The prevalence and severity of root surface caries across Australian generations

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The prevalence and severity of root surface caries across Australian generations

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Abstract

Background: The "failure of success" theory predicts that as subsequent generations of older adults retain more teeth, those additional teeth will experience more oral disease like root surface caries. The theory in relation to root surface caries has never been tested in a cross-generational study. This study aims to compare root surface caries across generations of South Australian older adults to test the theory and explore risk indicators for root surface caries.

Methods: Data were from the baseline of two South Australian studies separated by 22 years. In both studies, stratified random samples of people aged 60+ years from Adelaide and Mount Gambier were recruited. Dental examinations were performed by trained and calibrated dentists. One of the dental examiners from the earlier study was the gold standard examiner in the second study. Risk indicators included behavioural factors, clinical oral conditions, sociodemographic and socioeconomic status. Root surface caries was assessed as untreated root surface caries (root decayed surfaces [RDS]), treated root surface caries (root filled surfaces [RFS]) and treated or untreated root surface caries (root decayed and filled surfaces [RDFS]) and was presented as the prevalence and summed count. Multivariable models for Poisson and negative binomial distributions were used to estimate prevalence ratios (PR) and mean ratios (MR), respectively, and their 95% confidence intervals (95% CI).

Results: The current generation of South Australian older adults has significantly lower RDS (PR [95% CI] = 0.65 [0.47-0.89]; MR [95% CI] = 0.51 [0.35-0.73]) and RDFS (PR [95% CI] = 0.84 [0.71-0.99]; MR [95% CI] = 0.76 [0.65-0.90]) than the previous generation. The RFS in the previous and current generation was similar. Gingival recession, irregular brushing, dental visiting for a problem and smoking were the indicators for RDS, while age, gingival recession, tooth brushing frequency, time since last dental visit and reason of visiting were the indicators for RFS or RDFS.

Conclusions: These results do not support the "failure of success" theory in relation to root surface caries among South Australian older adults. Despite the higher number of teeth retained, the current generation of older adults has less root surface caries than the previous generation. Behavioural factors remain the indicators of root surface caries across the generations.

KEYWORDS
across generation, "failure of success", root surface caries

1 | INTRODUCTION

Root surface caries has become a subject of interest among researchers in dentistry across the last several decades. It was predicted that the burden of root surface caries would become more apparent as the life expectancy increased and tooth loss in older adults decreased.[1,2] With the increased number of teeth retained, more teeth would be at risk of developing root surface caries. This assumption, congruent with the "failure of success" theory raised by Gruenberg in 1977,[3] was part of the "more teeth, more disease" theory[4] accepted in dentistry. Cross-sectional data have confirmed that the more the teeth retained, the more the caries and periodontal disease encountered.[4,5] Cross-sectional data can measure the effect of ageing on risk of having caries within a generation. Nevertheless, the evidence has led to a hypothesis that the current generation who has retained more teeth will also have more root surface caries, which will have implications for the burden of oral diseases in the future. However, the "failure of success" or "more teeth, more disease" theories have not yet been tested using data across two different generations.

Comparative analysis across generations is useful in a number of aspects. It can comment on changes over time of the disease burden in the population. Documenting those changes can inform relevant population health policies. Different generations may have different levels of exposure to risk and protective factors. In this situation, a comparative analysis across generations can evaluate relative importance of those risk and protective factors.

There have been changes across generations such as exposure to fluoridated water or use of fluoridated toothpaste as part of improved oral hygiene and an increased awareness of the dangers of smoking. Hence, it is possible that the indicators for root surface caries will differ across generations. An important change was that the contemporary generation retained more teeth than the previous generation. Thus, this study aims to test the "failure of success" or the "more teeth, more disease" theories related to root surface caries using two cross-sectional studies of South Australian older adults and to explore the possible indicators for root surface caries across the generations.

2 | MATERIALS AND METHODS

2.1 | Study population and research design

The first South Australian Dental Longitudinal Study commenced in 1991/1992 (SADLS1). SADLS1 consisted of three strata of older adults 60+ years old from both Adelaide, the capital city of South Australia, and Mount Gambier, a regional city in the south-east of the state. A recent Intergenerational Change in Oral Health in Australia Study (SADLS2) was conducted to measure the disease among a current generation of Australian older adults 60+ years in the same locations 22 years later.[6] A comparison of root surface caries prevalence and severity among the current and the previous generation of Australian older adults was made by comparing the results of the two studies. Drawing participants from the same background population allowed comparison of the two cohorts with minimal confounding. SADLS1 and SADLS2's participants represent the generation of older adults born before 1931 and 1953 which hereafter will be called as the previous and current generations, respectively.

SADLS1 and SADLS2 both adopted a longitudinal study design. This article presents the analysis of only the baseline data. The details of the recruitment procedures of SADLS1 have been published previously.[7] SADLS2 adopted similar strategy design, using a stratified random sample of persons aged 60+ years old selected from the Australian Electoral Roll, which is a compulsory register for Australian citizens.[6]

2.2 | Data collection and management

Each SADLS contained both a social survey (interview or mailed questionnaire) and oral examination at baseline. A participating dental examiner in SADLS1 was retained as the gold examiner in SADLS2 for the oral examinations. SADLS1 and SADLS2 adopted different rules in handling cases where a caries lesion or filling involved both the coronal and root surfaces. SADLS1 used the "half rule" while SADLS2 used "one millimetre rule." With the "half rule," a root caries lesion was recorded only if more than half of the lesion was located on the root surface, while, with the "one millimetre rule," root caries was recorded if the lesion extended at least 1 mm onto the root surface. In the oral examination, all teeth and retained roots present in the mouth, including the third molars, were examined for root surface caries. Teeth were categorized as present if more than a quarter of the natural or restored coronal tooth structure was present, otherwise it was coded separately as retained roots.

For each tooth present, the status of four root surfaces was recorded. Root surface caries was recorded by differentiating root surfaces which were decayed, filled or sound. To be recorded as sound, the root surface had to be visible. Root surfaces in which there had been no recession of the gingival margin apical to the cemento-enamel junction were recorded as unexposed. In the coding scheme, examiners differentiated recurrent/secondary decay from primary decay, as well as filled unsatisfactory from filled satisfactory. No distinction was made between caries-related and noncaries-related root restorations. Each retained root was coded as retained root decayed or sound, which then was translated as the status of the four root surfaces of the same retained root. The same procedure was applied in both SADLS1 and SADLS2. The outcomes presented in this article were the prevalence and the severity of root surface caries, each was measured in three different formats: root decayed surfaces (RDS); root filled surfaces (RFS); and root decayed and filled surfaces (RDFS).

Risk indicators were collected through self-reported social surveys (interview in SADLS1 and questionnaire in SADLS2) and oral examination during the baseline. Risk indicators included sociodemographic status (age, sex, highest school/tertiary qualification, residential place and private insurance), socioeconomic status (household income), clinical condition (number of teeth and the number of exposed root surfaces) and oral health–related behaviours. Oral health-related behaviours were tooth brushing frequency (twice a day or more vs less than twice a day), flossing frequency (once a day or more vs not every day), dental visiting (last visit was less than 1 year ago vs last visit that was more than 1 year ago), reason for visit (check-up vs problem) and smoking status (never smoked vs currently or used to smoke). Age was dichotomized into 60-69 years and ≥70 years. The level of education was dichotomized into trade/diploma or higher and senior high school or less. Residential location was divided into living in Adelaide and Mount Gambier, which also could represent the access of the study participants to the water fluoridation. Adelaide, the capital city of South Australia, had water fluoridated since 1971, while Mount Gambier's water was not fluoridated until 2010. Private dental insurance was categorized as having private insurance or not.

Socioeconomic status was measured by household income (categorized as low, medium and high income). Income was collected in different dollar value categories due to the collection being 22 years apart. Household income was categorized into three almost equal groups based on the distribution of income in each study. For SADLS1, <$12 000, $12 000 to <$16 000 and ≥$16 000 were categorized as relatively low, medium and high income, respectively, while for SADLS2, <$20 000, $20 000 to <$40 000 and ≥$40 000 were categorized as low, medium and high income, respectively.

In the multivariable analysis, gingival recession was expressed as a count of the number of surfaces with recession of 1 mm or more, while the number of teeth was presented as the total count of teeth and teeth roots presents in the mouth.

2.3 | Statistical analysis

The statistical analysis was performed in SAS-callable SUDAAN. Background characteristics and clinical conditions of the two generations were described using prevalence and means. Indicators of root surface caries prevalence and severity for each generation were examined using bivariate and multivariable analyses. For root surface caries prevalence (RDS, RFS and RDFS prevalence), bivariate analysis was conducted using chi-square for categorical predictors and logistic regression for the continuous predictors. For root surface caries severities (mean RDS, RFS and RDFS), bivariate analysis was conducted using the Mann-Whitney U test for the predictors with two categories, the Kruskal-Wallis one-way ANOVA for a predictor with three categories and Spearman's rho correlation for continuous predictor as all distributions were not normal. Separate multivariable models for each generation were performed using SAS Proc Genmod[8] to check the risk indicators of root surface caries prevalence and severity in each generation. Proc Genmod fits generalized linear regression models with robust standard error estimation.[8] Multivariable log Poisson regression models were performed to investigate factors associated with the RDS, RFS and RDFS prevalence. Adjusted prevalence ratio (PR) and its 95% CI were estimated. Multivariable log negative binomial regression models separately were performed to investigate factors associated with mean RDS, RFS and RDFS. Adjusted mean ratio (MR) and its 95% CI were estimated. Finally, the two generations data were combined, and the generation variable was included in all models. Two models were generated for each outcome. The first model adjusted for the generation, sex and age (a minimally adjusted model). The full models also adjusted for SES, clinical conditions and health behaviours. Interactions between the generation and risk indicators were tested and included in the full model if their inclusion improved model fit. The best model (final model) was a model presenting the lowest DIC (deviance information criteria) and AIC (Akaike information criterion).[9] A variance inflation factor was used to check the multicollinearity. As there was no evidence of multicollinearity, all of the indicators were included in the multivariable analysis. All analyses were unweighted. The statistical significance of the associations was evaluated at $P < 0.05$.

2.4 | Ethical review

Both SADLS1 and SADLS2 received ethical approval from the University of Adelaide Human Research Ethics Committee. In addition, SADLS2 also received ethical approval from the South Australia Health Human Research Ethics Committee. The participants in both the studies provided written informed consent for the self-reported social survey and the oral examination.

3 | RESULTS

A total of 913 and 486 dentate respondents underwent an oral examination in SADLS1 and SADLS2, respectively. Appendix S1 presents characteristics of dentate surveyed people in both SADLS1 and SADLS2, comparing those who participated in the oral examination with those who did not. The characteristics of older adults who were dentally examined and those not examined were not significantly different, except that in the SADLS1 those examined were more likely to have higher education, while in SADLS2 those examined were younger and more likely to have made a dental visit within the previous year. Compared to those in SADLS1, participants who were examined in SADLS2 were more likely to live in Mount Gambier (51.9% compared to 38.7%) and to hold private dental insurance (61.6% compared to 41.9%).

The clinical oral examination (Appendix S1) indicates that the current generation retained significantly more teeth than the previous generation (mean [95% CI] = 21.6 [21.0-22.3] compared to mean [95% CI] = 16.3 [15.8-16.8], respectively). The prevalence and the mean number of sites with gingival recession in the current generation were also higher (% [95% CI] = 99.4 [98.7-100] vs 97.5 [96.5-98.5] and mean number of sites [95% CI] = 38.3 [36.3-40.1] vs 26.9 [25.8-28.0], respectively). However, the prevalence of root surface caries was lower in the current generation. The prevalence and the severity of untreated root surface caries were significantly lower in the current generation than the previous generation (% [95% CI] = 16.5 [13.2-19.8] vs 27.3 [24.4-30.2] and mean count [95% CI] = 0.41 [0.27-0.56] vs 0.95 [0.74-1.17] respectively), while the mean of treated root surface caries (RFS) in the current generation was slightly higher, but not significantly different from the previous generation (mean count [95% CI] = 2.87 [2.49-3.26] vs 2.54 [2.32-2.76], respectively). The mean of treated and untreated root surface caries (RDFS) was still lower in the current generation than that of the previous generation (mean count [95% CI] = 3.29 [2.88-3.70] vs 3.49 [3.20-3.79], respectively).

The findings from the bivariate analysis of the prevalence and severity of root surface caries with risk indicators are presented in Appendix S2 and S3, respectively. While there are some differences in the indicators for root surface caries between the generations, the direction of associations was mostly the same. Having private dental insurance and visiting a dentist for check-up were associated with a lower RDS prevalence in all generations. More frequent brushing and dental visiting were associated with higher RFS, while greater age was associated with higher RDFS in both generations. The multivariable analysis of root surface caries in each generation is presented in the Appendix S4 and S5. The multivariable analysis across generations is presented in Tables 1 and 2.

The AIC and DIC of the final models are lower than the minimally adjusted model for all root surface caries measurements showing the better fit of models after being adjusted for all indicators. We also observed that interaction resulted in improved model fit (smaller AIC and DIC) only for the model for mean RFS. In the root surface caries final models, the current generation had a lower untreated root surface caries (RDS prevalence PR [95% CI] = 0.65 [0.47-0.89] and mean RDS (MR [95% CI] = 0.51 [0.35-0.73]) and untreated or treated root surface caries (RDFS prevalence PR [95% CI] = 0.84 [0.71-0.99] and mean RDFS (MR [95% CI] = 0.76 [0.65-0.90]) than the previous generation. The RFS did not differ across the generations. None of the sociodemographic factors included in the final model were indicators for root surface caries prevalence. Being female was an indicator for having a lower mean of untreated root surface caries (MR [95% CI] = 0.62 [0.43-0.89]), while lower income was an indicator for having higher mean of RDS (MR [95% CI] = 1.56 [1.03-2.34]). Younger age was associated with lower mean of RFS (MR [95% CI] = 0.80 [0.68-0.95]) and RDFS (MR [95% CI] = 0.82 [0.70-0.95]). Higher number of sites with gingival recession was associated with higher RDS prevalence and with the severity of root surface caries in all types of measurement (RDS, RFS and RDFS), while a higher number of teeth was associated with a lower prevalence and severity of RDS only. Among the oral health–related behaviours included in the final model, brushing less than twice a day, visiting a dentist only for a problem and smoking were associated with a higher RDS prevalence (PR [95% CI] = 1.54 [1.20-1.96], 1.81 [1.32-2.48] and 1.36 [1.03-1.79], respectively) and mean RDS (MR [95% CI] = 1.53 [1.10-2.11], 2.40 [1.65-3.51] and 1.50 [1.08-2.08], respectively). Making a dental visit in the previous year was associated with higher RFS prevalence and the mean of RFS and RDFS. Brushing less than twice a day was an indicator for lower mean number of treated root surface caries (MR [95% CI] = 0.82 [0.69-0.97]), while making a dental visit for a problem was an indicator for lower prevalence and lower severity of treated root surface caries (PR [95% CI] = 0.81 [0.68-0.98] and MR [95% CI] = 0.59 [0.47-0.72], respectively). Dental visit in the previous year was an indicator for having higher mean of RDFS (MR [95% CI] = 1.27 [1.07-1.52]).

4 | DISCUSSION

This research shows that the current generation of Australian older adults has retained more teeth than the previous generation, and despite the increase in sites with gingival recession compared to the previous generation, the current generation has less root surface caries. The "half rule" applied in the SADLS1 oral examinations tended to underestimate root caries. Therefore, the difference in the rule of handling a condition where a caries lesion involved both the coronal and root surfaces applied in SADLS1 and SADLS2 did not affect the conclusion that the current generation had lower root caries than the previous generation.

Our findings do not support the "failure of success" or "more teeth, more disease" theory in relation to root surface caries. The finding that the number of teeth was significantly higher among the current generation substantiated the downward trend of edentulism and upward retention of teeth in older adults in Australia.[10] With an increase in sites with gingival recession but most of those sites remain root surface caries free, Australia seems to have a successfully ageing generation of older adults.

When the "more teeth, more disease" theory[4] was developed, reported that in contrast to other oral conditions, the number of teeth/surfaces with untreated caries (both coronal and root surface caries) was lower as the number of teeth increased. They argued that this phenomenon was caused by tooth extraction. Teeth that were extracted had higher rates of caries, reducing the number of teeth with disease. However, by comparing the root surface caries in two generations and controlling for the number of teeth, we showed that the reduction in root surface caries in this across generational study was a result of successful ageing.

Our findings showed that despite the increase in the number of sites with gingival recession, the root surface caries was lower in the current generation, demonstrating that it is possible to avoid or postpone the onset of root surface caries cases and keep the majority of exposed root surface caries free. It is likely that water fluoridation plays a role in this finding. People living in Adelaide region have benefited more from water fluoridation than those living in Mount Gambier whose water was only fluoridated almost 40 years later. Prevalence of RDFS in Adelaide declined from 74% to 62% but did

TABLE 1 Multivariable analysis of root surface caries prevalence in the South Australian elders across generations (SADLS1 and SADLS2)

	Root surface caries prevalence					
Risk indicator	**Minimally adjusted model RDS PrevalencePR [95% CI]**	**Final model RDS PrevalencePR [95% CI]**	**Minimally adjusted model RFS PrevalencePR [95% CI]**	**Final model RFS PrevalencePR [95% CI]**	**Minimally adjusted model RDFS PrevalencePR [95% CI]**	**Final model RDFS PrevalencePR [95% CI]**
Generation						
Current generation (ref. previous generation)	**0.62 [0.48-0.80]**	**0.65 [0.47-0.89]**	0.98 [0.85-1.14]	0.84 [0.70-1.01]	0.92 [0.80-1.05]	**0.84 [0.71-0.99]**
Sociodemographic						
Age						
60-69 y (ref. ≥70 y)	**0.70 [0.56-0.88]**	0.87 [0.68-1.11]	0.89 [0.78-1.02]	0.91 [0.78-1.07]	0.89 [0.78-1.01]	0.93 [0.80-1.07]
Sex						
Female (ref. male)	**0.62 [0.49-0.79]**	0.82 [0.61-1.10]	1.07 [0.93-1.22]	1.01 [0.86-1.20]	1.00 [0.88-1.14]	1.00 [0.85-1.17]
Highest school/tertiary qualification						
Senior high school or less (ref. trade/diploma or higher)		0.91 [0.71-1.16]		1.03 [0.88-1.21]		1.03 [0.89-1.19]
Residential place						
Adelaide (ref. Mt Gambier)		0.95 [0.74-1.20]		0.98 [0.84-1.14]		0.99 [0.86-1.14]
Private dental insurance						
No (ref. yes)		0.92 [0.70-1.21]		1.04 [0.87-1.23]		1.02 [0.87-1.19]
Socioeconomic						
Income*						
Low (ref. high)		1.29 [0.95-1.77]		1.04 [0.85-1.27]		1.06 [0.88-1.28]
Medium (ref. high)		1.16 [0.85-1.57]		1.03 [0.85-1.25]		1.05 [0.88-1.26]
Clinical conditions						
Exposed root surfaces[a]	**1.01 [1.01-1.02]**		1.01 [1.00-1.01]		1.01 [1.00-1.01]	
Number of teeth	**0.96 [0.94-0.98]**		1.01 [0.99-1.02]		1.00 [0.99-1.01]	
Oral health behaviours						
Frequency of brushing						
Less than twice a day (ref. Twice a day or more)		**1.54 [1.20-1.96]**		0.89 [0.75-1.05]		0.99 [0.86-1.16]
Frequency of flossing						
Not every day (ref. once a day or more)		0.86 [0.67-1.12]		0.99 [0.84-1.16]		0.99 [0.85-1.15]
Dental visit						
Last visit is less than 1 y ago (ref. Last visit is more than 1 y ago)		1.14 [0.88-1.49]		**1.37 [1.13-1.67]**		1.16 [0.98-1.38]
Usual reason for visiting						
Problem (ref. check-up)		**1.81 [1.32-2.48]**		**0.81 [0.68-0.98]**		0.92 [0.77-1.09]
Smoking						
Current or ex-smoker (ref. Nonsmoker)		**1.36 [1.03-1.79]**		1.01 [0.86-1.19]		1.05 [0.91-1.22]
Model comparison						
AIC	1558.2	1313.3	2529.9	2133.9	2634.4	2265.9
DIC	1579.1	1394.7	2550.8	2215.2	2655.3	2347.3

Abbreviations: 95% CI, 95% confidence interval; AIC, Akaike information criterion (smaller is better); DFS, decayed filled surfaces; DIC, deviance information criteria = −2RLL (smaller is better); DS, decayed surfaces; FS, filled surfaces; PR, prevalence ratio; log Poisson regression model.
Bold: Significant.
[a]Number of surfaces with gingival recession.

TABLE 2 Multivariable analysis of root caries experience (the severity of root surface caries) in South Australian elders across generations (SADLS1 and SADLS2)

Risk Indicator	The severity of root surface caries Minimally adjusted model RDS MR [95% CI]	Final model RDS MR [95% CI]	Minimally adjusted model RFS MR [95% CI]	Final model RFS[b,c] MR [95% CI]	Minimally adjusted model RDFS MR [95% CI]	Final model RDFS MR [95% CI]
Generation						
Current generations (ref. generation 20 y ago)	**0.48 [0.34-0.66]**	**0.51 [0.35-0.73]**	1.13 [0.96-1.33]	0.76 [0.55-1.05]	0.96 [0.83-1.11]	**0.76 [0.65-0.90]**
Sociodemographic						
Age						
60-69 y (ref. ≥70 y)	**0.62 [0.46-0.83]**	0.74 [0.54-1.00]	**0.77 [0.66-0.90]**	**0.80 [0.68-0.95]**	**0.75 [0.65-0.86]**	**0.82 [0.70-0.95]**
Sex						
Female (ref. male)	**0.44 [0.32-0.59]**	**0.62 [0.43-0.89]**	1.01 [0.86-1.19]	1.00 [0.84-1.19]	**0.85 [0.74-0.98]**	0.90 [0.77-1.06]
Highest school/tertiary qualification						
Senior high school or less (ref. Trade/diploma or higher)		0.74 [0.53-1.03]		0.91 [0.78-1.07]		0.93 [0.80-1.07]
Residential place						
Adelaide (ref. Mt Gambier)		0.84 [0.62-1.13]		0.91 [0.77-1.07]		0.92 [0.80-1.07]
Private dental insurance						
No (ref. yes)		1.05 [0.72-1.52]		0.95 [0.80-1.14]		1.05 [0.89-1.24]
Socioeconomic						
Income*						
Low (ref. high)		**1.56 [1.03-2.34]**		1.10 [0.89-1.35]		1.09 [0.91-1.32]
Medium (ref. high)		1.10 [0.75-1.62]		1.13 [0.92-1.38]		1.05 [0.87-1.26]
Clinical conditions						
Exposed root surfaces[a]	**1.03 [1.02-1.04]**		**1.02 [1.02-1.03]**		**1.03 [1.02-1.03]**	
Number of teeth	**0.94 [0.92-0.96]**		1.01 [1.00-1.02]		0.99 [0.98-1.00]	
Oral health behaviours						
Frequency of brushing						
Less than twice a day (ref. Twice a day or more)		**1.53 [1.10-2.11]**		**0.82 [0.69-0.97]**		0.97 [0.83-1.13]
Frequency of flossing						
Not every day (ref. once a day or more)		1.07 [0.76-1.50]		1.11 [0.91-1.37]		1.05 [0.90-1.23]
Dental visit						
Last visit is less than 1 y ago (ref. last visit is more than 1 y ago)		0.78 [0.55-1.10]		**1.61 [1.32-1.95]**		**1.27 [1.07-1.52]**
Usual reason for visiting						
Problem (ref. check-up)		**2.40 [1.65-3.51]**		**0.59 [0.47-0.72]**		0.84 [0.71-1.00]
Smoking						
Current or ex-smoker (ref. nonsmoker)		**1.50 [1.08-2.08]**		1.02 [0.86-1.20]		1.09 [0.94-1.27]

(Continues)

TABLE 2 (Continued)

Risk Indicator	The severity of root surface caries Minimally adjusted model RDS MR [95% CI]	Final model RDS MR [95% CI]	Minimally adjusted model RFS MR [95% CI]	Final model RFS[b,c] MR [95% CI]	Minimally adjusted model RDFS MR [95% CI]	Final model RDFS MR [95% CI]
Interaction						
Generation × frequency of flossing			0.71 [0.50-1.01]			
Generation × usual reason for visiting			**1.79 [1.28-2.50]**			
Model comparison						
AIC	2682.1	2230.0	5822.0	4817.3	6482.4	5451.6
DIC	2708.3	2316.4	5848.2	4913.8	6508.6	5538.0

Abbreviations: 95% CI, 95% confidence interval; AIC, Akaike information criterion (smaller is better); DFS, decayed filled surfaces; DIC, deviance information criteria = −2RLL (smaller is better).; DS, decayed surfaces; FS, filled surfaces; MR, mean ratio; log negative binomial regression model.
Bold: Significant.
[a]Number of surfaces with gingival recession.
[b]Final model is full model with interaction.
[c]Only significant interactions were included in the final model.

not change (69%) in Mount Gambier, and the severity of RDFS decreased from 3.58 to 2.94 in Adelaide, but increased from 3.35 to 3.61 in Mount Gambier. However, these changes were not statistically significant. Water fluoridation has been found to be a significant predictor for lower root surface caries in some previous studies,[11,12] but not in another study.[13] However, even though the magnitude of root surface caries is not as high as predicted, root surface caries was still a dental problem in the current generation of Australian older adults 60+ years old. Almost two-thirds of older adults still showed RDFS while almost 17% had untreated root surface caries.

Some sociodemographic, clinical and oral health–related behaviours were found as indicators for root surface caries. Younger age was associated with lower mean of root surface caries, supporting previous understanding that root surface caries increased in older aged.[1] As RDFS is a cumulative index and as root surface caries was related to exposed root surfaces whose prevalence increased with ageing, it is understandable that older people exhibit more root surface caries. Being male and having a lower income were indicators for higher RDS, also consistent with previous research.[14,15]

In terms of clinical indicators, increased number of surfaces with gingival recession was associated with the mean increase of root surface caries in all kind of measurements. Research has consistently shown this association.[14,16] Gingival recession puts the exposed root in contact with the oral environment, increasing the risk to developing root surface caries. Having more teeth was significantly related to lower untreated root surface caries in this study, supporting previous research.[17,18]

The behavioural indicators for RDS and RFS or RDFS were quite different. It is important to first note that a measurement in root caries fillings was problematic. All root surfaces with a filling are usually recorded as filled surfaces despite uncertainty as to why a filling has been placed. Walls et al.[19] undertook a prospective study among the UK dentist and reported that 45% of restoration were placed because of decay while 55% were done for other reasons. Accordingly, including all the filled root surfaces could overestimate root surface caries. Therefore, we provided RDS, RFS and RDFS measurements to acknowledge this problem and to provide more detailed assessment. Less frequent tooth brushing, dental visiting for a problem and smoking were indicators for untreated root surface caries, while frequent tooth brushing, frequent dental visiting and visiting a dentist for a check-up were indicators for treated root surface caries. As tooth brushing could remove plaque and usually involves a fluoridated toothpaste, tooth brushing could have a preventive effect for root surface caries, supporting previous research.[14,20] Smoking could contribute to a lower buffering capacity of saliva[21] while at the same time, being related to the increased number of *mutans streptococci* and *lactobacilli*[22] made it as a risk for root surface caries. However, this association was still inconclusive.[23] Compared to those who visited a dentist for a check-up, people who visited a dentist for a problem had a higher risk of having untreated root surface caries and a lower risk of having root filling. Furthermore, those who reported more frequent dental visits had more root fillings. These facts may suggest that people who visit a dentist more frequently are more likely to have a problem detected early enough for restorative intervention and possibly more likely to be able to afford restoration over extraction. Alternatively, more frequent dental visiting may provide more opportunities for decisions to fill root surfaces for reasons other than root surface caries. The association of more frequent brushing with more filled root surfaces may indicate a clustering of oral health behaviours with people who brush regularly usually routine dental attenders.[24] Research on the clustering of behaviours as a risk for root surface caries warrants a future investigation.

There are some strength in this study. To our knowledge, this is the first study testing the "failure of success" or "more teeth, more disease" theory in root caries cases across generations. The 22-year gap between the two studies provided an opportune time to assess the different generations of older adults 60+ years old as there would be little intersection in participants in the studies. Furthermore, the high number of participants pooled from the studies could increase the study power in terms of the estimates. However, not knowing the root caries history of missing teeth, not using radiographs and conducting examinations under field condition could underestimate root surface caries. Not including coronal caries experience in the model was another limitation in this study as previous research showed that coronal caries experience through the life course is a risk factor for root caries.[25] As this research was a secondary data analysis, it was not possible to evaluate other known risk factors for root surface caries, such as alcohol intake or sugary diet. Furthermore, as unweighted analysis was performed, these results cannot be generalized to Australian older adults. As this study involves two cross-sectional samples of older adults, we were unable to investigate whether more teeth retained in middle age individuals in the current generation will translate into more disease in their older age, as well as being unable to directly investigate whether the ongoing incidence and risk of root surface caries through old age is the same across generations. To be able to answer these questions, longitudinal data are needed. The availability of our longitudinal data from these two cohorts will provide an opportunity to examine these issues in the future research.

5 | CONCLUSIONS

These findings of this study do not support the "failure of success" theory in relation to root surface caries among South Australian older adults. The current generation of South Australian older adults was demonstrating successful ageing, presenting more teeth at risk, but less root surface caries compared to the previous generation. However, root surface caries is still a dental problem in many of the current generation of Australian older adults.

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AUTHOR CONTRIBUTION

Ninuk Hariyani contributed to the conception of the article, data request, data cleaning, data analysis and interpretation and result interpretation and drafted the manuscript. John Spencer and Kaye Roberts-Thomson contributed to the study design in both generations, data acquisition and result interpretation and critically revised the manuscript. Liana Luzzi, Jane Harford, Haiping Tan and Gloria Mejia contributed to the study design in the current generations, data acquisition and result interpretation and critically revised the manuscript. Loc Giang Do contributed to the conception of the article, data analysis and interpretation and result interpretation and critically revised the manuscript. All authors gave final approval and agreed to be accountable for all aspects of the work.

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REFERENCES

1. Banting DW. Dental caries in the elderly. *Gerodontology*. 1984;3:55-61.
2. Reinhardt JW, Douglass CW. The need for operative dentistry services: projecting the effects of changing disease patterns. *Oper Dent*. 1989;14:114-120.
3. Gruenberg EM. The failures of success. *Milbank Mem Fund Q*. 1977;55:3-24.
4. Joshi A, Douglass C, Feldman H, Mitchell P, Jette A. Consequences of success: do more teeth translate into more disease and utilization? *J Pub Health Dent*. 1996;56:190-197.
5. Nicolau B, Srisilapana P, Marcenes W. Number of teeth and risk of root caries. *Gerodontology*. 2000;17:91-96.
6. Harford JE, Luzzi L, Tan H, Mejia G, Roberts-Thomson K, Spencer AJ. NHMRC project grant. Intergenerational change in oral health in Australia. 2011. Application ID: 1011589.
7. Slade GD, Spencer AJ. Distribution of coronal and root caries experience among persons aged 60+ in South Australia. *Aust Dent J*. 1997;42:178-184.
8. SAS Institute Inc. The GENMOD procedure (book excerpt). In: *SAS/STAT® 92 User's Guide*. Cary, NC: SAS Institute Inc.; 2010.
9. Beal DJ. Information criteria methods in SAS for multiple linear regression models. SESUG Proceedings Paper SA05. Raleigh, NC: North Carolina State University; 2007.
10. Slade GD, Sanders A. Trends in oral health 1987-2006. In: Slade GD, Spencer AJ, Roberts-Thomson KF, eds. *Australia's Dental Generations: The National Survey of Adult Oral Health 2004-06*. AIHW cat. No. DEN 165. Canberra, ACT: Australian Institute of Health and Welfare; 2007:196-235.
11. Burt BA, Ismail AI, Eklund SA. Root caries in an optimally fluoridated and a high-fluoride community. *J Dent Res*. 1986;65:1154-1158.
12. Stamm JW, Banting DW, Imrey PB. Adult root caries survey of two similar communities with contrasting natural water fluoride levels. *J Am Dent Assoc*. 1990;120:143-149.
13. Rihs LB, DaLuzRosárioDeSousa M, Wada RS. Root caries in areas with and without fluoridated water at the southeast region of São Paulo State, Brazil. *J Appl Oral Sci*. 2008;16:70-74.
14. Hariyani N, Spencer AJ, Luzzi L, Do LG. Root caries experience among Australian adults. *Gerodontology*. 2017;34:365-376.

15. Ritter A, Preisser J, Chung Y, et al. Risk indicators for the presence and extent of root caries among caries-active adults enrolled in the Xylitol for Adult Caries Trial (X-ACT). *Clin Oral Investig.* 2012;16:1647-1657.
16. Lawrence HP, Hunt RJ, Beck JD. Three-year root caries incidence and risk modeling in older adults in North Carolina. *J Pub Health Dent*. 1995;55:69-78.
17. Beck JD, Kohout F, Hunt RJ. Identification of high caries risk adults: attitudes, social factors and diseases. *Int Dent J*. 1988;38:231-238.
18. Fure S, Zickert I. Root surface caries and associated factors. *Scand J Dent Res*. 1990;98:391-400.
19. Walls AWG, Silver PT, Steele JG. Impact of treatment provision on the epidemiological recording of root caries. *Eur J Oral Sci.* 2000;108:3-8.
20. Vehkalahti MM, Paunio IK. Occurrence of root caries in relation to dental health behavior. *J Dent Res.* 1988;67:911-914.
21. Wikner S, Söder PÖ. Factors associated with salivary buffering capacity in young adults in Stockholm, Sweden. *Eur J Oral Sci.* 1994;102:50-53.
22. Sakki T, Knuuttila M. Controlled study of the association of smoking with lactobacilli, mutans streptococci and yeasts in saliva. *Eur J Oral Sci.* 1996;104:619-622.
23. Ritter AV, Shugars DA, Bader JD. Root caries risk indicators: a systematic review of risk models. *Community Dent Oral Epidemiol.* 2010;38:383-397.
24. Lopez R, Baelum V. Factors associated with dental attendance among adolescents in Santiago, Chile. *BMC Oral Health.* 2007;7:4.
25. Thomson WM, Broadbent JM, Foster Page LA, Poulton R. Antecedents and associations of root surface caries experience among 38-year-olds. *Caries Res.* 2013;47:128-134.

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Additional supporting information may be found online in the Supporting Information section at the end of the article.

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PAGE 7

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