Periodontal disease, tooth loss and daily life in older adults in South Australia: a longitudinal study

by

Xiangqun Ju

A thesis submitted for the degree of Doctor of Philosophy

School of Dentistry
The University of Adelaide
South Australia.
2016

Principal Supervisor:
Professor Andrew John Spencer
Australian Research Centre for Population Oral Health

Co-supervisors:
Associate Professor Loc Giang Do
Australian Research Centre for Population Oral Health

Dr Gloria Cecilia Mejia
Australian Research Centre for Population Oral Health

(Assistant Professor, Epidemiology, School of Dental Medicine, East Carolina University)
# Table of Contents

Table of Contents ................................................................. i

List of Tables........................................................................ vi

List of Figures ...................................................................... viii

List of Abbreviations............................................................ ix

List of Symbols ................................................................... xi

Research outcome ................................................................ xii

Oral and poster presentations during time of candidature .................... xii

Grants and awards received ................................................................... xiii

Preface .................................................................................... xiv

Abstract .................................................................................. xv

Declaration ................................................................................ xvii

Acknowledgements ................................................................... xviii

Chapter 1: Introduction ................................................................ 1

1.1: Background ...................................................................... 1

1.1.1: Periodontal disease ....................................................... 1

1.1.2: Tooth loss ..................................................................... 2

1.1.3: Systemic illness, cognitive and functional status in geriatric dental research ...... 2

1.2: Purpose and significance of the study ........................................... 3

1.3: Thesis framework ................................................................ 4

Chapter 2: Research Aims ............................................................ 5

2.1: Aims ............................................................................... 5

2.2: Objectives and hypotheses ....................................................... 5

2.3: Rationale ......................................................................... 6

2.4: Research questions ............................................................. 6

Chapter 3: Literature Review ..................................................... 7

3.1: Epidemiology of periodontal disease ............................................ 7

3.1.1: Periodontal disease ....................................................... 7

3.1.2: Epidemiological studies of periodontal disease ......................... 8

3.1.2.1: Case definition ....................................................... 8

3.1.2.2: Study designs .......................................................... 10

3.2: Tooth loss and the progression of periodontal disease ....................... 12

3.2.1: Tooth loss ..................................................................... 12
3.2.2: Tooth loss affects the measurement of the progression of periodontal disease..... 13

3.3: The relationship between systemic ill-health, functional limitation and cognitive impairment, and periodontal disease ......................................................... 14
  3.3.1: Systemic ill-health ......................................................................................... 14
    3.3.1.1: Diabetes mellitus ....................................................................................... 15
    3.3.1.2: Cardiovascular disease .............................................................................. 15
    3.3.1.3: Respiratory infections ............................................................................... 16
    3.3.1.4: Osteoporosis ............................................................................................. 17
    3.3.1.5: Rheumatoid arthritis ................................................................................ 17
    3.3.1.6: Other systemic diseases .......................................................................... 17
  3.3.2: Functional limitation...................................................................................... 18
  3.3.3: Cognitive impairment.................................................................................... 20
  3.3.4: Other factors associated with periodontal disease ......................................... 22
    3.3.4.1: Smoking..................................................................................................... 22
    3.3.4.2: Dental care behaviours .............................................................................. 23
    3.3.4.3: Socio-economic status ............................................................................. 24

Chapter 4: Study methods ..................................................................................... 25
  4.1: Data source ...................................................................................................... 25
    4.1.1: Study design ................................................................................................ 25
    4.1.2: Ethics approval ............................................................................................ 25
    4.1.3: Data collection ............................................................................................. 25
      4.1.3.1: Data collection at baseline (1991-1992) .................................................. 27
      4.1.3.2: Data collection at 2 year follow-up (1993-1994) .................................... 31
      4.1.3.3: Data collection at 5 year follow-up (1996-1997) .................................... 31
      4.1.3.4: Data collection at 11 year follow-up (2002-2003) ............................... 31
    4.1.4: Samples for the study ................................................................................ 32
  4.2: Data analyses planning .................................................................................. 38

Chapter 5: Periodontal disease and tooth loss in older South Australians.. 40
  5.1: Introduction ..................................................................................................... 40
  5.2: Aims ................................................................................................................ 41
  5.3: Methods .......................................................................................................... 42
    5.3.1: Samples ...................................................................................................... 42
    5.3.2: Periodontal disease case definitions ............................................................ 42
    5.3.3: Data analysis .............................................................................................. 43
  5.4: Results ............................................................................................................. 44
    5.4.1: Demographic and dental status characteristics ........................................... 44
    5.4.2: The prevalence of periodontal disease ....................................................... 45
    5.4.3: The incidence and reversal of periodontal disease .................................... 46
  5.5: Summary ........................................................................................................ 47
    5.5.1: Main findings ............................................................................................ 47
Chapter 6: Incidence and progression of periodontal disease in the people with high levels of tooth loss ................................................................. 50

6.1: Introduction .................................................................................. 50
6.2: Aims .............................................................................................. 51
6.3: Methods ......................................................................................... 52
  6.3.1: Samples ................................................................................... 52
  6.3.2: Estimating the incidence and progression of periodontal disease ......................................................................................... 52
    6.3.2.1: Definition ........................................................................... 52
    6.3.2.2: Individual incidence density of ALOSS new events calculation ................................................................. 53
    6.3.2.3: Illustration ........................................................................ 57
  6.3.3: Statistical analyses ..................................................................... 61
6.4: Results ......................................................................................... 61
6.5: Summary ....................................................................................... 69
  6.5.1: Main findings .......................................................................... 69
  6.5.2: Advantages of individual incidence density calculation .......... 70

Chapter 7: Systemic diseases and periodontal disease ......................... 72

7.1: Introduction ................................................................................ 72
7.2: Aim .............................................................................................. 73
7.3: Methods ......................................................................................... 73
  7.3.1: Sample ................................................................................... 73
  7.3.2: Variables ................................................................................ 74
    7.3.2.1: Risk predictors variables .................................................. 74
    7.3.2.2: Covariates (other independent variables) ......................... 74
    7.3.2.3: Outcome variable ............................................................. 75
  7.3.3: Statistical analyses .................................................................. 75
    7.3.3.1: Descriptive analyses ........................................................ 75
    7.3.3.2: Multivariate analyses ....................................................... 75
7.4: Results ......................................................................................... 76
  7.4.1: Sample characteristics and association with periodontal disease progression ..................................................... 77
  7.4.2: Association between periodontal disease progression and systemic diseases .......... 81
7.5: Summary ....................................................................................... 82
  7.5.1: Main findings .......................................................................... 82
  7.5.2: Association between systemic ill-health and periodontal disease progression .... 82

Chapter 8: Daily life effects on the incidence and progression of periodontal disease ............................................................................. 84

8.1: Introduction ................................................................................ 84
8.2: Aim: ............................................................................................. 86
# Table of Content

8.3: Conceptual frame work ................................................................. 87
8.4: Data........................................................................................... 88
8.5: Statistical analyses .................................................................... 88
8.6: Functional limitation.................................................................. 90
  8.6.1: Aim....................................................................................... 90
  8.6.2: Sample ............................................................................... 90
  8.6.3: Variables ........................................................................... 91
  8.6.4: Analyses ............................................................................ 92
  8.6.5: Results ............................................................................. 93
8.7: Cognitive impairment ................................................................. 98
  8.7.1: Aim ................................................................................... 98
  8.7.2: Sample ............................................................................... 98
  8.7.3: Variable ........................................................................... 98
  8.7.4: Analyses ............................................................................ 100
  8.7.5: Results ............................................................................. 101
8.8: Daily life effect analyses ........................................................... 106
  8.8.1: Analyses ............................................................................ 107
  8.8.2: Results ............................................................................. 108
8.9: Summary ................................................................................... 113
  8.9.1: Main findings .................................................................... 113
  8.9.2: Daily life effect on the periodontal disease progression ....... 113

## Chapter 9: Discussion ................................................................. 116

  9.1: An overview of periodontal disease .......................................... 117
  9.2: The main findings in relation to the research aims and questions... 118
  9.3: Prevalence, incidence and reversal of periodontal disease and tooth loss ................................................................. 119
  9.4: Incidence and progression of periodontal disease ..................... 119
  9.5: Systemic disease and periodontal disease incidence and progression ................................................................. 120
  9.6: Daily life conditions and periodontal disease progression ....... 121
  9.7: Strengths and limitations of this study ...................................... 123
    9.7.1: Strengths ....................................................................... 123
    9.7.2: Limitations ..................................................................... 126

## Chapter 10: Conclusions ............................................................... 128

### Appendices ................................................................................ 130

  Appendix 1: Baseline Questionnaire .............................................. 130
  Appendix 2: Two-year Follow-up Questionnaire ............................ 141
  Appendix 3: Five-year Follow-up Questionnaire ............................ 149
Appendix 4: Eleven-year Follow-up Questionnaire .................................................................160
Appendix 5: Oral examination.................................................................................................168
Appendix 6: Oral examination forms .......................................................................................179
Appendix 7: Clock-draw Test ....................................................................................................181

**Bibliography** ............................................................................................................................. 182
List of Tables

Table 1: Samples socio-demographic characteristics for the study ...........................................33
Table 2: Samples general health conditions for the study ..........................................................34
Table 3: Samples functional and cognitive status for the study ...................................................35
Table 4: Sample dental and other health-related behaviours for the study ..................................36
Table 5: Tooth loss and periodontal status of participants for the study ....................................37
Table 6: Different periodontal disease case definitions ...............................................................43
Table 7: Incidence and reversal of periodontal disease by baseline tooth loss ..........................46
Table 8: Association between tooth loss and the incidence or reversal of periodontal disease at each interval based on AAP-CDC case definition .......................................................47
Table 9: The probability (x100) of ALOSS new event occurrence by sites, teeth, CAL conditions and intervals ...........................................................................................................56
Table 10: Examples of ALOSS new events calculation (actual scenarios) .................................60
Table 11: Number of sites, teeth and people by the time of data collection ...............................61
Table 12: Number and percentage of ALOSS progression and reversal by intervals ...............62
Table 13: Number and percentage of ALOSS new events (ΔCAL ≥ 3mm) by sites, teeth and people under the different intervals .........................................................................................62
Table 14: Mean individual incidence density of periodontal disease per 1,000 tooth-years under the Scenario I by sample characteristic and different intervals ........................................66
Table 15: The mean individual incidence of ALOSS new events under the different scenarios by length of follow-up time ..................................................................................................67
Table 16: Comparing the mean difference of the individual incidence density of ALOSS new events per 1,000 tooth-years between scenarios ................................................................68
Table 17: Association between the individual incidence densities of ALOSS new events per 1,000 tooth-years and teeth lost under the difference scenarios over 11 years period .69
Table 18: Sample socio-demographic characteristics (baseline) and association with periodontal disease incidence and progression measured using incidence density of ALOSS new events per 1,000 tooth-years .................................................................77
Table 19: Sample dental and other health-related behaviours characteristics (baseline) and association with periodontal disease incidence and progression measured by incidence density of ALOSS new events per 1,000 tooth-years .................................................................78
Table 20: Prevalence of chronic diseases at baseline and association with periodontal disease progression measured by incidence density of ALOSS new events per 1,000 tooth-years .................................................................................................78
Table 21: Association between systemic diseases and the periodontal disease progression (Poisson regression model) ..................................................................................................81
Table 22: Sample characteristics of functional status data, and the association with periodontal disease progression ........................................................................................................84
Table 23: Associations between functional limitation and dental behaviours ............................94
Table 24: Adjusted direct effects of functional limitation and dental behaviours ........................95
Table 25: Controlled direct effect of functional limitation on the incidence and progression of periodontal disease by using MSMs .................................................................97
List of tables

Table 26: Sample characteristics of cognitive status data and the association with periodontal disease progression .................................................................102
Table 27: Associations between cognitive impairment and dental behaviours .............103
Table 28: Adjusted direct effects of cognitive impairment on periodontal disease progression .............................................................................................................104
Table 29: Controlled direct effect of cognitive impairment on the incidence and progression of periodontal disease (MSMs)..................................................................................................................105
Table 30: Sample characteristics of daily life and the association with periodontal disease progression .................................................................................................................................108
Table 31: Associations between daily life conditions and oral hygiene .........................109
Table 32: Associations between daily life and dental visiting behaviour ......................110
Table 33: The total and adjusted effect of daily life on periodontal disease progression ......111
Table 34: Effect of daily life on periodontal disease progression (MSMs).........................112
List of Figures

Figure 1: Flow chart of data collection at baseline (1991-1992) .................................................26
Figure 2: Samples for the study ........................................................................................................32
Figure 3: Prevalence of periodontal disease at each follow-up time point under the different case definitions. .............................................................................................................45
Figure 4: Example of ALOSS new events, tooth loss and the number of tooth-years at risk .59
Figure 5: Distribution of IR of ALOSS new events per 1,000 tooth-years (Scenario I) ..............63
Figure 6: Distribution of IR of ALOSS events per 1,000 tooth-years (Scenario II) .................64
Figure 7: Distribution of IR of ALOSS events per 1,000 tooth-years (Scenario III) ..............65
Figure 8: Directed acyclic graph (DAG) for the testing of effect of functional limitation and/or cognitive impairment on the incidence and progression of periodontal disease. ..........87
Figure 9: Directed acyclic graph between functional limitations and the incidence and progression of periodontal disease .................................................................................................................92
Figure 10: Directed acyclic graph between cognitive impairment and periodontal disease progression ........................................................................................................................100
Figure 11: Directed acyclic graph between daily life and periodontal disease progression...107
List of abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAP-CDC</td>
<td>The American Association of Periodontology and the U.S. Centres for Disease Control and Prevention</td>
</tr>
<tr>
<td>AD</td>
<td>Alzheimer’s Disease</td>
</tr>
<tr>
<td>ADTP</td>
<td>The Australasian Digital Theses Program</td>
</tr>
<tr>
<td>ALOSS</td>
<td>Attachment Loss</td>
</tr>
<tr>
<td>BMI</td>
<td>Body Mass Index</td>
</tr>
<tr>
<td>CAL</td>
<td>Clinical Attachment Level</td>
</tr>
<tr>
<td>CDT</td>
<td>Clock-Drawing Test</td>
</tr>
<tr>
<td>CHD</td>
<td>Coronary heart disease</td>
</tr>
<tr>
<td>COPD</td>
<td>Chronic obstructive pulmonary disease</td>
</tr>
<tr>
<td>CI</td>
<td>Cognitive impairment</td>
</tr>
<tr>
<td>CIs</td>
<td>Confidence intervals</td>
</tr>
<tr>
<td>CRP</td>
<td>C-reactive protein</td>
</tr>
<tr>
<td>CVD</td>
<td>Cardiovascular diseases</td>
</tr>
<tr>
<td>EFP</td>
<td>The European Federation of Periodontology</td>
</tr>
<tr>
<td>FL</td>
<td>Functional limitation</td>
</tr>
<tr>
<td>GCF</td>
<td>Gingival crevicular fluid</td>
</tr>
<tr>
<td>GDS</td>
<td>The Global Deterioration Scale</td>
</tr>
<tr>
<td>GR</td>
<td>Gingival Recession</td>
</tr>
<tr>
<td>Hs-CRP</td>
<td>High-sensitive C-reactive protein</td>
</tr>
<tr>
<td>IADL</td>
<td>Instrumental Activities of Daily Living</td>
</tr>
<tr>
<td>ID</td>
<td>Identity Number</td>
</tr>
<tr>
<td>IFG</td>
<td>Impaired fasting glucose</td>
</tr>
<tr>
<td>IL-1ß</td>
<td>Interleukin-1 beta</td>
</tr>
<tr>
<td>IR</td>
<td>Incidence (rate) density</td>
</tr>
<tr>
<td>IRR</td>
<td>Incidence (rate) density ratio</td>
</tr>
<tr>
<td>MI</td>
<td>Myocardial infarction</td>
</tr>
<tr>
<td>MMSE</td>
<td>The Mini-Mental State Examination</td>
</tr>
<tr>
<td>MSMs</td>
<td>The marginal structural models</td>
</tr>
<tr>
<td>NCHS</td>
<td>The US National Centre for Health Statistics</td>
</tr>
<tr>
<td>NSAOH</td>
<td>The National Survey of Adult Oral Health</td>
</tr>
<tr>
<td>OR</td>
<td>Odds Ratio</td>
</tr>
<tr>
<td>PGE2</td>
<td>Prostaglandin-E2</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>PPD</td>
<td>Probing Pocket Depth</td>
</tr>
<tr>
<td>PR</td>
<td>Prevalence Ratio</td>
</tr>
<tr>
<td>RA</td>
<td>Rheumatoid arthritis</td>
</tr>
<tr>
<td>SADLS</td>
<td>The South Australian Dental Longitudinal Study</td>
</tr>
<tr>
<td>SD</td>
<td>Standard deviation</td>
</tr>
<tr>
<td>SES</td>
<td>Socio-economic status</td>
</tr>
<tr>
<td>TIA</td>
<td>A stroke or a small stroke</td>
</tr>
<tr>
<td>TNF-α</td>
<td>Tumour necrosis factor-α</td>
</tr>
</tbody>
</table>
List of Symbols

%  Percentage
-  Not available
N  Sample size
i.e. For example
Δ  Change
Research outcome

Dissemination of these research findings has already commenced in order to create discussion and debate, and to inform agencies with influence over oral health policy. Oral and poster presentations to local, national and international audiences, and funding bodies associated with this study, are listed below.

Oral and poster presentations during time of candidature


27th June 2014: **Ju X**, Do LG, Mejia GC and Spencer AJ, Systemic diseases predict the progression of periodontal attachment loss: a longitudinal study, 92nd General Session and Exhibition of the International Association for Dental Research (IADR), Cape Town, South Africa. (Poster)


23rd March 2013: **Ju X**, Do LG and Spencer AJ, Suitability of periodontal disease case definitions for longitudinal data?, 91st General Session and Exhibition of the International Association for Dental Research (IADR), Seattle, Washington, USA.


### Grants and awards received

June 2014: J. Morita Junior investigation Award for Geriatric Oral Research (Second Prize) in the 92nd General Session and Exhibition of the International Association for Dental Research (IADR), 25-28 June 2014, Cape Town, South Africa.

March 2013: Travel Grant to attend 91st General Session and Exhibition of the International Association for Dental Research (IADR), 20-23 March 2013, Seattle, Washington, USA.

January 2011: Australian Postgraduate Award, the University of Adelaide.
Preface

This thesis reports on research which was conducted during the time of my candidature for the degree of Doctor of Philosophy (PhD) at the School of Dentistry, the University of Adelaide from January 2011 to July 2015. It relates to the incidence and progression of periodontal disease and daily life, which includes systemic illness, functional limitation, and cognitive impairment.
Abstract

Background: Periodontal disease is highly prevalent among older adults. The purpose of the current study was to improve the measurement of the incidence and progression of periodontal disease in older population with a high level of tooth loss, and to evaluate the relationship between daily life conditions (systemic diseases, functional limitation and cognitive impairment) and periodontal disease.

Methods: Data were from the South Australian Dental Longitudinal Study (SADLS). All participants were 60+ years. Data collection started in 1991/1992 and repeated 2, 5 and 11 years later. This study investigated the measurement of periodontal disease first by the use of periodontal disease case definitions; then the calculation of individual incidence density of periodontal attachment loss (ALLOSS ≥ 3mm) events. The role of systemic diseases in predicting the incidence and progression of periodontal disease was estimated after adjusting for social demographic, dental characteristics and health-related behaviour covariates using Poisson regression with robust standard errors. Marginal structural models (MSMs) with stabilised inverse-probability weights were used to estimate the direct effect of functional limitations and/or cognitive impairment on the incidence and progression of periodontal disease while controlling for other risk factors such as systemic diseases and dental behaviours.

Results: Of the 801 dentate participants examined at baseline (response rate: 66.5%), 596, 365 and 234 were re-examined at the 2, 5 and 11-year follow-up respectively. Large discrepancies in the prevalence of periodontal disease were found based on three different case definitions with the same population at different time points. Both the incidence and reversal of periodontal disease were associated with the number of teeth lost at baseline and across the follow-up intervals.

The mean individual incidence density of ALOSS new events was 8.3 per 1,000 tooth-years with imputed missing values due to tooth loss and loss of participants to follow-up. The individual incidence density of ALOSS new events was 2 times higher in the ‘tooth loss’ groups under the different scenarios, compared to ‘no tooth loss’ group.
The predictive analyses showed that among older adults who suffered from diabetes and chronic obstructive pulmonary disease (COPD), the average ALOSS events per 1,000 tooth-years was 1.3 and 1.2 times higher respectively than for those without these diseases.

The estimated direct effect of people with functional limitation increased the risk of periodontal disease progression around 1.6 times, compared with those without functional limitation; people with cognitive impairment had nearly 1.7 times greater progression of periodontal disease than those who did not have cognitive impairment; and having both functional limitations and cognitive impairment raised the progression of periodontal disease to 1.8 times compared to those who did not have functional limitation or cognitive impairment.

**Conclusion:** Individual-level incidence density of ALOSS new events was more appropriate to estimate the incidence and progression of periodontal disease in a population with a high level of tooth loss. Diabetes and COPD were risk predictors of the incidence and progression of periodontal attachment loss, and daily life (including functional limitation and/or cognitive impairment) had a direct effect on incidence and progression of periodontal disease that was not mediated by dental behaviours or systemic diseases.
Declaration

This work contains no material which has been accepted for the award of any other degree in any university or any tertiary institution. To the best of my knowledge and belief, this work contains no material previously published or written by any other person, except where due reference has been made in the text.

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 of those works.

I also give permission for the digital version of this thesis to be made available on the internet, via the University’s digital research repository, the Library catalogue, the Australasian Digital Thesis Program and also through web search engines, unless permission has been granted by the university to restrict access for a period of time.

Signature

Date
Acknowledgements

Firstly, I would like to give my sincere thanks to my Principal Supervisor, Professor Andrew John Spencer, and to my Co-supervisors, Associate Professor Loc Giang Do and Dr Gloria Cecilia Mejia for their support, encouragement and professional guidance throughout the study duration as a PhD candidate. Without their faith in my ability to undertake this project, it would not have happened. I will remain forever grateful.

I wish to acknowledge the support of Professor Brian Leroux, from the University of Washington, and Professor Gary Slade, from the University of North Carolina, who provided assistance and guidance with aspects of the statistical analysis. I thank Dr Najith Amarasena from ARCPOH, who provided preliminary analyses that revealed the research problem.

A special acknowledgement to Dr Suzanne Gardner from ARCPOH for assisting with the writing and editing of the thesis, as well as her emotional support and encouragement during my PhD candidature. I thank Dr Yvonne Miels from Editing & Publishing Services for proof-editing of the thesis. I sincerely thank you.

Finally, I am very grateful for my family’s unwavering support and understanding, particularly that of my husband Jin Wang, also my mother Hui Ying Chen and brother Yuan Ju, my son Yunze Wang and daughter-in-law Shi Yu Bai, which was paramount during the period leading up to and throughout my candidature.