in the effect of each food group as

a mediator, but further research could focus on the modelling of multiple mediators, thus considering the suggestion of Vansteelandt and Daniel.[43]

Hence, it can be concluded that general health may be improved for those older people with periodontitis by reducing the consumption of bread-cereal, meat-fish-eggs or sweet foods-snacks. The reduction of bread-cereal may be specified as a reduction of white bread or roll, English muffin, bagel or starchy white rice, etc. rather than high fibre bread cereal such as wholemeal/mixed grain bread or brown rice, etc. which are better for health. On the other hand, meat-fish-eggs may be better balanced by reducing red meat or fried fish rather than reducing cooked fish (steamed, baked or grilled). The reduction of sweet foods-snacks may be mainly linked to risk factors for the consumption of more free sugar and saturated fat.

Although the effect of periodontitis on SRGH was not mediated by the consumption of dairy, mixed vegetables, vegetables or fruits, the increased consumption of mixed vegetables, vegetables and fruits had a positive impact on general health.

The findings indicate the importance of considering periodontal status when developing nutrition intervention strategies for adults to maintain a healthy life.



a= association between oral and nutrition status (food groups)
b= association between nutrition status (food groups) and general health
c= association between general health and oral health
c´= association between general health and oral health after control for nutrition status (food groups)

- ❖ Controlled for age, gender, smoking-status, tooth brushing-habit, diabetes, alcohol consumption and social support

Figure 1: Conceptual model for mediation analysis**.**

Table 1: Mean (SD), Skewness, Kurtosis and correlations among main study variables**.**

Variable	Range	Mean (SD)	Skewness	Kurtosis	Correlations
					Self-rated general health
Self-rated general health	1-5	3.6 (0.96)	-0.36	-0.23	-
Dairy	0-51	25.6 (6.35)	-0.33	1.26	-0.028*
Bread-cereal	0-45	25.6 (5.51)	-0.49	2.63	-0.069*
Meat-fish-eggs	0-72	42.4 (8.55)	-0.22	2.23	-0.110*
Sweet foods-snacks	0-64	32.5 (8.39)	0.12	0.61	-0.045*
Mixed vegetables	1-15	12.4 (3.76)	-0.15	0.76	0.032*
Vegetables	1-107	61.9 (12.07	-0.41	2.23	0.032*
Fruits	1-64	28.4 (8.48)	0.19	0.71	0.025*

*p<0.001

Table 2: Regression analysis and multiple mediator models

Independent variable (X)	Mediator (M)	Dependent Variables	Path	B	Sobel Z	p	Degree of mediation
Periodontitis	-	Self-rated general health	*c*	0.13* 0.09*			
Periodontitis	Dairy	-	*a*	-0.31* -0.09*	-7.02 -2.39	p<0.001 p=0.016	Partial Mediation
-	Dairy	Self-rated general health	*b*	-0.003*			
Periodontitis	(Dairy)	Self-rated general health	*c´*	0.13* 0.09*			
Periodontitis	Bread-cereal	-	*a*	1.35* 0.43*	34.02 11.73	p<0.001 p<0.001	Partial Mediation
-	Bread-cereal	Self-rated general health	*b*	-0.01*			
Periodontitis	(Bread-cereal)	Self-rated general health	*c´*	0.15* 0.10*			
Periodontitis	Meat-fish-eggs	-	*a*	-0.75* -0.81*	-13.53 -14.46	p<0.001 p<0.001	Partial Mediation
-	Meat-fish-eggs	Self-rated general health	*b*	-0.01*			
Periodontitis	(Meat-fish-eggs)	Self-rated general health	*c´*	0.13* 0.09*			
Periodontitis	Sweet foods-snacks	-	*a*	2.20* 0.44*	33.57 8.14	p<0.001 p<0.001	Partial Mediation
-	Sweet foods-snacks	Self-rated general health	*b*	-0.007*			
Periodontitis	(Sweet foods-snacks)	Self-rated general health	*c´*	0.14* 0.09*			
Periodontitis	Mixed vegetables	-	*a*	0.05* 0.06*	-1.81 -1.96	p=0.050 p=0.049	Partial Mediation
-	Mixed vegetables	Self-rated general health	*b*	0.001*			
Periodontitis	(Mixed vegetable)	Self-rated general health	*c´*	0.13* 0.09*			
Periodontitis	Vegetables	-	*a*	6.31* 5.28*	-32.16 -32.08	p<0.001 p<0.001	Partial Mediation
-	Vegetables	Self-rated general health	*b*	0.003*			
Periodontitis	(Vegetables)	Self-rated general health	*c´*	0.12* 0.09*			
Periodontitis	Fruits	-	*a*	1.07* 0.54*	-12.34 -8.57	p<0.001 p<0.001	Partial Mediation
-	Fruits	Self-rated general health	*b*	0.002*			
Periodontitis	(Fruits)	Self-rated general health	*c´*	0.13 0.09			

*p<0.001

Table 3: Mediation results from Preacher and Hayes Bootstrap method and Structural Equation Model

Relationship	Bootstrap Bias Correction CI		SEM Result			Degree of mediation	VAF
	LL	UL	Direct without mediation	Direct with Mediation	Indirect effect		
General health depends on periodontitis (M: Dairy)	-0.0091	0.0052	0.016 (p=0.66)	0.02 (p=0.67)	0.000 (p= 0.76)	No mediation	-
General health depends on periodontitis (M: Bread-cereal)	-0.0012	0.0347	0.016 (p=0.66)	0.01 (p= 0.78)	0.006 (p= 0.045)	Partial mediation	35.71
General health depends on periodontitis (M: Meat-fish-eggs)	-0.0017	0.0303	0.016 (p=0.66)	0.01 (p=0.76)	0.005 (p=0.05)	Partial mediation	35.71
General health depends on periodontitis (M: Sweet foods-snacks)	-0.0028	0.0287	0.016 (p=0.66)	0.009 (p= 0.78)	0.006 (p= 0.015)	Partial mediation	39.28
General health depends on periodontitis (M: Mixed Vegetables)	-0.0036	0.0126	0.016 (p=0.66)	0.016 (p= 0.67)	0.000 (p=0.73)	No mediation	-
General health depends on periodontitis (M: Vegetables)	-0.0064	0.0132	0.016 (p=0.66)	0.016 (p= 0.65)	-0.001 (p= 0.42)	No mediation	-
General health depends on periodontitis (M: fruits)	-0.0021	0.0022	0.016 (p=0.66)	0.018 (p=0.63)	-0.00 (0.30)	No Mediation	-

For mediator dairy: CFI=1; R^2=0.075; f^2=0.001
For mediator bread-cereal: CFI=0.99; R^2=0.080; f^2=0.007
For mediator meat-fish-eggs: CFI=0.996; R^2=0.082; f^2=0.008
For mediator sweet foods-snacks: CFI=0.997; R^2=0.080; f^2=0.007
For mediator mixed vegetables: CFI=0.966; R^2=0.075; f^2=0.001
For mediator vegetables: CFI=0.989; R^2=0.075; f^2=0.001
For mediator fruits: CFI=0.998; R^2=0.075; f^2=0.001
*effect size $f^2=R^2_{included} - R^2_{excluded}/ 1- R^2_{included}$; LL=lower limit; UL=upper limit

4.3.3. References

1. Do LG, Slade GD, Roberts-thomson KF, Sanders AE. Smoking-attributable periodontal disease in the Australian adult population. Journal of Clinical Periodontology. 2008; 35: 398-404.

2. Irani FC, Wassall RR, Preshaw PM. Impact of periodontal status on oral health-related quality of life in patients with and without type 2 diabetes. Journal of dentistry. 2015; 43: 506-511.

3. Yoshihara A, Watanabe R, Hanada N, Miyazaki H. A longitudinal study of the relationship between diet intake and dental caries and periodontal disease in elderly Japanese subjects. Gerodontology. 2009; 26: 130-136.

4. Needleman I, McGrath C, Floyd P, Biddle A. Impact of oral health on the life quality of periodontal patients. Journal of Clinical Periodontology. 2004; 31: 454-457.

5. O' Dowd LK, Durham J, McCracken GI, Preshaw PM. Patients' experiences of the impact of periodontal disease. Journal of Clinical Periodontology. 2010; 37: 334-339.

6. Garcia RI, Henshaw MM, Krall EA. Relationship between periodontal disease and systemic health. Periodontology 2000. 2001; 25: 21-36.

7. Ritchie CS, Joshipura K, Hung HC, Douglass CW. Nutrition as a mediator in the relation between oral and systemic disease: Associations between specific measures of adult oral health and nutrition outcomes. Crit Rev Oral Biol Med. 2002;13: 291-300.

8. Budtz-Jørgensen E, Chung J-P, Rapin C-H. Nutrition and oral health. Best Practice & Research Clinical Gastroenterology. 2001; 15: 885-896.

9. Mattila KJ, Nieminen MS, Valtonen VV, et al. Association Between Dental Health And Acute Myocardial Infarction. BMJ: British Medical Journal. 1989; 298: 779-781.

10. D'Aiuto F, Parkar M, Nibali L, Suvan J, Lessem J, Tonetti MS. Periodontal infections cause changes in traditional and novel cardiovascular risk factors: Results from a randomized controlled clinical trial. American heart journal. 2006; 151: 977-984.

11. Osborn MO, Hornbuckle C, Stumbo P. Nutritional Evaluation of Food Intake Records of Periodontal Patients. Journal of periodontology. 1977; 48: 659-662.

12. Saito T, Shimazaki Y, Sakamoto M. Obesity and Periodontitis. The New England journal of medicine. 1998; 339: 482-483.

13. Javid ZA, Seal CJ, Heasman P, Moynihan PJ. Impact of a customised dietary intervention on antioxidant status, dietary intakes and periodontal indices in patients with adult periodontitis. Journal of Human Nutrition and Dietetics. 2014; 27: 523-532.

14. Callen BL, Wells TJ. Views of community-dwelling, old-old people on barriers and aids to nutritional health. Journal of nursing scholarship : an official publication of Sigma Theta Tau International Honor Society of Nursing / Sigma Theta Tau. 2003; 35: 257-262.

15. Laugero KD, Falcon LM, Tucker KL. Relationship between perceived stress and dietary and activity patterns in older adults participating in the Boston Puerto Rican Health Study. Appetite. 2011; 56: 194-204.

16. Nielsen SJ, Trak-Fellermeier MA, Joshipura K, Dye BA. Dietary fiber intake is inversely associated with periodontal disease among US adults.(Report)(Author abstract). The Journal of nutrition. 2016; 146: 2530.

17. Valeri L, Lin X, Vanderweele TJ. Mediation analysis when a continuous mediator is measured with error and the outcome follows a generalized linear model. Statistics in Medicine. 2014; 33: 4875-4890.

18. Slade GD, Spencer AJ, Roberts-Thomson KF. Australia's dental generations : the national survey of adult oral health 2004-06. Canberra: Australian Institute of Health and Welfare, 2007.

19. Australian Bureau of Statistics. National nutrition survey users' guide, 1995. Canberra: Australian Bureau of Statistics, 1998.

20. Griffin SO, Jones JA, Brunson D, Griffin PM, Bailey WD. Burden of oral disease among older adults and implications for public health priorities. The American Journal of Public Health. 2012; 102: 411-418.

21. Krause NM, Jay GM. What Do Global Self-Rated Health Items Measure? Medical Care. 1995; 32: 930-942.

22. Baker SR, Pearson NK, Robinson PG. Testing the applicability of a conceptual model of oral health in housebound edentulous older people. Community dentistry and oral epidemiology. 2008; 36: 237-248.

23. Center for Disease Control . National Health and Nutrition Examination Survey. Dental Examiners Procedures Manual .2002. Atlanta, GA: CDC., 2001.

24. Giovâni FDD, Markus VN, Diego ASS, Pedro Curi H, Deborah CM, Marco AP. Physical activity indicators in adults from a state capital in the South of Brazil: a comparison between telephone and face-to-face surveys. Cadernos de saude publica. 2013; 29: 2119-2129.

25. Zimet GD, Dahlem NW, Zimet SG, Farley GK. The Multidimensional Scale of Perceived Social Support. Journal of Personality Assessment. 1988; 52: 30-41.

26. Baron RM, Kenny DA. The Moderator-Mediator Variable Distinction in Social Psychological Research: Conceptual, Strategic, and Statistical Considerations. Journal of Personality and Social Psychology. 1986; 51: 1173-1182.

27. Preacher K, Hayes A. Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. Behavior Research Methods. 2008; 40: 879-891.

28. Hair JF, Hult GTM, Ringle CM, Sarstedt M. A Primer on Partial Least Squares structural Equation Modeling. Thousand Oaks: Sage, 2014.

29. Gawęda Ł, Prochwicz K, Cella M. Cognitive biases mediate the relationship between temperament and character and psychotic-like experiences in healthy adults. Psychiatry Research. 2015; 225: 50-57.

30. McLeod ER, Campbell KJ, Hesketh KD. Nutrition knowledge: a mediator between socioeconomic position and diet quality in Australian first-time mothers. Journal of the American Dietetic Association. 2011; 111: 696.

31. Stanley AM, Suzanne M. Psychological, Economic, and Social Mediators of the Education-Health Relationship in Older Adults. Journal of Aging and Health. 2002; 14: 527-550.

32. Watson HJ, Raykos BC, Street H, Fursland A, Nathan PR. Mediators between perfectionism and eating disorder psychopathology: shape and weight overvaluation and conditional goal-setting.(Report). The International Journal of Eating Disorders. 2011; 44: 142-149.

33. Pardo A, Román M. Reflections on the Baron and Kenny model of statistical mediation. Anales de psicologia. 2013; 29: 614-623.

34. Shrout PE, Bolger N. Mediation in experimental and non experimental study: New procedure and recomendations. Phychological Method. 2002; 7: 422-455.

35. Afthanorhan A, Ahmad S, Safee S. Moderated mediation using covariance-based structural equation modeling with amos graphic: volunteerism program. Advances in Natural and Applied Sciences. 2014; 8: 108+.

36. Hu L-T, Bentler PM. Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Structural Equation Modeling: A Multidisciplinary Journal. 1999; 6: 1-55.

37. Iacobucci D. Structural equations modeling: Fit Indices, sample size, and advanced topics. Journal of Consumer Psychology. 2010; 20: 90-98.

38. Fan X, Sivo SA. Sensitivity of Fit Indexes to Misspecified Structural or Measurement Model Components: Rationale of Two-Index Strategy Revisited. Structural Equation Modeling. 2005; 12: 343-367.

39. Kenny DA, McCoach DB. Effect of the Number of Variables on Measures of Fit in Structural Equation Modeling. Structural Equation Modeling. 2003; 10: 333-351.

40. Hu L-T and Bentler PM. Fit Indices in Covariance Structure Modeling: Sensitivity to Underparameterized Model Misspecification. Psychological Methods. 1998; 3: 424-453.

41. Ritchie CS, Kinane DF. Nutrition, inflammation, and periodontal disease. Nutrition. 2003; 19: 475-476.

42. VanderWeele T, Vansteelandt S. Mediation Analysis with Multiple Mediators. Epidemiologic Methods. 2014; 2: 95-115.

43. Vansteelandt S, Daniel RM. Interventional Effects for Mediation Analysis with Multiple Mediators. Epidemiology (Cambridge, Mass). 2017; 28: 258-265.

4.3.4 Appendix

Table: The table describes the food items that included in each food group

Food group	Food items
Dairy	Flavored milk, milk as a drink, milk on breakfast cereals, milk in hot beverages, cream or sour cream, ice-cream, yoghurt, cottage or ricotta cheese and cheddar and other cheeses
Bread-cereal	White bread or rolls, wholemeal/mixed grain bread or rolls, english muffin, bagel or crumpet, dry or savoury biscuits and crispbread, muesli, cooked porridge, breakfast cereal, rice (white or brown) and pasta-noodles
Meat-fish-eggs	Meat food items, four kinds of fish item include canned fish (tuna, salmon and sardines), cooked fish (steamed, baked and grilled), fried fish and other seafood, and egg
Sweet-snacks	Cakes that includes muffins, scones, and pikelets, sweet pies or sweet pastries, other puddings or desserts, plain sweet biscuits, cream/chocolate biscuits, meat pie, sausage roll or savoury pastry, pizza, hamburger, chocolate (including chocolate bars), other confectionary, jam-marmalade-syrup-honey**,** peanut butter and other nut spreads, vegemite, marmite and promite, nuts and potato chips, corn chips, twisties
Mixed vegetables	Green/mixed salad in a sandwich, as a side salad/with a main meal, stir-fried or mixed vegetables and vegetable casserole
Vegetables (including fresh, frozen and tinned)	Potato (boiled, mashed or baked), hot chips, pumpkin, sweet potato, peas, green beans, silverbeet/spinach, broccoli, cauliflower, brussel sprouts/cabbage/coleslaw, carrots, zucchini/ eggplant/squash, capsicum, sweetcorn or corn on the cob, mushrooms, tomatoes, lettuce, celery/cucumber, onions or leeks, soybeans or tofu, baked beans, and other beans-lentils
Fruits	Apple/pear, orange/mandarin/grapefruit, banana, stone fruits (peach, nectarine, plum, apricot), mango or paw-paw, pineapple, grapes or berries, melon (water-, rock-, honeydew-), lemon juice and other fruit juices or fruit drinks

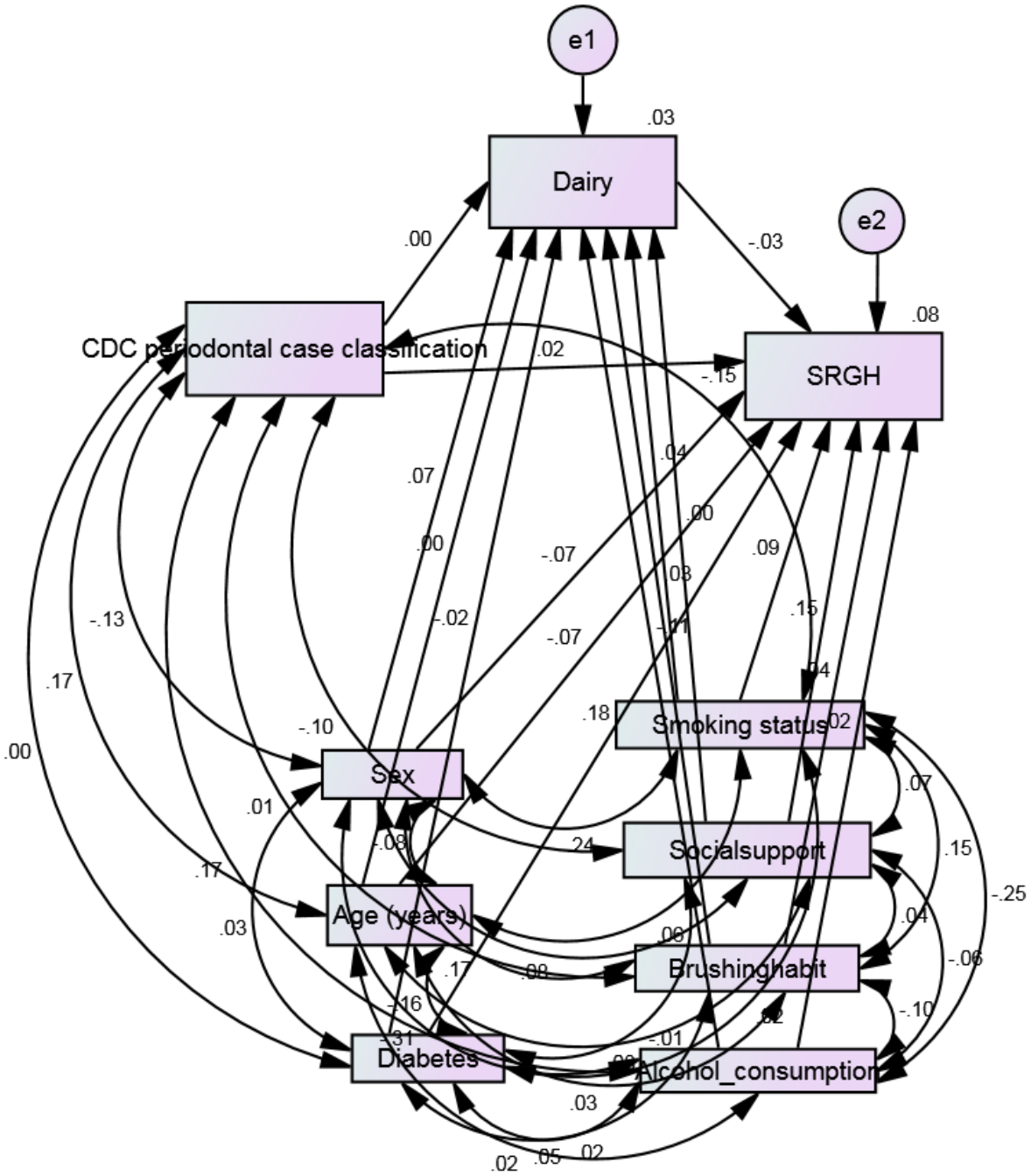


Figure A1: Structural equation model with mediator ‘Dairy’

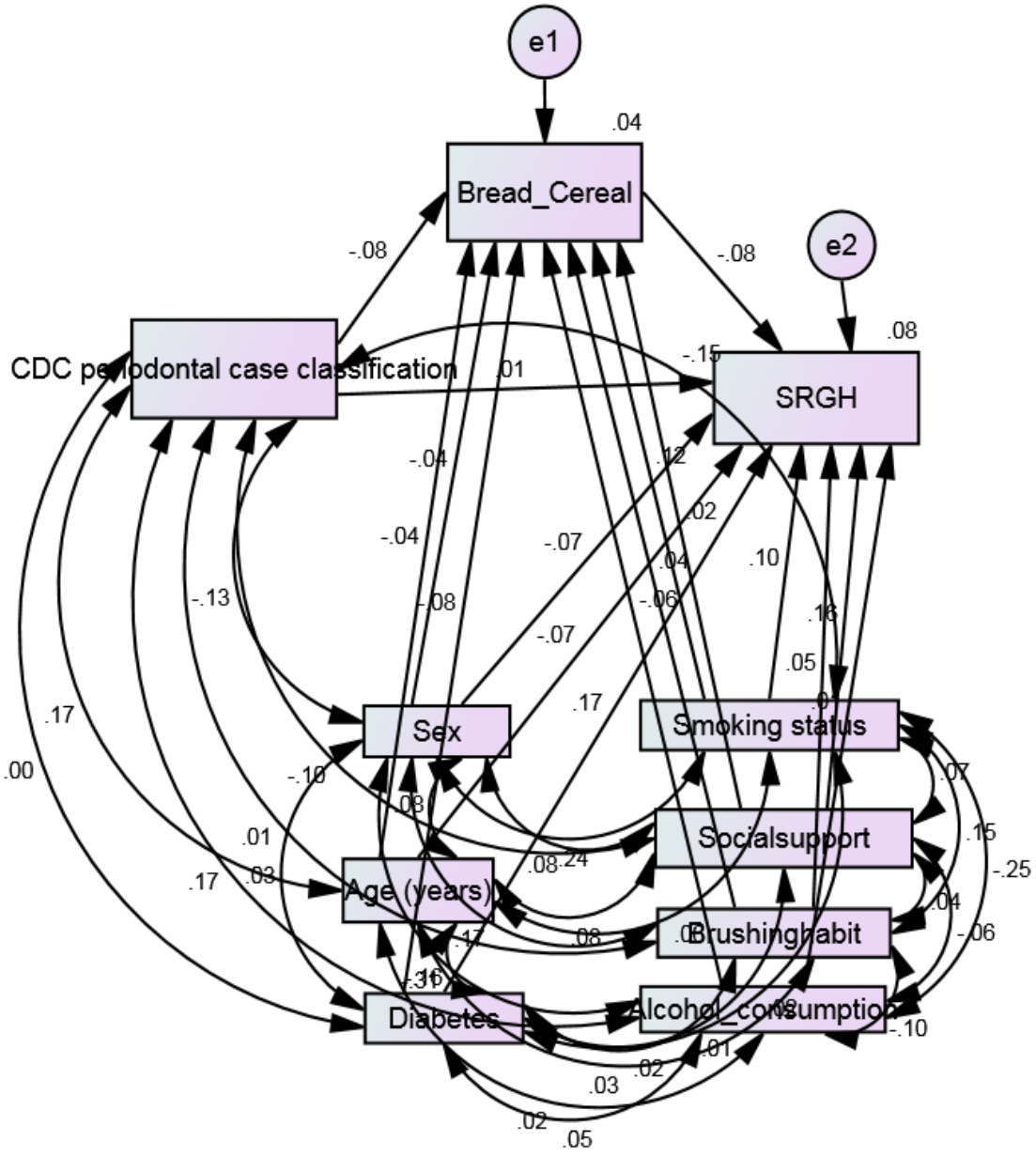


Figure A2: Structural equation model with mediator ‘Bread-cereal’

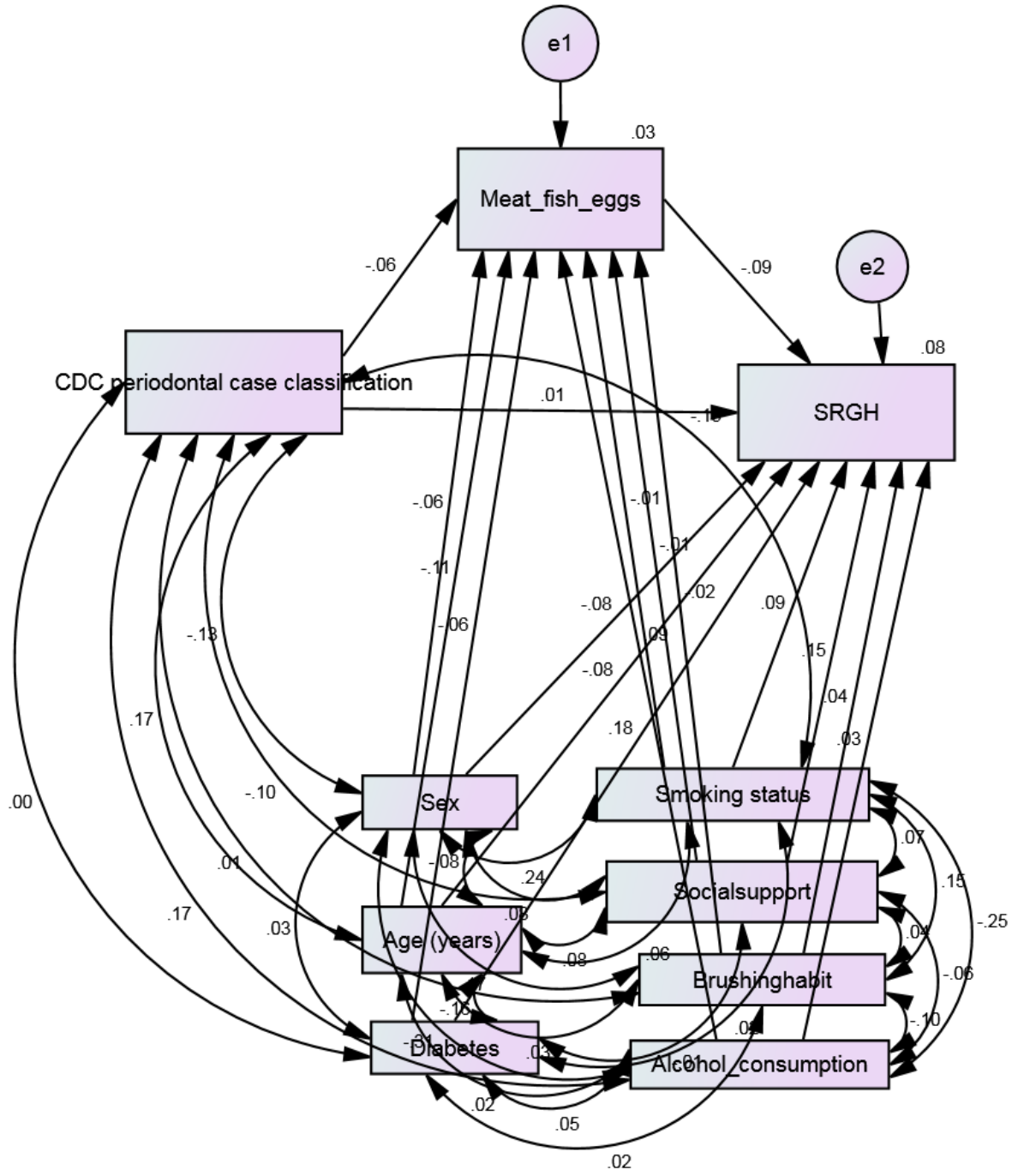


Figure A3: Structural equation model with mediator ‘Meat-fish-eggs’

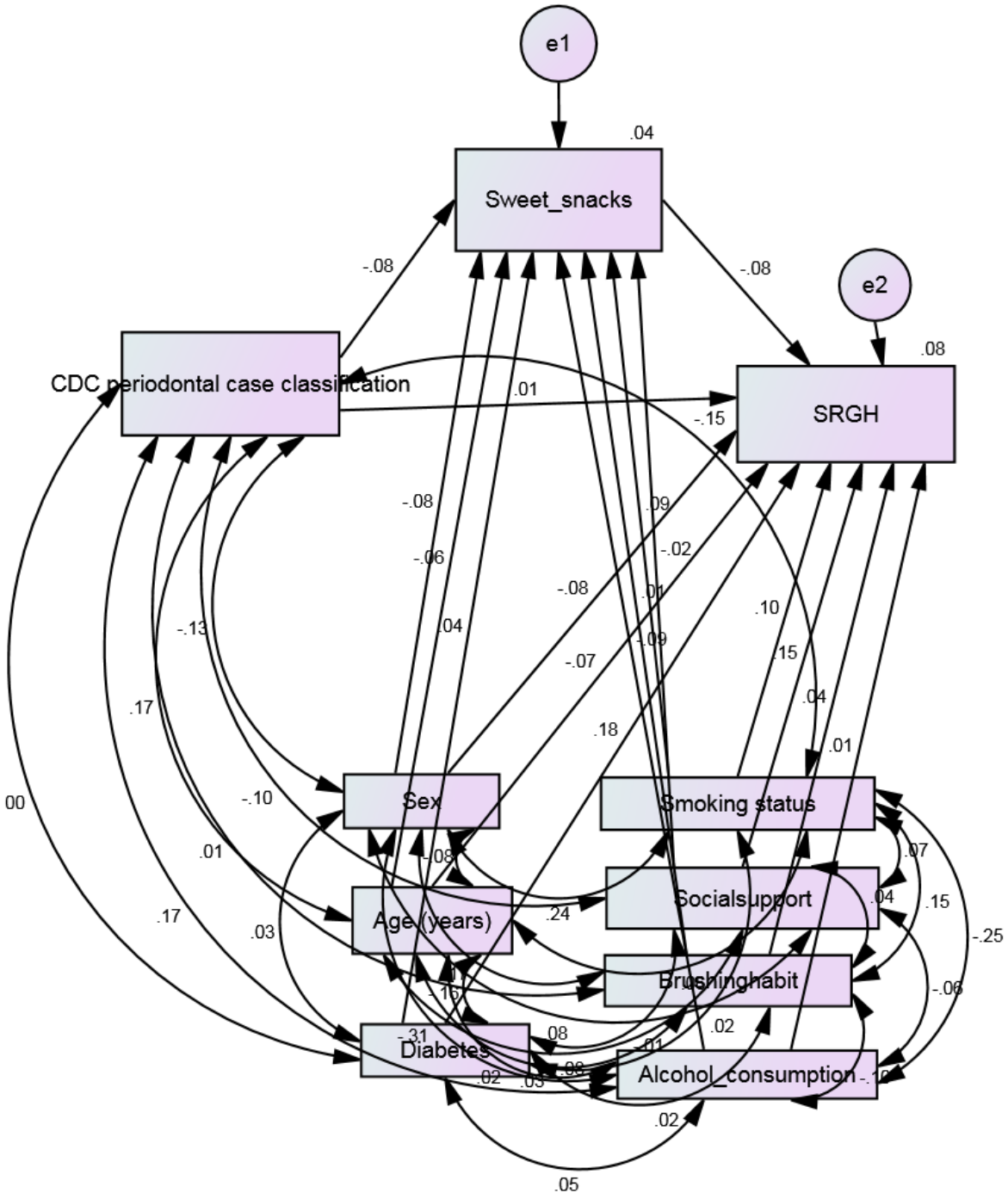


Figure A3: Structural equation model with mediator ‘Meat-fish-eggs’

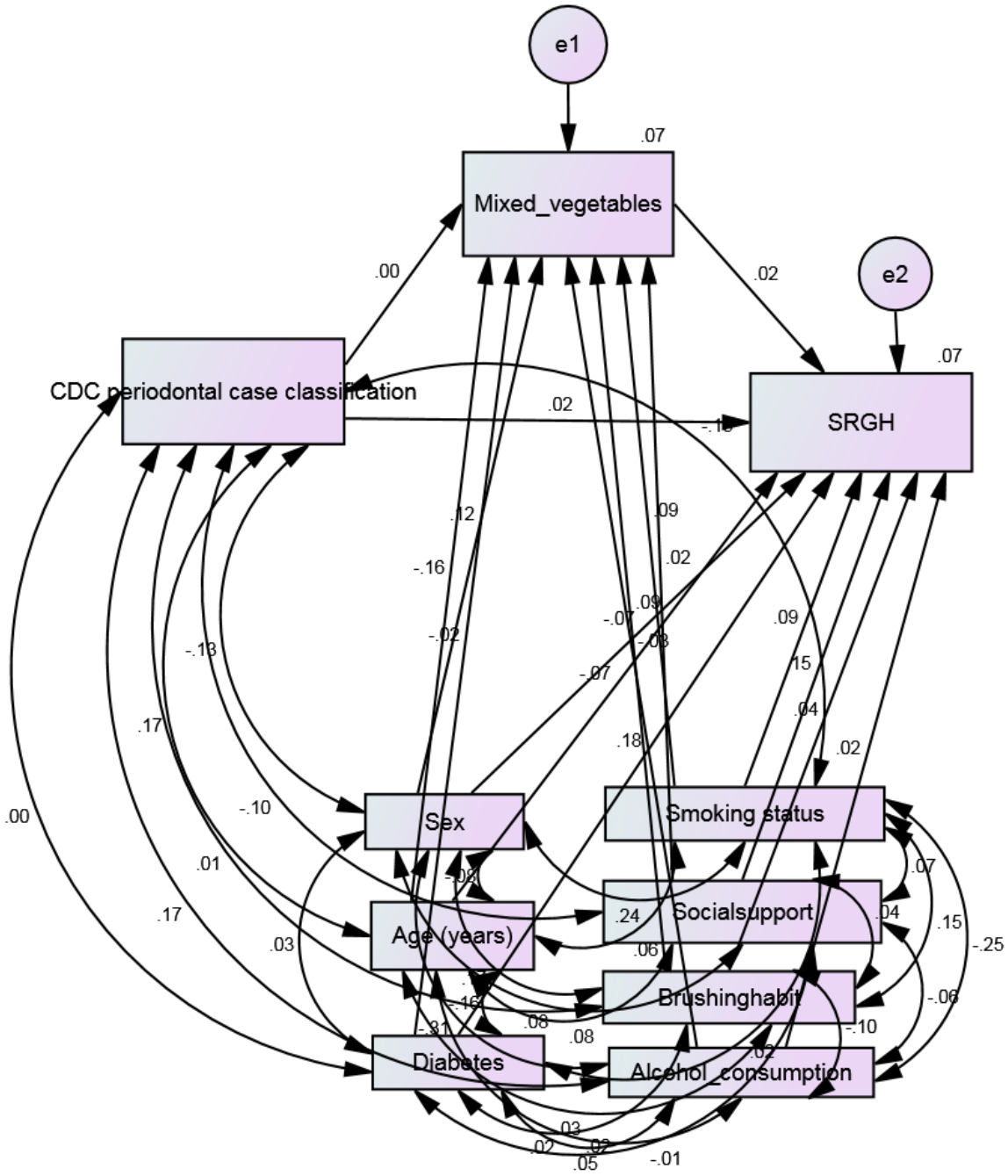


Figure A5: Structural equation model with mediator ‘Mixed vegetables’

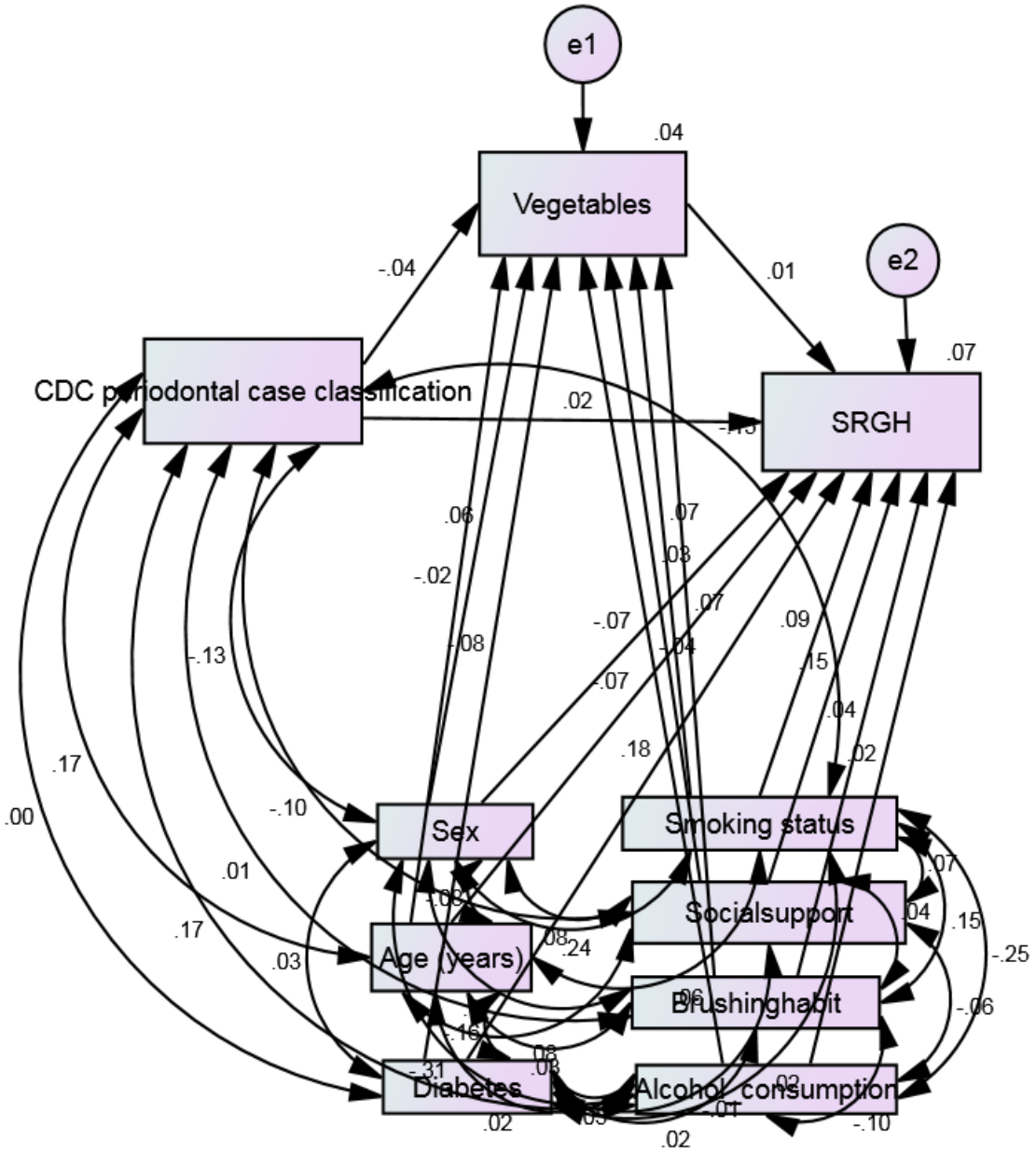


Figure A6: Structural equation model with mediator ‘Vegetables’

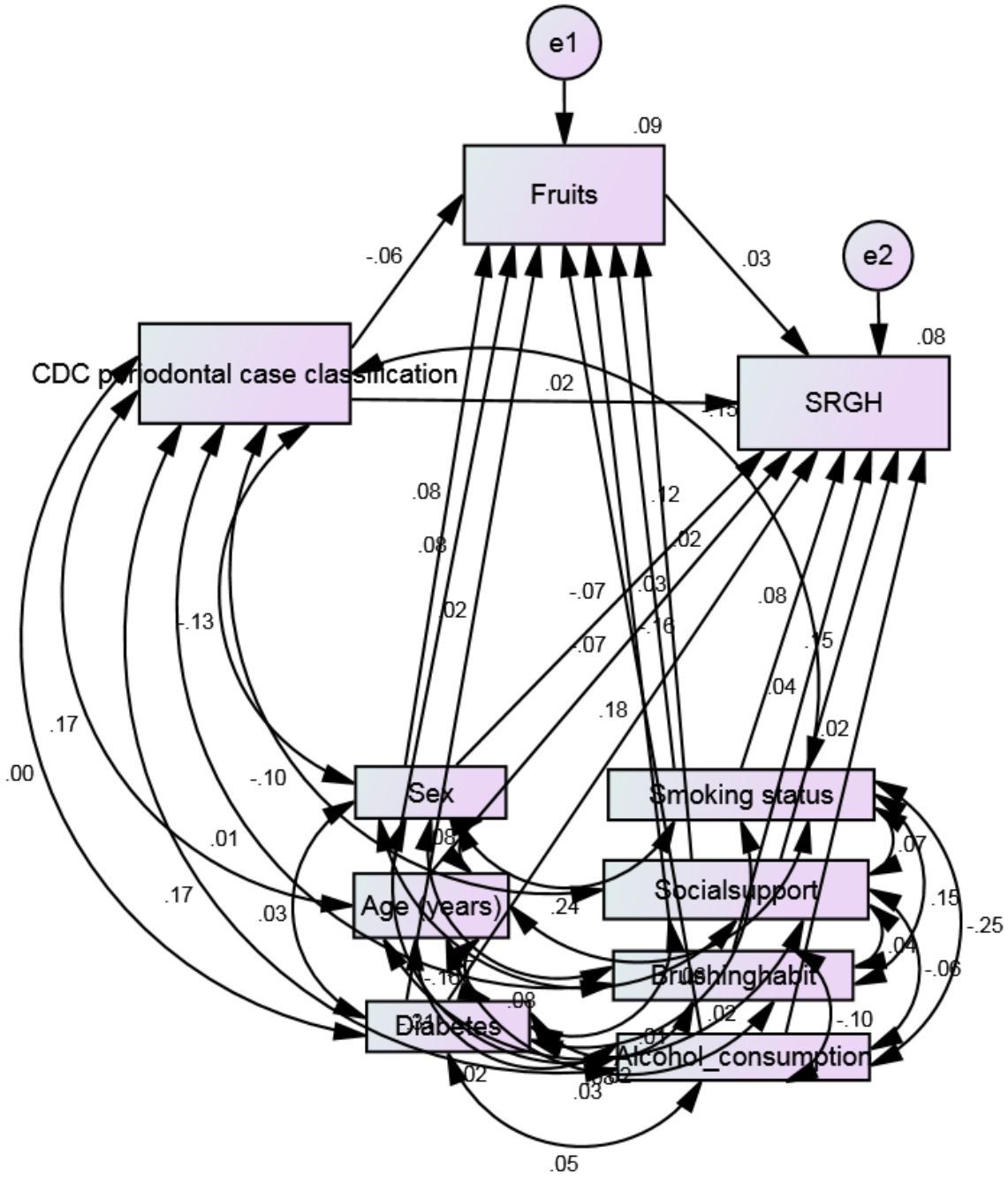


Figure A7: Structural equation model with mediator ‘Fruits’

4.4. Research Article 2

Islam S, Brennan DS, Roberts-Thomson K. Assessing Food Intake as a Mediator between Oral (Missing Teeth and OHIP) and General Health. *Australian Dental Journal*. [Submitted 8 May 2018]

Highlights:

- This article evaluates the mediation effects of food consumption on the relationship between oral health (missing teeth and OHIP score) and self-rated general health in Australian adults.
- Based on the research, we provide suggestions for all health care professionals to develop their understanding of the potential relationships among food consumption, oral health (missing teeth and OHIP) and self-rated general health and reinforce the importance to them of considering dietary guidelines so they can design oral health policy for adults with missing teeth and higher OHIP scores and, consequently, can design general health policy.

- Article has been submitted to *Australian Dental Journal* (see Appendix)

4.4.1. Statement of Authorship

Statement of Authorship

Title of Paper	Assessing Food Intake as a Mediator between Oral (Missing teeth and OHIP) and General Health
Publication Status	☐ Published ☐ Accepted for Publication ☑ Submitted for Publication ☐ Unpublished and Unsubmitted work written in manuscript style
Publication Details	Islam S, Brennan DS, Roberts-Thomson K. Assessing Food Intake as a Mediator between Oral (Missing teeth and OHIP) and General Health. [Australian Dental Journal] Submitted 8 May 2018.

Principal Author

Name of Principal Author (Candidate)	Saima Islam		
Contribution to the Paper	Designed the analytic plan and objective for the paper. Performed literature search, planned overall analysis, performed analysis and interpreted the findings. Wrote the manuscript.		
Overall percentage (%)	80%		
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	11 May 2018

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	David S Brennan		
Contribution to the Paper	Supervised the development and progress of the study. Contributed to the study design, and overall analysis strategy. Provided intellectual content and revised the manuscript		
Signature		Date	11 May 2018

Name of Co-Author	Kaye Roberts-Thomson		
Contribution to the Paper	Supervised the development of the study and revised the manuscript.		
Signature		Date	11 May 2018

Please cut and paste additional co-author panels here as required.

4.4.2. Submitted article

The article presented on pp 89-126 shows the mediation effects of food consumption in relation between oral health (missing teeth and OHIP score) and self-rated general health in Australian adults. This article has been submitted to the *Australian Dental Journal*, and is provided in the form submitted to the journal.

Assessing Food Intake as a Mediator between Oral (Missing teeth and OHIP) and General Health

Author

Saima Islam [1]

David S Brennan[1]

Kaye Roberts-Thomson[1]

[1]Australian Research Centre for Population Oral Health, Adelaide Dental School,

The University of Adelaide, South Australia, Australia.

Correspondence:

[1]AHMS, Level 9, 57 North Terrace, Adelaide SA 5000

Tel +61 8 8313 4048 Fax: +61 8 8313 3070

Email: Saima.islam@adelaide.edu.au

Running Head: Oral and general health

Acknowledgments: The research reported in this paper is a study of the Australian Primary Health Care Research Institute (APHCRI), which is supported under the Australian Government's Primary Health Care Research, Evaluation and Development Strategy. The information and opinions contained in it do not necessarily reflect the views or policy of the Australian Primary Health Care Research Institute or the Department of Health

Key words: Food Intake, Missing teeth, OHIP, Self-rated general health, Mediation.

No Conflict of interest to declare

Abstract

Background: Evaluate the association of oral health with general health and test whether food intake mediates the relationship. **Method**: Data were collected in 2004–06 from a sample of adults from New South Wales and Queensland, using a computer-assisted telephone interview (CATI), oral examination, and completion of a mailed questionnaire and a food frequency questionnaire (FFQ). Self-rated general health was the outcome variable, while the Oral Health Impact Profile (OHIP) score and missing teeth were explanatory variables, with food groups (dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables and fruits) as mediators. Baron and Kenny's (1986) mediation analysis was initially performed, followed by Sobel's (1982) test. Lastly, bootstrapping for standard errors and structural equation modelling (SEM) were conducted. **Result:** A total of 1,129 persons responded (92.7% response rate), with 62.6% aged 45+ years. Worse oral health was associated with worse general health (for OHIP score and missing teeth, β= -0.027 and -0.01, respectively; p<0.001). The Baron and Kenny and Sobel tests showed the associations were partially mediated by food intake (Sobel test: for all mediators p<0.001). For both explanatory variables, bootstrap results were indicative of no mediation. The SEM analysis showed p=0.04 for mixed vegetables and for the explanatory variable OHIP score, but variance accounted for (VAF) =1.8%, indicating no mediation. **Conclusion**: Worse oral health predicts worse general health, but this association was not mediated by food consumption

Assessing Food Intake as a Mediator between Oral (Missing teeth and OHIP) and General Health

1. Introduction

'Oral health'– the health of the teeth and mouth – is an important determinant of nutritional intake and thus part of overall health. Both oral health and general health are closely related. Therefore, maintaining good oral health can contribute to better general health and thus improve the quality of life (QoL).[1] On the other hand, lack of oral hygiene, missing teeth and tooth loss can have a negative influence on people's quality of life.[1]

The impact of oral health conditions on general health has been established in many studies.[2-6] However, quantifying the relationship between oral health and general health, the remaining number of teeth or tooth loss have been mostly used as measures of oral health.[5-8] According to the literature, tooth loss in adults can increase the risk of cardiovascular diseases and gastrointestinal disorders[9,10] in later life. Tooth loss can also increase the risk of electrocardiographic abnormalities, hypertension, heart failure, ischaemic heart disease, stroke and aortic valve sclerosis[11-13], and even increase the risk of chronic kidney disease.[14] Adults with higher levels of tooth loss can have decreased daily function, physical activity and physical domains of their health-related quality of life.[2,15]

The Oral Health Impact Profile (OHIP-14) is one of the most widely used instruments for measuring the oral health-related quality of life amongst adults.[16] As previously discussed, the number of teeth remaining or the number of missing teeth have mostly been used to assess oral health, but today the level of tooth loss is declining[17] as adults are retaining their natural dentition.[18] As a result, the number of teeth present in the mouth may give an overestimation of masticatory potential for any given person as this number does not take into account the functional arrangement of the teeth.[19] Therefore, parallel to the number of missing teeth, the OHIP-14 score has been introduced as a measure of oral health to capture the impact of oral health problems.

Oral health and nutrition status are associated in various ways. Tooth loss, poorly fitted dentures and poor gingival health eventually alter food intake and increase the risk of the negative effects of nutrition status for older people.[5,20,21] Decreased chewing ability has been found to affect eating habits[22-26] and result in individuals being less likely to meet the recommendations for the consumption of vegetables, dark green vegetables, orange

vegetables and legumes and more likely to consume calories from solid fats, alcohol and added sugar.[20] The oral health-related impact has a negative association with chewing ability[18], which causes an alteration in food choice.[19,27,28]. On the other hand, sugar-sweetened beverages are dietary sources of sugar that are factors in caries development and leading to tooth loss [72.]

General health, the functional ability of an individual, is dependent on nutrition intake. Some reports[29,30] state that poor dietary habits in older age increase the rate of developing chronic health problems. Other studies have found that lower intake of protein, fruit, vegetables, fibre and omega-3 fatty acids and higher intake of carbohydrate and food groups characterised by salty snacks, sweet foods and high Glycaemic Index (GI) foods affect physical activity patterns and the development of chronic health diseases.[30] On the other hand, a diet with less fat, saturated fat and cholesterol, and more carbohydrate, fibre, vitamins (especially folate, vitamins C and E, and β-carotenes) and minerals (iron and zinc) may be advisable not only to improve the general health of the elderly but also to improve their cognitive function.[31] That is, the improvement of eating habits was found to be associated with an improvement of the quality of life and maintenance of health.[32-34]

The concept of the relationship between oral health and general health has become an integral part of health research and they have been shown to be substantially connected. This has also raised the vital question of how different kinds of food consumption affect this relationship. Therefore, the purpose of this study is to explore the potential association between oral health status (number of missing teeth and OHIP score) and general health and to test whether the intake of different food groups mediates the relationship for adults.

Mediation analysis explores the role of intervening variables (mediators) in an observed relationship between an exposure variable and an outcome variable, rather than hypothesising only a direct relationship between the independent variable and the dependent variable. A mediational model (also called a ‘mediation model’) hypothesises that the exposure variable affects the mediator variable which, in turn, affects the outcome variable.[35] The impact of mediation analysis in this current study extends the previous research as it explicitly measures the mediation effect to provide a complete assessment of the relationship between oral health and general health.

In practice, dental professionals and health professionals seek to improve the health of their patients. Explaining this relationship might be helpful to nutritionists in developing dietary

guidelines which would assist health professionals to design oral health policy and, consequently, general health policy.

2. Method

2.1. Participants and data collection

Data for this study were derived from the 2004–2006 Australian National Survey of Adult Oral Health (NSAOH).[36] Study participants were selected at random using a multistage, stratified clustered sample selection procedure with a sampling frame compiled from listed telephone numbers in the Electronic White Pages (EWP) database.[36] Information was collected by a computer-assisted telephone interview (CATI) followed by an oral epidemiological examination, and completion of a mailed questionnaire and then a food frequency questionnaire (FFQ). An initial letter explaining the purpose of the survey was mailed to participants selected from sampled telephone numbers, approximately 10 days prior to dialling them. The telephone interview collected information on socio-demographic characteristics and on several health-related factors including smoking status. People who reported they were dentate were invited to participate in an oral epidemiological examination. Following the epidemiological examination, a questionnaire was mailed to all examined people containing information such as psycho-social variables. The subsequent FFQ collected data on the consumption of specific food items that included nine types of dairy, nine types of bread and cereal, 21 types of meat, fish and eggs, 15 types of sweet foods and snacks, four types of mixed vegetables, 25 types of vegetables and eight types of fruits, based on the items used in the National Nutrition Survey.[37] The food groups reflect the dietary guidelines for Australian and the Recommended Dietary Intake for use in Australia reviewed by the National Health and Medical Research Council (NHMRC) [37].

Tooth loss is age related and increases with age[38,39] as does the risk of chronic conditions.[40] As chronic health problems take time to develop and may not be noticeable among those of younger ages, we considered older adults aged 45 years and above as participants in this study. The details of participation in the study, together with descriptive findings, have been reported elsewhere.[36]

2.2. Study variables

Self-ratings of health were assessed using single-item global ratings measured on 5-point Likert scales[41], which included the question "how would you rate your general health?" Conceptually, this is considered as a general health perception in Wilson and Cleary's model.[42] The responses comprised the ordinal categories of 'poor', 'fair', 'good', 'very good' and 'excellent'.

The explanatory variable "number of missing teeth" was derived from the variable "number of teeth present", calculated from adding two variables "number of remaining teeth in your upper jaw" and "number of remaining teeth in your lower jaw", collected during the computer-assisted telephone interview (CATI).

The OHIP-14 was the instrument used to measure the impact of oral health on the quality of life.[43]. The explanatory variable "OHIP score" was derived from the mailed questionnaire. The questionnaire comprised 14 questions, corresponding to seven dimensions: functional limitation, pain, psychological discomfort, physical disability, psychological disability, social disability and handicap. Five answers were possible for each question, using the Likert-type scale: 'never', 'hardly ever', 'occasionally', 'fairly often' and 'very often'.[6]

The severity of the impact of oral health could be calculated by the sum of ordinal responses where 'never' is coded as 0, 'hardly ever 'as 1, 'occasionally' as 2, 'fairly often' as 3 and 'very often' as 4.This meant that a participant could have an OHIP-14 severity ranging from 0–56.[43] Higher OHIP-14 scores indicated the greater impact of dental problems.[44]

Seven groups of food items (dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables and fruits) from the FFQ were considered as mediators. For each of the food items, the average consumption frequency was recorded for the previous 12 months. The data for these items were collected on a 9-point scale ranging from 'never, or less than once a month' to '6+ times per day'.

Age, gender, tooth-brushing habits, diabetes, alcohol consumption and social support were the control variables. Control variables were selected initially from the review of the literature on the associations between the number of missing teeth and nutrition, nutrition

and self-rated general health, and the number of missing teeth and self-rated general health. The critical level of $p \leq 0.20$[45] was then used to select the control variables in this study. Age, tooth-brushing habits and alcohol consumption were used as continuous variables with ranges from 45–90 years, average number of tooth-brushing times per day, and the average number of standard alcohol drinks per day. Social support was also used as a continuous variable with values ranging from 12–60, using the Multidimensional Scale of Perceived Social Support Assessment, a 12-item scale of perceived social support from family and friends.[46] Respondents provided answers to items on a 5-point Likert-type scale ('strongly disagree' to 'strongly agree'), scored from 1–5. The total was the sum of all 12 items, with a possible range for the total of 5–60. Gender was dichotomised between male and female, and diabetes status was coded based on whether or not a doctor had told the respondent that they had diabetes.

2.3. Statistical analyses

Initially, the study assessed the variable distribution using the Kolmogorov–Smirnov test, and we then checked kurtosis and skewness.

Multivariate regression analyses were then used in three stages. First, we assessed the effect of missing teeth status and Oral Health Impact Profile (OHIP-14) score in relation to the consumption of different types of food. We then assessed the relationship between the consumption of different types of food and general health. Lastly, the association of the number of missing teeth and the OHIP score with general health was tested.

The hypothesis that oral health (number of missing teeth and OHIP-14 score) is related to general health (self-rated general health [SRGH]) through the consumption of food (seven different types of food groups) was tested in the mediation analysis, according to Baron and Kenny's (1986) recommendations.[47] The analyses were performed as follows: first, we checked in the regression analysis if a direct effect (path *c*) between the independent variable (number of missing teeth or OHIP score) and the dependent variable (self-rated general health [SRGH]) was significant (see Fig. 1). Second, we checked if the independent variable predicted the proposed mediator (M) (path *a*). Third, the mediator

was used as a predictor of the dependent variable (Y) (path *b*). Lastly, if non-zero relationships existed between paths *a*, *b* and *c*, then we checked the association of the independent variable to the dependent variable after controlling for the mediators (path *c*′).

Full mediation exists when the effect of the independent variable on the dependent variable is no longer significant after including the mediator in the model. Partial mediation occurs when the relationship between the independent variable and the dependent variable is significantly reduced but still significant when the mediator is included in the model. If Baron and Kenny's (1986) method for mediation analysis did not provide the significance level of mediation, to test this, Sobel's (1982) test was performed to test for an indirect effect using Winnifred's Mediation Program (WIMP), which is based on Kris Preacher's website <http://www.unc.edu/~preacher/sobel/sobel.htm>.

A non-parametric resampling procedure, bootstrapping, was also conducted to test for mediation, with this procedure not imposing the assumption of the normality of the sampling distribution. The bootstrapping for standard errors procedure with 2000 resampling iterations was conducted using Mediation Macro for SPSS by Preacher and Hayes (2008).[48] Lastly, structural equation modelling (SEM) for mediation analysis was conducted using AMOS graphics, in which all three paths (paths *a*, *b* and *c* from Fig. 1) were fit at the same time in a single model. The significance of the path coefficient was tested and compared in magnitude. If the indirect path was not significant, no mediation existed; if it was significant, we calculated the variance accounted for (VAF). According to Hair et al. (2014), a VAF value of greater than 80% is full mediation, a value 20%–80% is partial mediation and a value less than 20%, although the indirect effect is significant, means no mediation exists.[49] All analyses was performed using SPSS version 24.0.

3. Result

3.1. Response

In the NSAOH, a total of 14,123 adults responded to the CATI (49% response rate), and 5,505 were examined (44% of the interviewed people invited to the examination). In the nutrition sub-study, a total of 1,218 persons were approached in NSW and Queensland, with 1,129 responding (92.7% response rate). Among them, 752 respondents to the

nutrition sub-study were aged 45 years and over and these respondents comprised the analytic sample for the study reported in this paper.

3.2. Sampling distribution

The Kolmogorov–Smirnov test indicated that several variables deviated from normal distributions ($p<0.05$). However, the skewness and kurtosis were between -1 to 1 and -3 to 3 (Table 1). It was also found from graphical presentation that, for all continuous variables, the histograms approximated the shape of a normal curve. The means, standard deviations (SDs) and correlations of the main study variables are shown in Table 1.

3.3. Relationship between missing teeth, food groups and self-rated general health

Multivariate linear regression showed that adults with more missing teeth rated their general health worse. Adults with more missing teeth consumed less of any kind of food items from dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables or fruits. Again, those adults who consumed more dairy, bread-cereal, meat-fish-eggs and sweet foods-snacks rated their general health as poor. Furthermore, those who consumed more vegetables, fruits and mixed vegetables rated their general health higher.

3.4. Relationship between OHIP Score, food groups and self-rated general health

In exploring the relationship between oral health-related impact and general health (using multivariate linear regression), adults with a higher OHIP score (i.e., greater impact of dental problems) also rated their general health worse. Adults with a higher OHIP score also consumed more dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks and mixed vegetables and consumed fewer vegetables and fruits. Lastly, those adults who consumed more dairy, bread-cereal, meat-fish-eggs and sweet foods-snacks rated their general health as poor. Those adults who consumed more vegetables, fruits and mixed vegetables rated their general health higher.

Therefore, adults with greater impact from dental problems consumed more dairy, bread-cereal, meat-fish-eggs and sweet foods-snacks and also rated their general health as worse.

3.5. Mediation analysis

From Baron and Kenny's (1986) mediation analysis (Table 2), we see that model *a* shows a significant (p<0.001) relationship between the number of missing teeth and all kinds of food groups. For model *b*, all food groups were significantly (p<0.001) associated with self-rated general health (SRGH). For model *c*, the number of missing teeth was significantly (p<0.001) associated with self-rated general health (SRGH). In model *c′*, we saw that, after introducing food groups, the number of missing teeth and consumption of all food groups significantly (p<0.001) predicted self-rated general health (SRGH). Sobel's (1982) test reported that the association between the number of missing teeth and SRGH was partially mediated by the consumption of dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, vegetables and fruits (p<0.001) but was not mediated by the consumption of mixed vegetables (p=0.48).

For mediation analysis in the relationship between the Oral Health Impact Profile (OHIP) score and general health, from Baron and Kenny's (1986) mediation analysis, the study found that model *a* showed a significant (p<0.001) relationship between the OHIP score and consumption of all kinds of food groups. For model *b*, the consumption of all food groups was significantly (p<0.001) associated with self-rated general health (SRGH). For model *c*, the OHIP score was significantly (p<0.001) associated with self-rated general health (SRGH). In model *c′*, after introducing food groups, the OHIP score and the consumption of all food groups significantly (p<0.001) predicted self-rated general health (SRGH). Sobel's (1982) test ascertained that the association between the OHIP score and SRGH was partially mediated by the consumption of dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables and fruits (p<0.001).

From the bootstrapping test for standard errors, the study found that the bias correction confidence intervals (CIs) for all food groups included "0"; that is, they indicated that the indirect effect was not significant with no mediation established.

From the SEM analysis, the study found no significant indirect effect for any mediators (food items from the food groups) in the relationship between the number of missing teeth and general health. This, therefore, indicated that the association between the number of missing teeth and general health was not mediated by consumption of any food item from the following food groups: dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables and fruits.

A significant indirect association was also found for the mediator ‘mixed vegetables’ in the relationship between the OHIP score and general health. This, therefore, indicated that the association between the OHIP score and SRGH was partially mediated by mixed vegetables. The VAF was found to be 1.8% which was below the recommended level; therefore, although the indirect effect was significant, mediation effect was found.

4. Discussion

The current study shows a negative correlation between SRGH and oral health status (number of missing teeth and OHIP-14 score). These findings support previous studies which reported that the number of missing teeth was positively correlated to poorer general health status[50] and that OHIP-14 scores were negatively correlated with self-assessment of overall health.[16,51] The number of missing teeth was negatively correlated with the consumption of any food item from these food groups: dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables or fruits. Similar results were also found in some other studies. Some older studies found that people with fewer teeth reported a lower intake of root vegetables and other vegetables[52,53] and that those who lost five or more teeth in the previous four years had decreased their intake of vegetables, apples and pears.[52] A more recent study observed that lower consumption of fruits, vegetables and mixed vegetables was more prevalent among those with fewer teeth.[54] Another study reported that the number of food items that an individual was able to eat was significantly correlated with the number of present teeth, with more missing teeth leading to more limited choice of foods and consequent reduction of the intake of fruits, vegetables and fibres.[55] The impact of oral health was positively correlated with the consumption of dairy products, bread-cereal, meat-fish-eggs, sweet foods-snacks and mixed vegetables but was negatively correlated with the consumption of vegetables and fruits. In the systematic review Gaewkhiew et al., (2007) indicated there is a weak evidence that tooth loss affect dietary intake and nutritional status, but Bomfim et al., (2017) made a conclusion that tooth loss had a significant and strong effect on animal protein intake and a medium effect on all kind of protein intake as a group.

In the final result from the SEM method of mediation analysis between the number of missing teeth and general health with different types of food items (dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables and fruits) as the

mediators, the direct effect both with and without mediators was significant, but none of the indirect effects were significant. Therefore, the effect of the number of missing teeth on SRGH was not mediated by the consumption of any food item from the food groups: dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables or fruits. That is, consumption of these food items (dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables and fruits) had no effect on the relationship between the number of missing teeth and general health. It should be noted that if any mediation was present, there would be some significant indirect effect (i.e., some effect would be transmitted through the mediator variables).

Again, in the mediation analyses between the OHIP score and general health with different mediators from the type of food items (dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables and fruits), the direct effect both with and without mediators was significant, but none of the indirect effects were significant except for the mediator of mixed vegetables. The effect of the impact of oral health on general health was 1.8%, with this explained through the consumption of mixed vegetables which was found by the variation accounted for (VAF). According to Hair et al. (2014), a VAF value less than 20% means there is no mediation.[49] Therefore, we can conclude that the effect of the oral health impact on SRGH was not mediated by the consumption of any item from the food groups: dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables or fruits.

To discover the effect of mediation, a range of different approaches was tested in this study. Initially, the most classical approach of Baron and Kenny (1986) was conducted. The main criticism of this method is that mediation may be present even without finding any statistical significance of the dependent and independent variables.[56] Also, in Baron and Kenny's (1986) approach, if the relationship remains significant after inclusion of the mediator, mediation may be partial or absent but this is not specified. To identify appropriate specifications of mediation, Sobel's 1982) test measures whether an intermediation effect is significant.[56] The problem with Sobel's test is its dependence on distribution assumptions, which may affect the estimation of true *p*-values in smaller sample sizes. To address this problem, researchers[57,58] have suggested using bootstrapping for standard errors which seems to have greater power in a small sample. In modern mediation analysis, SEM is one of the prominent methods that can fulfil the requirements when mediation analysis is found to be necessary.[59] Structural equation modelling (SEM)

uses a conceptual model, a path diagram and a system of linked equations to capture complex and dynamic relationships within a web of observed and unobserved variables. It also provides a more appropriate inference framework for mediation analysis in a single analysis. Therefore, we focused on the result of the SEM mediation model in this study.

For the goodness of fit, the Comparative Fit Index (CFI) values have been reported. Ideally, for a model that fits the data, the CFI value would be close to 0.95 or higher.[60] Values for χ^2 or root mean square error of approximation (RMSEA) have not been reported as χ^2 is sensitive to a large sample size (n>250) for which it almost always indicates a poor fit[61], and the RMSEA worsens as the number of variables in the model increase.[62,63] Overall, in view of power and robustness, Hu and Bentler (1998) have demonstrated the CFI's strong performance.[64] The coefficient of determination (R^2) value for each model in this study was not strong, but these R^2 values were for the overall model, and we were interested in the effect of the mediators in our predictive model. The evaluation of goodness of fit using R^2 is somewhat subjective, and R^2 has no fixed guidelines.[61]. The effect size (f^2) of the mediators (dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables and fruits) in the relationships between the number of missing teeth and SRGH and between the OHIP score and SRGH are small.

The strength of this study is its large and representative sample derived from the Australian National Survey of Adult Oral Health (NSAOH). We have also used both classical and modern methods to more comprehensively analyse mediation. Very few studies[65] have been performed to examine the role of food intake as a mediator in the relationship between oral health and general health. These studies have only reviewed the literature in relation to oral conditions with nutrition or have linked various nutrition variables and systemic disease; however, relatively little work has been done on the hypothesised mediation model.

One limitation of the current study is its cross-sectional design, which makes it impossible to draw causal relationships between oral health status (number of missing teeth and OHIP score), the consumption of different kinds of food groups and general health. While consideration of cause is an important aspect of mediation, our aim was not to investigate the causal relationship. Instead, we have focused on establishing whether mediation is supported in terms of statistical associations. An additional limitation of this study is that we have conducted individual models for each mediator, which may violate the overall assessment of direct and indirect effects; however, according to our interests, we can

consider the mediators one at a time if the mediators do not affect one another. [66] In this study, we have been interested in testing the effect of each individual food group as a mediator. However, the next step for further research could focus on multiple mediators in the modelling process, considering the suggestion of Vansteelandt and Daniel (2017).[67]

Overall, the study's findings suggest that oral health and general health are related in this adult age group. Maintaining or taking care of teeth to retain teeth in healthy condition or to avoid any required extraction is important in maintaining better general health in adults. Taking care of teeth will flow through to lower the impact of the OHIP score which will consequently help to maintain a healthy life. Adults with more missing teeth and a high OHIP score have an association with lower consumption of vegetables and fruits, so it is recommended that they increase their consumption of mixed vegetables, vegetables and fruits to maintain better general health.

The study's findings reinforce the importance of health professionals considering dietary guidelines in designing oral health policy and, consequently, general health policy.

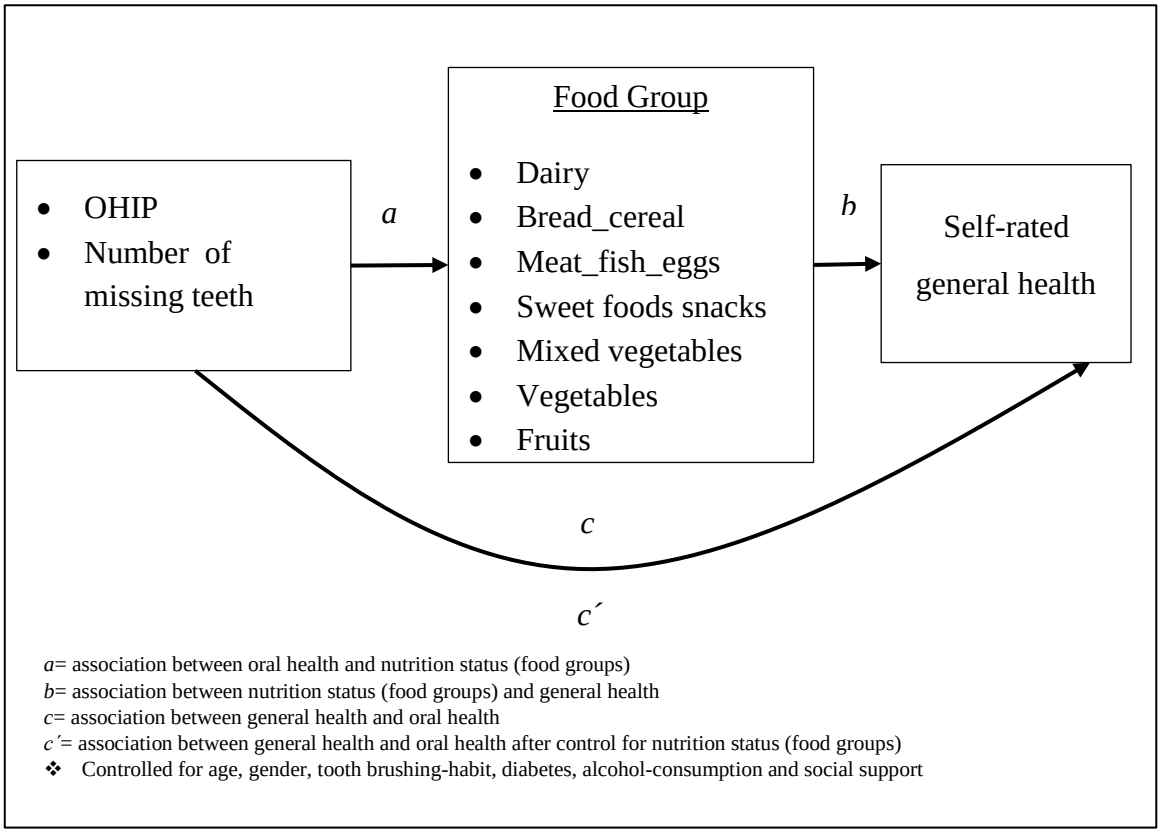


Figure 1: Conceptual model for mediation analysis

Table 1: Means (SDs), skewness, kurtosis and correlations among main study variables

Variable	Range	Mean (SD)	Skewness	Kurtosis	Correlation coefficient		
					1	2	3
1.Self-rated general health	1-5	3.6 (0.9)	-0.36	-0.23	-	-	-
2.OHIP Score	0-51	7.3 (7.9)	1.80	2.89	-0.229*	-	-
3. No. of missing teeth	0-28	7.7 (6.9)	1.20	0.61	-0.127*	-	-
Dairy	0-51	25.6 (6.4)	-0.33	1.26	-0.028*	0.077*	-0.084*
Bread-cereal	0-45	25.6 (5.5)	-0.49	2.63	-0.069*	0.008*	-0.095*
Meat-fish-eggs	0-72	42.4 (8.6)	-0.22	2.23	-0.110*	0.059*	-0.082*
Sweet foods-snacks	0-64	32.5 (8.4)	0.12	0.61	-0.045*	0.070*	-0.027*
Mixed vegetables	1-15	12.4 (3.8)	-0.15	0.76	0.032*	0.022*	-0.069*
Vegetables	1-107	61.9 (12.1)	-0.41	2.23	0.032*	-0.023*	-0.071*
Fruits	1-64	28.4 (8.5)	0.19	0.71	0.025*	-0.044*	-0.043*

*Correlation is significant at the 0.01 level (2-tailed); SD=standard deviation

Table 2: Regression analysis and multiple mediator model

Independent variable (X)	Mediator (M)	Dependent Variables	Path	B	Sobel Z	p-value	Degree of mediation
No. of Missing teeth	-	SRGH	*c*	-0.010*			
No. of Missing teeth	Dairy	-	*a*	-0.092*	17.83	<0.001	Partial
-	Dairy	SRGH	*b*	-0.003*			
No. of Missing teeth	(Dairy)	SRGH	*c´*	-0.011*			
No. of Missing teeth	Bread-cereal	-	*a*	-0.080*	50.71	<0.001	Partial
-	Bread-cereal	SRGH	*b*	-0.012*			
No. of Missing teeth	(Bread-cereal)	SRGH	*c´*	-0.011*			
No. of Missing teeth	Meat-fish-eggs	-	*a*	-0.086*	38.81	<0.001	Partial
-	Meat-fish-eggs	SRGH	*b*	-0.011*			
No. of Missing teeth	(Meat-fish-eggs)	SRGH	*c´*	-0.011*			
No. of Missing teeth	Sweet foods-snacks	-	*a*	-0.028*	25.16	<0.001	Partial
-	Sweet foods-snacks	SRGH	*b*	-0.007*			
No. of Missing teeth	Sweet foods-snacks	SRGH	*c´*	-0.010*			
No. of Missing teeth	Mixed vegetables	-	*a*	-0.026*	-0.69	0.48	No mediation
-	Mixed vegetables	SRGH	*b*	0.002*			
No. of Missing teeth	(Mixed vegetables)	SRGH	*c´*	-0.010*			
No. of Missing teeth	Vegetables	-	*a*	-0.160*	-31.97	<0.001	Partial
-	Vegetables	SRGH	*b*	0.003*			
No. of Missing teeth	(Vegetables)	SRGH	*c´*	-0.010*			
No. of Missing teeth	Fruits	-	*a*	-0.120*	-23.00	<0.001	Partial
-	Fruits	SRGH	*b*	0.003*			
No. of Missing teeth	(Fruits)	SRGH	*c´*	-0.010*			
OHIP-Score	-	SRGH	*c*	-0.027*			
OHIP-Score	Dairy	-	*a*	0.055*	-17.26	<0.001	Partial
-	Dairy	SRGH	*b*	-0.003*			
OHIP-Score	(Dairy)	SRGH	*c´*	-0.027*			
OHIP-Score	Bread-cereal	-	*a*	0.004*	-3.99	<0.001	Partial
-	Bread-cereal	SRGH	*b*	-0.012*			
OHIP-Score	(Bread-cereal)	SRGH	*c´*	-0.027*			
OHIP-Score	Meat-fish-eggs	-	*a*	0.035*	-32.63	<0.001	Partial
-	Meat-fish-eggs	SRGH	*b*	-0.011*			
OHIP-Score	(Meat-fish-eggs)	SRGH	*c´*	-0.026*			
OHIP-Score	Sweet foods-snacks	-	*a*	0.089*	-48.22	<0.001	Partial
-	Sweet foods -snacks	SRGH	*b*	-0.007*			
OHIP-Score	Sweet foods -snacks	SRGH	*c´*	-0.026*			
OHIP-Score	Mixed vegetables	-	*a*	0.014*	6.25	<0.001	Partial
-	Mixed vegetables	SRGH	*b*	0.002*			
OHIP-Score	(Mixed vegetables)	SRGH	*c´*	-0.027*			
OHIP-Score	Vegetables	-	*a*	-0.057*	-22.07	<0.001	Partial
-	Vegetables	SRGH	*b*	0.003*			
OHIP-Score	(Vegetables)	SRGH	*c´*	-0.026*			
OHIP-Score	Fruits	-	*a*	0.013*	-11.36	<0.001	Partial
-	Fruits	SRGH	*b*	0.003*			
OHIP-Score	(Fruits)	SRGH	*c´*	-0.027*			

*****p-value<0.001

Table 3: Mediation results from the Bootstrap method and Structural Equation Model.

Relationship	Bootstrap Bias Correction CI		SEM Result			Degree of mediation
	LL	UL	Direct without mediation	Direct with Mediation	Indirect effect	
General health depends on no. of missing teeth (M: Dairy)	-0.0004	0.0021	-0.098 (p<0.001)	-0.099 (p<0.001)	0.001 (p=0.362)	No mediation
General health depends on no. of missing teeth (M: Bread-cereal)	-0.0001	0.0032	-0.098 (p<0.001)	-0.1 (p<0.001)	0.002 (p=129)	No mediation
General health depends on no. of missing teeth (M: Meat-fish-eggs)	0.00	.0036	-0.098 (p<0.001)	-0.1 (p<0.001)	.002 (p=183)	No mediation
General health depends on no. of missing teeth (M: Sweet foods-snacks)	-.0009	.0011	-0.098 (p<0.001)	-0.098 (p=0.001)	00 (p=761)	No mediation
General health depends on no. of missing teeth (M: Mixed Vegetables)	-.0004	.0011	-0.098 (p<0.001)	-0.097 (p=0.001)	-0.001 (p=0.286)	No mediation
General health depends on no. of missing teeth (M: Vegetables)	-.0015	.0004	-0.098 (p<0.001)	-0.097 (p=0.001)	-0.001 (p=0.634)	No mediation
General health depends on no. of missing teeth (M: Fruits)	-.002	.0003	-0.098 (p<0.001)	0.06 (p=.002)	-0.003 (p=.121)	No mediation
General health depends on OHIP-score (M: Dairy)	-.001	.0003	-0.213 (p<0.001)	-0.213 (p<0.001)	0.00 (p=0.953)	No mediation
General health depends on OHIP-score (M: Bread-cereal)	-.0003	.0012	-0.213 (p<0.001)	-0.212 (p<0.001)	-0.001 (p=0.342)	No mediation
General health depends on OHIP-score (M: Meat-fish-eggs)	-.0013	0.0003	-0.213 (p<0.001)	-0.212 (p<0.001)	-0.001 (p=0.443)	No mediation
General health depends on OHIP-score (M: Sweet foods-snacks)	-.0015	.0002	-0.213 (p<0.001)	-0.212 (p<0.001)	-0.001 (p=0.402)	No mediation
General health depends on OHIP-score (M: Mixed Vegetables)	-.0002	.0012	-0.213 (p<0.001)	-0.216 (p<0.001)	0.004 (0.040)	Partial Mediation*
General health depends on OHIP-score (M: Vegetables)	-.0008	.0002	-0.213 (p<0.001))	-0.213 (p<0.001)	0.000 (p=.520)	No mediation
General health depends on OHIP-score (M: Fruits)	-.0003	.0014	-0.213 (p<0.001)	-0.214 (P<0.001)	0.002 (0.445)	No mediation

*VAF=indirect effect/total effect*100=1.8; No mediation.

Explanatory variable: No. of missing teeth
For mediator dairy: CFI=0.999; R^2=0.082; f^2= 0.002
For mediator bread-cereal: CFI=0.998; R^2=0.083; f^2=0.003
For mediator meat-fish-eggs: CFI=0.998; R^2=0.083; f^2=0.003
For mediator sweet foods-snacks: CFI=0.984; R^2=0.083; f^2=0.003
For mediator mixed vegetables: CFI=0.999; R^2=0.083; f^2=0.003
For mediator vegetables: CFI=0.989; R^2=0.082; f^2=0.002
For mediator fruits: CFI=0.997; R^2= 0.085; f^2=0.005

Explanatory variable: OHIP-score
For mediator dairy: CFI=0.995; R^2=0.116; f^2= 0.005
For mediator bread-cereal: CFI=0.991; R^2=0.116; f^2=0.005
For mediator meat-fish-eggs: CFI=0.991; R^2=0.116; f^2=0.005
For mediator sweet foods-snacks: CFI=0.994; R^2=0.116; f^2=0.005
For mediator mixed vegetables: CFI=0.989; R^2=0.118; f^2= 0.007
For mediator vegetables: CFI=0.988; R^2=0.116; f^2=0.005
For mediator fruits: CFI=0.995; R^2=0.12; f^2=0.007

**effect size $f^2 = R^2_{included} - R^2_{excluded} / 1 - R^2_{included}$

4.4.3. References

1. Sáez-Prado B, Haya-Fernández MC, Sanz-García MT. Oral health and quality of life in the municipal senior citizen's social clubs for people over 65 of Valencia, Spain. Medicina oral, patologia oral y cirugia bucal. 2016; 21: e672-e678.

2. Mack F, Schwahn C, Feine JS, et al. The impact of tooth loss on general health related to quality of life among elderly Pomeranians: results from the study of health in Pomerania (SHIP-O). The International journal of prosthodontics. 2005; 18: 414-419.

3. Makhija SK, Gilbert GH, Litaker MS, et al. Association between aspects of oral health-related quality of life and body mass index in community-dwelling older adults. Journal of the American Geriatrics Society. 2007; 55: 1808-1816.

4. Roberto CC-P, Borges-Yanez SA. Oral health conditions and frailty in Mexican community-dwelling elderly: a cross sectional analysis. Public Health nutrition. 2012; 12: 773

5. Saarela R, Soini H, Hiltunen K, et al. Dentition status, malnutrition and mortality among older service housing residents. The journal of nutrition, health & aging. 2014; 18: 34-38.

6. Ulinski KG, do Nascimento MA, Lima AM, et al. Factors related to oral health-related quality of life of independent brazilian elderly. International journal of Dentistry. 2013;2013: 1-8.

7. Brennan DS, Singh KA, Dietary, self-reported oral health and socio-demographic predictors of general health status among older adults. The Journal of Nutrition, Health & Aging. 2012; 16: 437-441.

8. Kaija K, Pekka Y, Anna-Maija S, et al. Oral health intervention among community-dwelling older people: a randomised 2-year intervention study. Gerodontology. 2015; 32: 62-72.

9. Hung HC, Colditz G Joshipura KJ. The association between tooth loss and the self-reported intake of selected CVD-related nutrients and foods among US women. Community dentistry and oral epidemiology. 2005; 33: 167-173.

10. Osterberg T, Dey DK, Sundh V, et al. Edentulism associated with obesity: a study of four national surveys of 16 416 Swedes aged 5584 years. Acta odontologica Scandinavica. 2010; 68: 360-367.

11. Abnet CC, Qiao YL, Dawsey SM, et al. Tooth loss is associated with increased risk of total death and death from upper gastrointestinal cancer, heart disease, and stroke in a Chinese population-based cohort. International journal of epidemiology. 2005; 34: 467-474.

12. Okoro CA, Balluz LS, Eke PI, et al. Tooth loss and heart disease: findings from the Behavioral Risk Factor Surveillance System. American Journal of Preventive Medicine. 2005; 29: 50-56.

13. Volzke H, Schwahn C, Hummel A, et al. Tooth loss is independently associated with the risk of acquired aortic valve sclerosis. American Heart Journal. 2005; 150: 1198-1203.

14. Fisher MA, Taylor GW, Shelton BJ, et al. Periodontal disease and other nontraditional risk factors for CKD. American journal of kidney diseases : the official journal of the National Kidney Foundation. 2008; 51: 45-52.

15. Mollaoglu N, Alpar R. The effect of dental profile on daily functions of the elderly. Clinical Oral Investigations. 2005; 9: 137-140.

16. Yu S-J, Chen P, Zhu G-X. Relationship between implantation of missing anterior teeth and oral health-related quality of life. An International Journal of Quality of Life Aspects of Treatment, Care and Rehabilitation - Official Journal of the International Society of Quality of Life Research. 2013; 22: 1613-1620.

17. Sanders AE, Slade GD, Carter KD, et al. Trends in prevalence of complete tooth loss among Australians, 1979–2002. Australian and New Zealand journal of public health. 2004; 28: 549-554.

18. Brennan Ds, Spencer A, Roberts-Thomson K. Tooth loss, chewing ability and quality of life. An International Journal of Quality of Life Aspects of Treatment, Care and Rehabilitation - Official Journal of the International Society of Quality of Life Research. 2008; 17: 227-235.

19. Hildebrandt GH, Dominguez BL, Schork MA, et al. Functional units, chewing, swallowing, and food avoidance among the elderly. The Journal of Prosthetic Dentistry. 1997; 77: 588-595.

20. Margaret RS, Thomas A. Arcury, Xiaoyan Leng, et al. Severe Tooth Loss in Older Adults as a Key Indicator of Compromised Diet Quality. Public Health nutrition. 2010; 13: 466–474.

21. Renato JDM, Fernando NH, Juliana BH, et al. Association between oral health status and nutritional status in south Brazilian independent-living older people. Nutrition. 2008; 24: 546–553.

22. Chauncey HH, Muench M, Kapur KK, et al. The effect of the loss of teeth on diet and nutrition. Int Dent J. 1984; 34: 98-104.

23. Drummond JR, Newton JP, Yemm R. Dentistry for the elderly: a review and an assessment of the future. J Dent. 1988; 16: 47-54.

24. Hand JS, Hunt RJ, Kohout FJ. Five-year incidence of tooth loss in Iowans aged 65 and older. Community Dent Oral Epidemiol. 1991; 19: 48-51.

25. Osterberg T, Steen B. Relationship between dental state and dietary intake in 70-year old males and females in Goteborg, Sweden. J Oral Rehabil. 1982; 9: 509-521.

26. Petersen PE, Nortov B. General and dental health in relation to life-style and social network activity among 67-year-old Danes. Scand J Prim Health Care. 1989; 7: 225-230.

27. Adiatman M, Ueno M, Ohnuki M, et al. Functional tooth units and nutritional status of older people in care homes in Indonesia. Gerodontology. 2013; 30: 262-269.

28. Sheiham A, Steele J. Does the condition of the mouth and teeth affect the ability to eat certain foods, nutrient and dietary intake and nutritional status amongst older people? Public Health Nutr. 2001; 4: 797-803.

29. Callen BL, Wells TJ. Views of community-dwelling, old-old people on barriers and aids to nutritional health. Journal of nursing scholarship : an official publication of Sigma Theta Tau International Honor Society of Nursing / Sigma Theta Tau. 2003; 35: 257-262.

30. Laugero KD, Falcon LM, Tucker KL. Relationship between perceived stress and dietary and activity patterns in older adults participating in the Boston Puerto Rican Health Study. Appetite. 2011; 56: 194-204.

31. Rosa MO, Ana MR, Pedro A, et al. Dietary intake and cognitive function in a group of elderly people. The American Journal of Clinical Nutrition. 1997; 66: 803-809.

32. Ferrucci L, Benvenuti E, Bandinelli S, et al. Preventive health care for older women: life-style recommendations and new directions. Ageing. 2000; 12: 113-131.

33. Hansen PF. Epidemiological observation of old age. Preventive Medicine. 1983; 12: 146-149.

34. Wahlqvist ML, Saviage GS. Interventions aimed at dietary and lifestyle changes to promote healthy aging. Eur J Clin Nutr. 2000; 54: 148-156.

35. Valeri L, Lin X, Vanderweele TJ. Mediation analysis when a continuous mediator is measured with error and the outcome follows a generalized linear model. Statistics in Medicine. 2014; 33: 4875-4890.

36. Slade GD, Spencer AJ, Roberts-Thomson KF. Australia's dental generations : the national survey of adult oral health 2004-06. Canberra: Australian Institute of Health and Welfare, 2007.

37. Australian Bureau of Statistics. National nutrition survey users' guide, 1995. Canberra: Australian Bureau of Statistics, 1998.

38. Åstrøm AN, Haugejorden O, Skaret E, et al. Oral Impacts on Daily Performance in Norwegian adults: the influence of age, number of missing teeth, and socio-demographic factors. European Journal of Oral Sciences. 2006; 114: 115-121.

39. Sanders AE, Spencer AJ. Social inequality in perceived oral health among adults in Australia.(Author Abstract). Australian and New Zealand journal of public health. 2004; 28: 159.

40. Griffin SO, Jones JA, Brunson D, et al. Burden of oral disease among older adults and implications for public health priorities. The American Journal of Public Health. 2012; 102: 411-418.

41. Krause NM, Jay GM. What Do Global Self-Rated Health Items Measure? Medical Care. 1995; 32: 930-942.

42. Baker SR, Pearson NK, Robinson PG. Testing the applicability of a conceptual model of oral health in housebound edentulous older people. Community dentistry and oral epidemiology. 2008; 36: 237-248.

43. Slade GD. Assessing change in quality of life using the Oral Health Impact Profile. Community dentistry and oral epidemiology. 1998; 26: 52-61.

44. Brennan DS, Singh KA. General health and oral health self-ratings, and impact of oral problems among older adults. European Journal of Oral Science. 2011; 119: 469-473.

45. Giovâni FDD, Markus VN, Diego ASS, et al. Physical activity indicators in adults from a state capital in the South of Brazil: a comparison between telephone and face-to-face surveys. Cadernos de saude publica. 2013; 29: 2119-2129.

46. Zimet GD, Dahlem NW, Zimet SG, et al. The Multidimensional Scale of Perceived Social Support. Journal of Personality Assessment. 1988; 52: 30-41.

47. Baron RM, Kenny DA. The Moderator-Mediator Variable Distinction in Social Psychological Research: Conceptual, Strategic, and Statistical Considerations. Journal of Personality and Social Psychology. 1986; 51: 1173-1182.

48. Preacher K, Hayes A. Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. Behavior Research Methods. 2008; 40: 879-891.

49. Hair JF, Hult GTM, Ringle CM, Sarstedt M. A Primer on Partial Least Squares structural Equation Modeling. Thousand Oaks: Sage, 2014.

50. Lee H-K, Lee K-D, Merchant AT, et al. More missing teeth are associated with poorer general health in the rural Korean elderly. Archives of gerontology and geriatrics. 2010; 50: 30-33.

51. Kieffer JM, Hoogstraten J. Linking oral health, general health, and quality of life. European Journal of Oral Sciences. 2008; 116: 445-450.

52. Joshipura KJ, Willett WC, Douglass CW. The impact of edentulousness on food and nutrient intake. Journal of the American Dental Association (1939). 1996; 127: 459-467.

53. Ranta K, Tuominen R, Paunio I et al. Dental status and intake of food items among an adult Finnish population. Gerodontics. 1988; 4: 32-35.

54. Brennan DS, Singh KA, Liu P, et al. Fruit and vegetable consumption among older adults by tooth loss and socio-economic status. Australian Dental Journal. 2010; 55: 143-149.

55. Toniazzo MP, Amorim PdS, Muniz FWMG, et al. Relationship of nutritional status and oral health in elderly: Systematic review with meta-analysis. Clinical Nutrition. 2017; 37:824-830

56. Gawęda Ł, Prochwicz K, Cella M. Cognitive biases mediate the relationship between temperament and character and psychotic-like experiences in healthy adults. Psychiatry Research. 2015; 225: 50-57.

57. McLeod ER, Campbell KJ, Hesketh KD. Nutrition knowledge: a mediator between socioeconomic position and diet quality in Australian first-time mothers. Journal of the American Dietetic Association. 2011; 111: 696-704.

58. Stanley AM, Suzanne M. Psychological, Economic, and Social Mediators of the Education-Health Relationship in Older Adults. Journal of Aging and Health. 2002; 14: 527-550.

59. Watson HJ, Raykos BC, Street H, et al. Mediators between perfectionism and eating disorder psychopathology: shape and weight overvaluation and conditional goal-setting. The International journal of eating disorders. 2011; 44: 142-149

60. Pardo A, Román M. Reflections on the Baron and Kenny model of statistical mediation. Anales de psicologia. 2013; 29: 614-623.

61. Preacher K, Hayes A. SPSS and SAS procedures for estimating indirect effects in simple mediation models. Behavior Research Methods, Instruments, & Computers. 2004; 36: 717-731.

62. Shrout PE, Bolger N. Mediation in experimental and non experimental study: New procedure and recomendations. Phychological Method. 2002; 7: 422-455.

63. Afthanorhan A, Ahmad S, Safee S. Moderated mediation using covariance-based structural equation modeling with amos graphic: volunteerism program. Advances in Natural and Applied Sciences. 2014; 8: 108+.

64. Hu L-T, Bentler PM. Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Structural Equation Modeling: A Multidisciplinary Journal. 1999; 6: 1-55.

65. Iacobucci D. Structural equations modeling: Fit Indices, sample size, and advanced topics. Journal of Consumer Psychology. 2010; 20: 90-98.

66. Fan X, Sivo SA. Sensitivity of Fit Indexes to Misspecified Structural or Measurement Model Components: Rationale of Two-Index Strategy Revisited. Structural Equation Modeling. 2005; 12: 343-367.

67. Kenny DA, McCoach DB. Effect of the Number of Variables on Measures of Fit in Structural Equation Modeling. Structural Equation Modeling. 2003; 10: 333-351.

68. Hu L-t, Bentler PM. Fit Indices in Covariance Structure Modeling: Sensitivity to Underparameterized Model Misspecification. Psychological Methods. 1998; 3: 424-453.

69. Ritchie CS, Joshipura K, Hung HC et al. Nutrition as a mediator in the relation between oral and systemic disease: Associations between specific measures of adult oral health and nutrition outcomes. Crit Rev Oral Biol Med. 2002; 13: 291-300.

70. VanderWeele T, Vansteelandt S. Mediation Analysis with Multiple Mediators. Epidemiologic Methods. 2014; 2: 95-115.

71. Vansteelandt S, Daniel RM. Interventional Effects for Mediation Analysis with Multiple Mediators. Epidemiology (Cambridge, Mass). 2017; 28: 258-265.

72. Wiener, R. C., Shen, C., Findley, P. A., Sambamoorthi, U., & Tan, X. (2017). The association between diabetes mellitus, sugar-sweetened beverages, and tooth loss in adults: Evidence from 18 states: Evidence from 18 states. The Journal of the American Dental Association, 148(7), 500-509.e504.

4.4.4 Appendix

Table: The table describes the food items that included in each food group

Food group	Food items
Dairy	Flavored milk, milk as a drink, milk on breakfast cereals, milk in hot beverages, cream or sour cream, ice-cream, yoghurt, cottage or ricotta cheese and cheddar and other cheeses
Bread-cereal	White bread or rolls, wholemeal/mixed grain bread or rolls, english muffin, bagel or crumpet, dry or savoury biscuits and crispbread, muesli, cooked porridge, breakfast cereal, rice (white or brown) and pasta-noodles
Meat-fish-eggs	Meat food items, four kinds of fish item include canned fish (tuna, salmon and sardines), cooked fish (steamed, baked and grilled), fried fish and other seafood, and egg
Sweet-snacks	Cakes that includes muffins, scones, and pikelets, sweet pies or sweet pastries, other puddings or desserts, plain sweet biscuits, cream/chocolate biscuits, meat pie, sausage roll or savoury pastry, pizza, hamburger, chocolate (including chocolate bars), other confectionary, jam-marmalade-syrup-honey**,** peanut butter and other nut spreads, vegemite, marmite and promite, nuts and potato chips, corn chips, twisties
Mixed vegetables	Green/mixed salad in a sandwich, as a side salad/with a main meal, stir-fried or mixed vegetables and vegetable casserole
Vegetables (including fresh, frozen and tinned)	Potato (boiled, mashed or baked), hot chips, pumpkin, sweet potato, peas, green beans, silverbeet/spinach, broccoli, cauliflower, brussel sprouts/cabbage/coleslaw, carrots, zucchini/ eggplant/squash, capsicum, sweetcorn or corn on the cob, mushrooms, tomatoes, lettuce, celery/cucumber, onions or leeks, soybeans or tofu, baked beans, and other beans-lentils
Fruits	Apple/pear, orange/mandarin/grapefruit, banana, stone fruits (peach, nectarine, plum, apricot), mango or paw-paw, pineapple, grapes or berries, melon (water-, rock-, honeydew-), lemon juice and other fruit juices or fruit drinks

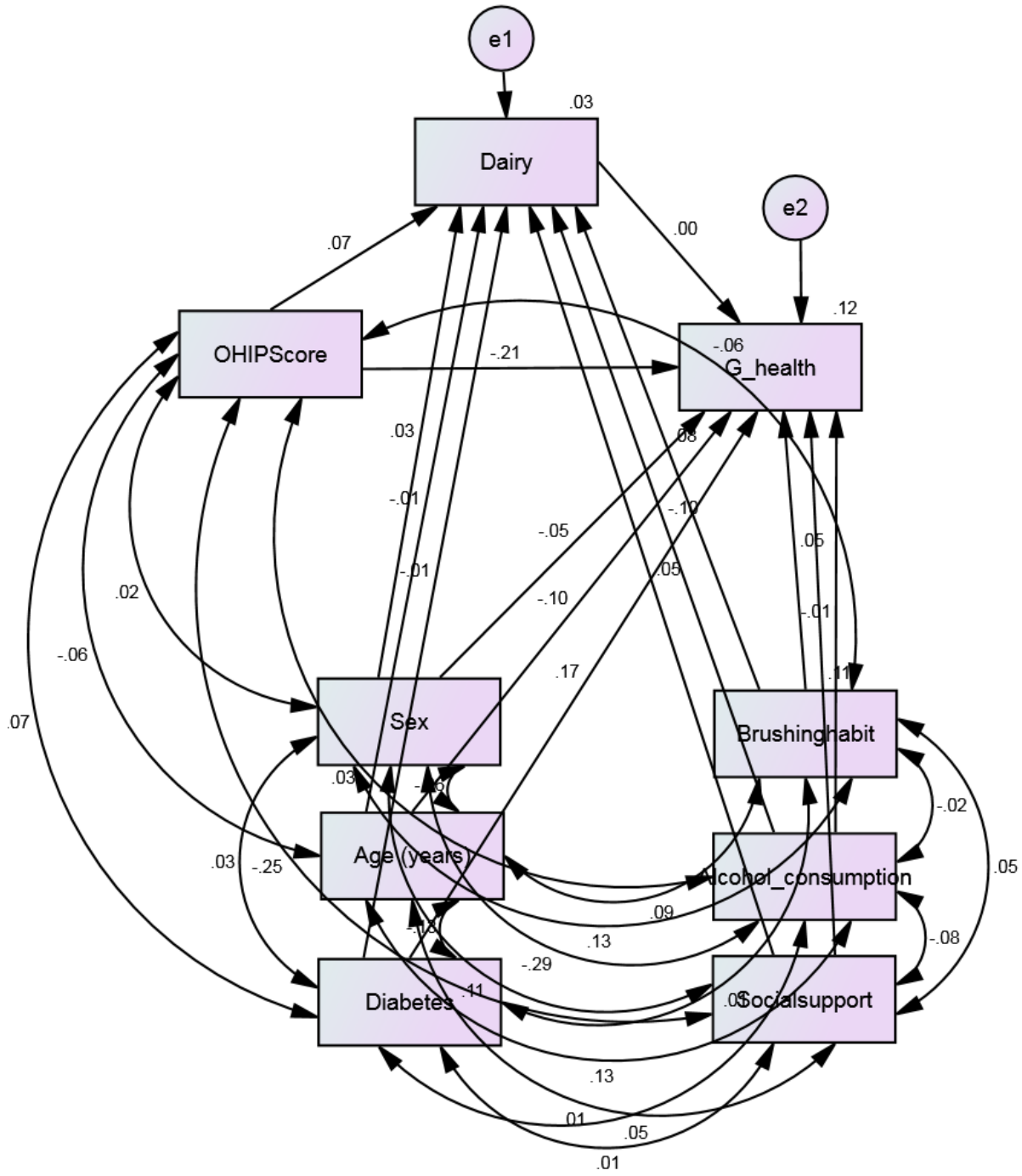


Figure A1: Structural equation model with explanatory variable 'OHIPScore', outcome variable 'Self-rated general health (G_health)' and mediator 'Dairy'

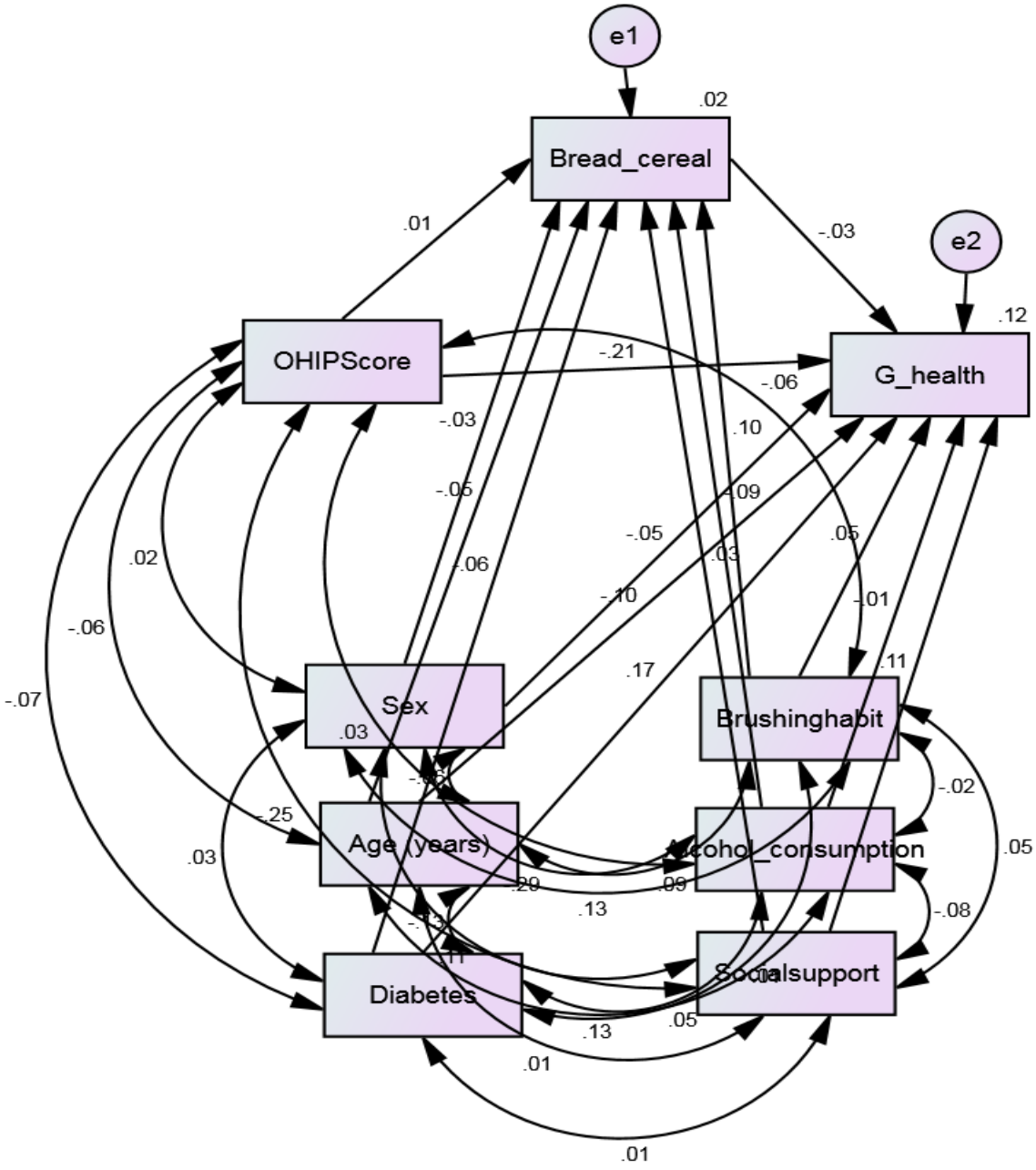


Figure A2: Structural equation model with explanatory variable 'OHIPScore', outcome variable 'Self-rated general health (G_health)' and mediator 'Bread-cereal'

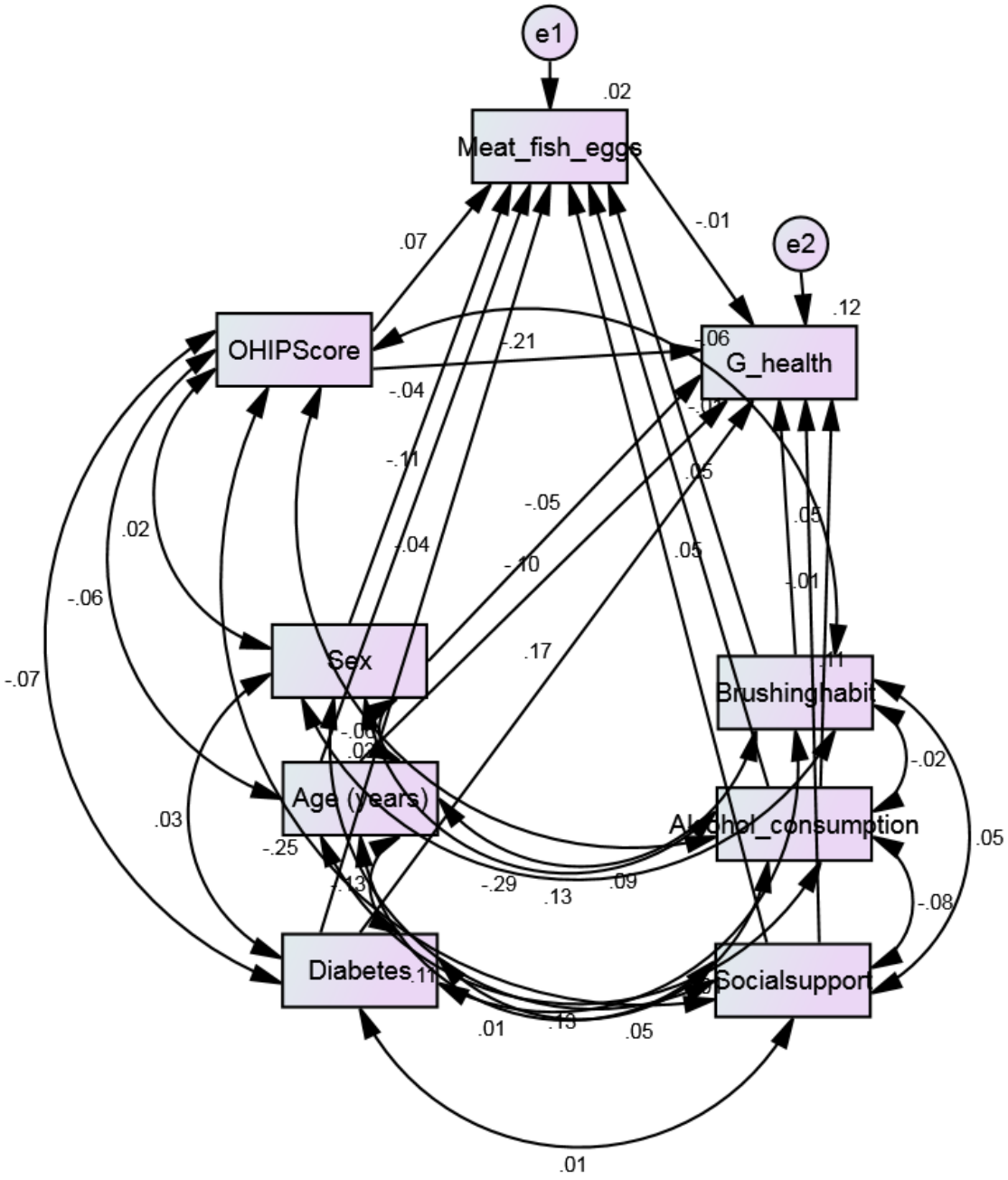


Figure A3: Structural equation model with explanatory variable 'OHIPScore', outcome variable 'Self-rated general health (G_health)' and mediator 'Meat-fish-eggs'

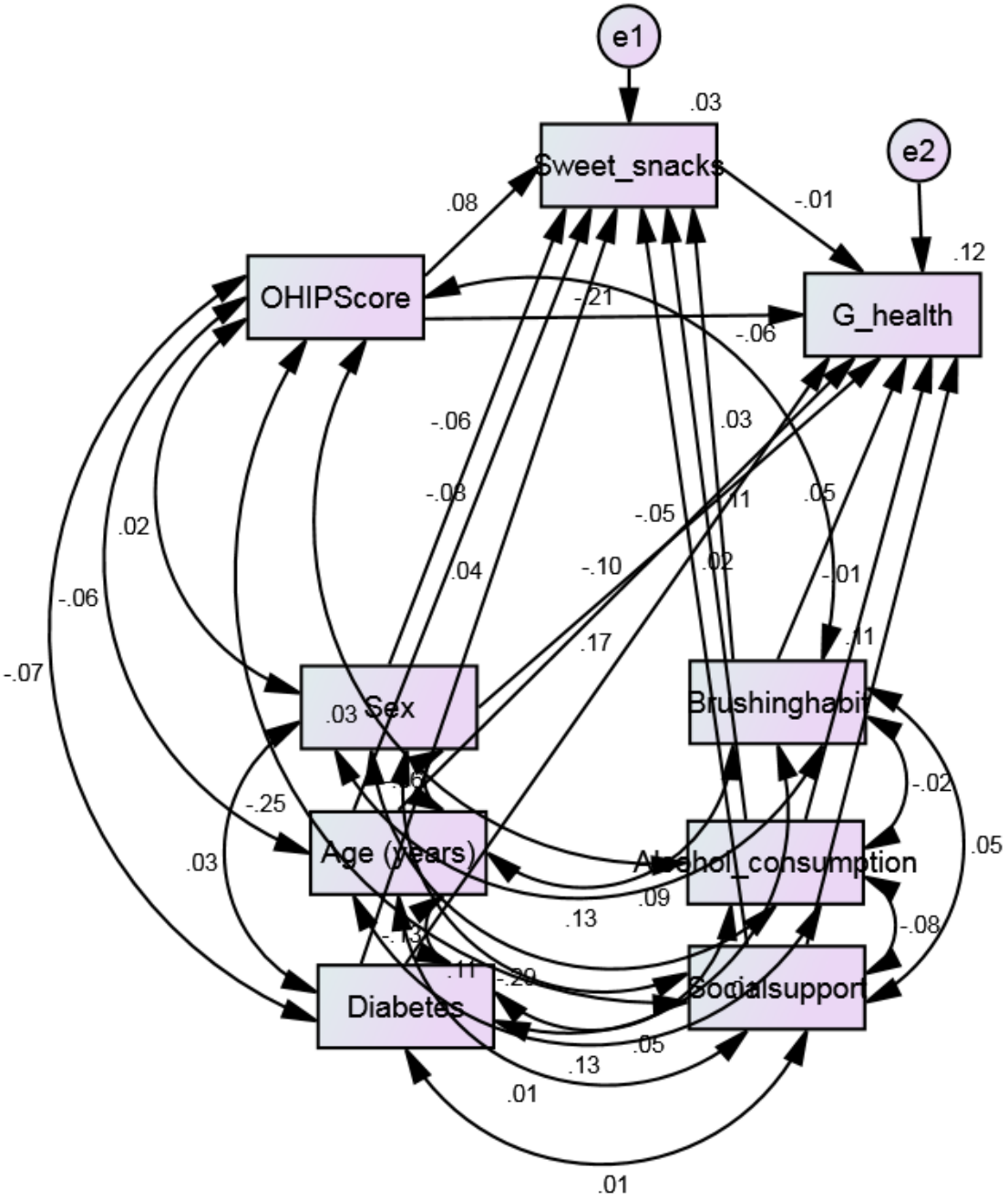


Figure A4: Structural equation model with explanatory variable 'OHIPScore', outcome variable 'Self-rated general health (G_health)' and mediator 'Sweet foods-snacks'

.

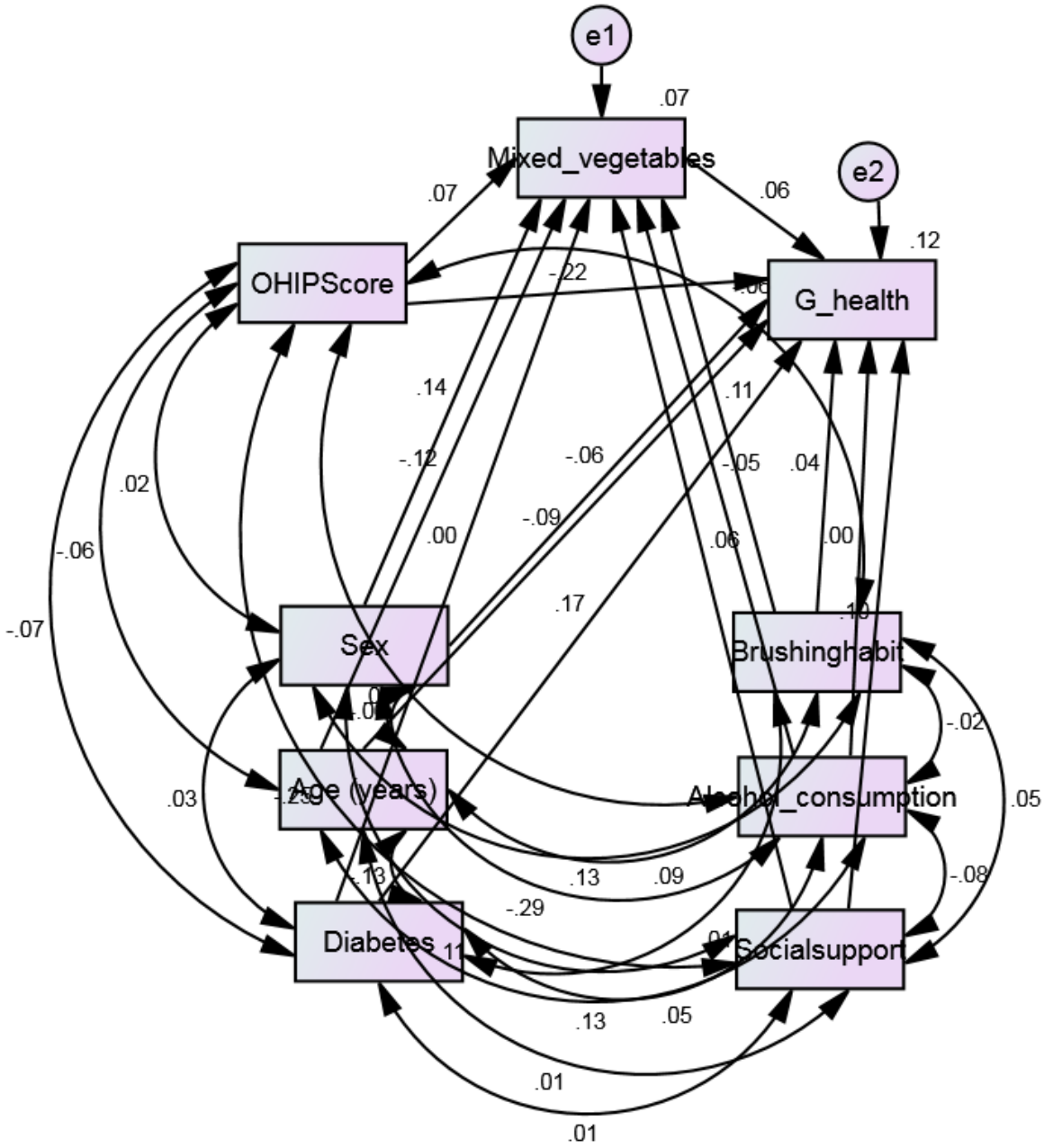


Figure A5: Structural equation model with explanatory variable 'OHIPScore', outcome variable 'Self-rated general health (G_health)' and mediator 'Mixed vegetables'

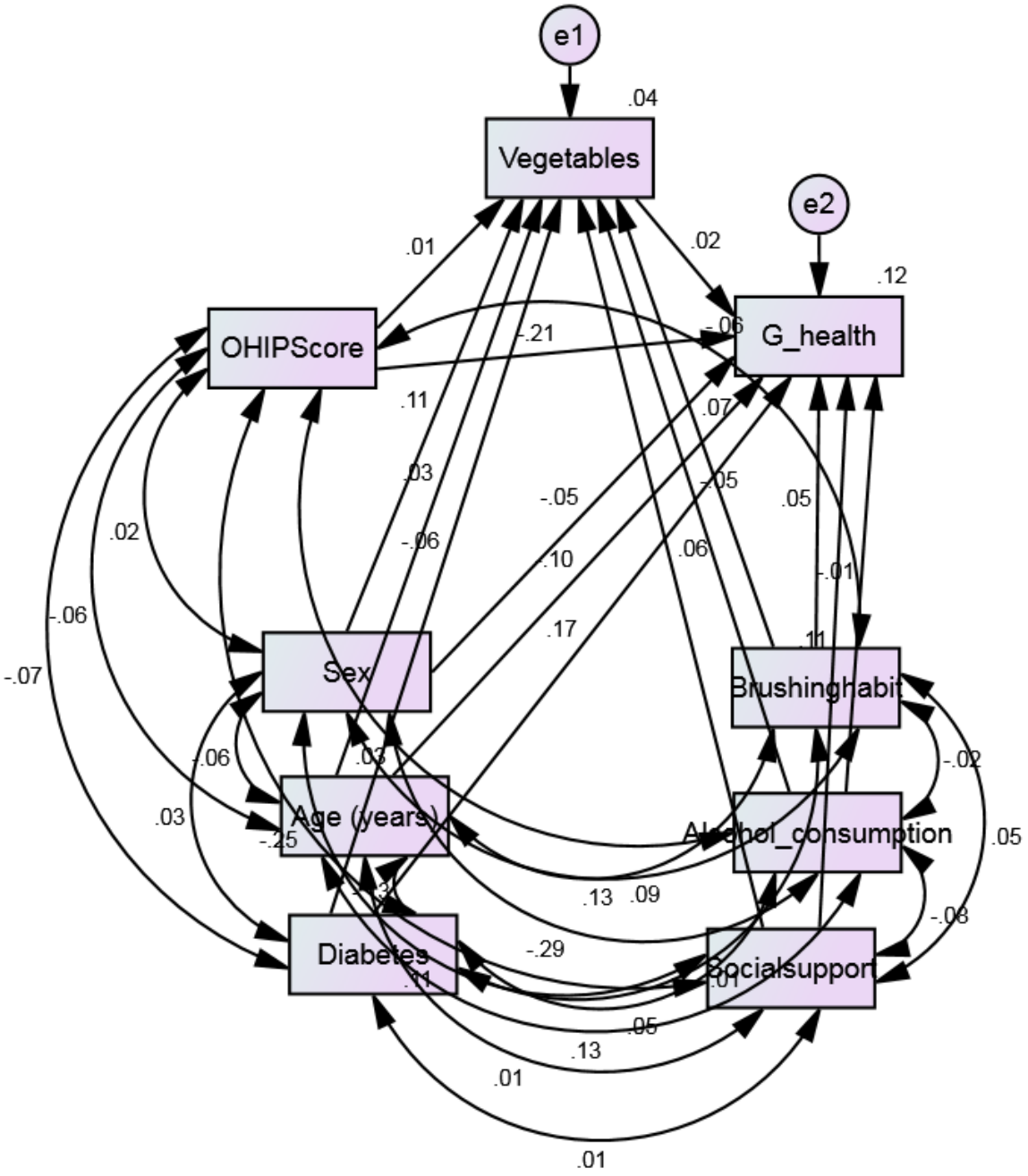


Figure A6: Structural equation model with explanatory variable 'OHIPScore', outcome variable 'Self-rated general health (G_health)' and mediator 'Vegetables'

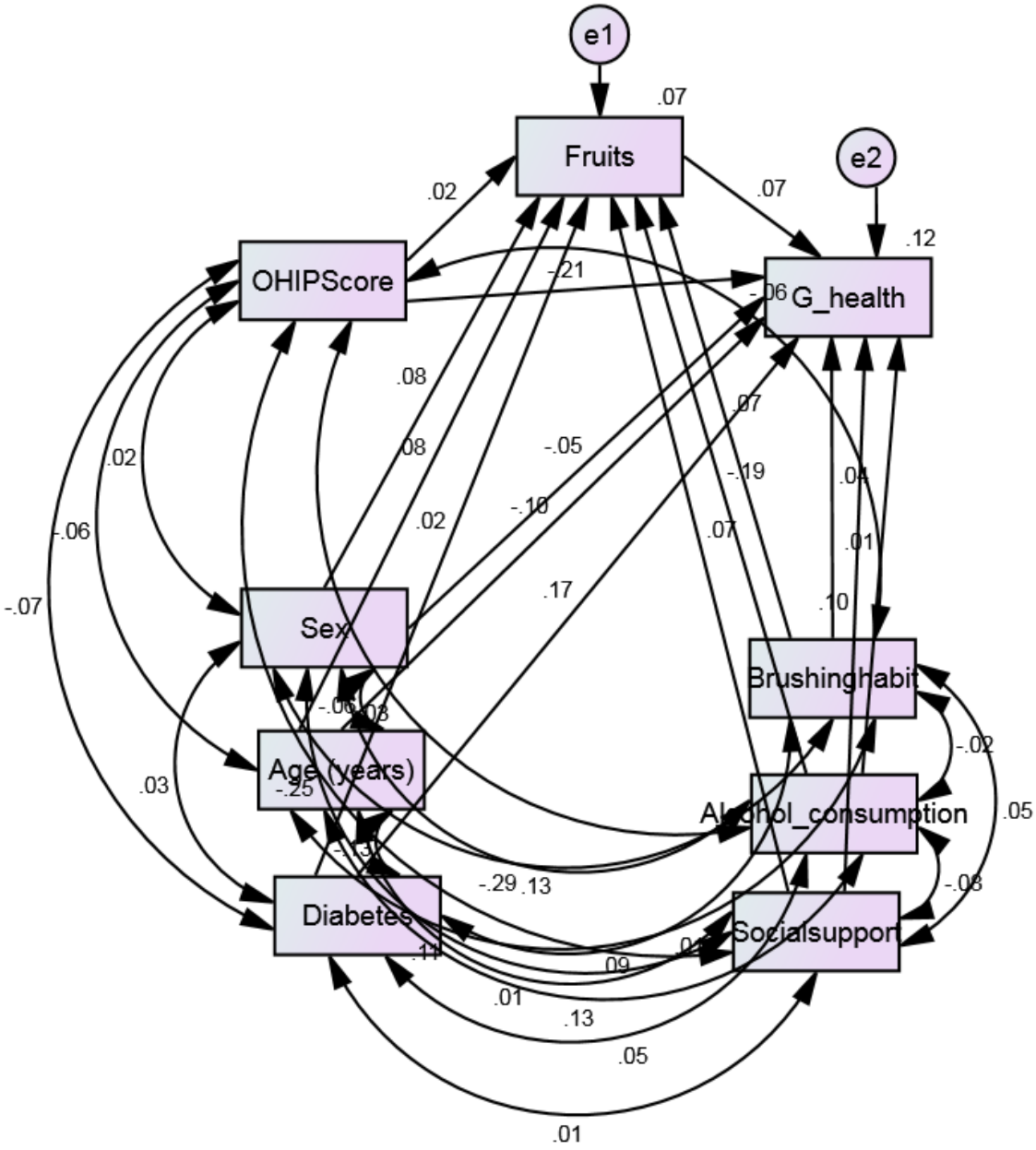


Figure A7: Structural equation model with explanatory variable 'OHIPScore', outcome variable 'Self-rated general health (G_health)' and mediator 'Fruits'

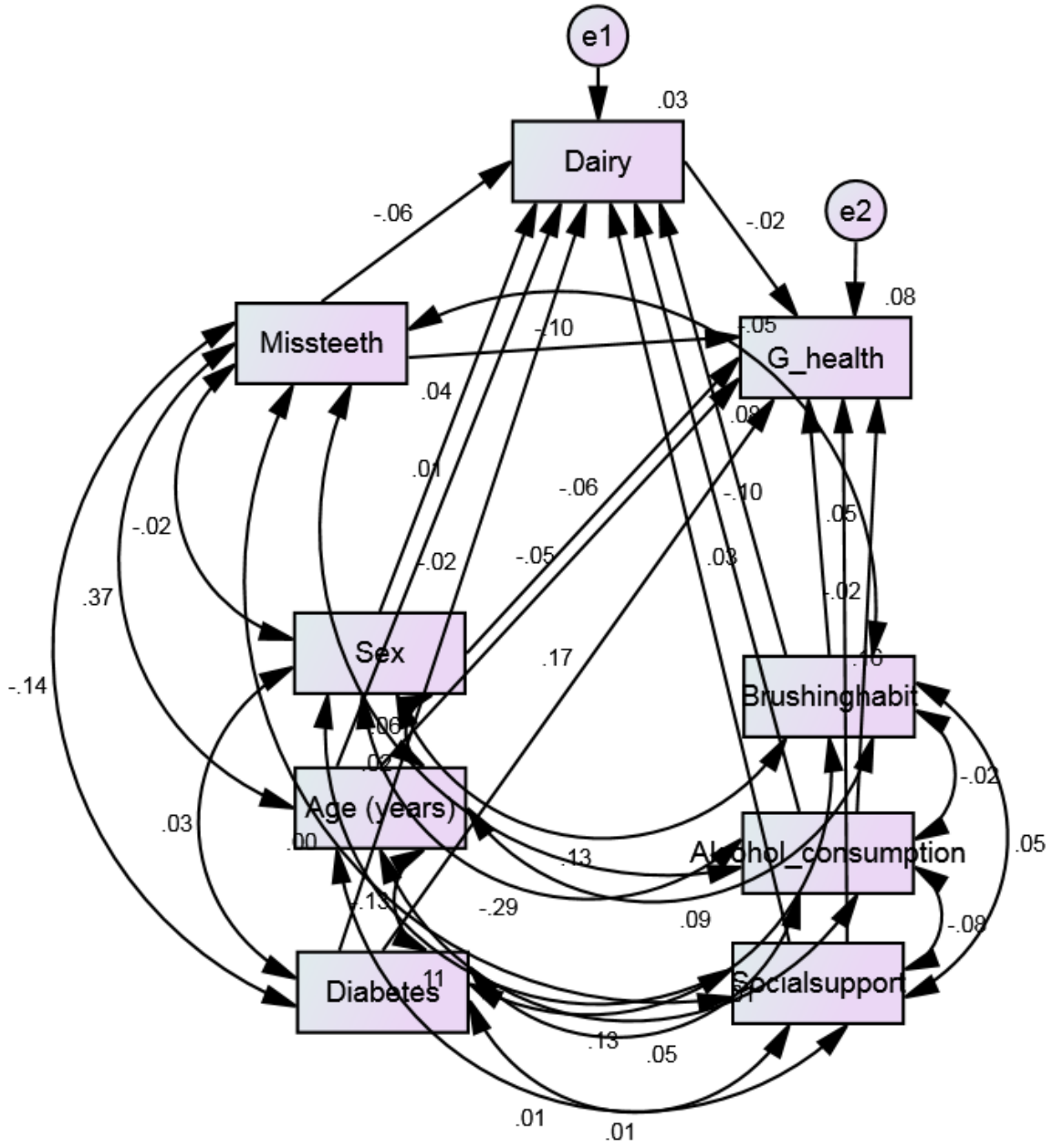


Figure A8: Structural equation model with explanatory variable 'No. of missing teeth (Missteeth)', outcome variable 'Self-rated general health (G_health)' and mediator 'Dairy'

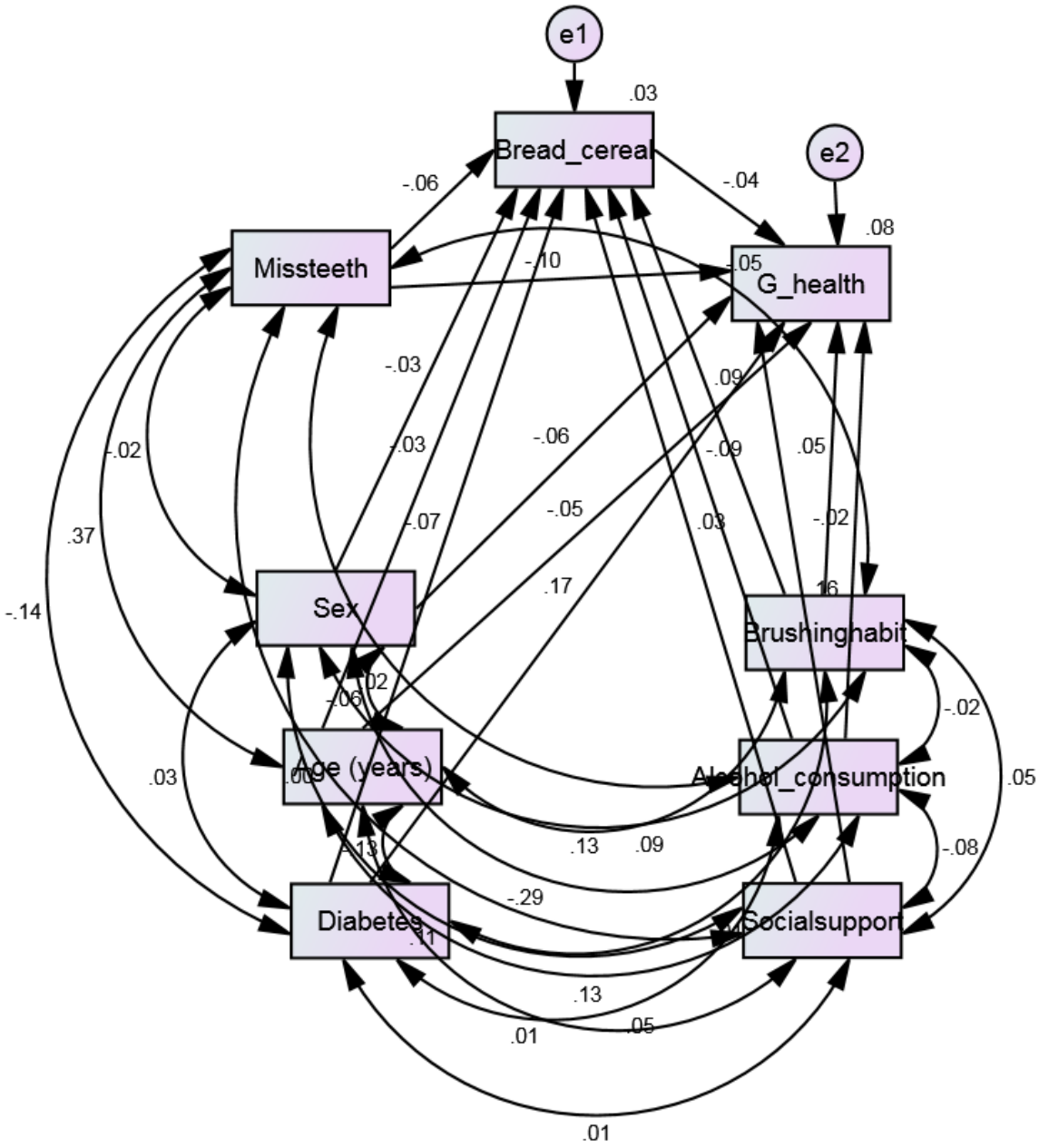


Figure A9: Structural equation model with explanatory variable ‘No. of missing teeth (Missteeth)’, outcome variable ‘Self-rated general health (G_health)’ and mediator ‘Bread-cereal’

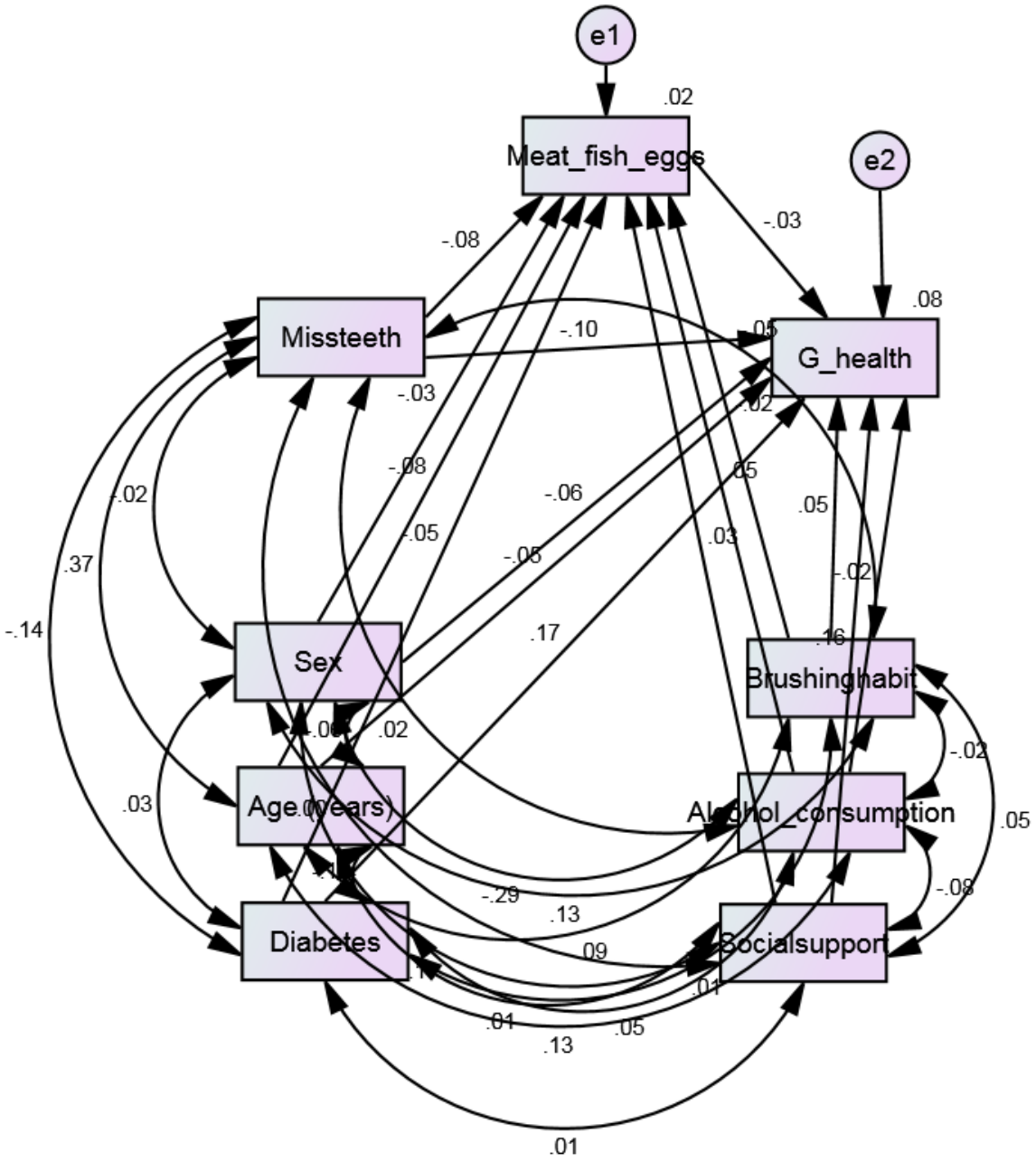


Figure A10: Structural equation model with explanatory variable 'No. of missing teeth (Missteeth)', outcome variable 'Self-rated general health (G_health)' and mediator 'Meat-fish-eggs'

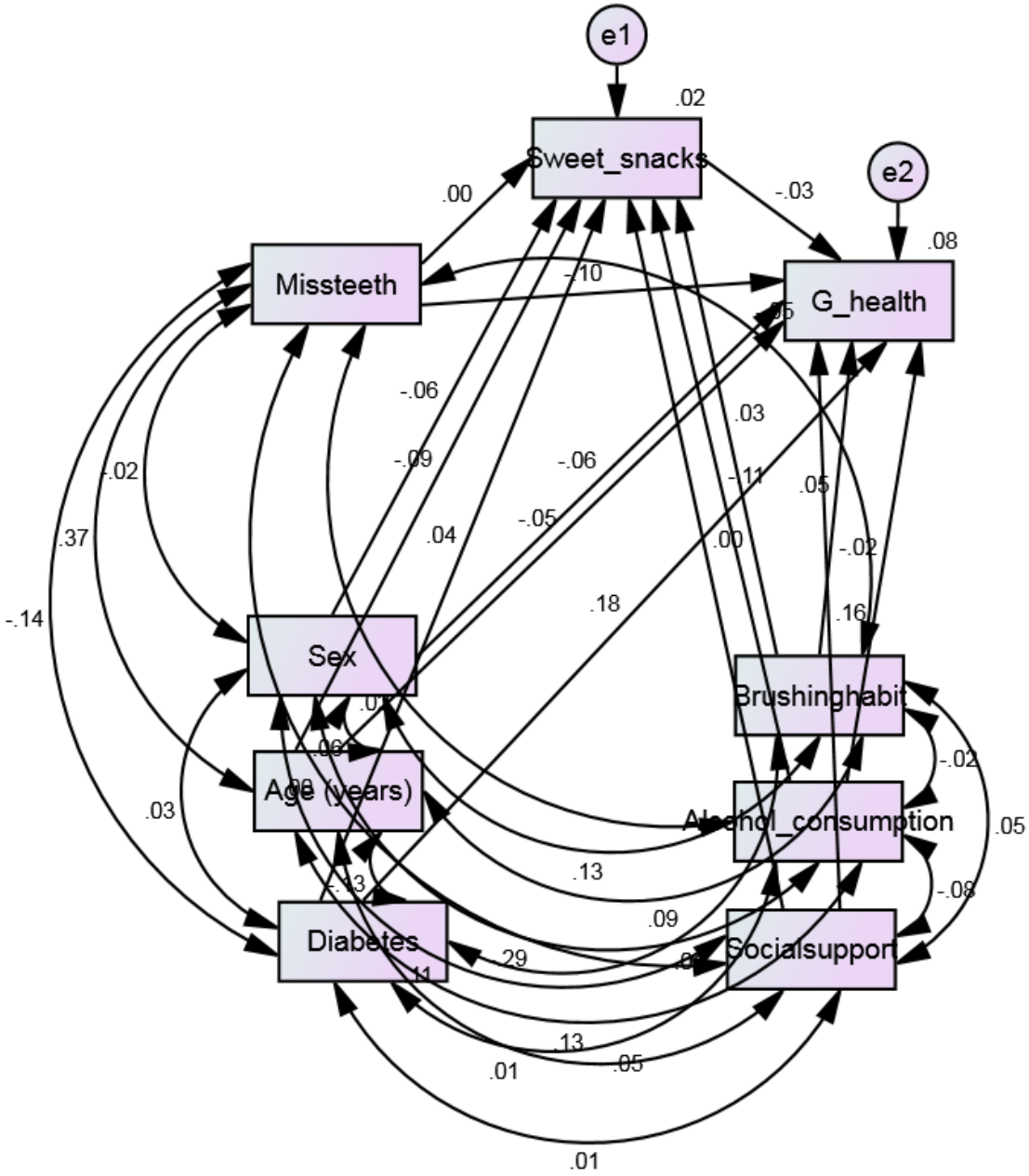


Figure A11: Structural equation model with explanatory variable ‘No. of missing teeth (Missteeth)’, outcome variable ‘Self-rated general health (G_health)’ and mediator ‘Sweet foods-snacks’

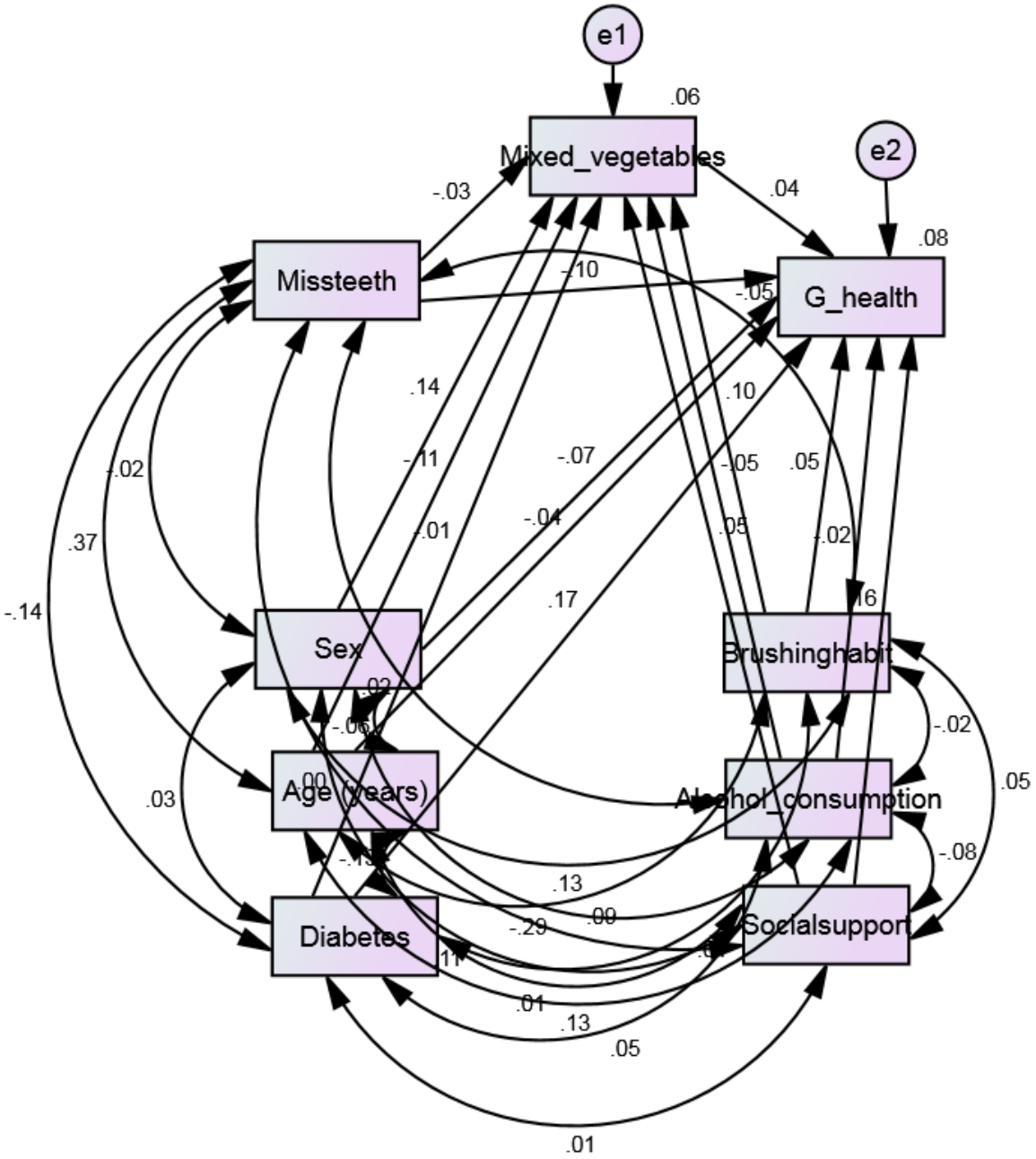


Figure A12: Structural equation model with explanatory variable 'No. of missing teeth (Missteeth)', outcome variable 'Self-rated general health (G_health)' and mediator 'Mixed vegetables'

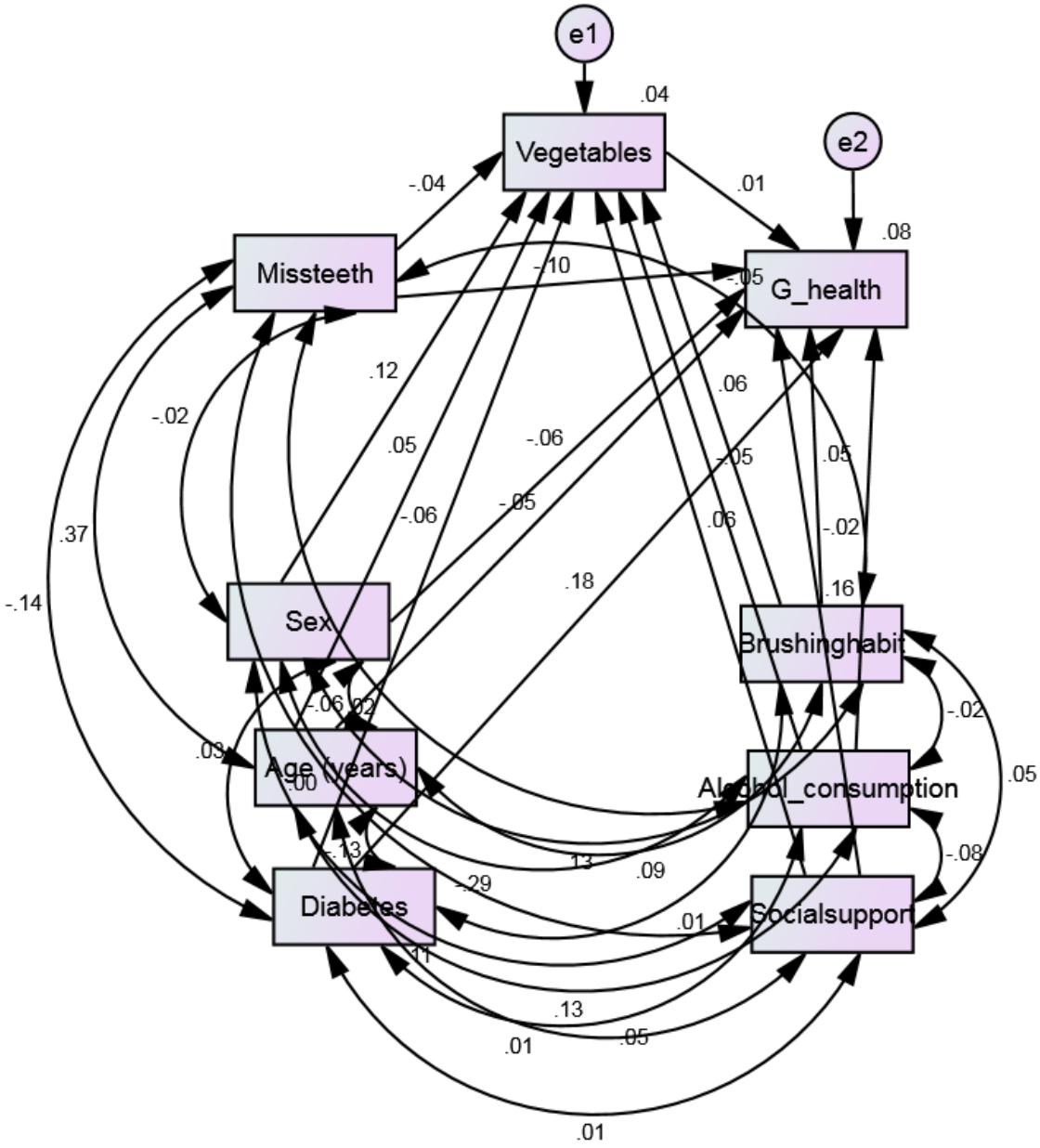


Figure A13: Structural equation model with explanatory variable 'No. of missing teeth (Missteeth)', outcome variable 'Self-rated general health (G_health)' and mediator 'Vegetables'

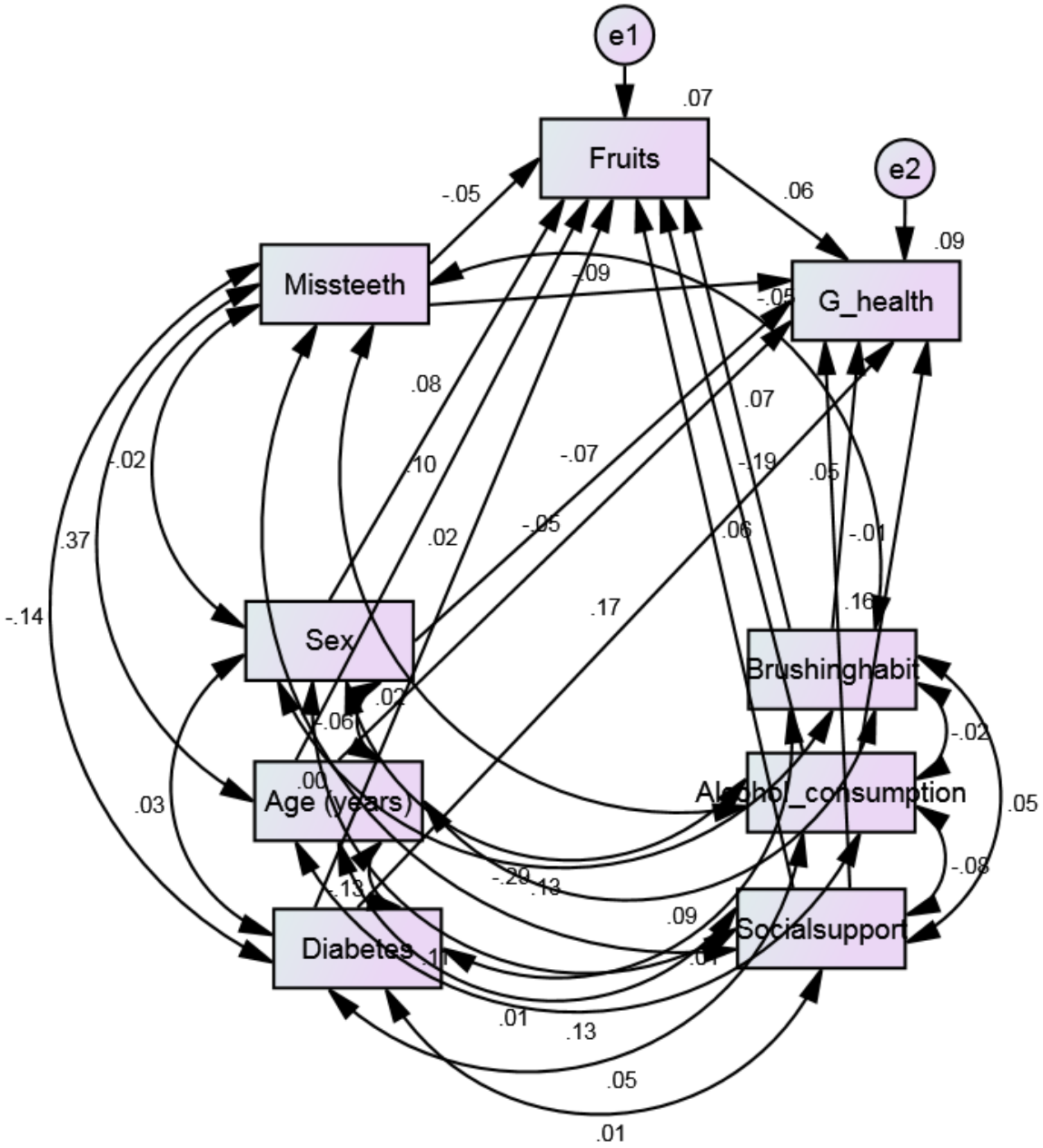


Figure A14: Structural equation model with explanatory variable 'No. of missing teeth (Missteeth)', outcome variable 'Self-rated general health (G_health)' and mediator 'Fruits'

4.5. Research Article 3

Islam S, Brennan DS, Roberts-Thomson K. Assessing food intake as a mediator of the association between self-rated oral health and self-rated general health. Community Dental Health Journal. [Submitted 8 May 2018]

Highlights:

- This article assesses the mediation effects of food consumption in the relationship between self-rated oral health and self-rated general health in Australian adults.
- Based on the research, we provide information for all health care professionals about adult's perceptions of their own oral health, their own general health and their food consumption and important suggestions for dietary guidelines to design oral health policy and; consequently general health policy.

- Article has been submitted to Community Dental Health Journal (see Appendix)

4.3.1. Statement of Authorship

Statement of Authorship

Title of Paper	Assessing food intake as a mediator of the association between self-rated oral health and general health
Publication Status	☐ Published ☐ Accepted for Publication ☑ Submitted for Publication ☐ Unpublished and Unsubmitted w ork w ritten in manuscript style
Publication Details	Islam S, Brennan DS, Roberts-Thomson K. Assessing food intake as a mediator of the association between self-rated oral health and general health. [Community Dental Health journal] submitted 8 May 2018.

Principal Author

Name of Principal Author (Candidate)	Saima Islam		
Contribution to the Paper	Designed the analytic plan and objective for the paper. Performed literature search, planned overall analysis, performed analysis and interpreted the findings. Wrote the manuscript.		
Overall percentage (%)	80%		
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	11 May 2018

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	David S Brennan		
Contribution to the Paper	Supervised the development and progress of the study. Contributed to the study design, and overall analysis strategy. Provided intellectual content and revised the manuscript		
Signature		Date	11 May 2018

Name of Co-Author	Kaye Roberts-Thomson		
Contribution to the Paper	Supervised the development of the study and revised the manuscript.		
Signature		Date	11 May 2018

Please cut and paste additional co-author panels here as required.

4.5.2 Submitted article

The article presented on pp 130-159 shows the mediation effects of food consumption in relation between self-rated oral health and self-rated general health in Australian adults. This article has been submitted to the *Community Dental Health Journal*, and is provided in the form submitted to the journal.

Assessing food intake as a mediator of the association between self-rated oral health and self-rated general health

Author

Saima Islam [1]
David S Brennan[1]
Kaye Roberts-Thomson[1]

[1]Australian Research Centre for Population Oral Health, Adelaide Dental School, The University of Adelaide, South Australia, Australia.

Correspondence:

[1]AHMS, Level 9, 57 North Terrace, Adelaide SA 5000
Tel +61 8 8313 4048 Fax: +61 8 8313 3070
Email: Saima.islam@adelaide.edu.au

Running Head: Self-rated oral and general health.

Acknowledgments: The research reported in this paper is a study of the Australian Primary Health Care Research Institute (APHCRI), which is supported under the Australian Government's Primary Health Care Research, Evaluation and Development Strategy. The information and opinions contained in it do not necessarily reflect the views or policy of the Australian Primary Health Care Research Institute or the Department of Health

Key words: Food Intake, Self-rated oral health, Self-rated general health, Mediation.

No Conflict of interest to declare

Abstract

Objective: To evaluate the association of self-rated oral health with self-rated general health and to test whether the intake of different food groups mediates the relationship. ***Method***: Data were collected in 2004–06 in a sample of adults from New South Wales (NSW) and Queensland, two states of Australia, using a computer-assisted telephone interview (CATI), oral examination, and completion of a mailed questionnaire and a food frequency questionnaire (FFQ). Self-rated general health and self-rated oral health were used as the outcome and explanatory variables, food groups (dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables and fruits) were the mediators. Baron and Kenny's (1986) mediation analysis was initially performed, followed by Sobel's (1982) test. Lastly, bootstrapping for standard errors and structural equation modelling (SEM) were conducted. ***Result***: A total of 1,129 persons responded to the FFQ with 62.6% aged 45+ years. Self-rated dental and self-rated general health were found to be associated (β=0.408 with p<0.001). Self-rated dental health was also associated with food groups (for all mediators, p<0.001). The Baron and Kenny and Sobel tests showed worse oral health was associated with worse general health, which was partially mediated by food intake except for bread-cereal (Sobel test: for all mediators, except bread-cereal, p<0.05). Bootstrap results were indicative of no mediation. The SEM analysis for mediation showed p=0.74 for dairy; p=0.55 for bread-cereal; p=0.56 for meat-fish-eggs; p=0.42 for sweet foods-snacks; p=0.23 for mixed vegetables; p=0.52 for vegetables; and p=0.57 for fruits, which were not statistically significant and which supported the bootstrap method result. ***Conclusion***: Better oral health is associated with better general health, but structural equation modelling (SEM) indicated that this association is not mediated by food consumption.

Assessing food intake as a mediator of the association between self-rated oral health and self-rated general health

1. Introduction

Oral health is one of the domains of health that can affect functioning and, hence, the overall feeling of health (Benyamini et al., 2004). The impact of oral health on general health is very evident in the literature. An extant literature review (Brennan & Singh, 2011; Fabioa et al., 2013) has revealed that people with healthy teeth and gums tend to have better general health and less sickness than people with teeth and gum disease. People perceived their oral health status as important to their quality of life through a variety of physical, social and psychological ways (McGrath & Bedi, 1999). Poor oral health and dental pain impact on older adults' general well-being and their quality of life.

Self-rated oral health is a single-item global rating of oral health that has often been used in research (Jones et al., 2001; Locker et al., 2002; Matthias et al., 1993) as it is easy to use and refers to a wide, multidimensional definition of oral health (Matthias et al., 1995). It is related to clinical oral health status (Locker et al., 2005; Thomson et al., 2012; Zaitsu et al., 2011), correlated with dentists' rating of oral health (Atchison et al., 1993) and associated with measures of oral functional impairment and discomfort (Atchison & Dolan, 1990), indicating that self-rated dental health (SRDH) is a valid measure of oral health status.

Self-rating of general health is a global self-rating summary measure of people's general health that has been used extensively in research to measure people's general health status (Benyamini et al., 2004; Brennan & Singh, 2011; Krause & Jay, 1995) and has also been found to predict future health outcomes (Benyamini et al., 2004). As a predictor, self-rated oral health predicts concurrent and future self-rated general health (SRGH) (Benyamini et al., 2004).

6 Tooth loss, poorly fitted dentures and poor gingival health (Margaret et al., 2010; Renato et al., 2008; Saarela et al., 2014) eventually alter food intake and increase the risk of negative effects on the nutrition status of older people. Decreased chewing ability was found to affect eating habits (Chauncey et al., 1984; Drummond et al., 1988; Hand et al., 1991; Osterberg & Steen, 1982; Petersen & Nortov, 1989). It was also associated with less likelihood of to meeting recommendations for the consumption of vegetables, dark green and orange vegetables, and legumes and being more likely to consume calories from solid fats, alcohol and added sugar (Margaret et al., 2010), and also with feeling tired or needing help with mobility (Avlund et al., 2001). Poor self-perception of oral health is also considered a possible risk marker for frailty syndrome, that is, unintentional weight loss, poor endurance and energy, low physical activity, slowness and weakness (Castrejón-Pérez et al., 2012). On the other hand, good oral health influences physical and psycho-social health among adults in a positive way, which raises their quality of life. Oral health influences nutritional status, physical health and social functioning in adults (Jung & Shin, 2008).

General health, the functional ability of an individual, is dependent on nutritional intake. Some studies have stated that poor dietary habits in older age increase the rate of developing chronic health problems (Callen & Wells, 2003; Laugero et al., 2011). Other studies have found that a lower intake of protein, fruits, vegetables, fibre and omega-3 fatty acids and a higher intake of carbohydrate and food groups, characterized by salty snacks, sweet foods, and high Glycaemic Index (GI) foods along with physical activity patterns affect the development of chronic health diseases in older age (Laugero et al., 2011). An improvement of eating habits was associated with an improvement of the quality of life and the maintenance of health in old age (Ferrucci et al., 2000; Hansen, 1983; Wahlqvist & Saviage, 2000).

According to Nishida et al., (2004), to reduce risk for cardiovascular health a diet should provide very low (<1% of daily energy intake) intake of trans fatty acids, adequate intake (6-10% of daily energy intake) of Polyunsaturated fatty acids and lowering intake for sodium chloride (less than 5g/d). The joint consultation report of WHO/FAO (2003) states that adequate intake of non-starch polysaccharides fibre such as whole-grain cereals and legumes (> 20 g/d) and fruits and vegetables (≥400g/d) have potential health benefits in preventing obesity, diabetes, cardiovascular disease and various cancers. The restriction of free sugar intake (< 10% of total energy) also contribute to reducing the risk of unhealthy weight gain (Nishida et al., 2004).

The systematic review and meta-analysis by Hosseini et al (2018) explain that a diet high in fruit and vegetables may lead to reduction in inflammation, (where inflammation is one of the major cause of a range of chronic diseases) and enhanced immune cell profile.

While the impact of oral health on general health is well established, oral health and nutritional status are also associated in various ways, with the relationship between nutritional status and general health documented in the literature. Therefore, the research on the impact of oral health on general health can be extended by testing the hypothesis that food consumption may mediate the relationship between them.

Mediation analysis explores the role of intervening variables (mediators) in an observed relationship between an exposure variable and an outcome variable, rather than hypothesising only a direct relationship between the independent variable and the dependent variable. A mediational model (also called a ‘mediation model’) hypothesises that the exposure variable affects the mediator variable which, in turn, affects the outcome variable (Valeri et al., 2014).

Therefore, the purpose of this study to investigate the potential association of self-rated oral health and self-rated general health (SRGH) and to test whether the intake of different

food groups mediates this association for adults. We believe that elucidating this relationship might be helpful knowledge in relation to the perceptions of adults about their oral health and general health, leading to the selection of appropriate food to maintain their healthy lives.

2. Method

2.1. Participants and data collection

Data for this study were derived from the 2004–2006 Australian National Survey of Adult Oral Health (NSAOH) (Slade et al., 2007). Study participants were selected at random using a multistage, stratified clustered sample selection procedure with a sampling frame compiled from listed telephone numbers in the Electronic White Pages (EWP) database (Slade et al., 2007). Information was collected by a computer-assisted telephone interview (CATI) followed by an oral epidemiological examination, and completion of a mailed questionnaire, and then a food frequency questionnaire (FFQ). An initial letter explaining the purpose of the survey was mailed to the selected participants, approximately 10 days prior to dialling them. The telephone interview collected information on socio-demographic characteristics and on several health-related factors. Participants who reported they were dentate were invited to participate in an oral epidemiological examination. Following the epidemiological examination, a questionnaire was mailed to all examined people containing information such as psycho-social variables. The subsequent FFQ collected data on the consumption of specific food items that included nine types of dairy; nine types of bread and cereal; 21 types of meat, fish and eggs; 15 types of sweet foods and snacks; four types of mixed vegetables; 25 types of vegetables; and eight types of fruits based on the items used in the National Nutrition Survey (ABS, 1998). Both self-rated oral health and self-rated general health (SRGH) are related to quality of life, especially in old age (Benyamini et al., 2004). As the risk of chronic conditions increases

with age (Griffin et al., 2012) and may not be noticeable among those of younger ages, we considered adults aged 45 years or over as participants in this study. The details of participation in the study, together with descriptive findings, have been reported elsewhere (Slade et al., 2007).

2.2. Study variables

The outcome variable was self-rated general health (SRGH). Self-ratings of health were assessed using single-item global ratings measured on 5-point Likert scales (Krause & Jay, 1995), which included the question "how would you rate your general health?" Conceptually, this is considered as a general health perception in Wilson and Cleary's model (Baker et al., 2008). The responses comprised the ordinal categories of 'poor', 'fair', 'good', 'very good' and 'excellent'.

The explanatory variable "self-rated oral health", a single-item global rating of oral health that has often been used in research (Jones et al., 2001; Locker et al., 2002; Matthias et al., 1993), was based on those used in previous population oral health surveys conducted by the Australian Research Centre for Population Oral Health (Carter & Stewart, 1999, 2002; Carter et al., 1994). It was assessed by the question "how would you rate your own dental health?", with responses that comprised the ordinal categories of 'poor', 'fair', 'good', 'very good' and 'excellent'.

Seven types of food items (dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables and fruits) from the subsequent FFQ based on the National Nutrition Survey (ABS, 1998) were considered as mediators. For each food item, the annual consumption frequency was recorded for the previous 12 months. The data on these items were collected on a 9-point scale ranging from 'never, or less than once a month' to '6+ times per day'.

Age, gender, tooth-brushing habits, diabetes, alcohol consumption and social support were the control variables. Control variables were selected initially from the review of the literature on the associations between oral health and nutrition, nutrition and general health, and oral health and general health. The critical level of $p \leq 0.20$ (Del Duca et al., 2013) was then used to select the control variables in this study.

Age, tooth-brushing habits and alcohol consumption were used as continuous variables with ranges from 45–90 years, the average number of tooth-brushing times per day, and the average number of standard alcohol drinks per day, respectively. Social support was also used as a continuous variable with a score range of 12–60, using the Multidimensional Scale of Perceived Social Support Assessment, a 12-item scale of perceived social support from family and friends (Zimet et al., 1988). Respondents answered items on a 5-point Likert-type scale ('strongly disagree' to 'strongly agree'), scored 1–5. The total is the sum of all 12 items, with the possible range for the total being 12–60. Gender was dichotomised between male and female, and diabetic status was coded based on whether or not a doctor had told respondents that they had diabetes.

2.3. Statistical analyses

Initially, the variable distribution was assessed using the Kolmogorov–Smirnov test, with kurtosis and skewness also checked.

Multivariate regression analyses were then used in three stages: first, the relationship of self-rated oral health to the consumption of different types of food; then the effect of the consumption of different types of food on general health; and, lastly, the association of oral health with general health.

The hypothesis that self-rated oral health is related to self-rated general health (SRGH) through consumption of food intake (seven different types of food groups) was tested, according to Baron and Kenny's (1986) recommendations. The analyses were performed

as follows: first, the regression analysis was checked to see if a direct effect (path *c*) between the independent variable (self-rated oral health) and the dependent variable (self-rated general health [SRGH]) was significant (see Fig. 1). Second, the independent variable was checked to see if it predicted the proposed mediator (M) (path *a*). Third, the mediator was used as a predictor of the dependent variable (Y) (path *b*). Lastly, if non-zero relationships existed between paths *a*, *b* and *c*, then the association of the independent variable to the dependent variable existed after controlling for mediators (path *c´*).

Full mediation exists when the effect of the independent variable on the dependent variable is no longer significant after including the mediator in the model. Partial mediation occurs when the relationship between independent and dependent variables is significantly reduced, but still significant when the mediator is included in the model. In order to test the significance of the mediation, Sobel's (1982) test was performed for an indirect effect using Winnifred's Mediation Program (WIMP), which is based on Kris Preacher's website, <http://www.unc.edu/~preacher/sobel/sobel.htm>.

A non-parametric resampling procedure, bootstrapping for standard errors, was also conducted for testing mediation, with this not imposing the assumption of the normality of the sampling distribution. The bootstrapping for standard errors with 2000 resampling iterations was conducted using Mediation Macro for SPSS by Preacher and Hayes (2008).

Lastly, structural equation modelling (SEM) for mediation analysis was conducted using AMOS graphics, in which all three paths (paths *a*, *b* and *c* from Fig. 1) were fit into a single model. The significance of the path coefficient was tested and compared in magnitude. All analyses was performed using the SPSS package (version 24.0).

3. Results

3.1. Response

In the NSAOH, a total of 14,123 adults responded to the CATI (49% response rate) and 5,505 were examined (44% of the interviewed people invited to the examination). In the nutrition sub-study, a total of 1,218 persons were approached in New South Wales and Queensland, with 1,129 responding (92.7% response rate). Among them, 752 respondents to the nutrition sub-study were aged 45 years and over.

3.2. Sampling distribution

3.3. The Kolmogorov–Smirnov test indicated that several variables deviated from normal distributions ($p<0.05$). However, skewness and kurtosis were between -1 to 1 and -3 to 3 (Table 1). The means, standard deviations and correlations of the main study variables are shown in Table 1.

3.4. Relationship between self-rated oral health, food items and self-rated general health

From multivariate linear regression analysis (Table 2), the study found that those who rated their oral health higher consumed more dairy products, bread-cereal, mixed vegetables, vegetables and fruits. Furthermore, adults with better oral health consumed fewer meat-fish-eggs and sweet foods-snacks.

Again, those who consumed more dairy products, bread-cereal, meat-fish-eggs and sweet foods-snacks rated their general health worse. On the other hand, adults who consumed more mixed vegetables, vegetables and fruits rated their general health higher. Lastly, adults with higher self-rated oral health rated their general health higher.

Therefore, adults with better oral health consumed more mixed vegetables, vegetables and fruits, and also less meat-fish-eggs and sweet foods-snacks, and rated their general health higher.

3.5. Mediation analysis

From Baron and Kenny's (1986) mediation analysis, the study found that model *a* showed a significant ($p<0.001$) relationship between self-rated dental health (SRDH) and the different kinds of food groups. All food groups were significantly ($p<0.001$) associated with self-rated general health (SRGH) (model *b*). For model *c*, self-rated oral health was significantly ($p<0.001$) associated with self-rated general health (SRGH). After inclusion of food groups (model *c'*), self-rated oral health was significantly ($p<0.001$) related to self-rated general health (SRGH). Therefore, it is possible that no mediation or partial mediation in the relationship between self-rated oral health and self-rated general health (SRGH). The outcome of the Sobel test indicated that the association between self-rated oral health and SRGH is partially mediated by the consumption of dairy products, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables and fruits, but is not mediated by bread-cereal.

From the bootstrapping test for standard errors (Table 3), implemented by Preacher and Hayes (2008), the bias correction confidence intervals (CIs) for all food groups included "0"; that is, the indirect effect was not significant, and no mediation was established.

From the SEM analysis, no significant indirect effect was found for any mediators (food groups). This, therefore, indicated that the association between self-rated dental health (SRDH) and SRGH was not mediated by consumption of any food items from the food groups: dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables and fruits.

Again, from the value of the coefficient of determination (R^2), self-rated oral health, together with the consumption of dairy, explained 20.9% of the variance of self-rated general health (SRGH). With the consumption of sweet foods-snacks and vegetables, we also found the same R^2 value. In other cases, for example, consumption of meat-fish-eggs and mixed vegetables, self-rated oral health explained 21% of the variance of self-rated general health (SRGH). Self-rated oral health together with the consumption of fruits explained 21.1% and bread-cereal 21.6% of the variance of self-rated general health (SRGH).

4. Discussion

The result of this study showed that a significant positive correlation existed between self-rated oral health and SRGH, which also supported the findings of previous studies (Kieffer & Hoogstraten, 2008). Both self-rated oral health and SRGH had a positive correlation with the consumption of mixed vegetables, vegetables and fruits and had a negative correlation with the consumption of meat-fish-eggs and sweet foods-snacks.

Applying the SEM method produced the final result. Although direct effects both with and without mediation were significant for all models, none of the indirect effects were significant. The effect of self-rated oral health on SRGH was not mediated by the consumption of any food item from the food groups: dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables or fruits. That is, consumption of these food items (dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables and fruits) had no effect on the relationship between SRDH and self-rated general health (SRGH). It should be noted that, if any mediation occurred, some significant indirect effect would occur (i.e., some effect would be transmitted through the mediator variables).

To discover the effect of mediation, several different approaches (classical and modern) were tested in this study. Initially, the most classical approach of Baron and Kenny (1986) was conducted. The main criticism of this method is that mediation may work out even results find no statistical significance of the dependent and independent variables (Pardo & Román, 2013). In Baron and Kenny's (1986) approach, if the relationship stays significant after inclusion of the mediator, mediation may be partial or absent, with this not specified. To identify proper specifications of mediation, Sobel's (1982) test was popularised, with this test measuring whether an intermediation effect is significant (Pardo & Román, 2013). The problem with Sobel's (1982) test is its dependence on distribution assumptions, which may affect the estimation of true *p*-values in smaller sample sizes. As a way to address this problem, researchers (Preacher & Hayes, 2004; Shrout & Bolger, 2002) have suggested using bootstrapping for standard errors which seems to have greater power in a small sample. In modern mediation analysis, structural equation modelling (SEM) is one of the most prominent methods that can fulfil the requirements of mediation analysis if it is considered necessary (Afthanorhan et al., 2014). Structural equation modelling (SEM) uses a conceptual model, a path diagram and a system of linked equations to capture complex and dynamic relationships within a web of observed and unobserved variables and provides a more appropriate inference framework for mediation analysis in a single analysis. Therefore, in this study, we focused on the result from the SEM mediation model using AMOS software.

For goodness of fit, the current study reported Comparative Fit Index (CFI) values. Ideally, for a model that fits the data, the CFI would be close to 0.95 or higher (Hu & Bentler, 1999). We have not reported χ^2 or the root mean square error of approximation (RMSEA) because χ^2 is sensitive to a large sample size (n>250), almost always indicating a poor fit, (Iacobucci, 2010) and the RMSEA worsens as the number of variables in the model

increases (Fan & Sivo, 2005; Kenny & McCoach, 2003). Overall, in view of power and robustness, Hu and Bentler (1998) have demonstrated strong CFI performance. We also calculated the coefficient of determination (R^2) value for each model. This coefficient of determination represents the combined effects of all independent variables, including the mediator variable on the dependent variable. The effect size (f^2) of our mediators (dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables and fruits) in the relationship between self-rated oral health and SRGH was small.

The main strength of this study is its large and representative sample derived from the Australian National Survey of Adult Oral Health (NSAOH). We used both classical and modern methods to analyse mediation.

Very few studies have been conducted to determine if nutrition is a mediator in the relationship between oral health and general health (Ritchie et al., 2002). These studies have only reviewed the literature in relation to oral conditions with nutrition and the links between various nutrition measures and systemic disease; however, relatively little work has been done on the hypothesised mediation model.

One limitation of this study is its cross-sectional design which makes it impossible to draw causal relationships between self-rated oral health, consumption of different kinds of food groups and self-rated general health (SRGH). However, the aim of this study was not to investigate the causal relationship. Instead, the focus was on testing whether statistical mediation was supported by the analysis. An additional limitation of this study was that individual models for each mediator were considered which may violate the overall assessment of direct and indirect effects. However, according to interests, we can consider the mediators one at a time if they do not affect one another (VanderWeele & Vansteelandt, 2014). This study was initially interested in the effect of each individual food group as a mediator, but further research could focus on the modelling of multiple

mediators, considering the suggestion of Vansteelandt and Daniel, (2017), due to the interrelationships between mediator variables.

Patient-reported self-assessment has become accepted as important for the evaluation and comparison of treatments and for the assessment and management of individual patients, with this described as a uniquely personal perception that represents the way that individuals feel about their health status (Fayers & Sprangers, 2002). Self-rated general health (SRGH) is a powerful predictor of clinical outcome and mortality (Fayers & Sprangers, 2002), and self-rated oral health is also a reasonable measure of clinically-determined oral health status (Mejia et al., 2014). However, these are completely analytical measures rather than clinical indicators. In future, we may consider more specific clinical oral health measures such as tooth loss, periodontal status or dental caries to test the more specific relationship between oral health and general health.

Therefore, the study found a direct effect of self-rated oral health on SRGH but this is not mediated by the consumption of food items (dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables and fruits). In the current study, the effect size for mediated variables is small, which may lead to the null findings, but the sample size of this current study is big enough, where power is not an issue. The main significance of our findings is that if elders maintain better oral health, this may also help them to maintain better general health. Furthermore, the consumption of mixed vegetables, vegetables and fruits has a positive impact on oral health and general health, which support the current literature (Hosseini et al 2018) and recommendation from WHO/AFO (The Joint Consultation Report 2003) that encourage consumption of fruits and vegetables.

Acknowledgments: The research reported in this paper is a study of the Australian Primary Health Care Research Institute (APHCRI), which is supported under the Australian Government's Primary Health Care Research, Evaluation and Development

Strategy. The information and opinions contained in it do not necessarily reflect the views or policy of the Australian Primary Health Care Research Institute or the Department of Health

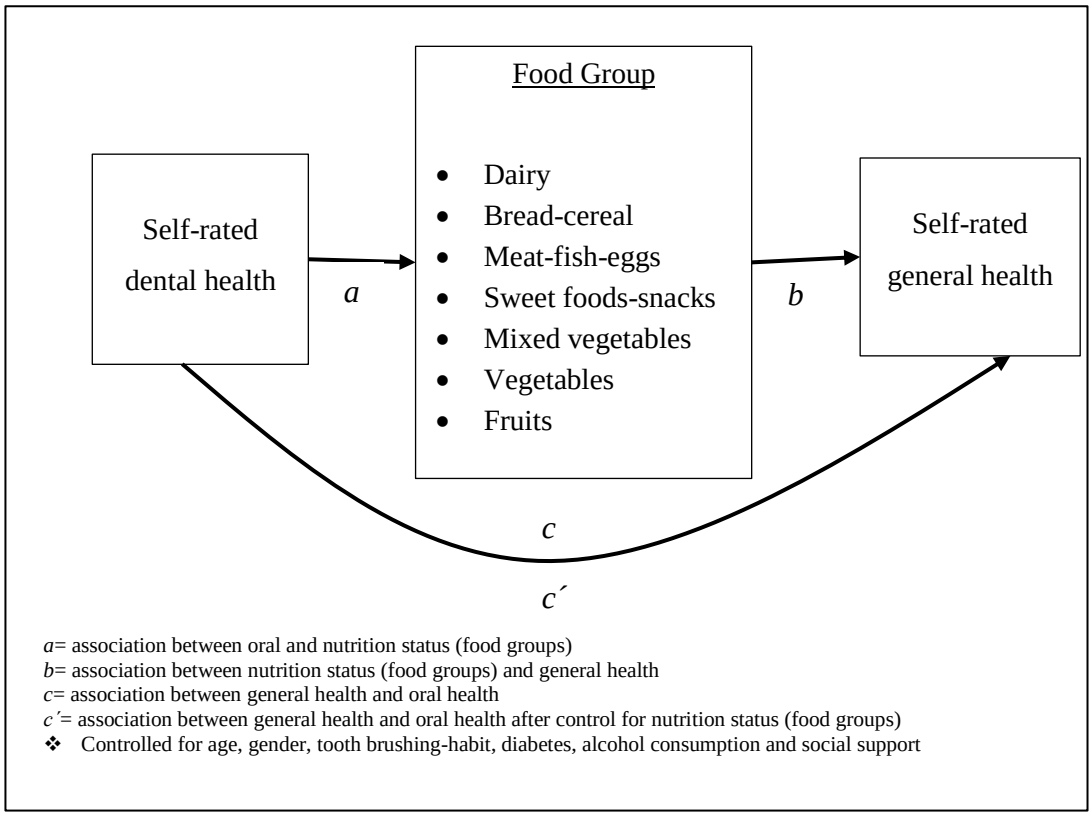


Figure 1: Conceptual model for mediation analysis

Table 1: Mean (SD), Skewness, Kurtosis and correlations among main study Variables

Variable	Range	Mean (SD)	Skewness	Kurtosis	Correlation coefficient	
					1	2
1.Self-rated general health	1-5	3.6 (0.9)	-0.36	-0.23	-	-
2. Self-rated dental health	1-5	3.3 (0.9)	-0.21	-0.19	0.427*	-
Dairy	0-51	25.6 (6.4)	-0.33	1.26	-0.028*	0.005*
Bread-cereal	0-45	25.6 (5.5)	-0.49	2.63	-0.069*	0.005*
Meat-fish-eggs	0-72	42.4 (8.6)	-0.22	2.23	-0.110*	-0.035*
Sweet foods-snacks	0-64	32.5 (8.5)	0.12	0.61	-0.045*	-0.047*
Mixed vegetables	1-15	12.4 (3.8)	-0.15	0.76	0.032*	0.018*
Vegetables	1-107	61.9 (12.1)	-0.41	2.23	0.032*	0.044*
Fruits	1-64	28.4 (8.5)	0.19	0.71	0.025*	0.038*

*****$p<0.001$; SD=standard deviation

Table 2: Regression analysis and multiple mediator model

Independent variable (X)	Mediator (M)	Dependent Variables	Path	B	Sobel Z	p	Degree of mediation
SRDH	-	SRGH	*c*	0.408*			
SRDH	Dairy	-	*a*	0.140*	-13.45	<0.001	Partial Mediation
-	Dairy	SRGH	*b*	-0.003*			
SRDH	(Dairy)	SRGH	*c´*	0.409*			
SRDH	Bread-cereal	-	*a*	0.014*	-1.89	0.06	No mediation
-	Bread-cereal	SRGH	*b*	-0.012*			
SRDH	(Bread-cereal)	SRGH	*c´*	0.408*			
SRDH	Meat-fish-eggs	-	*a*	-0.025*	2.49	0.01	Partial Mediation
-	Meat-fish-eggs	SRGH	*b*	-0.011*			
SRDH	(Meat-fish-eggs)	SRGH	*c´*	0.408*			
SRDH	Sweet foods-snacks	-	*a*	-0.403*	32.98	<0.001	Partial Mediation
-	Sweet foods-snacks	SRGH	*b*	-0.007*			
SRDH	Sweet foods-snacks	SRGH	*c´*	0.406*			
SRDH	Mixed vegetables	-	*a*	0.043*	9.62	<0.001	Partial Mediation
-	Mixed vegetables	SRGH	*b*	0.002*			
SRDH	(Mixed vegetable)	SRGH	*c´*	0.409*			
SRDH	Vegetables	-	*a*	0.436*	23.23	<0.001	Partial Mediation
-	Vegetables	SRGH	*b*	0.003*			
SRDH	(Vegetables)	SRGH	*c´*	0.407*			
SRDH	Fruits	-	*a*	0.081*	7.66	<0.001	Partial Mediation
-	Fruits	SRGH	*b*	0.003*			
SRDH	(Fruits)	SRGH	*c´*	0.408*			

*****p<0.001
SRDH= Self-rated dental health
SRGH= Self-rated general health

Table 3: Mediation results from Bootstrap method and SEM

Relationship	Bootstrap Bias Correction CI		SEM Result			Degree of mediation
	LL	UL	Direct without mediation	Direct with Mediation	Indirect effect	
General health depends on dental health (M: Dairy)	-0.0071	0.0014	0.378 (p<0.001)	0.378 (p<0.001)	0.00 (p=0.74)	No mediation
General health depends on dental health (M: Bread-cereal)	-0.0115	0.0016	0.378 (p<0.001)	0.378 (p<0.001)	0.00 (p=0.55)	No mediation
General health depends on dental health (M: Meat-fish-eggs)	-0.0116	0.0028	0.378 (p<0.001)	0.377 (p<0.001)	0.00 (p=0.56)	No mediation
General health depends on dental health (M: Sweet foods-snacks)	-0.0028	0.0086	0.378 (p<0.001)	0.377 (p<0.001)	0.00 (p=0.42)	No mediation
General health depends on dental health (M: Mixed vegetables)	-0.0023	0.0054	0.378 (p<0.001)	0.377 (p<0.001)	0.001 (p=0.23)	No mediation
General health depends on dental health (M: Vegetables)	-0.0015	0.0071	0.378 (p<0.001)	0.378 (p<0.001)	0.00 (p=0.52)	No mediation
General health depends on dental health (M: Fruits)	-0.0064	0.0024	0.378 (p<0.001)	0.379 (p<0.001)	0.001 (p=0.57)	No mediation

For mediator dairy: CFI=1; R^2 =0.209; f^2= 0.001
For mediator bread-cereal: CFI=0.996; R^2 =0.216; f^2= 0.003
For mediator meat-fish-eggs: CFI=0.998; R^2 =0.210; f^2= 0.003
For mediator sweet foods-snacks: CFI=0.999; R^2 =0.209; f^2= 0.001
For mediator mixed vegetables: CFI=0.999; R^2 =0.210; f^2= 0.003
For mediator vegetables: CFI=0.994; R^2 =0.209; f^2= 0.001
For mediator fruits: CFI=0.993; R^2 =0.211; f^2= 0.004
*effect size $f^2 = R^2_{included} - R^2_{excluded} / 1 - R^2_{included}$

4.5.3. References

Afthanorhan, A., Ahmad, S., and Safee, S. (2014). Moderated mediation using covariance-based structural equation modeling with amos graphic: volunteerism program. [Report]. *Advances in Natural and Applied Sciences,* **8**, 108+.

Atchison, K.A., and Dolan, T.A. (1990). Development of the Geriatric Oral Health Assessment Index. *J Dent Educ,* **54**, 680-687.

Atchison, K.A., Matthias, R.E., Dolan, T.A., et al. (1993). Comparison of Oral Health Ratings by Dentists and Dentate Elders. *J Public Health Dent,* **53** 223-230

Australian Bureau of Statistics. (1998). *National nutrition survey users' guide, 1995*. Canberra: Australian Bureau of Statistics.

Avlund, K., Holm-Pedersen, P., and Schroll, M. (2001). Functional Ability and Oral Health Among Older People: A Longitudinal Study from Age 75 to 80. *Journal of the American Geriatrics Society*, **49**, 954-962.

Baker, S. R., Pearson, N. K., and Robinson, P.G. (2008). Testing the applicability of a conceptual model of oral health in housebound edentulous older people. *Community Dent Oral Epidemiol,* **36**, 237-248.

Baron, R.M., and Kenny, D.A. (1986). The Moderator-Mediator Variable Distinction in Social Psychological Research: Conceptual, Strategic, and Statistical Considerations. *Journal of Personality and Social Psychology*, **51**, 1173-1182.

Benyamini, Y., Leventhal, H., and Leventhal E.A. (2004). Self-rated oral health as an independent predictor of self-rated general health, self-esteem and life satisfaction. *Social Science & Medicine,* **59**, 1109-1116.

Brennan, D.S., and Singh, K.A. (2011). General health and oral health self-ratings, and impact of oral problems among older adults. *European Journal of Oral Science,* **119**, 469-473.

Callen, B.L., and Wells, T.J. (2003). Views of community-dwelling, old-old people on barriers and aids to nutritional health. *J Nurs Scholarsh,* **35**, 257-262.

Carter, K.D., and Stewart, J.F. (1999). *Influence of perceived need on use of dental services*. Adelaide: AIHW

Carter, K.D., and Stewart, J.F. (2002). *National dental telephone interview survey 1999*. Adelaide: AIHW.

Carter, K.D., Stewart, J.F., Davies, M.J., Szuster, F.S., Allister, J.H., Slade, G.D., and Spencer, A.J. (1994). *National dental telephone interview survey 1994*. Adelaide: AIHW.

Chauncey, H.H., Muench, M., Kapur, K.K., and Wayler, A.H. (1984). The effect of the loss of teeth on diet and nutrition. *Int. Dent. J.,* **34**, 98-104.

Del Duca G. F., Markus V.N., Diego, A.S.S., et al. (2013). Physical activity indicators in adults from a state capital in the South of Brazil: a comparison between telephone and face-to-face surveys. *Cad Saude Publica,* **29**, 2119-2129.

Drummond, J.R., Newton, J.P.,and Yemm, R. (1988). Dentistry for the elderly: a review and an assessment of the future. *J. Dent,* **16**, 47-54.

Fabiola, B.A., Maria, L.L., Jair, L.F.S., and Yeda, A.O.D. (2013). Relationship between oral health and frailty in community-dwelling elderly individuals in Brazil. *J Am Geriatr Soc,* **61**, 809-814.

Fan, X., and Sivo, S.A. (2005). Sensitivity of Fit Indexes to Misspecified Structural or Measurement Model Components: Rationale of Two-Index Strategy Revisited. *Structural Equation Modeling,* **12**, 343-367.

Fayers, P.M., and Sprangers, M.A.G. (2002). Understanding self-rated health. *The Lancet,* **359**, 187-188.

Ferrucci, L., Benvenuti, E., Bandinelli, S., et al. (2000). Preventive health care for older women: life-style recommendations and new directions. *Ageing, **12***, 113-131.

Gil-Montoya, J. A., Ponce, G., Sanchez, L.I., et al. (2013). Association of the oral health impact profile with malnutrition risk in Spanish elders. *Archives of Gerontology and Geriatrics,* **57**, 398-402.

Griffin, S.O., Jones, J.A., Brunson, D., et al. (2012). Burden of oral disease among older adults and implications for public health priorities. *The American Journal of Public Health,* **102**, 411.

Hand, J.S., Hunt, R.J., and Kohout, F.J. (1991). Five-year incidence of tooth loss in Iowans aged 65 and older. *Community Dent. Oral Epidemiol,* **19**, 48-51.

Hansen, P.F. (1983). Epidemiological observation of old age. *Preventive Medicine,* **12**, 146-149.

Hu, L.-T., and Bentler, P.M. (1998). Fit Indices in Covariance Structure Modeling: Sensitivity to Underparameterized Model Misspecification. *Psychological Methods,* **3**, 424-453.

Hu, L.-T., and Bentler, P.M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal,* **6**, 1-55.

Iacobucci, D. (2010). Structural equations modeling: Fit Indices, sample size, and advanced topics. *Journal of Consumer Psychology,* **20**, 90-98.

Jones, J.A., Kressin, N.R., Spiro, I.A., et al. (2001). Self-reported and clinical oral health in users of VA health care. *Journals of Gerontology - Series A Biological Sciences and Medical Sciences,* **56**, M55-M62.

Jung, Y.-M., and Shin, D.-S. (2008). Oral Health, Nutrition and Oral Health-related Quality of Life- among Korian older adults. *Journal of Gerontological Nursing,* **34**, 28-35.

Kenny, D.A., and McCoach, D.B. (2003). Effect of the Number of Variables on Measures of Fit in Structural Equation Modeling. *Structural Equation Modeling,* **10**, 333-351.

Kieffer, J.M., and Hoogstraten, J. (2008). Linking oral health, general health, and quality of life. *European Journal of Oral Sciences,* **116**, 445-450.

Krause, N.M., and Jay, G.M. (1995). What Do Global Self-Rated Health Items Measure? *Medical Care,* **32**, 930-942.

Laugero, K.D., Falcon, L. M., and Tucker, K.L. (2011). Relationship between perceived stress and dietary and activity patterns in older adults participating in the Boston Puerto Rican Health Study. *Appetite*, **56**, 194-204.

Locker, D., Matear, D., Stephen, M. and Jokovic, A. (2002). Oral health-related quality of life of a population of medically compromised elderly people. *Community Dent Health,* **19**, 90-97.

Locker, D., Wexler, E., and Jokovic, A. (2005). What Do Older Adults' Global Self-ratings of Oral Health Measure? *J Public Health Dent,* **65**, 146-152.

Margaret, R.S., Thomas A.A., Xiaoyan, L., et al. (2010). Severe Tooth Loss in Older Adults as a Key Indicator of Compromised Diet Quality. *Public Health nutrition,* **13**, 466–474.

Matthias, R.E., Atchison, K.A., Lubben, J.E. et al. (1995). Factors Affecting Self-ratings of Oral Health. *J Public Health Dent,* **55**, 197-204.

Matthias, R.E., Atchison, K.A., Schweitzer, S.O., et al. (1993). Comparisons between dentist ratings and self-ratings of dental appearance in an elderly population. *Special Care in Dentistry,* **13**, 53-60

McGrath, C., and Bedi, R. (1999). The important of oral health to older people's quality of life. *Gerodontology, 16*(1), 59-63.

Mejia, G., Armfield, J., and Jamieson, L. (2014). Self-rated oral health and oral health-related factors: the role of social inequality. *Australian Dental Journal,* **59**, 226-233.

Osterberg, T., and Steen, B. (1982). Relationship between dental state and dietary intake in 70-year old males and females in Goteborg, Sweden. *J. Oral Rehabil,* **9**, 509-521.

Pardo, A., and Román, M. (2013). Reflections on the Baron and Kenny model of statistical mediation. *Anales de psicologia,* **29**, 614-623.

Petersen, P.E., and Nortov, B. (1989). General and dental health in relation to life-style and social network activity among 67-year-old Danes. *Scand. J. Prim. Health Care,* **7**, 225-230.

Preacher, K., and Hayes, A. (2004). SPSS and SAS procedures for estimating indirect effects in simple mediation models. *Behavior Research Methods, Instruments, & Computers,* **36**, 717-731.

Preacher, K., and Hayes, A. (2008). Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. *Behavior Research Methods,* **40**, 879-891.

Renato, J.D.M., Fernando, N.H., Juliana, B.H., and Dalva, M.P.P. (2008). Association between oral health status and nutritional status in south Brazilian independent-living older people. *Nutrition,* **24**, 546–553.

Ritchie, C.S., Joshipura, K., Hung, H.C., and Douglass, C.W. (2002). Nutrition as a mediator in the relation between oral and systemic disease: Associations between specific measures of adult oral health and nutrition outcomes *Crit. Rev. Oral Biol. Med.* **13**, 291-300.

Roberto, C.C.-P., and Borges-Yanez, S.A. (2012). Oral health conditions and frailty in Mexican community-dwelling elderly: a cross sectional analysis. *Public Health nutrition,* **12**.

Saarela, R., Soini, H., et al. (2014). Dentition status, malnutrition and mortality among older service housing residents. *The journal of nutrition, health & aging, 18*(1), 34-38. doi: 10.1007/s12603-013-0358-3

Shrout, P. E., & Bolger, N. (2002). Mediation in experimental and non experimental study: New procedure and recomendations. *Phychological Method, 7,* 422-455.

Slade, G.D., Spencer, A.J., Hiltunen, K., et al. (2007). *Australia's dental generations : the national survey of adult oral health 2004-06*. Canberra: Australian Institute of Health and Welfare.

Thomson, W.M., Mejia, G.C., Broadbent, J. M. and Poulton, R. (2012). Construct Validity of Locker's Global Oral Health Item. *J Dent Res,* **91**, 1038-1042.

Valeri, L., Lin, X., and Vanderweele, Tyler, J. (2014). Mediation analysis when a continuous mediator is measured with error and the outcome follows a generalized linear model. *Statistics in Medicine,* **33**, 4875-4890.

VanderWeele, T., and Vansteelandt, S. (2014). Mediation Analysis with Multiple Mediators. *Epidemiologic Methods,* **2**, 95-115.

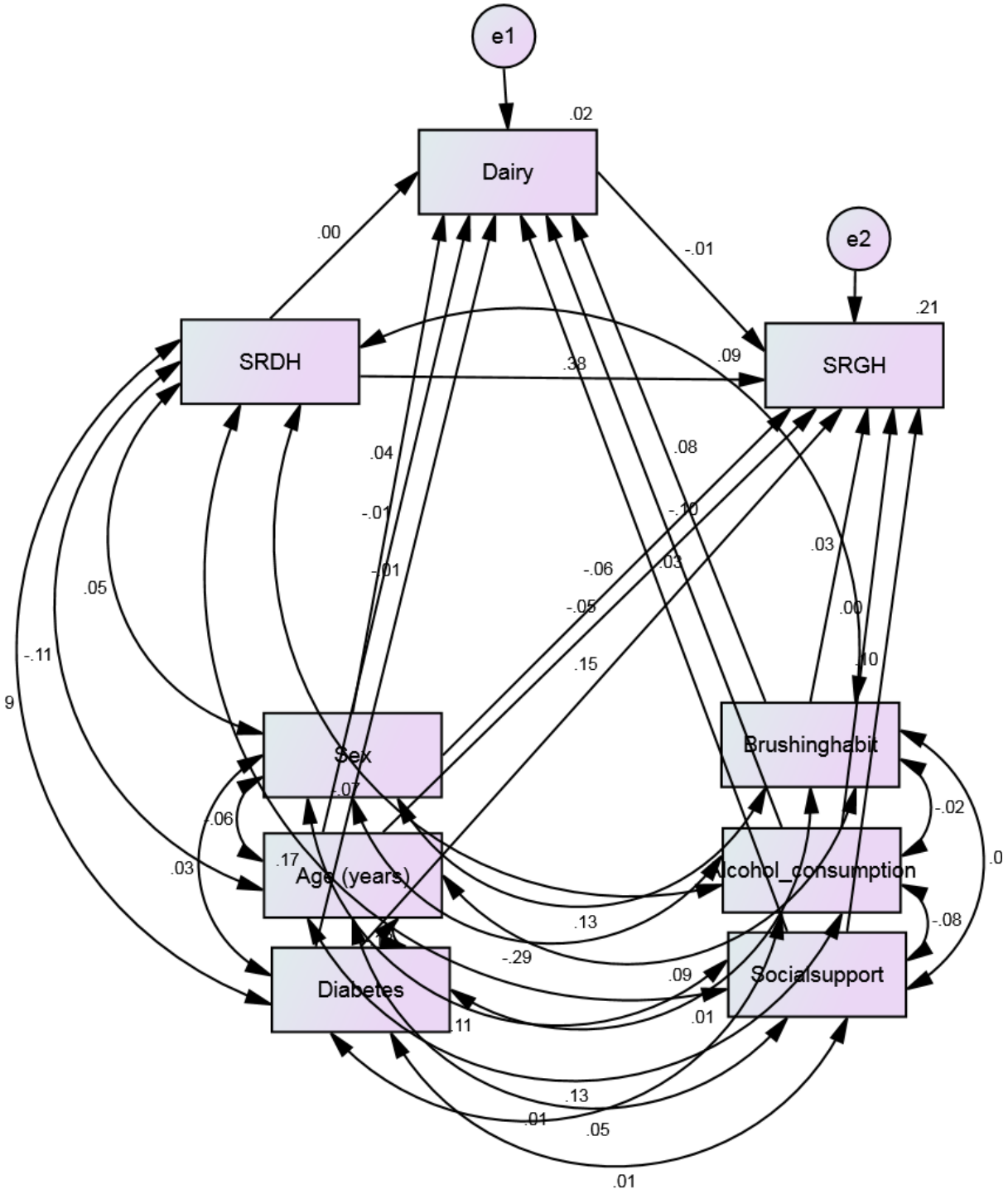
Vansteelandt, S., and Daniel, R.M. (2017). Interventional Effects for Mediation Analysis with Multiple Mediators. *Epidemiology (Cambridge, Mass.),* **28**, 258.

Wahlqvist, M.L., and Saviage, G.S. (2000). Interventions aimed at dietary and lifestyle changes to promote healthy aging. *Eur. J. Clin. Nutr,* **54**, 148-156.

Zaitsu, T., Ueno, T., Shinada, T., et al. (2011). Association of clinical oral health status with self-rated oral health and GOHAI in Japanese adults. *Community Dent Health,* **28**, 297-300.

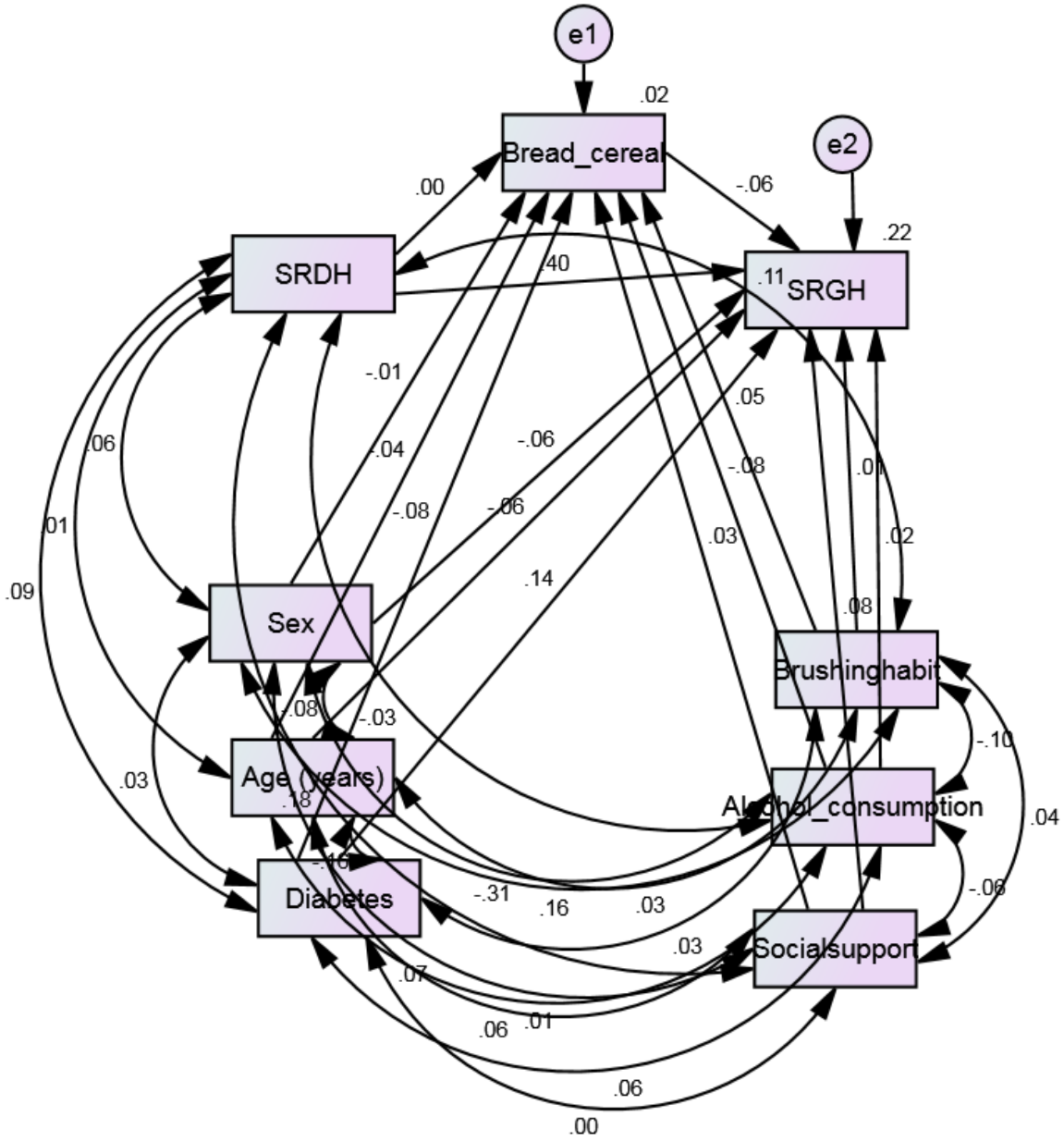
Zimet, G.D., Dahlem, N. W., Zimet, S.G., and Farley, G,K. (1988). The Multidimensional Scale of Perceived Social Support. *Journal of Personality Assessment,* **52**, 30-41.

4.5.4. Appendix



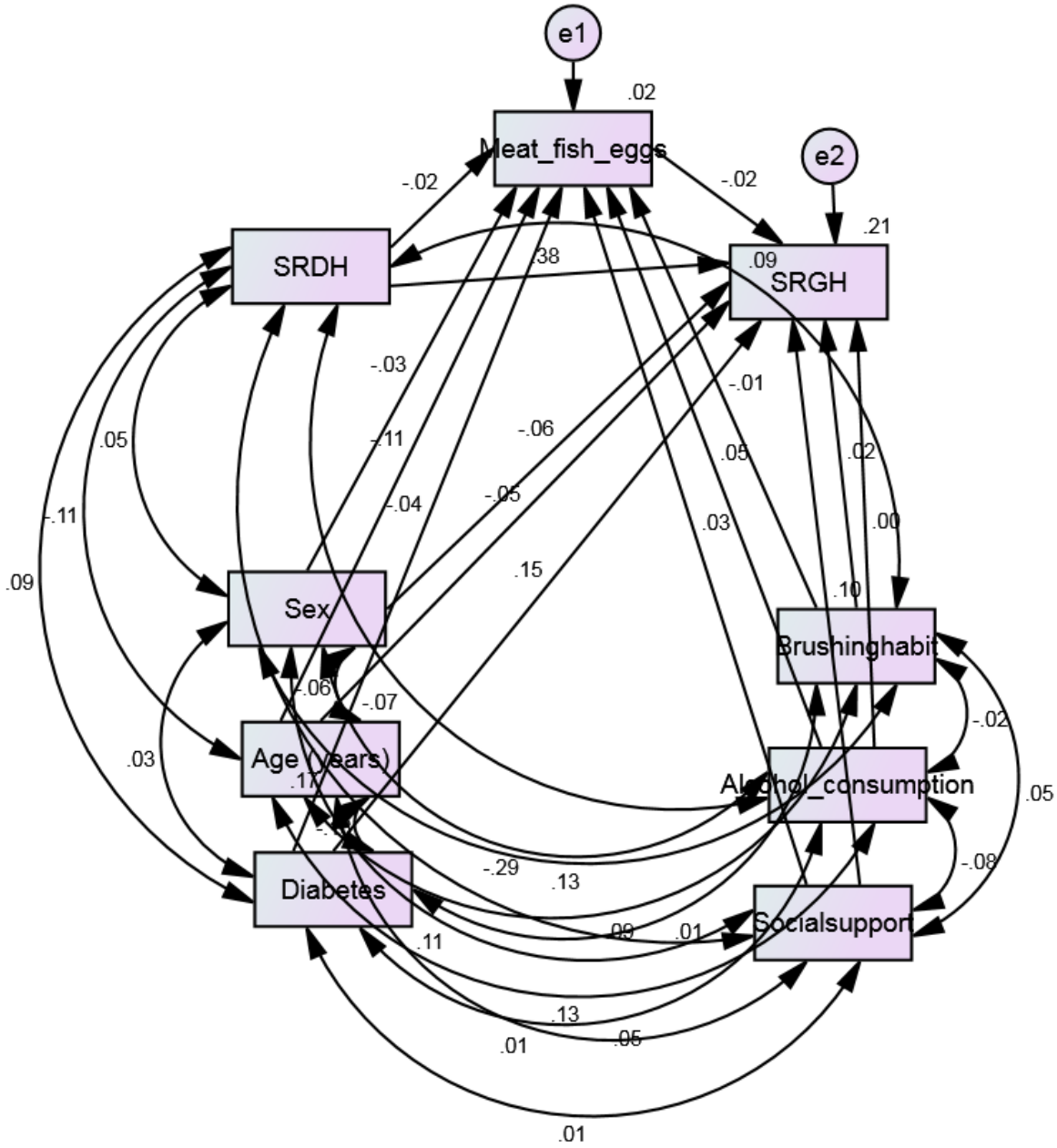
SRDH= Self-rated dental health
SRGH= Self-rated general health

Figure A1: Structural equation model with mediator 'Dairy'



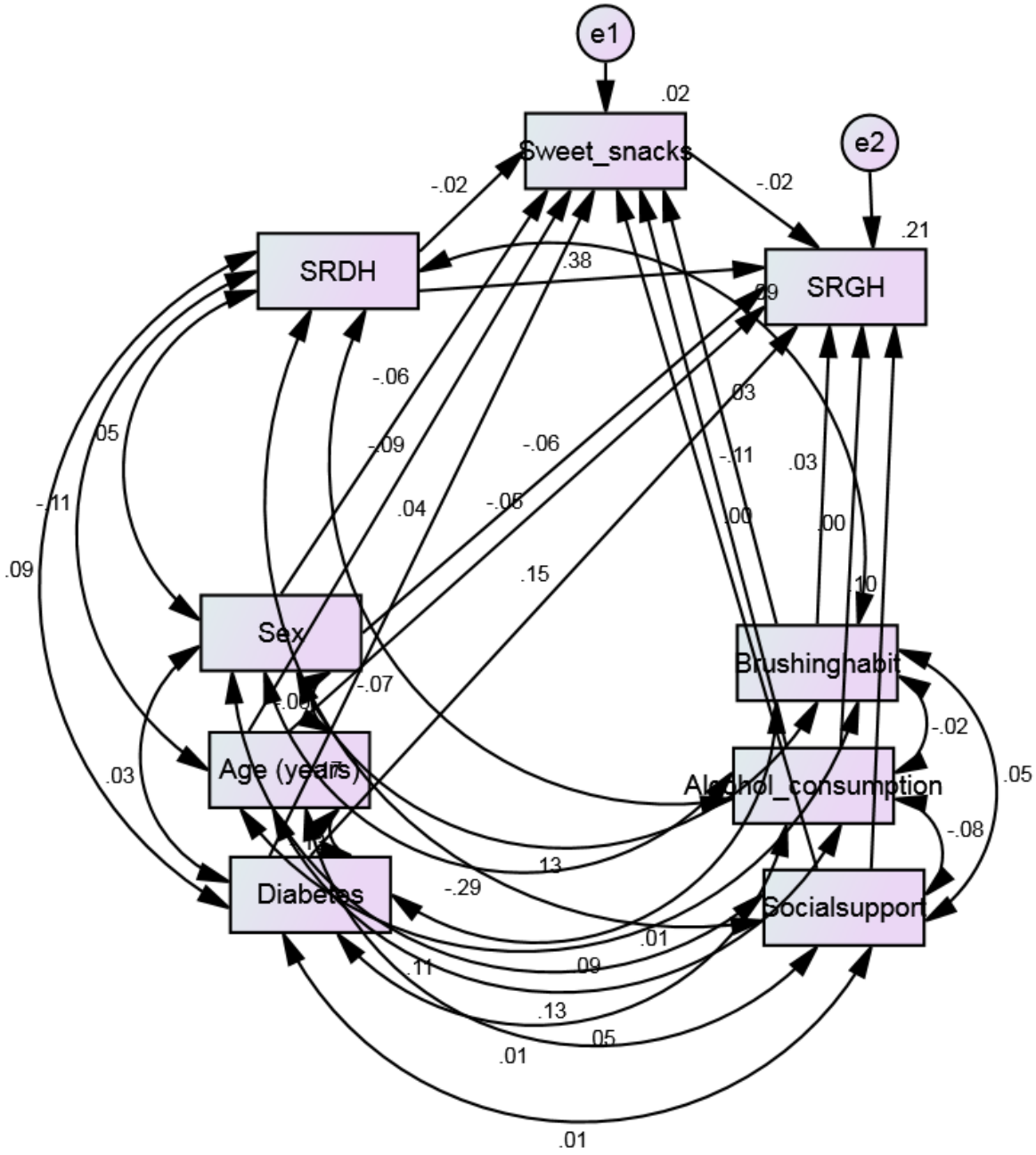
SRDH= Self-rated dental health
SRGH= Self-rated general health

Figure A2: Structural equation model with mediator ‘Bread-Cereal’



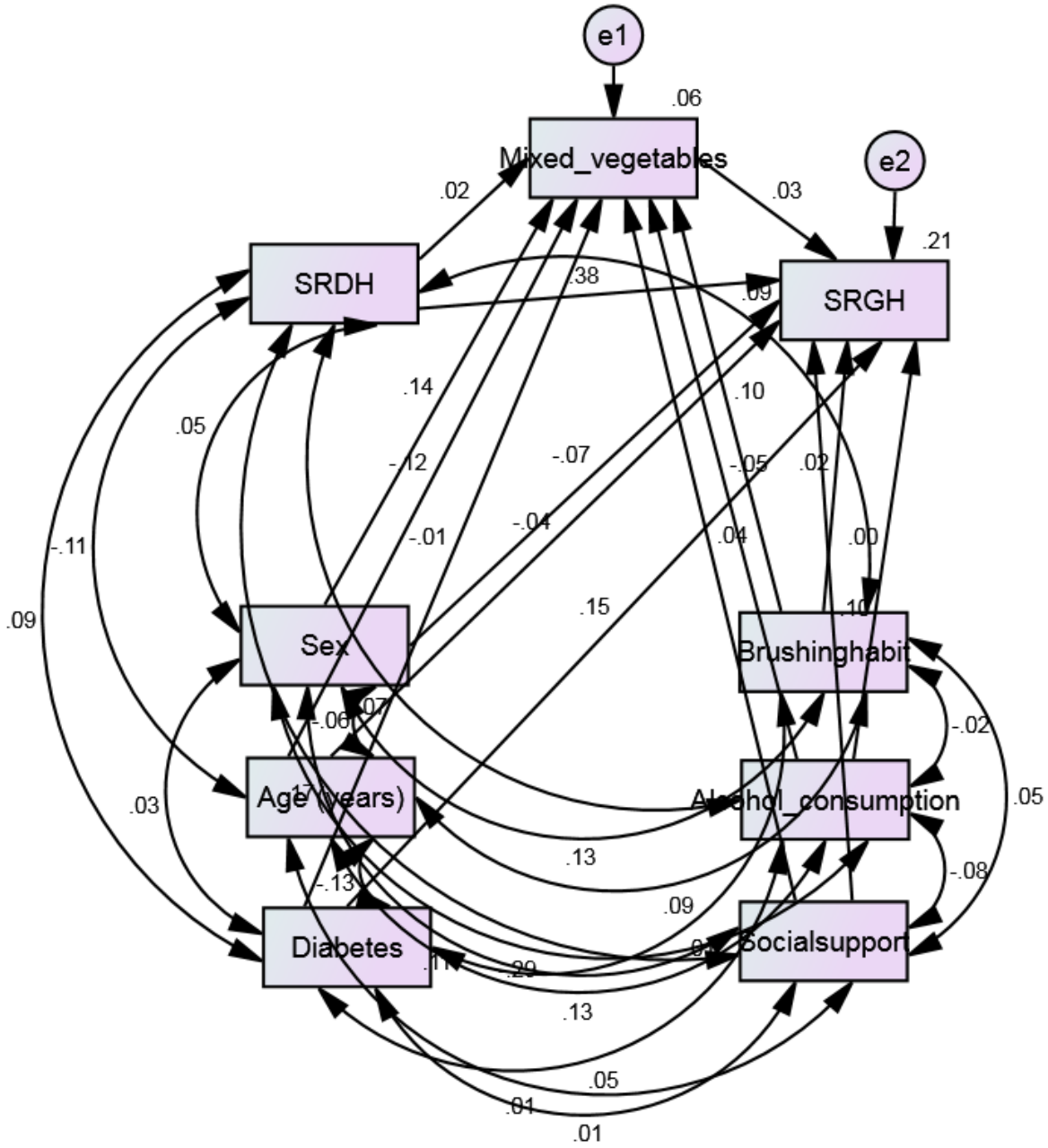
SRDH= Self-rated dental health
SRGH= Self-rated general health

Figure A3: Structural equation model with mediator ‘Meat-fish-eggs’



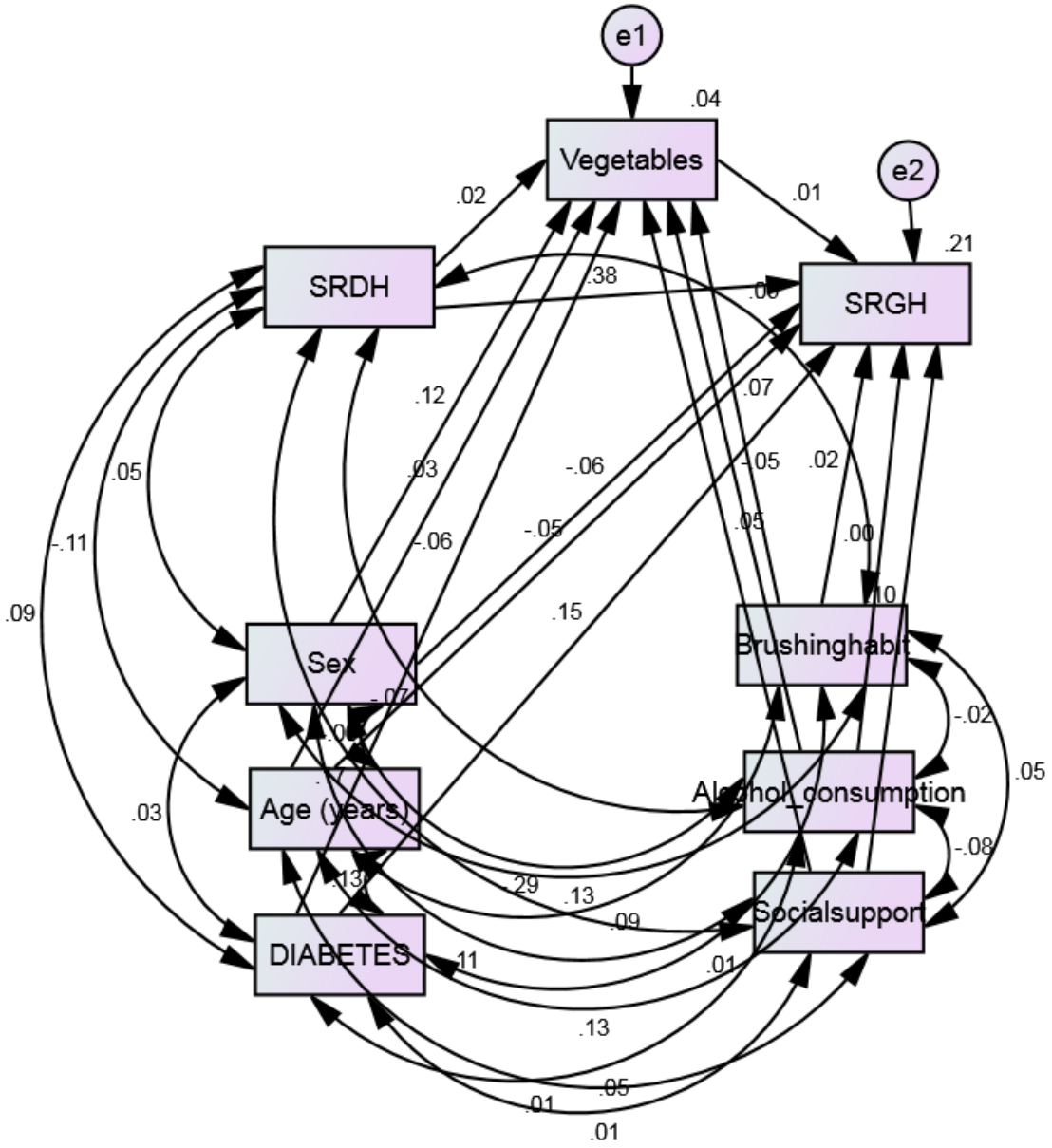
SRDH= Self-rated dental health
SRGH= Self-rated general health

Figure A4: Structural equation model with mediator ‘Sweet foods-snacks’



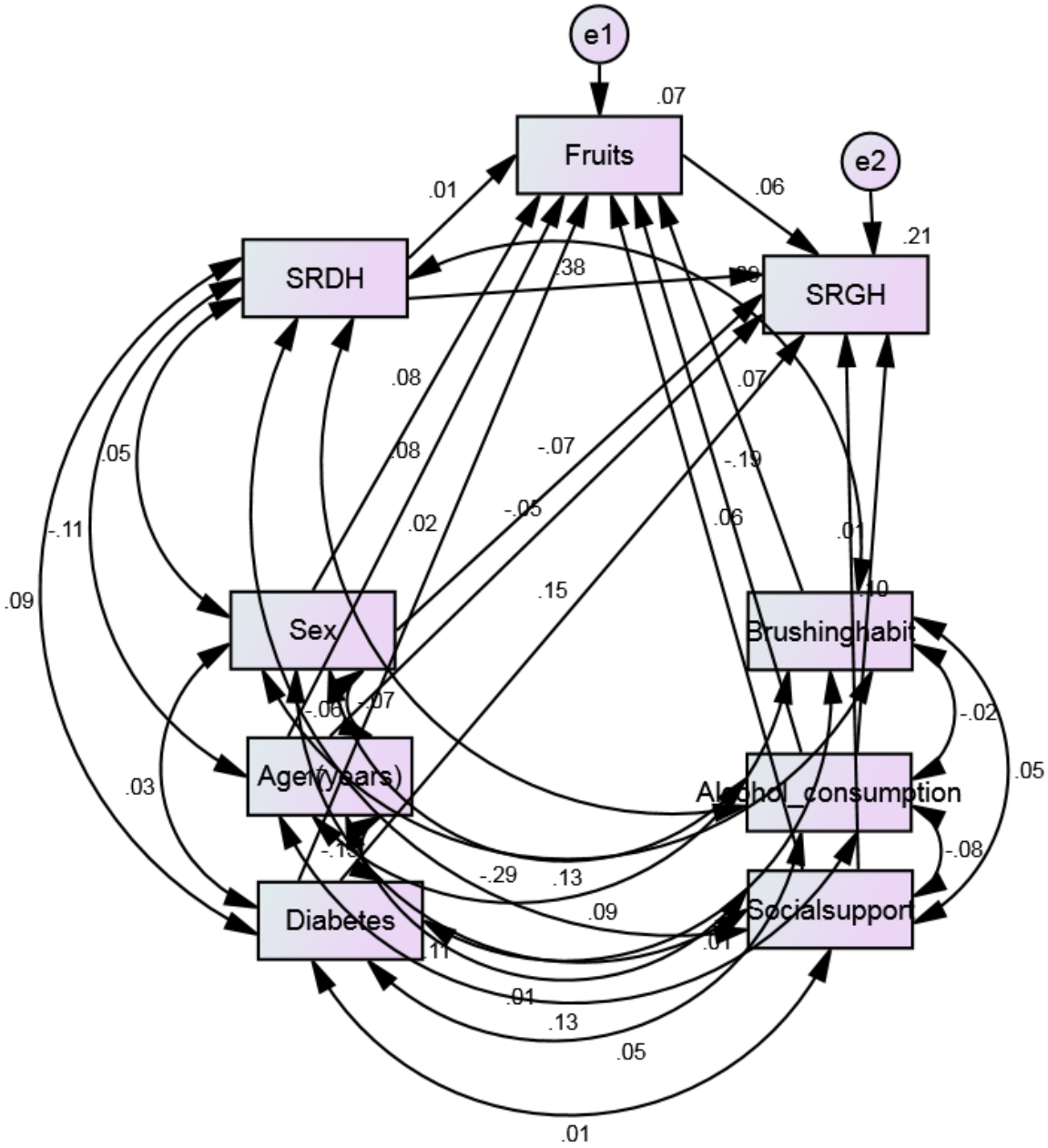
SRDH= Self-rated dental health
SRGH= Self-rated general health

Figure A5: Structural equation model with mediator ‘Mixed vegetables’



SRDH= Self-rated dental health
SRGH= Self-rated general health

Figure A6: Structural equation model with mediator ‘Vegetables’



SRDH= Self-rated dental health
SRGH= Self-rated general health

Figure A7: Structural equation model with mediator ‘Fruits’

Chapter 5: Discussion and Conclusions

This chapter presents the summary, strengths and limitations related to the study, as well as the methodology and discussion of the results presented in the three papers (Chapter 4), and finishes with the conclusion.

5.1. Summary

The present research study was undertaken based on Australian adults. A population-based study was conducted with the focus on "Assessing intake of different food groups as a mediator in the relationship between oral health and general health". More specifically the focus of the study was to;

1. Investigate the potential association between periodontal status and general health and test whether the intake of different food groups (dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables and fruits) mediates this relationship for adult Australians.
2. Explore the potential association between oral health status (number of missing teeth and OHIP score) and general health and test with mediation analysis whether the intake of different food groups (dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables and fruits) mediates the relationship for adult Australians.
3. Investigate the potential association between self-rated dental health (SRDH) and self-rated general health (SRGH) and test whether the intake of different food groups (dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables and fruits) mediates the relationship for adult Australians.

These three aspects have been addressed in Chapter 4.

The study found an indirect effect of periodontitis on SRGH which was partially mediated by the consumption of different kinds of food groups, namely, bread-cereal, meat-fish-eggs and sweet foods-snacks. The study also found that the effect of periodontitis on SRGH was not mediated by the consumption of dairy, mixed vegetables, vegetables or fruits, but that increased consumption of mixed vegetables, vegetables and fruits had a positive impact on general health.

The effect of the number of missing teeth on SRGH was not mediated by the consumption of any kind of food groups among dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables or fruits. In addition, the consumption of different food group items (dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables and fruits) did not mediate the relationship between the impact of oral health and general health. Furthermore, adults with more missing teeth and a high OHIP score had an association with the lower consumption of vegetables and fruits: increasing the consumption of mixed vegetables, vegetables and fruits is recommended to maintain better general health.

The effect of SRDH on SRGH was not mediated by the consumption of any of the food groups among dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables or fruits. However, a direct effect of SRDH on SFGH was found. In addition, the consumption of mixed vegetables, vegetables and fruits had a positive impact on both dental health and general health

5.2. Why Mediation Analysis?

Mediation analysis explores the role of intervening variables (mediators) in an observed relationship between an exposure variable and an outcome variable, rather than hypothesising only a direct relationship between the exposure variable and the outcome

variable. A mediational model (also called a ‘mediation model’) hypothesises that the exposure variable has an effect on the mediator variable which, in turn, has an effect on the outcome variable (Valeri et al., 2014).

The assessment of mediation presents an important way to address the criticism of ‘black box’ epidemiology by moving beyond the identification of simple exposure–disease relationships to open the black box to see its inner workings (Hafeman & Schwartz, 2009). Mediation, in this context, is defined as the totality of processes that explain an observed relationship between exposure and disease (Hafeman, 2008).

In other words, mediation analysis seeks a more accurate explanation of the effect that exposure has on the outcome, with a focus on the mechanisms that make the causal chain possible.

5.3. Why Considering the SEM Result to be the Final Result of Mediation Analysis?

To discover the effect of mediation, a range of different approaches (classical and modern) was tested in this study. Initially, the most classical approach of Baron and Kenny (1986) was conducted, with this having been used by many researchers (Gawęda et al., 2015; McLeod et al., 2011; Murrell & Meeks, 2002; Watson et al., 2011). Baron and Kenny’s (1986) method is a four-step approach in which several regression analyses are conducted, with the significance of the coefficients examined at each step. The main criticism of this method is that mediation may be present even when no statistical significance of the dependent and independent variables is apparent (Pardo & Román, 2013). Furthermore, in Baron and Kenny’s (1986) approach, if the relationship remains significant after inclusion of the mediator, mediation may be partial or absent, but this is not specified.

To identify the proper specifications of the mediation, the Sobel (1982) test has become popular as it measures whether or not an intermediation effect is significant (Pardo & Román, 2013). The Sobel (1982) test evaluates the significance of the mediator by the product of the coefficients which can easily be found from simple regression analysis. The problem with Sobel's (1982) test is its dependence on distributional assumptions which may affect the estimation of true *p*-values for smaller sample sizes. To address this problem, researchers (Preacher & Hayes, 2004; Shrout & Bolger, 2002) have suggested using bootstrapping for standard errors which seems to have greater power in a small sample. Bootstrapping for standard errors is a non-parametric method based on resampling with a replacement which can be done many times. From each sample, the indirect effect is computed, and a sampling distribution can be empirically generated. As the mean of the bootstrapped distribution will not exactly equal the indirect effect, a correction for bias can be made. More recently, Fritz et al. (2012) raised a concern that bias-corrected bootstrapping is too liberal with alpha (Type I error) being around 0.07. In fact, not doing the bias correction seems to improve the Type I error rate. According to Hayes and Scharkow (2013), if power is a major concern, then the bias-corrected bootstrap is recommended, but if the Type I error rate is a major concern, it is not recommended.

In modern mediation analysis, structural equation modelling (SEM) is one of the prominent methods that can fulfil the requirements of mediation analysis if it is necessary (Afthanorhan et al., 2014). Structural equation modelling (SEM) uses a conceptual model, a path diagram and a system of linked equations (regression style) to capture complex and dynamic relationships within a web of observed and unobserved variables. In addition, it provides a more appropriate inference framework for mediation analysis in a single analysis. Therefore, in this study, we focused on the result of the SEM mediation model.

5.4. Study Findings

This section discusses the study findings of Chapter 4, Section 4.3, 4.4 and 4.5.

5.4.1. Association between periodontitis and self-rated general health is partially mediated by the consumption of the food groups of bread-cereal, meat-fish-eggs and sweet foods-snacks

In Chapter 4, the study presented in Section 4.3 (Research Article 1) aimed to investigate the association between periodontal status and self-rated general health (SRGH) and to test whether the intake of different food groups (dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables and fruits) mediated the relationship. The underlying hypotheses postulated that severe periodontal problems predict worse SRGH and that the intake of unhealthy kinds of food mediates the relationship for the adult Australian population aged 45 and over. The findings showed that less severe periodontal problems predicted better general health and that this association was partially mediated by the consumption of bread-cereal, meat-fish-eggs and sweet foods-snacks.

A range of different approaches was tested in this study to measure the support for the hypotheses. From Baron and Kenny's (1986) mediation analysis, we see a significant (p<0.005) relationship between periodontitis and the consumption of all kinds of food groups. Moreover, consumption of all food groups is significantly (p<0.001) associated with self-rated general health (SRGH). In addition, periodontitis is significantly (p<0.001) associated with self-rated general health (SRGH). After the food groups are introduced, periodontitis and the consumption of all food groups (except dairy) significantly (p<0.001) predict self-rated general health (SRGH). The findings support the view that partial mediation or no mediation may occur between periodontitis and SRGH with the consumption of bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables and fruits. However, from Sobel's (1982) test, we can see that the association

between periodontitis and SRGH are partially mediated by the consumption of dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables and fruits (p<0.005).

From the bootstrap test for standard errors, as implemented by Preacher and Hayes (2008), the bias correction confidence intervals (CIs) for the consumption of all food groups include "0"; that is, they indicate that the indirect effect is not significant, with no mediation established.

The SEM analysis indicates that the association between periodontitis and SRGH was partially mediated by the consumption of bread-cereal, meat-fish-eggs and sweet foods-snacks. The study's calculation of variance accounted for (VAF) finds that 35.7% of the effect of periodontitis on SRGH was explained by the consumption of bread and cereal. Again 35.7% of the effect of periodontitis on SRGH was explained by the consumption of meat, fish and eggs. Moreover, 39.3% of the effect of periodontitis on SRGH was explained by the consumption of sweet foods-snacks.

5.4.2. Association between oral health (missing teeth and OHIP score) and general health (self-rated general health) is not mediated by the consumption of the food groups of dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables or fruits

In Chapter 4, the study described in Section 4.4 (Research Article 2) aimed to investigate the effect of the number of missing teeth and the OHIP score on SRGH and to test whether the intake of different food groups (dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables and fruits) mediates the relationship. Two hypotheses were considered: (1) adults with more missing teeth predict worse SRGH and the intake of unhealthy kinds of food mediates the relationship, and (2) adults with a higher OHIP score rated their general health worse, and the intake of unhealthy kinds of food mediates the relationship. The findings show that adults with more missing teeth rated their general

health worse, but that the association was not mediated by consumption of any of these food groups: dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables and fruits. Adults with a higher OHIP score (i.e., greater impact of dental problems) also rated their general health worse, with this not mediated by consumption of any of these food groups: dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables and fruits.

As described next, a range of different approaches was tested in this study to measure the support for these hypotheses. Baron and Kenny's (1986) mediation analysis shows a significant (p<0.001) relationship between the number of missing teeth and consumption of all kinds of food groups. Consumption of all food groups is significantly (p<0.001) associated with self-rated general health (SRGH). In addition, the number of missing teeth is significantly (p<0.001) associated with self-rated general health (SRGH). After food groups are introduced, the number of missing teeth and the consumption of all food groups significantly (p<0.001) predict self-rated general health (SRGJ). Therefore, we can say that it is possible that no mediation or partial mediation exists in the relationship between the number of missing teeth and self-rated general health (SRGH). From Sobel's(1982) test, it can be concluded that the association between the number of missing teeth and SRGH was partially mediated by the consumption of dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, vegetables and fruits (p<0.001), but not mediated by the consumption of mixed vegetables (p=0.48).

Again, for mediation analysis in the relationship between the Oral Health Impact Profile (OHIP) score and general health, Baron and Kenny's (1986) mediation analysis shows a significant (p<0.001) relationship between the OHIP score and the consumption of all kinds of food groups. The consumption of all food groups was significantly (p<0.001) associated with self-rated general health (SRGH). The OHIP score was also significantly

(p<0.001) associated with self-rated general health (SRGH). Lastly, after introducing food groups, the OHIP score and consumption of all food groups significantly (p<0.001) predicted self-rated general health (SRGH). Therefore, we can say that no mediation or partial mediation exists in the relationship between the OHIP score and self-rated general health (SRGH). From Sobel's (1982) test, we can conclude that the association between the OHIP score and SRGH was partially mediated by the consumption of dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables and fruits (p<0.001).

From testing both hypotheses using the bootstrap test for standard errors, the result shows that the bias correction confidence intervals (CIs) for the consumption of all food groups for both cases included "0", that is, they indicate that the indirect effect was not significant and that no mediation was established.

The SEM analysis indicates that the association between the number of missing teeth and general health was not mediated by consumption of any of the food groups of dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables or fruits. The same result was also found in the mediation analysis when SEM was used with the exposure variable of OHIP score, the outcome variable of SRGH and the mediator variable being the consumption of the different food groups (dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables and fruits); that is, no mediation effects were found in the relationship between the OHIP score and self-rated general health (SRGH).

5.4.3. Association between self-rated dental and general health is not mediated by food groups of dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables or fruits.

Chapter 4, the study described in Section 4.5 (Research Article 3) aimed to investigate the association between self-rated dental health (SRDH) and self-rated general health (SRGH) and to test whether the intake of different food groups (dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables and fruits) mediates the relationship. The underlying hypotheses were that worse SRDH predicts worse SRGH and that the intake of unhealthy kinds of food mediates the relationship for the adult Australian population aged 45 years and over. The findings also show that adults with better SRDH rated their general health better, but that the association was not mediated by consumption of any of these food groups: dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables and fruits.

As described next, a range of different approaches was tested in this study to measure the support for these hypotheses. Baron and Kenny's (1986) mediation analysis shows that SRDH was significantly (p<0.001) associated with the consumption of all kinds of food groups. Consumption of all food groups was significantly (p<0.001) associated with self-rated general health (SRGH). In addition, SRDH was significantly (p<0.001) associated with self-rated general health (SRGH). After the food groups were included, SRDH was still significantly (p<0.001) related to self-rated general health (SRGH). Therefore, we can say that possibly no mediation or partial mediation exists in the relationship between SRDH and self-rated general health (SRGH). From Sobel's (1982) test, it can be concluded that the association between SRDH and SRGH was partially mediated by the consumption of dairy products, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables and fruits, but that it was not mediated by bread-cereal.

The bootstrap test for standard errors, implemented by Preacher and Hayes (2008), indicates that the bias correction confidence intervals (CIs) for the consumption of all food groups included “0”; that is, the indirect effect was not significant, and no mediation was established.

The SEM analysis indicates that the association between SRDH and SRGH was not mediated by consumption of any of the food groups: dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables or fruits.

5.5. Compare and Contrast the Study Findings

Oral health is an important determinant of overall health. The current study has found that adults with none/mild and moderate periodontal problems compared to those with severe periodontal problems rated their general health better. In the literature, the study found a similar pattern and broader explanation of this relationship and that periodontal disease explained a part of the aetiology of various systemic diseases, that is, non-oral diseases that cause direct infection in the heart, the lungs, the brain, the head and the neck region (Slots, 2003). Furthermore, severe periodontitis has been associated with adverse changes in blood pressure and in serum cholesterol level (D'Aiuto et al., 2006). Durham et al. (2013) stated that, compared to periodontally healthy patients, patients with chronic periodontitis reported significantly poorer oral health-related quality of life.

The current study found that adults with more missing teeth and a higher OHIP score (indicating more impact from oral health problems) rated their general health worse. Similar patterns were also seen in the literature. Reissmann et al. (2013) found that denture patients reported higher OHIP scores, indicating lower health-related quality of life than the general population, while OHIP-14 scores were negatively correlated with self-assessment of overall health (Kieffer & Hoogstraten, 2008; Yu et al., 2013). Moreover,

Brennan and Singh (2011) stated that SRGH was worse for those with higher OHIP scores and those with more health problems.Tooth loss is also related to sytemic health. For example, tooth loss can increase the risk of cardiovascular diseases and gastrointestinal disorders (Hung et al., 2005; Osterberg et al., 2010), and can also increase the risk of non-insulin-dependent diabetes mellitus (Cleary & Hutton, 1995; Medina-Solis et al., 2006) and chronic kidney disease (Fisher et al., 2008).

In the current study, the self-assessment of dental and general health is found to be related and adults with better SRDH rated their general health better, with this finding also supported by previous studies (Benyamini et al., 2004; Brennan & Singh, 2011; Kieffer & Hoogstraten, 2008). Kieffer and Hoogstraten's (2008) study indicated a moderate relationship between self-rated oral health and general health. Furthermore, Benyamini et al. (2004) stated that self-rated oral health not only contributed to predicting SRGH, it also predicted the future level of self-rated general health (SRGH). In addition, Brennan and Singh (2011) stated that SRGH is positively associated with SRDH, but that this depended on the number and level of the individual's health problems.

Given the cross-sectional nature of the design it is difficult to identify causal relationships. Other possibilities include common risk factors for periodontitis, diet and general health such as lower socioeconomic status and age. Also, with a cross-sectional design the direction of associations and possible causal relationships is difficult to discern.

To live a healthy life, appropriate food consumption is necessary. The current study shows that adults who consume more vegetables, fruits and mixed vegetables rated their general health higher, with this also supported in the study by Laugero et al. (2011) study. In their study, they stated that a lower intake of protein, fruits, vegetables, fibre and omega-3 fatty acids and a higher intake of carbohydrate and food groups characterized by salty snacks,

sweet foods, and high Glycaemic Index (GI)food along with physical activity patterns affect the development of chronic health diseases in older age. In addition, fruits, vegetables, whole-grains, low-fat dairy products, poultry, fish and nut consumption were recommended for preventing heart disease and stroke in the at-risk population (Nielsen et al., 2016). In the systematic review and meta-analysis, Hosseini et al (2018) also suggested that a diet high in fruit and vegetables may lead to reduction in inflammation, (where inflammation is one of the major cause of a range of chronic diseases) and enhanced immune cell profile.

Furthermore, oral health is important in an individual's ability to consume appropriate food to maintain a healthy life. The current study found that adults with compromised oral health (more missing teeth, a higher OHIP score and severe periodontitis) consumed less fruits and vegetables, whereas the intake of fruits and vegetables is recommended for maintaining a healthy life (Laugero et al., 2011; Nielsen et al., 2016). Similar results were found in other studies. Some studies found that people with fewer teeth reported a lower intake of root vegetables and other vegetables (Joshipura et al., 1996; Ratna et al., 1988) and those who had lost five or more teeth in the previous four years decreased their intake of vegetables, apples and pears (Joshipura et al., 1996). Another study observed that lower consumption of fruits, vegetables and mixed vegetables was more prevalent among those with fewer teeth (Brennan et al., 2010). It was also found that the number of food items that the individual was able to eat was significantly correlated with the number of present teeth, with more missing teeth leading to more limited choice of foods and consequent reduction of the intake of fruits, vegetables and fibre (Toniazzo et al., 2017). On the other hand, sugar-sweetened beverages are dietary sources of sugar that are factors in caries development and leading to tooth loss (Wiener et al., 2017).

5.6. Strengths and Limitations of the Study

For interpretation of the results, it is essential to state the strengths and limitations of the study. In this part of the thesis, the strengths and limitations of the methodological approaches followed in Chapter 4, Sections 4.3, 4.4 and 4.5 are discussed.

5.6.1. Strengths

1. The current study was conducted with a large and representative sample of Australian adults derived from the Australian National Survey of Adult Oral Health (NSAOH).
2. Both classical and modern methods for analysing mediation have been used in this study and the sequence of using the different methods has been described.
3. Oral health was considered from different dimensions, in view of perceptions (self-rated general health [SRGH] and the OHIP score) and clinical measures (number of missing teeth and periodontitis)
4. Nutrition data were collected using a Food Frequency Questionnaire (FFQ), in which the average consumption frequency was recorded for the previous 12 months on a 9-point scale ranging from ‘never, or less than once a month’ to ‘6+ times per day’ which accounted for daily variation in food intake.
5. A range of food groups was considered to check their mediation effect. Each of the food group items included were based on the National Nutrition Survey (ABS, 1995).

5.6.2. Limitations

1. In the current study, a cross-sectional design has been adopted to collect data which makes it impossible to draw causal relationships between oral health, the

consumption of different kinds of food groups and general health. While consideration of cause is an important aspect of mediation, the aim of this study was not to investigate the causal relationship. Instead, the focus was on establishing whether mediation is supported in terms of statistical associations.

2. In the current study, a less healthy and healthy food items were considered in the same food group. For example, all kind of dairy such as low fat and full fat dairy were considered as a "dairy" Sugary fruits, fruit juice and other all kind of fruits considered as a "fruits". Starchy vegetables, fried vegetables, boiled/mashed/baked vegetables, raw vegetables and cooked vegetables considered as 'vegetables'. Even good protein (fish), protein with saturated fat (red meat) and eggs considered in a same food group. However, according to initial research interest, overall food group was considered, further research could focus on less healthy and healthy food groups or consider nutrient variables, such as saturated fat, poly- or mono-fats, protein, carbohydrate, sugar, fibre, calcium, cholesterol, iron, folate, etc., from consumed food.
3. The current study conducted individual models for each mediator. This may violate the overall assessment of direct and indirect effects. However, according to research interests, one can consider the mediators one at a time if the mediators do not affect one another (VanderWeele & Vansteelandt, 2014). The initial interest of this research was in the effect of the consumption of each individual food group as a mediator; however, further research could focus on the modelling of multiple mediators modelling, thus considering the suggestion of Vansteelandt and Daniel (2017).

5.7. Implications

The current research articulates the impact of oral health on nutrition intake and general health in Australia. The study findings are relevant to public health.

5.7.1. Implications for public health

The current research has provided evidence of the mediation effect of adult food consumption in the relationship between oral health and general health. Different levels of periodontal problems in adults were partially mediated by the consumption of bread-cereal, meat-fish-eggs and sweet foods-snacks to maintain a better level of general health. Although the effect of periodontitis on SRGH was not mediated by the consumption of dairy, mixed vegetables, vegetables or fruits, increased consumption of mixed vegetables, vegetables and fruits had a positive impact on general health. The effects of the number of missing teeth and the OHIP score were not mediated by any of the food groups. However, adults with more missing teeth and a high OHIP score were found to have an association with lower consumption of vegetables and fruits: increasing their consumption of mixed vegetables, vegetables and fruits is thus recommended to maintain better general health.

The current study's findings show Australian adults' self-perception of oral and general health. Self-rated dental health (SRDH) has a direct effect on SRGH but this is not mediated by the consumption of food items. However, the consumption of mixed vegetables, vegetables and fruits has a positive impact on dental health and general health, which underlines the importance of dietary guidelines for health professionals to design not only oral health policy but, consequently, general health policy.

In practice, dental professionals and health professionals seek to improve the health of their patients. This research will help all health care professionals to understand the potential

relationships between nutrition, oral health and general health and to adopt an interdisciplinary approach to providing optimal care to adults. More specifically, explaining this relationship might assist nutritionists to develop dietary guidelines in view of different levels of oral health status, with these guidelines helpful to health professionals in designing general health policy.

5.7.2. Implications for the epidemiological literature

The findings of the current study contribute to the knowledge of mediation effects in the relationships between oral health, nutrition and general health. Oral health has been considered from the perspectives of different dimensions by the measures in this study. For future researchers, the study provides a broader view of oral health in relation to nutrition and general health.

Using and describing the sequence of the different approaches to mediation analysis and comparing them in this study will help future researchers to make decisions on why, when and how to use different mediation analysis approaches in their research.

5.8. Future Work

The current study's findings show that, in some cases, the consumption of food is a mediator between oral health and general health but that, in some cases, it is not. To investigate more closely, the next step of this study would be to:

- consider more specific food groups instead of including less healthy and healthy food items in the same food group. For example, dairy could be closely monitored as low fat and full fat dairy. Sugary fruits and fruit juice could be excluded from the fruit group. Starchy and fried vegetables could be excluded from the vegetable group and be considered as a different group. Meat-fish-eggs could be divided into

good protein and protein with saturated fat. Wholemeal/mixed grain bread-cereal could be separated from white bread and sugary cereal.

- consider nutrient variables, such as saturated fat, poly- or mono-fats, protein, carbohydrate, sugar, fibre, calcium, cholesterol, iron, folate, etc., from consumed food as mediators which are more known to impact on general health.
- consider non-communicable diseases, such as diabetes, cancer, lung diseases, stroke, heart disease, etc. as a proxy for general health with these diseases more related to food and nutrition.
- consider the modelling of multiple mediators instead of using single mediator modelling.

5.9. Conclusions

The current study has explored the association between oral health and general health from different aspects of oral health and has tested whether and how the intake of different food groups (dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables and fruits) mediates this relationship for adult Australians.

The main conclusions are described below:

Australian adults with none/mild and moderate periodontal problems compared to those with severe periodontal problems were more likely to rate their general health better with this association partially mediated by the consumption of bread-cereal, meat-fish-eggs and sweet foods-snacks. Around 35.7% of the effect of periodontitis on self-rated general health (SRGH) is explained by the consumption of bread and cereal; 35.7% of the effect of periodontitis on SRGH is explained by the consumption of meat, fish and eggs; and 39.3% of the effect of periodontitis on SRGH is explained via the consumption of sweet foods-snacks. Australian adults with more missing teeth and a higher OHIP score (i.e., greater

impact of dental problems) rated their general health worse, while Australian adults who rated their oral health higher were more likely to rate their general health higher. However, the associations between the number of missing teeth, self-rated dental health (SRDH), Oral Health Impact Profile (OHIP) score and SRGH were not mediated by the consumption of any item from these food groups: dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables and fruits.

The other conclusions are next described:

- Australian adults with severe periodontal problems compared to those with moderate or less periodontal problems consumed less bread-cereal, sweet foods-snacks, mixed vegetables, vegetables and fruits, and more dairy and meat-fish-eggs. Australian adults with more missing teeth consumed less of any kind of food item from the food groups: dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks, mixed vegetables, vegetables or fruits. Those with higher OHIP scores (greater impact of dental problems) consumed more dairy, bread-cereal, meat-fish-eggs, sweet foods-snacks or mixed vegetables and consumed fewer vegetables and fruits. Australian adults who rated their dental health higher consumed more dairy, bread-cereal, mixed vegetables, vegetables and fruits, and less meat-fish-eggs and sweet foods-snacks.
- Australian adults who consumed more dairy, bread-cereal, meat-fish-eggs and sweet foods-snacks rated their general health as poor and those who consumed more vegetables, fruits and mixed vegetables rated their general health higher.
- Australian adults with more missing teeth and a higher OHIP score (i.e., greater impact of dental problems) rated their general health worse, while Australian adults who rated their oral health higher were more likely to rate their general health higher.

6. References

Abnet CC, Qiao YL, Dawsey SM, Dong Z W, Taylor PR, & Mark SD (2005). Tooth loss is associated with increased risk of total death and death from upper gastrointestinal cancer, heart disease, and stroke in a Chinese population-based cohort. *International Journal of Epidemiology 34*(2), 467-474. doi: 10.1093/ije/dyh375

Adiatman, M., Ueno, M., Ohnuki, M., Hakuta, C., Shinada, K., & Kawaguchi, Y. (2013). Functional tooth units and nutritional status of older people in care homes in Indonesia. *Gerodontology, 30*(4), 262-269. doi: 10.1111/j.1741-2358.2012.00673.x

Afthanorhan A, Ahmad S, & Safee S (2014). Moderated mediation using covariance-based structural equation modeling with amos graphic: volunteerism program. [Report]. *Advances in Natural and Applied Sciences, 8*, 108+.

Åstrøm AN, Haugejorden O, Skaret E, Trovik TA, & Klock KS (2006). Oral Impacts on Daily Performance in Norwegian adults: the influence of age, number of missing teeth, and socio-demographic factors. *European Journal of Oral Sciences, 114*(2), 115-121. doi: 10.1111/j.1600-0722.2006.00336.x

Australian Bureau of Statistics. (1998). *National nutrition survey users' guide, 1995*. Canberra: Australian Bureau of Statistics.

Avlund K, Holm-Pedersen P, & Schroll M (2001). Functional Ability and Oral Health Among Older People: A Longitudinal Study from Age 75 to 80. *Journal of the American Geriatrics Society, 49*(7), 954-962. doi: 10.1046/j.1532-5415.2001.49187.x

Baker SR, Pearson NK, & Robinson PG (2008). Testing the applicability of a conceptual model of oral health in housebound edentulous older people. *Community Dentistry Oral Epidemiology, 36*(3), 237-248. doi: 10.1111/j.1600-0528.2007.00394.x

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), 1173-1182. doi: 10.1037/0022-3514.51.6.1173

Bates CJ, Nelson M, & Ulijaszek SJ (2005). Nutritional assessment methods. *Human Nutrition*, 573-595.

Bentler PM (1990). Comparative Fit Indexes in Structural Models. *Psychological Bulletin, 107*(2), 238-246. doi: 10.1037/0033-2909.107.2.238

Benyamini Y, Leventhal H, & Leventhal EA (2004). Self-rated oral health as an independent predictor of self-rated general health, self-esteem and life satisfaction. *Social Science & Medicine, 59*(5), 1109-1116. doi: 10.1016/j.socscimed.2003.12.021

Bischoff, H. A., Staehelin, H. B., & Willett, W. C. (2006). The Effect of Undernutrition in the Development of Frailty in Older Persons. *The Journals of Gerontology: Series A, 61(6),* 585-589. doi:10.1093/gerona/61.6.585.

Bomfim, R. A., De Souza, L. B., & Corrente, J. E. (2018). Tooth loss and its relationship with protein intake by elderly Brazilians—A structural equation modelling approach. *Gerontology*, 35(1), 51-58. doi:10.1111/ger.12317

Bortoluzzi, M., Traebert, J., Lasta, R., Da Rosa, T., Capella, D., & Presta, A. (2012). Tooth loss, chewing ability and quality of life. Contemporary *Clinical Dentistry, 3(4),* 393-397. doi:10.4103/0976-237X.107424

Bradbury J, Thomason JM, JepsonNJ, Walls AW, Allen PF, & Moynihan PJ (2006). Nutrition counseling increases fruit and vegetable intake in the edentulous. *Journal of Dental Research, 85*(5), 463-468.

Brennan DS, Singh KA, Liu P, & Spencer A (2010). Fruit and vegetable consumption among older adults by tooth loss and socio-economic status. *Australian Dental Journal, 55*(2), 143-149. doi: 10.1111/j.1834-7819.2010.01217.x

Brennan DS, & Singh KA (2011). General health and oral health self-ratings, and impact of oral problems among older adults. *European Journal of Oral Science, 119*(6), 469-473. doi: 10.1111/j.1600-0722.2011.00873.x

Brennan DS, & Singh KA (2012). Dietary, Self-reported oral health and socio-demographic predictores of general health status among older adults. *The Journal of Nutrition, Health & Aging, 16*(5), 437-441.

Callen BL, & Wells TJ (2003). Views of community-dwelling, old-old people on barriers and aids to nutritional health. *Journal of Nursing Scholarship, 35*(3), 257-262.

Carter KD, & Stewart JF (1999). Influence of perceived need on use of dental services. *American Association of Public Health Dentistry, 62nd Annual Meeting*. 6–8 October, 1999

Carter KD, & Stewart JF (2002). *National dental telephone interview survey 1999*. Adelaide: AIHW.

Carter KD, Stewart JF, Davies MJ, Szuster FS, Allister JH, Slade GD, & Spencer AJ (1994). *National dental telephone interview survey 1994*. Adelaide: AIHW.

Centre for Disease Control (CDC). (2001). *National Health and Nutrition Examination Survey. Dental Examiners Procedures Manual .2002*: Atlanta, GA: CDC.

Chaffee, B. W., & Weston, S. J. (2010). Association between Chronic Periodontal Disease and Obesity: A Systematic Review and Meta-Analysis. *Journal of Periodontology*, 81(12), 1708-1724. doi:10.1902/jop.2010.100321

Cleary T, & Hutton JE (1995). An assessment of the association between functional edentulism, obesity, and NIDDM. *Diabetes Care, 18*(7), 1007-1009.

D'Aiuto F, Parkar M, Nibali L, Suvan J, Lessem J, & Tonett, MS (2006). Periodontal infections cause changes in traditional and novel cardiovascular risk factors: Results from a randomized controlled clinical trial. *American Heart Journal, 151*(5), 977-984. doi: 10.1016/j.ahj.2005.06.018

Dallal GE (1986). PC-SIZE: A Program for Sample-Size Determinations. *The American Statistician, 40*(1), 52-52. doi: 10.2307/2683121

Dallal GE, & Wilkinson L (1986). An Analytic Approximation to the Distribution of Lilliefors's Test Statistic for Normality. *The American Statistician, 40*(4), 294-296. doi: 10.1080/00031305.1986.10475419

Daly RM, Elsner R, Allen P, & Burke F. (2003). Associations between self-reported dental status and diet. *Journal of Oral Rehabilitation, 30*(10), 964-970.

Del Duca, G. F., Nahas, M. V., Silva, D. A. S., Hallal, P. C., Malta, D. C., & Peres, M. A. (2013). Physical activity indicators in adults from a state capital in the South of Brazil: a comparison between telephone and face-to-face surveys. *Cadernos de Saúde Pública,* 29(10), 2119-2129. doi:10.1590/0102-311X00130412

Do, L. G., Slade, G. D., Roberts-Thomson, K. F., & Sanders, A. E. (2008). Smoking-attributable periodontal disease in the Australian adult population. *Journal of Clinical Periodontology,* 35(5), 398-404. doi:10.1111/j.1600-051X.2008.01223.x

Dormenval V, Budtz-Jørgensen E, Mojon P, Bruyère A, & Rapin CH (1995). Nutrition, general health status and oral health status in hospitalised elders. *Gerodontology, 12*(2), 73-80. doi: 10.1111/j.1741-2358.1995.tb00134.x

Douglas G, Tian C, Pan W, & Hui Z (2013). Introduction to mediation analysis with structural equation modeling *Biostatistics in Psychiatry, 25*(06), 390-394.

Durham J, Fraser HM, McCracken GI, Stone KM, John MT, & Preshaw PM (2013). Impact of periodontitis on oral health-related quality of life. *Journal of Dentistry, 41*(4), 370-376. doi: 10.1016/j.jdent.2013.01.008

Einarson S, Gerdin EW, & Hugoson A (2009). Oral health impact on quality of life in an adult Swedish population. *Acta Odontologica, 2009, Vol.67(2), p.85-93, 67*(2), 85-93. doi: 10.1080/00016350802665597

Emami E, de Souza RF, Kabawat M, & Feine JS (2013). The impact of edentulism on oral and general health. *International Journal of Dentistry, 2013*, 498305. doi: 10.1155/2013/498305

Fan X, & Sivo SA (2005). Sensitivity of Fit Indexes to Misspecified Structural or Measurement Model Components: Rationale of Two-Index Strategy Revisited. *Structural Equation Modeling, 12*(3), 343-367. doi: 10.1207/s15328007sem1203_1

Fan X, Thompson B, & Wang L (1999). Effects of sample size, estimation methods, and model specification on structural equation modeling fit indexes. *Structural Equation Modeling: A Multidisciplinary Journal, 6*(1), 56-83. doi: 10.1080/10705519909540119

Farre TB, Formiga F, Ferrer A, Plana-Ripoll O, Almeda J, & Pujol R (2013). Risk of being undernourished in a cohort of community-dwelling 85-year-olds: The Octabaix study. *Geriatrics & Gerontology International,* doi: 10.1111/ggi.12142

Feart, C. (2019). Nutrition and frailty: Current knowledge. Neuropsychopharmacology & Biological Psychiatry, 95. doi:https://doi.org/10.1016/j.pnpbp.2019.109703

Fisher M A, Taylor GW, Shelton BJ, Jamerson KA, Rahman M, Ojo AO, & Sehgal A R (2008). Periodontal disease and other nontraditional risk factors for CKD. *American Journal of Kidney Diseases, 51*(1), 45-52. doi: 10.1053/j.ajkd.2007.09.018

Fritz MS, Taylor AB, & Mackinnon DP (2012). Explanation of Two Anomalous Results in Statistical Mediation Analysis. *Multivariate Behavioral Research, 47*(1), 61-87. doi: 10.1080/00273171.2012.640596

Gaewkhiew, P., Sabbah, W., & Bernabé, E. (2017). Does tooth loss affect dietary intake and nutritional status? A systematic review of longitudinal studies. Journal of Dentistry, 67, 1-8. doi:10.1016/j.jdent.2017.10.012

Gawęda Ł, Prochwicz K, & Cella M (2015). Cognitive biases mediate the relationship between temperament and character and psychotic-like experiences in healthy adults. *Psychiatry Research, 225*(1-2), 50-57. doi: 10.1016/j.psychres.2014.10.006

Ghezzi EM, & Ship JA (2000). Dementia and oral health.(Author abstract)(Disease/Disorder overview). *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology, 89*(1), 2. doi: 10.1016/S1079-2104(00)80003-7

Gil-Montoya JA, Ponce G, Sanchez Lara I, Barrios R, Llodra JC, & Bravo M (2013). Association of the oral health impact profile with malnutrition risk in Spanish elders. *Archives of Gerontology and Geriatrics, 57*(3), 398-402. doi: 10.1016/j.archger.2013.05.002

Glick M, Williams DM, Kleinman DV, Vujicic M, Watt RG, & Weyant RJ (2016). A new definition for oral health developed by the FDI World Dental Federation opens the door to a universal definition of oral health (Vol. 147, pp. 915-917).

Griffin SO, Jones JA, Brunson D, Griffin PM, & Bailey WD (2012). Burden of oral disease among older adults and implications for public health priorities. *The American Journal of Public Health, 102*(3), 411. doi: 10.2105/AJPH.2011.300362

Guigoz Y, Vellas BJ, & Garry PJ (1994). Mini Nutritional Assessment: a practical assessment tool for grading nutritional state of elderly patients. *Facts and Research in Gerontology, 4*(2), 15-59.

Hadi NU, Abdullah N, & Sentosa I (2016). Making Sense of Mediating Analysis: A Marketing Perspective. *Review of Integrative Business & Economics Research, 5*(2), 15.

Hariyani, N., Spencer, A. J., Luzzi, L., & Do, L. G. (2017). Root caries experience among Australian adults. *Gerodontology*, 34(3), 365-376. doi:10.1111/ger.12275

Hae-Young K (2013). Statistical notes for clinical researchers: assessing normal distribution (2) using skewness and kurtosis. *Restorative Dentistry & Endodontics, 38*(1), 52-54. doi: 10.5395/rde.2013.38.1.52

Hafeman D (2008). Opening the black box: A reassessment of mediation from a counterfactual perspective. In S. Schwartz (Ed.): ProQuest Dissertations Publishing.

Hafeman DM, & Schwartz S (2009). Opening the Black Box: a motivation for the assessment of mediation. *International Journal of Epidemiology, 38*(3), 838-845. doi: 10.1093/ije/dyn372

Hair JF, Hult GTM, Ringle CM, & Sarstedt M (2014). *A Primer on Partial Least Squares structural Equation Modeling*: Thousand Oaks: Sage.

Hayes AF, & Scharkow M (2013). The Relative Trustworthiness of Inferential Tests of the Indirect Effect in Statistical Mediation Analysis. *Psychological Science, 24*(10), 1918-1927. doi: 10.1177/0956797613480187

Holmlund A, Holm G, & Lind L (2010). Number of teeth as a predictor of cardiovascular mortality in a cohort of 7,674 subjects followed for 12 years. *Journal of Periodontology, 81*(6), 870-876. doi: 10.1902/jop.2010.090680

Hooper D, Coughlan J, & Mullen MR (2008). Structural equation modelling: Guidelines for determining model fit. *Electronic Journal of Business Research Methods, 6*(1), 53-60.

Hosseini, B., Berthon, B. S., Saedisomeolia, A., Starkey, M. R., Collison, A., Wark, P. A. B., & Wood, L. G. (2018). Effects of fruit and vegetable consumption on inflammatory biomarkers and immune cell populations: a systematic literature review and meta-analysis. *The American Journal of Clinical Nutrition*, 108(1), 136-155. doi:10.1093/ajcn/nqy082

Hu L-T, & Bentler PM.(1998). Fit Indices in Covariance Structure Modeling: Sensitivity to Underparameterized Model Misspecification. *Psychological Methods, 3*(4), 424-453. doi: 10.1037/1082-989X.3.4.424

Hu L-T, & Bentler PM (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal, 6*(1), 1-55. doi: 10.1080/10705519909540118

Hung HC, Colditz G, & Joshipura KJ (2005). The association between tooth loss and the self-reported intake of selected CVD-related nutrients and foods among US women. *Community Dentistry Oral Epidemiol, 33*(3), 167-173. doi: 10.1111/j.1600-0528.2005.00200.x

Iacobucci D (2008). *Mediation Analysis*: Thousand Oaks, CA: Sage.

Iacobucci D (2010). Structural equations modeling: Fit Indices, sample size, and advanced topics. *Journal of Consumer Psychology, 20*(1), 90-98. doi: 10.1016/j.jcps.2009.09.003

Inkrot, S., Lainscak, M., Edelmann, F., Loncar, G., Stankovic, I., Celic, V., Düngen, H.-D. (2015). Poor self-rated health predicts mortality in patients with stable chronic heart

failure. European *Journal of Cardiovascular Nursing, 15(7),* 504-512. doi:10.1177/1474515115615254

Iwasaki M, Taylor GW, Manz M C, Yoshihara A, Sato M, Muramatsu K, &. Miyazak H (2014). Oral health status: relationship to nutrient and food intake among 80-year-old Japanese adults. *Community Dentistry Oral Epidemiol*. doi: DOI: 10.1111/cdoe.12100

Jamieson, L., Brennan, D., Peres, M. A., Luzzi, L., Miller, C., Bowden, J., & McCaffrey, N. (2017). Having fewer than 21 teeth associated with poorer general health among South Australians. *Journal of Public Health Dentistry*, 77(3), 216-224. doi:10.1111/jphd.12200

Javid ZA, Seal CJ, Heasman P, & Moynihan PJ (2014). Impact of a customised dietary intervention on antioxidant status, dietary intakes and periodontal indices in patients with adult periodontitis. *Journal of Human Nutrition and Dietetics, 27*(6), 523-532. doi: 10.1111/jhn.12184

Joint WHO/FAO Expert Report on Diet, Nutrition and the Prevention of Chronic Diseases: Executive Summary. (2003). *Food and Nutrition Bulletin, 24(3),* 285-286. doi:10.1177/156482650302400307

Jones JA, Kressin NR, Spiro Iii A, Randall CW, Miller DR, Hayes C, & Garcia RI (2001). Self-reported and clinical oral health in users of VA health care. *Journals of Gerontology - Series A Biological Sciences and Medical Sciences, 56*(1), M55-M62. doi: 10.1093/gerona/56.1.M55

Joshipura KJ, Willett WC, & Douglass CW (1996). The impact of edentulousness on food and nutrient intake. *Journal of the American Dental Association, 127*(4), 459-467.

Judd CM, & Kenny DA (1981). Process Analysis: Estimating Mediation in Treatment Evaluations. *Evaluation Review, 5*(5), 602-619. doi: 10.1177/0193841X8100500502

Jung Y-M, & Shin D-S (2008). Oral Health, Nutrition and Oral Health-related Quality of Life- among Korian older adults. *Journal of Gerontological Nursing, 34*(10), 28-35.

Kaija K, Pekka Y, Anna-Maija S, Piia R, Matti K, Raimo S, & Sirpa H (2013). Oral health intervention among community-dwelling older people: a randomised 2-year intervention study. *Gerodontology*. doi: 10.1111/ger.12067

Kennedy-Malone L, Fletcher K, Plank L, & Fletcher M (2004). Management Guidelines for Nurse Practitioners Working with Older Adults, 2nd ed. In (Vol. 100, pp. 14). Philadelphia: Davis.

Kenny DA, & McCoach DB (2003). Effect of the Number of Variables on Measures of Fit in Structural Equation Modeling. *Structural Equation Modeling, 10*(3), 333-351. doi: 10.1207/S15328007SEM1003_1

Kieffer JM, & Hoogstraten J (2008). Linking oral health, general health, and quality of life. *European Journal of Oral Sciences, 116*(5), 445-450. doi: 10.1111/j.1600-0722.2008.00564.x

Kinney, J. M. (2004). Nutritional frailty, sarcopenia and falls in the elderly. *Current opinion in clinical nutrition and metabolic care, 7(1)*, 15. doi:10.1097/00075197-200401000-00004

Kline RB (2005). *Principles and Practice of Structural Equation Modeling*. 2nd ed. New York: The Guilford Press.

Krall E, Hayes C, & Garcia R (1998). How dentation status and masticatory function affect nutrition intake. *The Journal of the American Dental Association, 129*(9), 1261-1269. doi: 10.14219/jada.archive.1998.0423

Krause NM, & Jay GM (1995). What Do Global Self-Rated Health Items Measure? *Medical Care, 32*(9), 930-942. doi: http://www.jstor.org/stable/3766597

Kumar, A. P., Kumar, M. P., Rao, K. A., & Dileep, K. G. (2013). Periodontal disease and obesity. *International journal of stomatology & occlusion medicine*, 6(1), 1-5. doi:10.1007/s12548-012-0069-0

Laugero KD, Falcon LM, & Tucker KL (2011). Relationship between perceived stress and dietary and activity patterns in older adults participating in the Boston Puerto Rican Health Study. *Appetite, 56*(1), 194-204. doi: 10.1016/j.appet.2010.11.001

Lexomboon, D., WÅRdh, I., Thorslund, M., & Parker, M. G. (2015). Determinants of tooth loss and chewing ability in mid- and late life in three Swedish birth cohorts. *Ageing and Society*.35 (6), 1304-1317. doi:10.1017/S0144686X14000282

Lilliefors HW (1967). On the Kolmogorov-Smirnov Test for Normality with Mean and Variance Unknown. *Journal of the American Statistical Association, 62*(318), 399-402. doi: 10.1080/01621459.1967.10482916

Locker D, Matear D, Stephen M, & Jokovic A (2002). Oral health-related quality of life of a population of medically compromised elderly people. *Community Dental Health, 19*(2), 90-97.

Loesche WJ, Abrams J, Terpenning MS, Bretz WA, Dominguez BL, Grossman NS, & Lopatin DE (1995). Dental findings in geriatric populations with diverse medical backgrounds. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology, 80*(1), 43-54. doi: 10.1016/S1079-2104(95)80015-8

Loesche WJ, & Lopatin DE (1998). Interactions between periodontal disease, medical diseases and immunity in the older individual. *Periodontology 2000, 16*(1), 80-105. doi: 10.1111/j.1600-0757.1998.tb00117.x

Lyytinen K, & Gaskin J (2012). Mediation and Multi-group Analyses. Retrieved [Online] 1 September 2014, Available at: http://www.kolobkreations.com/Mediation%20and%20Multi-group%20Moderation.pptx

Mack F, Schwahn C, Feine JS, Mundt T, Bernhardt O, John U, .& . Biffar R (2005). The impact of tooth loss on general health related to quality of life among elderly Pomeranians: results from the study of health in Pomerania (SHIP-O). *International Journal of Prosthodontics, 18*(5), 414-419.

Makhija SK, Gilbert GH, Litaker MS, Allman RM., Sawyer P, Locher JL, & Ritchie CS (2007). Association between aspects of oral health-related quality of life and body mass index in community-dwelling older adults. *Journal of American Geriatrics Society, 55*(11), 1808-1816. doi: 10.1111/j.1532-5415.2007.01391.x

Marcenes W, Steele JG, Sheiham A, & Walls AW (2003). The relationship between dental status, food selection, nutrient intake, nutritional status, and body mass index in older people. *Cad Saude Publica, 19*(3), 809-816.

Margaret RS, Thomas AA, Xiaoyan L, Haiying C, Ronny AB, Andrea MA, .&. Quandt, SA. (2010). Severe Tooth Loss in Older Adults as a Key Indicator of Compromised Diet Quality. *Public Health nutrition, 13*(4), 466–474.

Massey FJ (1951). The Kolmogorov-Smirnov Test for Goodness of Fit. *Journal of the American Statistical Association, 46*(253), 68-78. doi: 10.1080/01621459.1951.10500769

Matthias RE, Atchison KA, Schweitzer SO, Lubben JE, Mayer-Oakes A, & Jong FD (1993). Comparisons between dentist ratings and self-ratings of dental appearance in an elderly population. *Special Care in Dentistry, 13*(2), 53-60. doi: 10.1111/j.1754-4505.1993.tb01455.x

Mattila KJ, Nieminen MS, Valtonen VV, Rasi VP, Kesäniemi YA, Syrjälä SL, .& Huttunen JK (1989). Association Between Dental Health And Acute Myocardial Infarction. *BMJ: British Medical Journal, 298*(6676), 779-781.

McLeod ER, Campbell KJ, & HeskethKD (2011). Nutrition knowledge: a mediator between socioeconomic position and diet quality in Australian first-time mothers. *Journal of the American Dietetic Association, 111*(5), 696. doi: 10.1016/j.jada.2011.02.011

Medina-Solis CE, Perez-Nunez R, Maupome G, & Casanova-Rosado JF (2006). Edentulism among Mexican adults aged 35 years and older and associated factors. *Am J Public Health, 96*(9), 1578-1581. doi: 10.2105/ajph.2005.071209

Mojon P, Budtz-Jorgensen E, & Rapin C-H (1999). Relationship between oral health and nutrition in very old people.(Statistical Data Included). *Age Ageing, 28*(5), 463. doi: 10.1093/ageing/28.5.463

Mollaoglu N, & Alpar R (2005). The effect of dental profile on daily functions of the elderly. *Clinical Oral Investigations, 9*(3), 137-140. doi: 10.1007/s00784-005-0307-6

Moynihan P, Thomason M, Walls A, Gray-Donald, K, Morais, JA, Ghanem H, .&. Feine J (2009). Researching the impact of oral health on diet and nutritional status: methodological issues. *Journal of Dentistry, 37*(4), 237-249. doi: 10.1016/j.jdent.2008.12.003

Müller F, Shimazaki Y, Kahabuka F, & Schimmel M (2017). Oral health for an ageing population: the importance of a natural dentition in older adults. *International Dental Journal, 67*, 7-13. doi: 10.1111/idj.12329

N'Gom PI, & Woda A (2002). Influence of impaired mastication on nutrition. *The Journal of Prosthetic Dentistry, 87*(6), 667-673. doi: 10.1067/mpr.2002.123229

Nelson M (1991). Assesment of food consumption and nutrient intake: past intake In B. M. Margetts & M. Nelson (Eds.), *Design concepts in nutrianal epidemiology* (pp. 167-192). Oxford: Oxford Medical publication.

Nielsen SJ, Trak-Fellermeier MA, Joshipura K, & Dye BA (2016). Dietary fiber intake is inversely associated with periodontal disease among US adults.(Report). *Journal of Nutrition, 146*(12), 2530. doi: 10.3945/jn.116.237065

Nishida, C., Uauy, R., Kumanyika, S., & Shetty, P. ((2004). The Joint WHO/FAO Expert Consultation on diet, nutrition and the prevention of chronic diseases: Process, product and policy implications. *Public Health Nutrition*, 7(1a), 245-250. doi:doi:10.1079/PHN2003592

O'Connor, J.-L. P., Milledge, K. L., O'Leary, F., Cumming, R., Eberhard, J., & Hirani, V. (2019). Poor dietary intake of nutrients and food groups are associated with increased risk of periodontal disease among community-dwelling older adults: a systematic literature review. Nutrition reviews. doi:10.1093/nutrit/nuz035

Ocampo, J. M. (2011). Self-rated health: Importance of use in elderly adults .Auto-percepción de salud: importancia de su uso en adultos mayores. Revista Colombia Médica, 41(3).

Okoro CA, Balluz LS, Eke PI, Ajani UA, Strine TW, Town M, . &. Mokdad AH (2005). Tooth loss and heart disease: findings from the Behavioral Risk Factor Surveillance System. *American Journal of Preventive Medicine, 29*(5 Suppl 1), 50-56. doi: 10.1016/j.amepre.2005.07.006

Osterberg T, Dey DK, Sundh V, Carlsson GE, Jansson JO, & Mellstrom D (2010). Edentulism associated with obesity: a study of four national surveys of 16 416 Swedes aged 5584 years. *Acta Odontologica Scandinavica, 68*(6), 360-367. doi: 10.3109/00016357.2010.514721

Pablo d.P, Dietrich T, & McAlindon TE. (2008). Association of periodontal disease and tooth loss with rheumatoid arthritis in the US population. *Journal of Rheumatol, 35*(1), 70-76.

Page RC, & Eka PI (2007). Case definitions for use in population-based suveillance of periodontitis. *Journal of Periodontology, 78(Suppl. 7, 1387-1399.*

Palmer C, & Stanski R (2015). Oral health and nutrition as gatekeepers to overall health: We are all in this together. *European Journal of General Dentistry, 4*(3), 99. doi: 10.4103/2278-9626.163319

Papas AS, Joshi A, Giunta JL, & Palmer CA (1998). Relationships among education, dentate status, and diet in adults. *Special Care in Dentistry, 18*(1), 26-32. doi: 10.1111/j.1754-4505.1998.tb01355.x

Pardo A, & Román M (2013). Reflections on the Baron and Kenny model of statistical mediation. *Anales de Psicologia, 29*(2), 614-623. doi: http://dx.doi.org/10.6018/analesps.29.2.139241

Preacher K, & Hayes A (2004). SPSS and SAS procedures for estimating indirect effects in simple mediation models. *Behavior Research Methods, Instruments, & Computers, 36*(4), 717-731. doi: 10.3758/BF03206553

Preacher K, & Hayes A (2008). Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. *Behavior Research Methods, 40*(3), 879-891. doi: 10.3758/BRM.40.3.879

Quandt SA, Chen H, Bell RA, Savoca MR, Anderson AM, Leng X, .&. Arcury TA (2010). Food Avoidance and Food Modification Practices of Older Rural Adults: Association With Oral Health Status and Implications for Service Provision. *The Gerontologist, 50*(1), 100-111. doi: 10.1093/geront/gnp096

Ranta K, Tuominen R, Paunio I, & Seppänen R (1988). Dental status and intake of food items among an adult Finnish population. *Gerodontics, 4*(1), 32-35.

Reissmann DR, John MT, Schierz O, Kriston L, & Hinz A (2013). Association between perceived oral and general health. *Journal of Dentistry, 41*(7), 581-589. doi: https://doi.org/10.1016/j.jdent.2013.05.007

mul JDM, Fernando NH, Juliana BH, & Dalva MPP (2008). Association between oral health status and nutritional status in south Brazilian independent-living older people. *Nutrition, 24*, 546–553.

Rissanen PM, Laakkonen EI, Suntioinen S, Penttila IM, & Uusitupa MI (1996). The nutritional status of Finnish home-living elderly people and the relationship between energy intake and chronic diseases. *Age Ageing, 25*(2), 133-138.

Ritchie CS, Joshipura K, Hung HC, & Douglass CW (2002). Nutrition as a mediator in the relation between oral and systemic disease: Associations between specific measures of adult oral health and nutrition outcomes *Critical. Reviews in Oral Biololy &. Medicine.* (Vol. 13, pp. 291-300).

Roberto CC-P, & Borges-Yanez SA. (2012). Oral health conditions and frailty in Mexican community-dwelling elderly: a cross sectional analysis. *Public Health nutrition, 12*(773).

Rosa MO, Ana MR, Pedro A, Ana ML-S, Quintas ME, Redondo MR, & Rivas T. (1997). Dietary intake and cognitive function in a group of elderly people. *The American Journal of Clinical Nutrition, 66*, 803-809.

Saarela R, Soini H, Hiltunen K, Muurinen S, Suominen M, & Pitkala K. (2014). Dentition status, malnutrition and mortality among older service housing residents. *The journal of nutrition, health & aging, 18*(1), 34-38. doi: 10.1007/s12603-013-0358-3

Sáez-Prado B, Haya-Fernández MC, & Sanz-García MT (2016). Oral health and quality of life in the municipal senior citizen's social clubs for people over 65 of Valencia, Spain. *Medicina Oral, Patologia Oral Y Cirugia Bucal, 21*(6), e672. doi: 10.4317/medoral.21305

SaitoT, Shimazaki Y, & Sakamoto M (1998). Obesity and Periodontitis. *The New England Journal of Medicine, 339*(7), 482-483. doi: 10.1056/NEJM199808133390717

Samnieng P, Ueno M, Shinada K, Zaitsu T, Wright FAC, & Kawaguchi Y (2011). Oral Health Status and Chewing Ability is Related to Mini-Nutritional Assessment Results in an Older Adult Population in Thailand. *Journal of Nutrition in Gerontology and Geriatrics, 30*(3), 291-304. doi: 10.1080/21551197.2011.591271

Shrout PE, & Bolger N (2002). Mediation in experimental and non experimental study: New procedure and recomendations. *Phychological Method, 7*, 422-455.

Sierpinska T, Golebiewska M, Dlugosz J, Kemona A, & Laszewicz W (2007). Connection between masticatory efficiency and pathomorphologic changes in gastric mucosa. *Quintessence International, 38*(1), 31-37.

Slade GD (1998). Assessing change in quality of life using the Oral Health Impact Profile. *Community Dentistry Oral Epidemiol, 26*(1), 52-61.

Slade GD, Spencer AJ, & Roberts-Thomson KF (2007). *Australia's dental generations : the national survey of adult oral health 2004-06*. Canberra: Australian Institute of Health and Welfare.

Slade, G. D., Sanders, A. E., Do, L., Roberts-Thomson, K., & Spencer, A. J. (2013). Effects of Fluoridated Drinking Water on Dental Caries in Australian Adults. *Journal of Dental Research*, 92(4), 376-382. doi:10.1177/0022034513481190

Slots J (2003). Update on general health risk of periodontal disease. *International Dental Journal, 53*, 200-207. doi: https://doi.org/10.1111/j.1875-595X.2003.tb00771.x

Sobel M (1982). Asymptotic Confidence Intervals for Indirect Effects in Structural Equation Models. *Sociological Methodology*, 290-312.

Srivastava, P., Chen, G., & Harris, A. (2017). Oral Health, Dental Insurance and Dental Service use in Australia. *Health Economics*, 26(1), 35-53. doi:10.1002/hec.3272

Stanley AM, & Suzanne M (2002). Psychological, Economic, and Social Mediators of the Education-Health Relationship in Older Adults. *Journal of Aging and Health, 14*(4), 527-550. doi: 10.1177/089826402237182

Steele, J. G., Sanders, A. E., Slade, G. D., Allen, P. F., Lahti, S., Nuttall, N., & Spencer, A. J. (2004). How do age and tooth loss affect oral health impacts and quality of life? A study comparing two national samples. Community Dentistry and Oral Epidemiology, 32(2), 107-114. doi:10.1111/j.0301-5661.2004.00131.x

Steele JG, Sheiham A, Marcences W, & Walls AWG (1998). Natinal diet and nutrition survey: people aged 65 years and over . *Report of the oral health survey, 2*.

Toniazzo MP, Amorim PdS, Apos, Muniz FWMG, & Weidlich P (2017). Relationship of nutritional status and oral health in elderly: Systematic review with meta-analysis. *Clinical Nutrition*. doi: 10.1016/j.clnu.2017.03.014

Tsakos G, Herrick K, Sheiham A, & Watt RG (2010). Edentulism and fruit and vegetable intake in low-income adults. *Journal of Dental Research, 89*(5), 462-467. doi: 10.1177/0022034510363247

U.S. Department of Health and Human Services. (2000). Oral health in America: A report of the surgeon general, U.S.Department of Health and Human Services, . NIH publication 00–4713.: National Institutes of Health. National Institute of Dental and Craniofacial Research, Rockville, Md.

Ulinski KG, do Nascimento MA, Lima AM, Benetti AR, Poli-Frederico RC, Fernandes K B, & Maciel SM (2013). Factors related to oral health-related quality of life of independent brazilian elderly. *International journal of Dentistry, 2013*, 705047. doi: 10.1155/2013/705047

Valeri L, Lin X, & Vanderweele TJ (2014). Mediation analysis when a continuous mediator is measured with error and the outcome follows a generalized linear model. *Statistics in Medicine, 33*(28), 4875-4890. doi: 10.1002/sim.6295

Van Asselt, D. Z. B., Ringnalda, Y., Droogsma, E., Blaauw, M., Schuur, T., & van Steijn, J. (2013). Prevalence of frailty, sarcopenia and undernutrition in community-dwelling elderly receiving home-delivered dinners. *European Geriatric Medicine*, 4, S151-S151. doi:10.1016/j.eurger.2013.07.496

VanderWeele T, & Vansteelandt S (2014). Mediation Analysis with Multiple Mediators. *Epidemiologic Methods, 2*(1), 95-115. doi: https://doi.org/10.1515/em-2012-0010

Vansteelandt S, & Daniel RM (2017). Interventional Effects for Mediation Analysis with Multiple Mediators. *Epidemiology (Cambridge, Mass.), 28*(2), 258. doi: 10.1097/EDE.0000000000000596

Volzke H, Schwahn C, Hummel A, Wolff B, Kleine V, Robinson D M, & Kocher T (2005). Tooth loss is independently associated with the risk of acquired aortic valve sclerosis. *American Heart Journal, 150*(6), 1198-1203. doi: 10.1016/j.ahj.2005.01.004

Watson HJ, Raykos BC, Street H, Fursland A, & Nathan PR (2011). Mediators between perfectionism and eating disorder psychopathology: shape and weight overvaluation and conditional goal-setting. *The International journal of eating disorders, 44*(2), 142. doi: 10.1002/eat.20788

West SG, Finch JF, & Curran PJ (1996). Structural equation models with nonnormal variables: problems and remedies. *In RH Hoyle (Ed.). Structural equation modeling: Concepts, issues and applications*. Newbery Park, CA: Sage.

Wiener, R. C., Shen, C., Findley, P. A., Sambamoorthi, U., & Tan, X. (2017). The association between diabetes mellitus, sugar-sweetened beverages, and tooth loss in adults: Evidence from 18 states: Evidence from 18 states. The Journal of the

American Dental Association, 148(7), 500-509.e504. doi:10.1016/j.adaj.2017.03.012

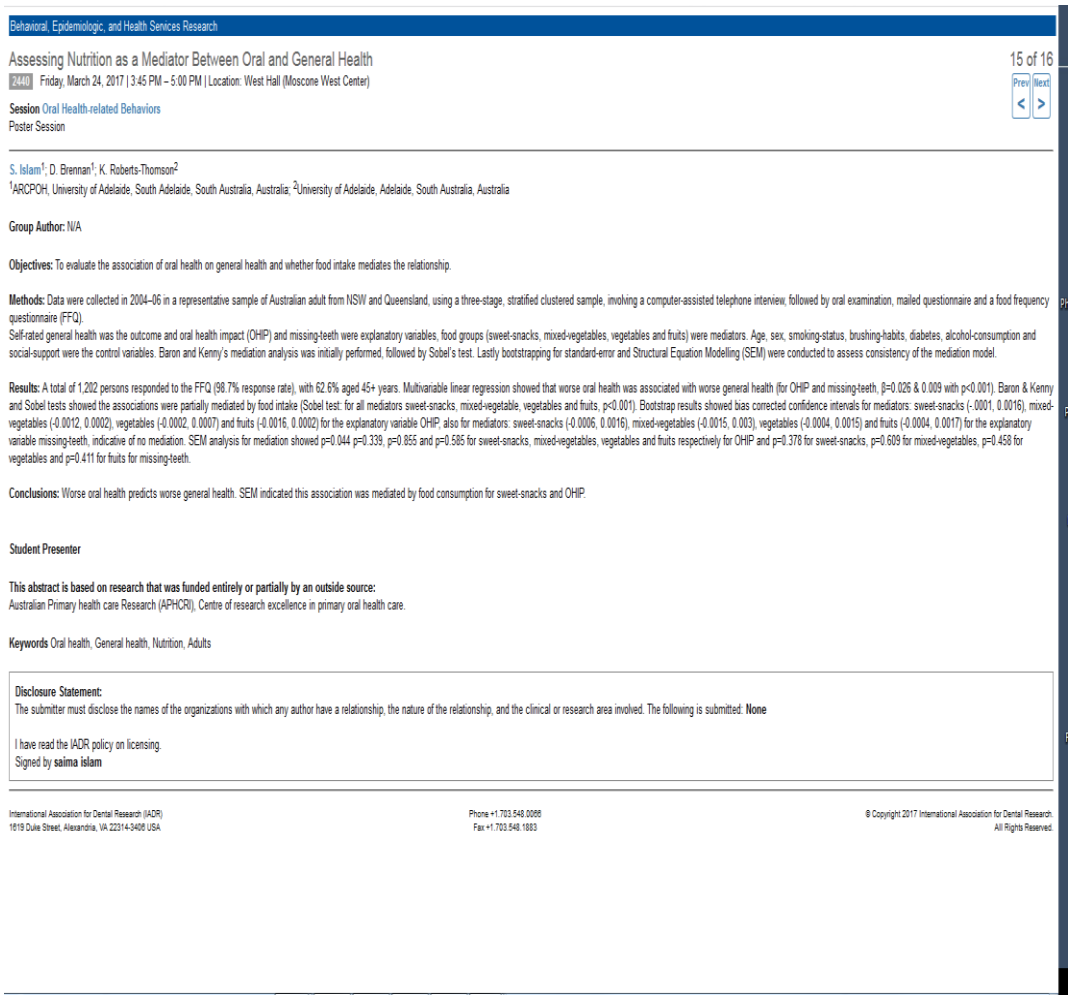
Yoshihara A, Watanabe R, Hanada N, & Miyazaki H (2009). A longitudinal study of the relationship between diet intake and dental caries and periodontal disease in elderly Japanese subjects. *Gerodontology*, *26*(2), 130-136. doi: 10.1111/j.1741-2358.2008.00244.x

Yu S-J, Chen P, & Zhu G-X (2013). Relationship between implantation of missing anterior teeth and oral health-related quality of life. *An International Journal of Quality of Life Aspects of Treatment, Care and Rehabilitation - Official Journal of the International Society of Quality of Life Research, 22*(7), 1613-1620. doi: 10.1007/s11136-012-0314-4

Zimet GD, Dahlem NW, Zimet SG, & Farley GK (1988). The Multidimensional Scale of Perceived Social Support. *Journal of Personality Assessment, 52*, 30-41.

7. Appendix

7.1 Abstract for IADR. San Francisco, USA, 2017



Behavioral, Epidemiologic, and Health Services Research

Assessing Nutrition as a Mediator Between Oral and General Health

15 of 16

Prev Next

2440 Friday, March 24, 2017 | 3:45 PM – 5:00 PM | Location: West Hall (Moscone West Center)

Session Oral Health-related Behaviors
Poster Session

S. Islam[1]; D. Brennan[1]; K. Roberts-Thomson[2]
[1]ARCPOH, University of Adelaide, South Adelaide, South Australia, Australia; [2]University of Adelaide, Adelaide, South Australia, Australia

Group Author: N/A

Objectives: To evaluate the association of oral health on general health and whether food intake mediates the relationship.

Methods: Data were collected in 2004–06 in a representative sample of Australian adult from NSW and Queensland, using a three-stage, stratified clustered sample, involving a computer-assisted telephone interview, followed by oral examination, mailed questionnaire and a food frequency questionnaire (FFQ).
Self-rated general health was the outcome and oral health impact (OHIP) and missing-teeth were explanatory variables, food groups (sweet-snacks, mixed-vegetables, vegetables and fruits) were mediators. Age, sex, smoking-status, brushing-habits, diabetes, alcohol-consumption and social-support were the control variables. Baron and Kenny's mediation analysis was initially performed, followed by Sobel's test. Lastly bootstrapping for standard-error and Structural Equation Modelling (SEM) were conducted to assess consistency of the mediation model.

Results: A total of 1,202 persons responded to the FFQ (98.7% response rate), with 62.6% aged 45+ years. Multivariable linear regression showed that worse oral health was associated with worse general health (for OHIP and missing-teeth, β=0.026 & 0.009 with p<0.001). Baron & Kenny and Sobel tests showed the associations were partially mediated by food intake (Sobel test: for all mediators sweet-snacks, mixed-vegetable, vegetables and fruits, p<0.001). Bootstrap results showed bias corrected confidence intervals for mediators: sweet-snacks (-.0001, 0.0016), mixed-vegetables (-0.0012, 0.0002), vegetables (-0.0002, 0.0007) and fruits (-0.0016, 0.0002) for the explanatory variable OHIP, also for mediators: sweet-snacks (-0.0006, 0.0016), mixed-vegetables (-0.0015, 0.003), vegetables (-0.0004, 0.0015) and fruits (-0.0004, 0.0017) for the explanatory variable missing-teeth, indicative of no mediation. SEM analysis for mediation showed p=0.044 p=0.339, p=0.855 and p=0.585 for sweet-snacks, mixed-vegetables, vegetables and fruits respectively for OHIP and p=0.378 for sweet-snacks, p=0.609 for mixed-vegetables, p=0.458 for vegetables and p=0.411 for fruits for missing-teeth.

Conclusions: Worse oral health predicts worse general health. SEM indicated this association was mediated by food consumption for sweet-snacks and OHIP.

Student Presenter

This abstract is based on research that was funded entirely or partially by an outside source:
Australian Primary health care Research (APHCRI), Centre of research excellence in primary oral health care.

Keywords Oral health, General health, Nutrition, Adults

Disclosure Statement:
The submitter must disclose the names of the organizations with which any author have a relationship, the nature of the relationship, and the clinical or research area involved. The following is submitted: **None**

I have read the IADR policy on licensing.
Signed by **saima islam**

International Association for Dental Research (IADR)
1619 Duke Street, Alexandria, VA 22314-3406 USA

Phone +1.703.548.0066
Fax +1.703.548.1883

7.2. Poster for IADR. San Francisco, USA, 2017

THE UNIVERSITY of ADELAIDE

Assessing Nutrition as a Mediator between Oral and General Health

Saima Islam, David Brennan, Kaye Roberts-Thomson

Australian Research Centre for Population Oral Health, Adelaide Dental School, University of Adelaide, Australia

Poster #: 2440

Introduction

Background

Oral health has a significant impact on general health especially among older adults, as the ability to chew influences patterns of food consumption and diet quality[1]. Self-rated general health is a useful summary of people's general health and was found to predict future health outcomes[2]. The Oral health impact Profile (OHIP) and number of missing teeth are widely used measures of oral health and both are related to quality of life, especially at old age[3]. Proper food consumption is essential for health, especially in the elderly.

Objective

To evaluate the association between oral health and general health and test whether intake of different food groups mediates this relationship.

Method

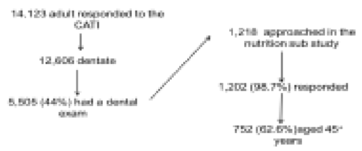
Sample

Data were collected in 2004–06, using a three-stage, stratified clustered sample, involving a computer-assisted telephone interview (CATI), oral examination and mailed questionnaire followed by a food frequency questionnaire.

A total of 14,123 adults responded to the CATI (49% response) of whom 5505 (44% of those interviewed) agreed to undergo an oral epidemiological examination. In the nutrition sub-study, a total of n = 1,218 persons were approached in New South Wales and Queensland, with n = 1202 responding (98.7% response rate). Results presented refer to the 752 respondents aged 45 years or more.

Data were weighted by state/territory, metropolitan/non-metropolitan location, age and gender. To account for design effects associated with the complex sample design, data were analysed using Survey procedures that adjusted for strata and primary sampling units. (StataCorp. Stata statistical software: release 6.0. College Station, TX: Stata Corporation, 1999.)

Sampling frame



Variables

Self-rated general health was the outcome. ("1" excellent…"5" poor)

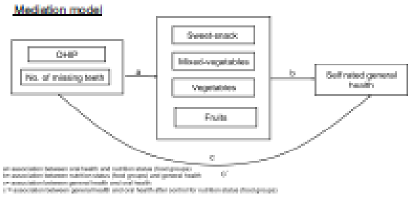
Oral health impact profile (OHIP) and number missing-teeth were explanatory variables.

Food groups* (sweet-snacks, mixed-vegetables, vegetables and fruits) were mediators.

Age, sex, smoking-status, brushing-habits, diabetes, alcohol-consumption and social-support were the control variables.

*The food frequency questionnaire collected data on consumption of specific food items including 15 types of sweet-snacks, 8 types of fruits, 25 types of vegetables and 4 types of mixed vegetables and based on the items used in the National Nutrition Survey. These items were collected on a 9-point scale ranging from 'never, or less than once a month' to '6+ times per day'.

Mediation model



Statistical analysis

Multivariate linear regression was conducted to assess relations between variables. Baron and Kenny's[4] mediation analysis was initially performed, followed by Sobel's test[4] for mediation. Lastly bootstrapping for standard error (Preacher & Hayes (2008) multiple mediation) to measure the indirect effect and Structural Equation Modelling (SEM) were conducted to assess consistency of the mediation model to the data.

Results

Table 1: Descriptive statistics for continuous variables

Variables	Range	Mean (SD)	Skewness	Kurtosis
No. of missing teeth	0 to 28	7.7 (6.9)	1.20	0.61
OHIP Score	0 to 51	7.3(7.9)	1.81	3.90
Self-rated general health	1 to 5	2.4 (0.9)	0.38	-0.25
Sweet-snacks	0 to 64	32.3(8.7)	0.01	0.78
Mixed vegetables	0 to 25	12.3(3.8)	-0.15	0.81
Vegetables	0 to 107	61.7 (12.5)	-0.68	3.37
Fruits	0 to 64	28.2 (8.7)	0.09	0.67
Age	45 to 90	60.5(10.1)	0.44	-0.63
Average number of brushing per day	0 to 5	1.9 (0.7)	0.49	1.49
Average standard alcohol per day in grams	0 to 12	1.1(1.6)	2.78	11.03
Social support score	12 to 60	46.7(7.6)	-0.66	1.02

Table 2: Descriptive statistics for categorical variables

Variables	Categories	%
Sex	Male	49.6%
	Female	50.4%
Smoking status	Currently smoke	13.1%
	Don't smoke now but used to smoke	35.2%
	Never smoke	51.6%
Doctor said have diabetes	Yes	7.7%
	No	92.3%

Table 3: Mediation analysis for Oral health and General health

Independent variable (X)	Mediator (M)	Dependent variable (Y)	Med. Schem.	β	Sobel Z	p	Degree of mediation	Bootstrap** Bias Corrected CI 95%		SEM Result		
								LL	UL	Direct Effect without mediation	Direct effect with Mediation	Indirect effect#
OHIP Score		Self-Rated General Health	c	0.026*								
OHIP Score	Sweet-snacks		a	0.102*								
	Sweet-snacks	Self-Rated General Health	b	0.007*								
OHIP Score	(Sweet-snacks)	Self-Rated General Health	c'	0.025*	57.71	<0.001	Partial	-0.0001	0.0016	0.21 (p<0.001)	0.21 (p<0.001)	P=0.044 (Partial Mediation)
OHIP Score	Mixed-vegetables		a	0.019*								
	Mixed-vegetables	Self-Rated General Health	b	-0.001*								
OHIP Score	(Mixed-vegetables)	Self-Rated General Health	c'	0.026*	-3.28	<0.001	Partial	-0.0012	0.0002	0.21 (p<0.001)	-0.31 (p<0.001)	P=0.339 (No Mediation)
OHIP Score	Vegetables		a	-0.032*								
	Vegetables	Self-Rated General Health	b	-0.003*								
OHIP Score	(Vegetables)	Self-Rated General Health	c'	0.026*	14.12	<0.001	Partial	-0.0002	0.0007	0.21 (p<0.001)	0.21(p<0.001)	P=0.655 (No Mediation)
OHIP Score	Fruits		a	0.010*								
	Fruits	Self-Rated General Health	b	-0.002*								
OHIP Score	(Fruits)	Self-Rated General Health	c'	0.026*	-6.94	<0.001	Partial	-0.0016	0.0002	0.21 (p<0.001)	0.21(p<0.001)	P=0.585 (No Mediation)
No. of missing teeth		Self-Rated General Health	c	0.009*								
No. of missing teeth	Sweet-snacks		a	0.030*								
	Sweet-snacks	Self-Rated General Health	b	0.007*								
No. of missing teeth	(Sweet-snacks)	Self-Rated General Health	c'	0.009*	14.67	<0.001	Partial	-0.0006	0.0016	0.074 (p=0.025)	0.04(p= .027)	p= 0.378 (No Mediation)
No. of missing teeth	Mixed-vegetables		a	0.009*								
	Mixed-vegetables	Self-Rated General Health	b	-0.001*								
No. of missing teeth	(Mixed-vegetables)	Self-Rated General Health	c'	0.009*	-5.38	<0.001	Partial	-0.0015	0.0003	0.074 (p=0.025)	0.012 (p=0.26)	P=0.609 (No Mediation)
No. of missing teeth	Vegetables		a	-0.127*								
	Vegetables	Self-Rated General Health	b	-0.003*								
No. of missing teeth	(Vegetables)	Self-Rated General Health	c'	0.009*	26.96	<0.001	Partial	-0.0004	0.0015	0.074 (p=0.025)	0.065 (p=0.027)	P=0.456 (No Mediation)
No. of missing teeth	Fruits		a	-0.067*								
	Fruits	Self-Rated General Health	b	-0.002*								
No. of missing teeth	(Fruits)	Self-Rated General Health	c'	0.009*	19.49	<0.001	Partial	-0.0004	0.0017	0.074 (p=0.025)	0.07 (p=0.034)	p=0.411 (No Mediation)

* P<0.001; ** Number of iterations =2000; # Standardised Indirect Effect – Two Tailed Significance test

Discussion and Conclusion

Worse oral health predicts worse general health. Degrees of mediation are interpreted according to Baron and Kenny if the direct effect (c') became insignificant mediation was considered as full; partial mediation was interpreted as significant Sobel test, but still direct effect (c') significant . Preacher and Hayes (2008) multiple mediation bootstrap shows insignificant results. SEM established that the consumption of sweet-snacks mediated the relationship between OHIP score & self-rated general health (all other mediation analysis were insignificant).

References

7.3. Abstract acceptance letter for IADR2017_ANZ

Monday, 21-Aug-2017

Ms. Saima Islam
Adelaide, Australia

Abstract Control ID#: 2808307
Abstract Title: Nutrition mediates the relationship between periodontal status and general health

Dear Ms. Saima Islam,

It is a pleasure to inform you that your abstract has been ACCEPTED for oral presentation at the 57th Annual Scientific Meeting of the IADR ANZ Division. The meeting will take place at the University of Adelaide Health and Medical Science building, Adelaide on 25th-27th September 2017.

Please note that some colleagues have provided an alternate email address for notification, so if this letter is addressed to a colleague, please forward it to his/her attention. Email notifications are sent only to the address provided for the presenter when the abstract was submitted; it is the presenter's responsibility to notify co-authors.

DO NOT lose this notification. The mode of your presentation has been assigned by the Group Program Chair and must be followed as we are unable to change it at this date. Assignments were based on authors' requests as much as possible.

PRESENTATION INFORMATION

Presentation Mode: Oral
Presentation Date: To be announced
Session Title: To be announced
Session Time: To be announced
Presentation Duration: 10 minutes, plus 5 minutes for discussion

REGISTRATION REQUIREMENT

All presenters must register and pay the applicable fee by 1st September 2017. If you do not register, you will NOT be allowed to present at the meeting and your abstract will be withdrawn from the final printed Program Book.
Notices will be sent to all presenters after the registration deadline.

7.4. Abstract for IADR2017_ANZ

Nutrition mediates the relationship between periodontal status and general health

Objectives: Periodontitis is a chronic inflammatory disease affecting the supporting structures of the teeth. It plays a significant role in the systemic health of adults. Our objective is to investigate the association of periodontal status and general health and to test whether intake of different food groups mediates this relationship.

Method: Data were collected in 2004–06, using a computer-assisted telephone interview, followed by oral examination, mailed questionnaire and a food frequency questionnaire (FFQ) in New South Wales and Queensland.

Multivariate linear regression was conducted to assess relations between variables. Self-rated general health and periodontal status were used as outcome and explanatory variables, food groups (dairy, bread-cereal, meat-fish-eggs, sweet-snacks, mixed-vegetables, vegetables and fruits) were the mediators. Age, sex, smoking-status, brushing-habits, diabetes, alcohol-consumption and social-support were the control variables. Baron and Kenny's mediation analysis was initially performed, followed by Sobel's test for mediation. Lastly bootstrapping for standard error and Structural Equation Modelling (SEM) were conducted to assess consistency of the mediation model to the data.

Result: A total of 1,202 persons responded to the FFQ (98.7% response rate), with 62.6% aged 45+ years. Adults with none/mild and moderate periodontal problems compared to severe periodontal problems rated their general health better (β_1=0.13 with p<0.001 and β_2=0.09 with p<0.001). Baron and Kenny and Sobel-tests showed the associations were partially mediated by food intake (Sobel test: for all mediators dairy, bread & cereal, meat-fish-eggs, sweet-snacks, mixed-vegetable, vegetables and fruits, p<0.05). Multiple mediation bootstrap results showed bias corrected confidence intervals (-0.0091, 0, 0052) for the mediators: dairy, (-0.0012, 0.0347) bread-cereal, (-0.0017, 0.0303) fish-meat-eggs, (-0.0028, 0.0287) sweet-snacks, (-0.0036, 0.0126) mixed-vegetables, (-0.0064, 0.0132) vegetables, and (-0.00205, 0.0022) fruits, indicative of no mediation. SEM analysis for mediation showed p= 0.76, p=0.045, p=0.050, p=0.015, p=0.73, p=0.42 and p= 0.30 for dairy, bread-cereal, meat-fish-eggs, sweet-snacks, mixed-vegetables, vegetables and fruits.

Conclusion: Less severe periodontal problems predicted better general health. SEM indicated that this association was mediated by consumption of bread-cereal, meat-fish-eggs and sweet-snacks.

7.5. Abstract for Research day 2016

RESEARCH DAY 2016
ABSTRACT

Oral Presentation ☐√

Title of presentation:

"Assessing nutrition as a mediator of the association between oral health and general health"

Authors & Affiliations (list affiliation in brackets after name):

Saima Islam (PhD Candidate, ARCPOH, School of Dentistry, University of Adelaide)

Professor David Brennan (Professor, ARCPOH, School of Dentistry, University of Adelaide)

Professor Kaye Roberts-Thomson (Adjunct Professor, ARCPOH, School of Dentistry, University of Adelaide)

Presenter is: PhD Student

Abstract:

Background: Self-rated health is a useful summary of people's general health and oral health, and both are related to quality of life, especially at old age. Proper food consumption is essential for health, especially in the elderly.

Objective: To evaluate the association of oral health on general health and test whether intake of different food groups mediates the relationship.

Method: Data were collected in 2004–06, using a three-stage, stratified clustered sample, involving a computer-assisted telephone interview (CATI), followed by oral examination, mailed questionnaire and a food frequency questionnaire in New South Wales and Queensland.

Multivariate Linear regression was conducted to assess relations between variables. Self-rated general and oral health ware used as outcome and explanatory variables, food groups (mixed vegetables, vegetables and fruits) were the mediators. Baron and Kenny's mediation analysis was initially performed, followed by Sobel's test for mediation. Lastly bootstrapping for standard error and Structural Equation Modelling (SEM) were conducted to assess consistency of the mediation model to the data.

Result: A total of 1,202 persons responded (98.7% response rate), with 62.6% aged 45+ years. Self-rated dental and general health were associated (β=-0.697; $p<0.001$) controlling for age and sex. Self-rated dental health was also associated with food groups (mixed vegetable: β=0.096; $p<0.001$; vegetables: β=1.42; $p<0.001$; fruits: β=0.251; $p<0.001$). Barron & Kenny and Sobel tests showed worse oral health was associated with worse general health, which was partially mediated by food intake (Sobel test: $p<0.001$, $p<0.001$ and $p<0.001$ for mediator: mixed vegetable, vegetables and fruits). Multiple mediation bootstrap results showed bias corrected confidence intervals (-0.0032, 0.0220) for mediator: mixed vegetables, (-0.0057, 0.0136) vegetables, and (-0.0060, 0.0194) fruits, indicative of no mediation. SEM analysis for mediation showed p=0.328 for mixed vegetables, p=0.602 for vegetables and p=0.529 for fruits, which were not statistically significant and support the bootstrap result.

Conclusion: Better oral health is associated with better general health but SEM indicated this association is not mediated by food consumption.

7.6. Abstract for Research day 2017

2017 Adelaide Dental School Research Day

THE UNIVERSITY of ADELAIDE

Abstract:

(Up to 250 words including aims, methods, results and conclusion to be included)

Aim: Periodontitis is a chronic inflammatory disease affecting the supporting structures of the teeth and playing a significant role in the systemic health of adults. Our aim is to investigate the association of periodontal status and general health and test whether intake of different food groups mediates the relationship.

Method: Data were collected in 2004–06, using a computer-assisted telephone interview, followed by oral examination, mailed questionnaire and a food frequency questionnaire (FFQ) in New South Wales and Queensland.

Multivariate Linear regression was conducted to assess relations between variables. Self-rated general and periodontal status were used as outcome and explanatory variables, food groups (dairy, bread-cereal, meat-fish-eggs, sweet-snacks, mixed-vegetables, vegetables and fruits) were the mediators. Age, sex, smoking-status, brushing-habits, diabetes, alcohol-consumption and social-support were the control variables. Baron and Kenny's mediation analysis was initially performed, followed by Sobel's test for mediation. Lastly bootstrapping for standard error and Structural Equation Modelling (SEM) were conducted to assess consistency of the mediation model to the data.

Result: A total of 1,202 persons responded to the FFQ (98.7% response rate), with 62.6% aged 45+ years. Adults with none/mild and moderate periodontal problems compared to severe periodontal problems rated their general health better (β_1=-0.13 with $p<0.001$ and β_2=-0.09 with $p<0.001$). Baron and Kenny and Sobel-tests showed the associations were partially mediated by food intake (Sobel test: for all mediators dairy, bread & cereal, meat-fish-eggs, sweet-snacks, mixed-vegetable, vegetables and fruits, $p<0.05$). Multiple mediation bootstrap results showed bias corrected confidence intervals (-0.0047, 0.0082) for the mediators: dairy, (-0.0383, 0, 0016) bread-cereal, (-0.0316, 0.0013) fish-meat-eggs, (-0.0292, 0.0027) sweet-snacks, (-0.0136, 0.0041) mixed-vegetables, (-0.0116, 0.0070) vegetables, and (-0.0021, 0.0237) fruits, indicative of no mediation. SEM analysis for mediation showed p= 0.76, p=0.045, p=0.050, p=0.015, p=0.73, p=0.42 and p= 0.30 for dairy, bread-cereal, meat-fish-eggs, sweet-snacks, mixed-vegetables, vegetables and fruits.

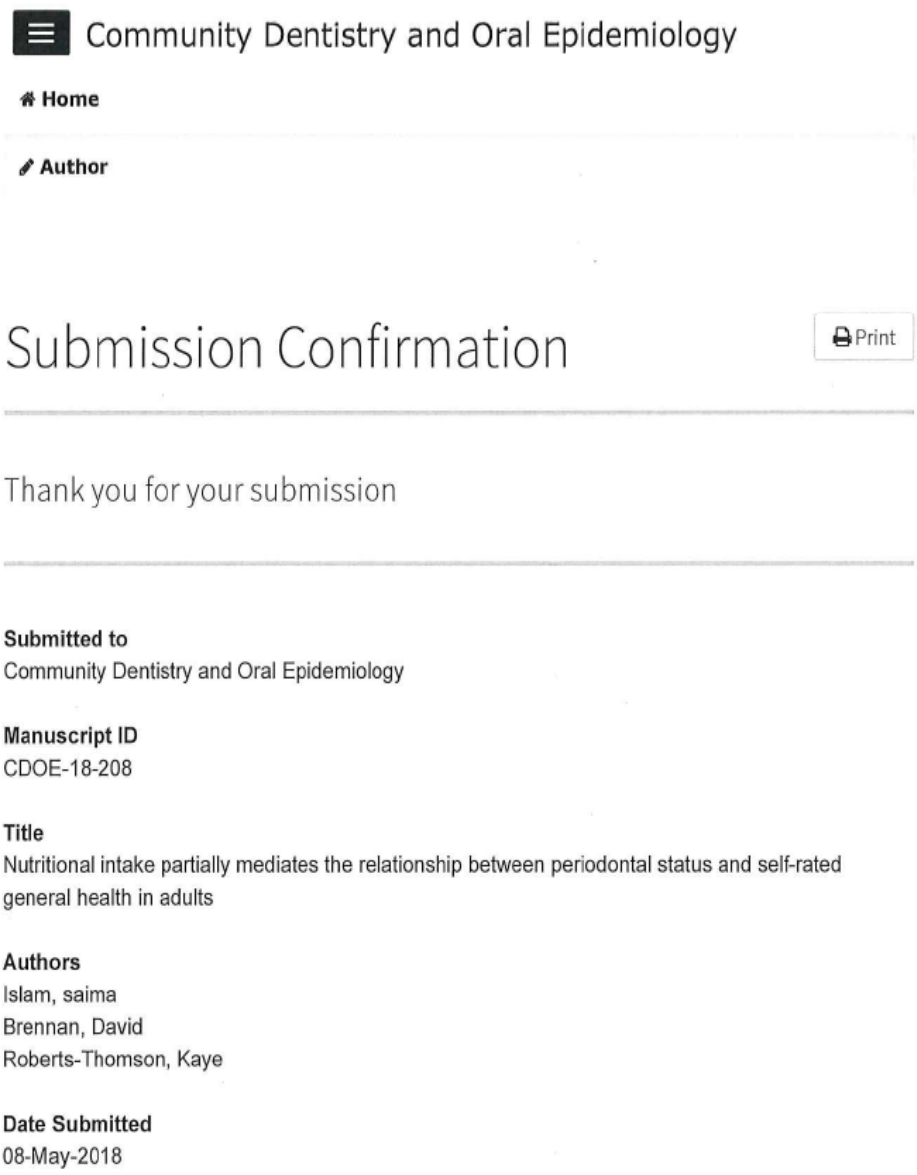
Conclusion: Less severe periodontal problems predicted better general health. SEM indicated that this association was mediated by consumption of bread-cereal, meat-fish-eggs and sweet-snacks.

DECLARATION

I declare that to the best of my knowledge and belief, the information supplied in this registration is correct and complete.

Applicant's signature:	**Date**: 16/06/2017

7.7. Submission Confirmation Community Dentistry and Oral Epidemiology



Community Dentistry and Oral Epidemiology

Home

Author

Submission Confirmation

Print

Thank you for your submission

Submitted to
Community Dentistry and Oral Epidemiology

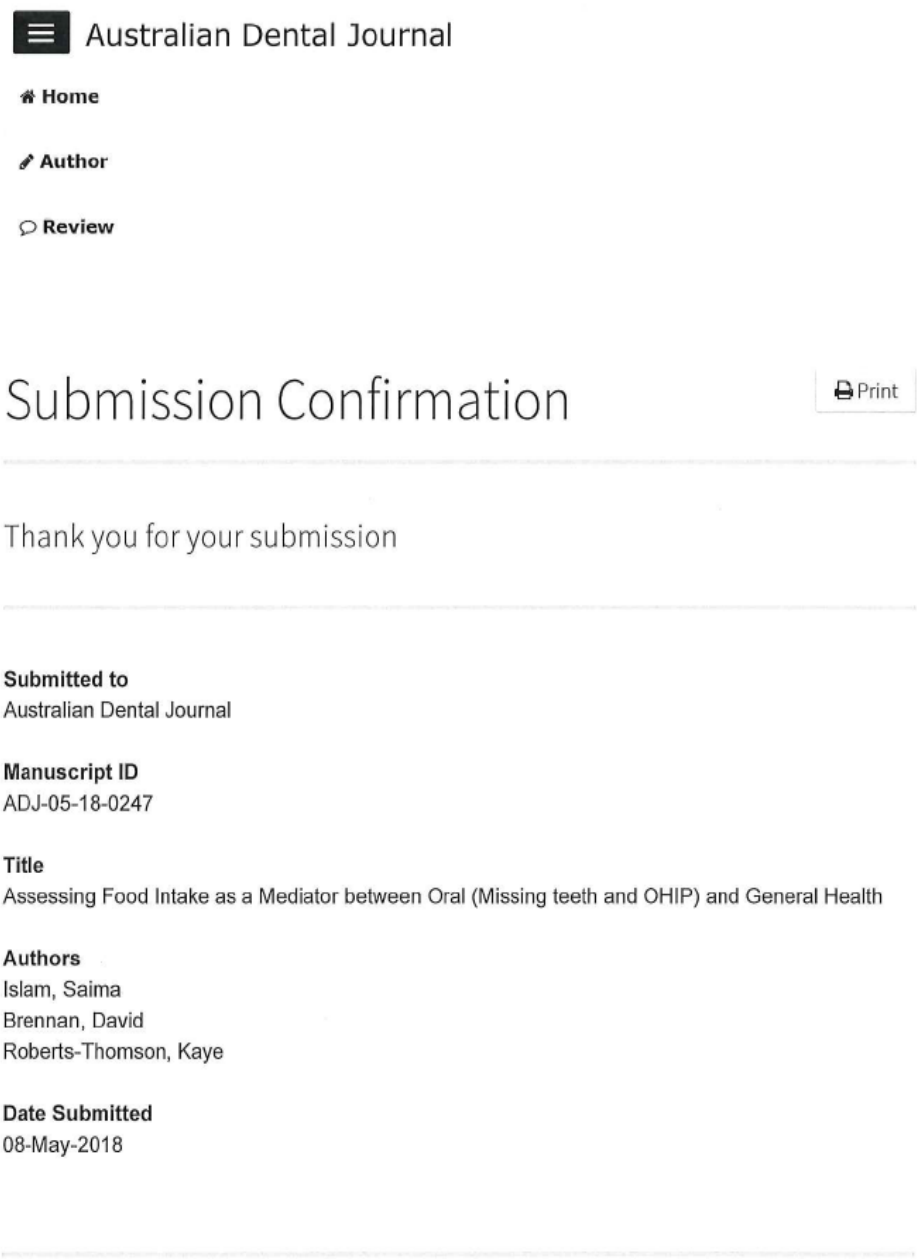
Manuscript ID
CDOE-18-208

Title
Nutritional intake partially mediates the relationship between periodontal status and self-rated general health in adults

Authors
Islam, saima
Brennan, David
Roberts-Thomson, Kaye

Date Submitted
08-May-2018

7.8. Submission Confirmation Australian Dental Journal



Australian Dental Journal

Home

Author

Review

Submission Confirmation

Print

Thank you for your submission

Submitted to
Australian Dental Journal

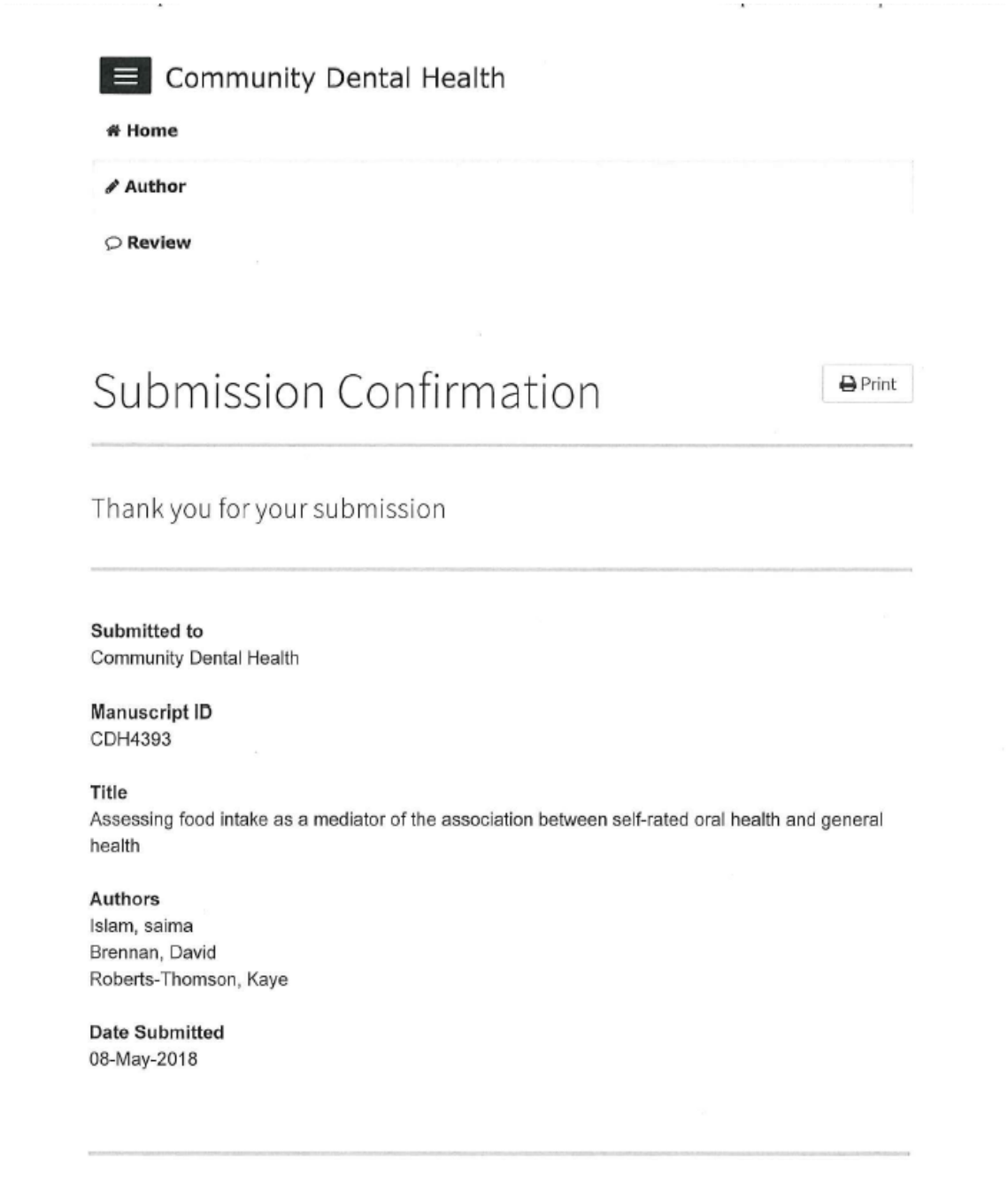
Manuscript ID
ADJ-05-18-0247

Title
Assessing Food Intake as a Mediator between Oral (Missing teeth and OHIP) and General Health

Authors
Islam, Saima
Brennan, David
Roberts-Thomson, Kaye

Date Submitted
08-May-2018

7.9. Submission Confirmation Community Dental Health



Community Dental Health

Home

Author

Review

Submission Confirmation

Print

Thank you for your submission

Submitted to
Community Dental Health

Manuscript ID
CDH4393

Title
Assessing food intake as a mediator of the association between self-rated oral health and general health

Authors
Islam, saima
Brennan, David
Roberts-Thomson, Kaye

Date Submitted
08-May-2018