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Tooth loss, chewing ability and quality of life

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Abstract
Objectives Middle-aged and older adults are retaining teeth and avoiding dentures, which should impact quality of life. The aims of our study were to investigate tooth loss and chewing ability and their association with oral- and general-health-related quality of life and life satisfaction.
Methods A random sample of 45- to 54-year-olds from Adelaide, South Australia, was surveyed by self-complete questionnaire in 2004–2005 ($n = 879$, response rate = 43.8%). Health-related quality of life was measured with the Oral Health Impact Profile 14-item version and EuroQol Visual Analogue Scale instruments and life satisfaction by the Satisfaction with Life Scale. Functional tooth units were recorded at oral examinations performed by calibrated dentists on 709 persons (completion rate = 80.7%).
Results Number of functional teeth was positively associated with chewing ability ($\beta = 0.31$, $P < 0.01$). In multivariate analyses, controlling for number of functional teeth and other explanatory variables spanning dental visit pattern, dental behaviour, socio-demographics and socio-economic status, chewing ability was negatively associated with oral-health-related impacts ($\beta = -0.37$, $P < 0.01$) and positively associated with general health ($\beta = 0.10$, $P < 0.05$) and well-being ($\beta = 0.16$, $P < 0.01$).
Conclusions Chewing ability was related to oral-health-related quality of life and general health, possibly reflecting the impact of chewing on food choice and enjoyment of meals and diet, and also indicated the importance of oral health to general well-being.

Keywords 45- to 54-year-olds · Tooth loss · Chewing ability · Quality of life

Abbreviations

EQ-VAS	EuroQol Visual Analogue Scale
ICC	intraclass correlation coefficient
OHIP-14	Oral Health Impact Profile 14-item version
SWLS	Satisfaction with Life Scale

Introduction

Australia, like many industrialised countries, is experiencing an increase in life expectancy and projected increases in middle-aged and older adults [1]. At the same time, levels of tooth loss are also declining [2]. Current generations of adults are retaining natural dentitions, often with a history of prior treatment such as restorations and extractions, rather than becoming edentulous and moving into full upper and lower dentures. Whereas avoidance of complete dentures should have benefits in terms of quality of life, this may be dictated by the relationship between number of teeth retained and the ability to chew. This relationship may be influenced not just by the total number of teeth lost but also by the distribution of teeth that are present. A tooth should occlude with another tooth in the opposing jaw to act as a functional unit [3].

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The ability to chew is not only an important dimension of oral-health-related quality of life [4], but it is increasingly recognised that there are connections with general health. The ability to masticate food may affect dietary choices and nutritional intake and have consequences for general health [5–8]. This may be reflected in generic health-related quality of life. In addition, there is a positive aspect to health, measured through aspects of well-being [9]. These positive life influences may also be influenced by basic biological conditions and related functions such as the ability to chew.

The aims of this study were to investigate the relationship between tooth loss and chewing ability and their association with oral- and general-health-related quality of life and life satisfaction.

Methods

Sampling and data collection

A total of 2,248 persons aged 45–54 years were randomly sampled from metropolitan Adelaide, South Australia, using the electoral roll as a sampling frame. Sampled persons were surveyed by mailed self-complete questionnaire during 2004–2005. A primary approach letter was mailed initially, followed a week later by the questionnaire, then by a reminder card and up to four follow-up mailings of the questionnaire to non-respondents to achieve a higher response rate [10]. Respondents ($n = 879$) were then approached by telephone to participate in an oral examination where clinical measures of tooth status, caries experience, periodontal disease and treatment need were recorded using standard criteria [11]. Examining dentists underwent training to calibrate their level of agreement on diagnostic criteria. Trained dentists conducted the examinations using mirrors and probes under standardised illumination. Radiographs were not taken. A subset of $n = 11$ cases was re-examined to assess reliability of clinical measures.

Variables measured

Self-reported outcome variables collected in the questionnaire included oral-health-related quality of life, general-health-related quality of life and life satisfaction. Oral-health-related quality of life was collected using the Oral Health Impact Profile 14-item version (OHIP-14) [12], which captures measures of the seven dimensions of functional limitation, physical pain, psychological discomfort, physical disability, psychological disability, social disability and handicap. For each of the 14 OHIP questions, subjects were asked how frequently they had experienced impact in the preceding 12 months using a Likert-like scale coded 4 = very often, 3 = fairly often, 2 = occasionally, 1 = hardly ever and 0 = never. The responses were scored by counting the number of items, with codes indicating an impact by coding response levels 0 (never) and 1 (hardly ever) = 0, and response levels 2 (occasionally) to 4 (very often) = 1 and summing these coded responses across all items. The original OHIP-14 recommends using item weights, standardising and summing the sub-scales [12]. However, item weights have been shown not to be necessary, and hence have not been widely adopted [13]. Subsequent work by the original OHIP-14 developer outlines the use of a range of OHIP-14 measures (prevalence, extent and severity scores) [14]. Hence, a range of OHIP-14 measures are in use at present. In this paper, we code OHIP from 0 to 4 as per the original OHIP-14, use cut-points of never/hardly ever and occasionally/fairly often/very often to produce counts of extent scores. Higher OHIP scores indicate poorer oral-health-related quality of life. General-health-related quality of life was collected using the visual analogue scale of the European Quality of Life indicator or EuroQol (EQ-VAS), a standardised generic (non-disease-specific) instrument for describing and valuing health-related quality of life [15]. This was performed by placing a mark on a thermometer-like scale that ranged from 0 (worst possible health) to 100 (best possible health). The EuroQol user group outlines a range of ways in which the instrument and its components can be used [16]. The EQ-VAS can be used in two different ways: either in conjunction with the descriptive system to build a composite picture of the respondent's health status, or as we did here, as a quantitative measure. Differences in this scale can be used as a measure of outcome, as judged by the individual respondent. Higher EQ-VAS scores indicate better general health. Well-being was measured using the Satisfaction with Life Scale (SWLS), comprising five items measured on a 5-point Likert scale, where 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree and 5 = strongly agree [17], with the scale score created by summing the responses to the items. Higher SWLS scores indicate a higher level of well-being.

The main explanatory variables were number of teeth present, which was collected during the clinical examination [along with numbers of decayed and missing and filled teeth, which were summed to produce the Decayed/Missing/Filled Teeth (DMFT) index] and chewing ability, which was collected in the questionnaire. Number of teeth present was recorded in two ways: tooth status and functional teeth units. Tooth status was recorded as present or absent (i.e. missing due to caries, extracted for reasons other than caries, congenitally absent or unerupted) and whether replaced by a fixed or removable prosthesis or implant. Functional

tooth units were assessed as pairs of natural teeth, natural tooth opposing a removable replacement tooth, natural tooth opposing a fixed replacement tooth or pairs of replacement teeth [3]. Functional posterior pairs were defined as being in contact in centric occlusion, whereas functional anterior pairs were defined as being brought into contact in lateral or protrusive movements. Chewing ability was recorded by asking subjects to report either yes or no to whether they were usually able to chew a set of five food items based on a standard chewing ability index, where yes was coded as 1 and no as 0, and the index was created by summing the responses [18]. A range of other variables was measured through the questionnaire spanning dental visit pattern (time since last dental visit, last visit for relief pain), dental behaviour (tooth brushing frequency, use of mouth rinse, cleaning between teeth), socio-demographics (gender, place of birth, main language spoken at home, education) and socio-economic status (concession cardholder, household income). Cardholders comprise a low-income group eligible for government concession cards, such as the unemployed and aged pensioners.

Analysis

Response rates were adjusted by removing subjects who did not have a chance to respond because they were not residing at the sampled address and those who were no longer residing within the geographical scope of the study (e.g. were interstate or overseas). Persons who refused to participate were counted as non-respondents and retained in the denominator, as were persons who did not respond and about whom we had no information regarding residential status (i.e. we were not informed that they were not residing at the sampled address and we were not informed that they were interstate or overseas). Representativeness of the sample respondents was assessed by comparison of point estimates and 95% confidence intervals (CI) to a range of oral-health status, socio-demographic and dental visit pattern variables from another population survey [19]. Inter-rater reliability of dental examinations was measured using the intra-class correlation coefficient [20]. Association of number of functional teeth and chewing ability was assessed, and bivariate associations were assessed between the dependent variables of oral-health-related quality of life, general-health-related quality of life and life satisfaction, and the main explanatory variables of number of functional teeth and chewing ability using standardised beta coefficients from ordinary least squares regression. This was followed by multivariate models with two independent variables to assess the effect of including both number of functional teeth and chewing ability as explanatory variables in the same model. Then, multivariate models with more than two independent variables were constructed that also included a range of other potential confounding variables, such as dental visit pattern, dental behaviour, socio-demographics and socio-economic status. All variables were entered as a block with no hierarchy imposed. Number of functional teeth and chewing index scores were entered as continuous variables, whereas potential confounding variables (i.e. dental visit pattern, dental behaviour, socio-demographics and socio-economic status) were entered as indicator variables, with levels coded as 1 or 0 for the designated reference category. Ethics clearance was provided by the Human Research Ethics Committee of the University of Adelaide.

Results

Response

A total 879 persons responded, giving a response rate of 43.8%. Oral examinations were performed on 709 persons (giving an 80.7% completion rate). The study participants generally showed a close approximation to census data and a range of variables from a population sample with an adequate response rate (Table 1). Study participants had slightly fewer teeth, but there was no difference in denture wearing in comparison with the population profile. Study participants had a slightly lower percentage visiting a dentist in the last 12 months and slightly fewer numbers of visits in the last 12 months, as well as a lower percentage that visited privately at the last visit, but there was no difference in the percentage receiving checkups at the last dental visit. There were no differences in the percentage of females or Australian-born or of indigenous status, but study participants had a slightly higher percentage who spoke English as the main language at home as well as a slightly higher percentage who were concession-cardholders. There was no difference in the percentage of persons from higher income households.

Reliability of measures

Intraclass correlation coefficients (ICC) were excellent for DMFT (ICC = 0.84), for teeth missing for any reason (ICC = 0.94), for functional tooth units (ICC = 0.76) and for filled teeth (ICC = 0.78), and they were good for decayed teeth (ICC = 0.59).

Distribution of responses

The majority of functional tooth units comprised pairs of natural teeth, as shown in Table 1. There was a strong

Table 1 Distribution of explanatory variables and comparison of study participants with the population profile

	Census data[a]	Comparison data[b]	Study participants	
Oral-health status				(95% CI)
Number of teeth (mean)	–	26.9	25.4	(24.9–25.8)
Denture (upper jaw) (%)	–	13.7	13.6	(11.4–15.9)
Denture (lower jaw) (%)	–	5.8	6.4	(4.7–8.0)
Functional units				
Natural tooth with natural tooth (%)	–	–	95.3	(94.9–95.7)
Natural tooth with removable replacement (%)	–	–	2.3	(2.1–2.5)
Natural tooth with fixed replacement (%)	–	–	1.6	(1.3–1.9)
Replacement tooth with replacement tooth (%)	–	–	0.8	(0.6–1.0)
Dental visit pattern				
Last dental visit <12 months (%)	–	65.4	61.5	(58.3–64.7)
Check-up at last dental visit (%)	–	41.7	43.4	(40.1–46.7)
Last visit for relief of pain (%)	–	–	15.4	(12.7–18.1)
Number of dental visits in last 12 months (mean)	–	1.8	1.5	(1.4–1.7)
Visited private at last dental visit (%)	–	95.2	86.1	(83.8–88.4)
Dental behaviour				
Tooth brushing 8+ times per week (%)	–	–	78.7	(75.6–81.8)
Use of mouth rinse 1+ times per week (%)	–	–	26.4	(23.1–29.7)
Cleaned between teeth 1+ times per week (%)	–	–	32.1	(28.6–35.6)
Socio-demographics				
Female (%)	48.5	51.2	52.0	(48.7–55.3)
Australian born (%)	70.7	70.8	70.9	(67.9–74.0)
Indigenous (%)	0.7	1.3	0.4	(0–4.3)
English main language at home (%)	–	91.9	95.4	(94.0–96.8)
Education level of diploma or degree (%)	–	–	42.3	(38.6–46.0)
Socio-economic status				
Concession-cardholder (%)	–	15.4	19.0	(16.4–21.7)
Household income $80,000+ (%)	–	24.5	23.8	(20.9–26.6)

[a] Census 2006: Adelaide 45- to 54-year-olds

[b] National Dental Telephone Interview Survey 2002: South Australia—Adelaide 45- to 54-year-olds

correlation between tooth loss and functional units ($\rho = 0.90$, $P < 0.0001$), with the main findings replicated when tooth loss was used rather than for functional units. The majority of subjects was able to chew the five chewing ability index food items, as shown in Table 2. A minority of persons reported experiencing impacts in the past year on any item of the OHIP scale (Table 2). Over half of the survey participants reported agreement with the SWLS items, with the exception of the fifth item, 'If I could live my life over, I would change almost nothing' (Table 3). Measures of central tendency and dispersion for the continuous dependent and independent variables are presented in Table 4.

Unadjusted and adjusted associations

Unadjusted analyses showed that the number of functional tooth units was positively associated with chewing ability scores, as shown in Fig. 1. Functional tooth units were negatively associated with oral-health-related impacts as measured by OHIP-14 and positively associated with general health as measured by EQ-VAS and well-being as measured by SWLS score. Similar relationships were observed between functional tooth units and the three outcome variables when chewing ability was added to the models but with some attenuation of the strength of regression coefficients.

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Table 2 Frequency of responses to chewing ability items and Oral Health Impact Profile 14-item version items (%)

Questions	Responses
Chewing ability items	
Are you usually able to:	Yes (%)
Chew boiled vegetables?	99.7
Chew fresh lettuce salad?	99.6
Chew fresh carrot?	96.2
Chew firm foods such as steak or dried apricots?	96.9
Bite off and chew a piece of whole fresh apple?	93.9
OHIP items	
How often in the past year have you had the following problems?	Occasionally/fairly often/very often (%)
Functional limitation	
Trouble pronouncing any words	7.3
Sense of taste has worsened	8.0
Physical pain	
Painful aching in your mouth	25.0
Uncomfortable to eat any foods	32.7
Psychological discomfort	
Felt self-conscious	30.8
Felt tense	20.2
Physical disability	
Diet been unsatisfactory	6.0
Had to interrupt meals	8.8
Psychological disability	
Found it difficult to relax	11.4
Been a bit embarrassed	20.2
Social disability	
Been a bit irritable with other people	8.6
Had difficulty doing your usual jobs	3.4
Handicap	
Life in general was less satisfying	11.6
Been totally unable to function	2.5

Multivariate associations

Multivariate models of OHIP-14, EQ-VAS and SWLS scores that include functional tooth units; chewing ability and a range of dental visit, dental behaviour, socio-demographic and socio-economic status confounding variables are presented in Table 5, with the coefficients for functional units and chewing ability also included in Fig. 1 for reference with their coefficients from their respective one- and two-independent variable adjusted models. Multivariate results for the explanatory variable of functional tooth units showed similar but attenuated relationships with OHIP-14 and EQ-VAS, as observed in the one- and two-independent variable models, but no significant association was observed with SWLS (Fig. 1). Chewing ability showed similar but attenuated associations with OHIP-14, EQ-VAS and SWLS in the multivariate models as were observed in the one- and two-independent variable models (Fig. 1).

Discussion

Representativeness and reliability

Whereas the overall response yield of $n = 879$ provided sufficient numbers for analysis, the response rate was lower than anticipated. The use of the electoral roll should provide an adequate sampling frame for a population survey of 45- to 54-year-olds. Bias can distort research design, execution, analysis and interpretation [21]. Sampling bias is unlikely, as voting is compulsory for adults in Australia, and the sample was drawn at random. Legislation enables health researchers to sample from the electoral roll through the Australian Electoral Commission. Individuals cannot opt out of the roll, but residents who are not citizens will not be on the roll. It is also possible that some sub-groups of the population (e.g. the homeless) would be under-enumerated and create some bias to the extent that special groups were under-represented. Also, the use of restriction can limit selection bias in the design of a study [22], and a restricted age range was adopted in this study.

Generally, a response rate of 60% is considered adequate [23], with lower response rates requiring evidence to determine whether non-response bias has been introduced. Whereas direct comparison of respondents and non-respondents would be desirable to assess response bias, we

Table 3 Distribution of responses to Satisfaction with Life Scale items (%)

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
In most ways my life is close to ideal	3.4	18.2	25.9	46.4	6.2
The conditions of my life are excellent	3.4	16.8	25.3	46.2	8.3
I am satisfied with my life	2.5	12.8	20.2	54.1	10.4
So far I have acquired the important things I want in life	3.0	15.8	20.1	50.4	10.8
If I could live my life over, I would change almost nothing	9.3	33.5	21.2	29.5	6.5

Table 4 Distribution of dependent variables and key independent variables

	Mean	Standard deviation	Minimum	Maximum
Tooth loss				
Number of functional units	12.6	2.7	0	16
Chewing ability				
Chewing index score	4.9	0.5	0	5
Oral-health-related quality of Life				
OHIP-14 score	2.0	2.9	0	14
General-health-related quality of life				
EQ-VAS score	80.4	13.5	15	100
Well-being				
Satisfaction with Life Scale score	16.7	4.2	5	25

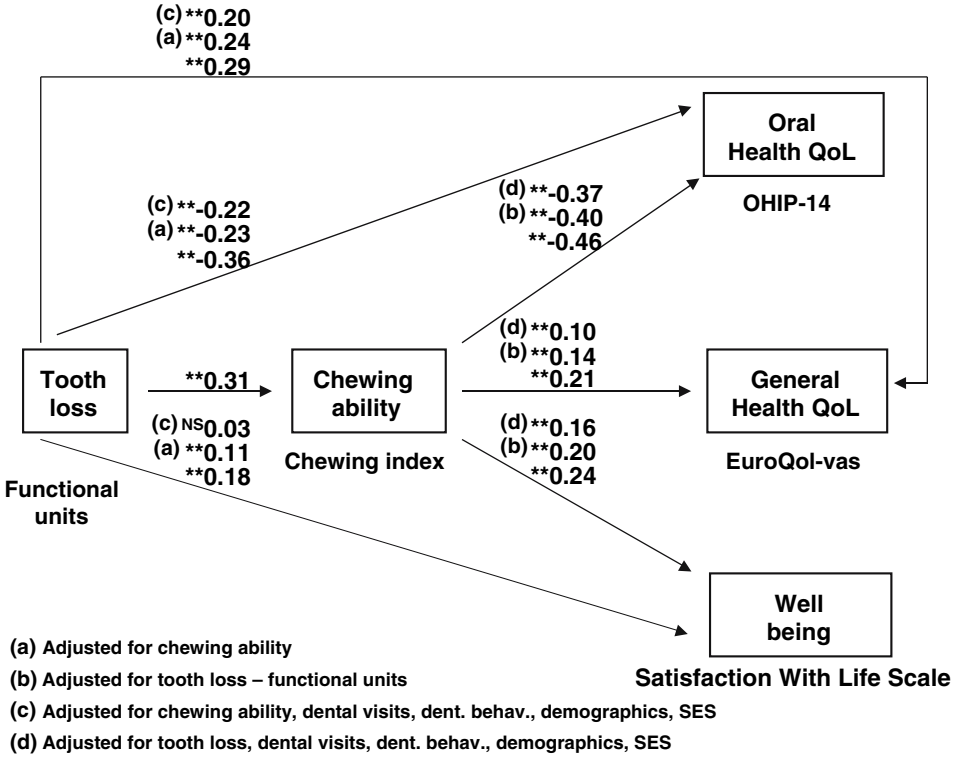

Fig. 1 Path diagram showing unadjusted and adjusted beta coefficients

were only able to compare the profile of respondents with limited population and other population-based sample data. Comparison of some key demographic characteristics, including the percentage that were female (48.5%), Australian born (70.7%) and indigenous (0.7%) from the 2006 Census among 45- to 54-year-old Adelaide residents showed a close approximation to that observed in the study [24]. Comparison with other sample data with an adequate response rate (65%) showed a range of generally small differences between these data and study participants. The main difference observed was the lower percentage of survey respondents that visited privately at the last dental visit compared with the population, consistent with the slightly higher percentage that was concession-cardholders. As cardholders are eligible for public dental care, this is also consistent with observed slightly lower numbers of teeth, lower percentage visiting in the last 12 months and fewer visits in the last 12 months. Selection bias can be controlled in a study analysis through adjustments such as stratification or multivariate analysis [22]. Hence, cardholder status was included in the statistical models, along with other explanatory variables such as number of functional teeth, dental visiting and dental behaviour, socio-demographics and socio-economic status. The extent that bias was introduced by the differences between the population and respondents should be considered in light of the

Table 5 Regression coefficients from multivariate models of Oral Health Impact Profile 14-item version (OHIP-14), EurQol Visual Analogue Scale (EQ-VAS) and Satisfaction with Life Scale (SWLS) scores

	OHIP-14	EQ-VAS	SWLS
Tooth loss and chewing			
Number of functional units	−0.217**	0.198**	0.025^{NS}
Chewing index score	−0.369**	0.096*	0.156**
Dental visit pattern			
Last dental visit			
<12 months	0.113**	0.049^{NS}	0.060^{NS}
12+ months (ref.)	–	–	–
Last visit for			
Relief of pain	0.076*	−0.009^{NS}	−0.004^{NS}
Checkup/other (ref.)	–	–	–
Dental behaviour			
Tooth brushing			
8+ times per week	−0.067^{NS}	0.126**	0.035^{NS}
0–7 times per week (ref.)	–	–	–
Use of mouth rinse			
1+ times per week	0.002^{NS}	0.013^{NS}	−0.024^{NS}
0 times per week (ref.)	–	–	–
Cleaned between teeth			
1+ times per week (ref.)	–	–	–
0 times per week	−0.035^{NS}	0.080*	0.032^{NS}
Socio-demographics			
Gender			
Male	−0.016^{NS}	−0.025^{NS}	−0.066^{NS}
Female (ref.)	–	–	–
Place of birth			
Australia	−0.077*	0.004^{NS}	−0.080*
Overseas (ref.)	–	–	–
Main language at home			
English	−0.035^{NS}	0.023^{NS}	0.028^{NS}
Other language (ref.)	–	–	–
Education level			
Diploma or degree	−0.039^{NS}	0.008^{NS}	0.062^{NS}
Primary/secondary/certificate (ref.)	–	–	–
Socio-economic status			
Concession cardholder			
Yes	0.172**	−0.193**	−0.250**
No (ref.)	–	–	–
Household income			
$80,000+	−0.061^{NS}	0.006^{NS}	0.135**
<$80,000 (ref.)	–	–	–
Model: P value	<0.0001	<0.0001	<0.0001
Model: R^2	35.7%	14.8%	18.2%

* $P < 0.05$; ** $P < 0.01$; NS, not statistically significant

direction of the study, which was to examine relationships between variables rather than produce population estimates of prevalence.

Data from the USA have shown a trend toward substantial increases in total non-response, primarily due to increased percentages of respondents who refused to be interviewed that was related to the level of urbanisation [25]. However, response rate is considered only an indirect indication of the extent of non-response bias, and more attention is required to assessments of bias rather than to specific response-rate thresholds [26]. It should be noted that although the response was relatively low in this study, it was obtained using the Total Design Method [10], incorporating aspects such as repeated contacts and return postage that have been shown to increase response behaviour [27]. Reliability of the clinical measures was excellent for number of teeth missing for any reason [20].

Functional units and chewing ability

Not surprisingly, there was a positive relationship between the number of functional tooth units and chewing ability scores, reflecting that avoidance of tooth loss and maintenance of more functional units is associated with better ability to chew food. This has been observed previously among older adults [3, 28, 29]. Both number of functional tooth units and chewing ability were independently associated with oral-health-related quality of life, as reflected by fewer reported oral-health impacts in the past year. Oral conditions such as infected or sore gums, loose teeth, toothache pain and fewer functional tooth units have been reported to be associated with onset of chewing difficulty [30]. It is expected that chewing ability would be related to specific oral-health impacts related to eating, such as "uncomfortable to eat any foods", "diet has been unsatisfactory" and "had to interrupt meals". It is likely that tooth loss would have impacts on oral-health-related quality of life in addition to those mediated through chewing ability, particularly those relating to psychological dimensions such as "felt self-conscious", "felt tense", and "been a bit embarrassed". Removable prostheses have been reported not to prevent the problems associated with chewing associated with tooth loss [3]. Where tooth loss is associated with denture wearing, it is also likely that impacts may also be experienced with items such as "painful aching in your mouth" and "trouble pronouncing any words".

Similar relationships to that proposed for functional tooth units and chewing ability with oral-health-related

quality of life may also pertain to general health. It is likely that chewing ability would affect general health through a pathway involving the impact of food selection or selective food avoidance on diet and nutrition. Having more teeth has been reported to be associated with having a healthy diet rich in fruit and vegetables, a satisfactory nutritional status and acceptable body mass index [31]. Tooth loss could also impact on general health through the operation of impacts involving the psychological dimensions of oral-health-related quality of life. Health has been defined by the World Health Organisation (WHO) as not the mere absence of disease but involving a state of well-being [9]. Additionally, it is possible that tooth loss may be associated with clustering of health-risk behaviours, such as smoking and alcohol consumption, which are reflected in both poorer oral and general health.

The association of chewing ability with well-being as measured by the SWLS underscores the importance of oral health and unimpaired oral function on general well-being. However, the lack of a significant relationship between tooth loss and well-being in the multivariate analysis indicates that other variables associated with tooth loss, particularly socio-economic status, have a more direct impact on well-being. Socio-economic status has been associated with tooth loss, both with complete tooth loss [32] and with levels of missing teeth, among the dentate [33].

Conclusions

Oral-health-related quality of life, self-reported health status and well-being showed consistent associations with chewing ability and socio-economic status. The association of chewing ability with oral-health-related quality of life and general health may reflect the impact of chewing on food choice, enjoyment of meals and diet, whereas the relationship with life satisfaction indicated the importance of oral health to general well-being.

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