

Original

Chewing ability and associated factors in a Sudanese population

Nadia Khalifa¹⁾, Patrick F. Allen²⁾, Neamat H. Abu-bakr³⁾,
and Manar E. Abdel-Rahman⁴⁾

¹⁾Prosthodontic Department, Faculty of Dentistry, Khartoum University, Khartoum, Sudan

²⁾Department of Restorative Dentistry, Cork University Dental School and Hospital, Wilton, Cork, Ireland

³⁾Conservation Department, Faculty of Dentistry, Khartoum University, Khartoum, Sudan

⁴⁾Department of Statistics, Faculty of Mathematics, Khartoum University, Khartoum, Sudan

(Received May 21, 2013; Accepted November 16, 2013)

Abstract: This study aimed to assess self-reported chewing ability among a sample of Sudanese adults and to identify factors associated with impaired oral function. A total of 1,888 adults (≥ 16 years old) attending outpatient clinics in Khartoum State were included. Subjective chewing ability was assessed by interviewing participants on chewing complaints and perceived difficulty of chewing 15 common Sudanese foods. Pearson and multivariate analyses were used to examine relationships between chewing ability and characteristics obtained from interviews and clinical examination. Chewing complaints were reported by 33.5% of subjects; 15.2-33.4% had perceived difficulty of chewing hard foods, whereas only 1.5-6.9% had difficulty eating soft foods. The likelihood of chewing complaints was higher in people with dry mouth, <20 teeth, tooth decay, poor self-rated oral health, perceived difficulty of chewing, and higher oral health-related quality of life (OHRQoL) scores. Individuals with <20 teeth, poor self-rated general health, and higher OHRQoL scores were all more likely to have perceived difficulty of chewing certain foods. Impaired chewing ability was rather highly prevalent among Sudanese adults. Addressing factors such as dry mouth and tooth loss/decay, which have

been identified to be associated with impaired oral function, might help to decrease the risk of omission of essential foods from the diet and improve OHRQoL. (J Oral Sci 55, 349-357, 2013)

Keywords: oral health; self-reported chewing ability.

Introduction

Chewing ability is influenced by several clinical and behavioural factors, such as the number of teeth (1), occluding pairs of teeth (2), presence of restorations (3), amount of saliva (4), and gender (5). Previous studies have revealed that chewing ability can affect an individual's oral health-related quality of life (6,7) and nutritional status (8-11). This is important, as research has established the existence of an interrelationship between oral and general health (12,13).

Chewing ability can be evaluated by an objective and repeatable laboratory test (14) or by subjective self-reporting (1). Some authors have assessed self-reported chewing ability through chewing complaints and perceived difficulty of chewing certain foods (15). Even though self-reported assessment of chewing ability is informative and valid for large samples (16), it could be argued that this method is more indicative of patient preference in food choice.

Only a few studies have investigated chewing ability in African countries (6,15), where the oral health status profile differs from that of many western countries (17), and data on this issue in Sudan are lacking. Therefore, this study aimed to assess self-reported chewing ability

Correspondence to Dr. Nadia Khalifa, Prosthodontic Department, Faculty of Dentistry, Khartoum University, P.O. Box 102, Khartoum, Sudan

Fax: +249-187557654 E-mail: nadiakhalifa@uofk.edu

doi.org/10.2334/josnusd.55.349

DN/JST.JSTAGE/josnusd/55.349

through chewing complaints and perceived difficulty of chewing common Sudanese foods, as well as to evaluate the relationship between self-reported chewing ability and other factors.

Materials and Methods

Study design

This study was part of a larger study, which, besides investigating oral health, assessed the psychosocial impact of dental disease in a Sudanese population. The study was carried out between August 2009 and March 2010. The study participants were recruited from among those attending outpatient dental hospitals ($n = 1,659$) and dental health centres ($n = 229$) distributed among seven provinces of Khartoum State. A formula for proportion estimates was used to calculate the sample size, taking into account a tooth loss prevalence of 67% according to previous Sudanese studies (18,19) and a precision of 3; the design effect was set as 2. Proportional sampling based on the attendance rate of outpatient clinics was carried out. Accordingly, patients were selected consecutively until the necessary number of respondents from the various hospitals and health centres was obtained. Full details of the sampling procedures have been published elsewhere (17). Written consent was obtained from the patients. In 2009, the National Ethical Clearance Committee of the Federal Ministry of Health in Khartoum approved the study protocol.

Data collection

Interviews

A questionnaire administered through interviews by five calibrated researchers was used to collect the data. Socio-demographic variables included age, gender, ethnic group, and socioeconomic status (occupation, total monthly income, education).

Behavioural variables included frequency and reason for dental visits, number of teeth removed at final visit (if applicable), tobacco use and method of consumption, and the frequency and method of dental hygiene.

Medical characteristics of the population sample were obtained through questions on use of medication, previous surgery, and details of diagnosed medical conditions. The respondents were also asked 'How often does your mouth feel dry?', with response options 'always', 'frequently', 'occasionally', or 'never'. At the analysis stage, those who had responded 'always' or 'frequently' were designated as xerostomic.

The shortened version of the Oral Health Impact Profile (OHIP-14) was translated into Sudanese Arabic and used as a measure of oral health-related quality of

life (OHRQoL). The format of the questions was 'How often during the last 12 months have you had (impact item) because of problems with your teeth, mouth, or dentures?'

Responses to each OHIP question were rated on a Likert-type scale to indicate whether the impact had occurred 'never', 'hardly ever', 'occasionally', 'fairly often', or 'very often'. For analysis, the answers were coded from 0 ('never') through 4 ('very often').

Global questions of perceived need for dental treatment were used, with response categories 'no', 'yes', and 'don't know'; self-perceived oral and general health was evaluated with responses provided on ordinal scales, 'good', 'fair', and 'poor'.

Subjective chewing ability was assessed by interviewing the 1,888 individuals from the oral health survey regarding chewing complaints and perceived difficulty of chewing common Sudanese foods (15). The perceived difficulty of chewing was evaluated by asking individuals about difficulty of chewing 15 common Sudanese hard and soft foods (15). A small pilot study was performed before the survey to identify foods considered easy and hard to chew by adults in Khartoum State, which helped to validate the questions. The foods considered hard included peanuts, meat, raw carrots, dates, nabak (a small dried fruit of the *Ziziphus mauritiana* tree), corn on the cob, and turmus (cream-coloured bean cooked in salty water), whereas those considered soft included lugma (stiff porridge), kisra (thin sheets of traditional bread), white bread, rice, fowl (cooked brown fava beans), cooked potatoes, tomatoes, and ripe bananas.

The foods were listed randomly and scored as follows: 0 = very easy; 1 = minor problems, adapted; 2 = minor problems, not adapted; 3 = difficult but not avoided; 4 = very difficult but not avoided; 5 = very difficult and avoided; 6 = have never eaten that food (not avoided). Easy-to-chew foods were given a score of 0 and foods chewed with difficulty from categories 1 to 5 were given a score of 1. The scores were then computed as count scores to give a maximum perceived difficulty of chewing (PDC) index score of 15. Participants with a score of 1 or more were classified as having perceived difficulty of chewing.

The PDC index in the current study proved to have good internal consistency with a high (0.89) Cronbach's α coefficient (Table 1). Test-retest reliability of questions from the PDC index was tested in a subset of 20 participants on two occasions with an interval of 2 weeks (Table 2).

Chewing complaints (CCs) were scored as follows: 0 = no complaints; 1 = chewing takes too long; 2 = must swallow food coarsely; 3 = cannot chew all kinds of

Table 1 Internal consistency (Cronbach's α) for perceived difficulty of chewing (PDC) index

Perceived difficulty of chewing	Cronbach's α
Item 1: Peanuts ^h	0.88
Item 2: Lugma (stiff porridge) ^s	0.90
Item 3: Meat ^h	0.88
Item 4: Kisra (thin sheets of traditional bread) ^s	0.90
Item 5: Raw carrots ^h	0.88
Item 6: White bread ^s	0.89
Item 7: Dates ^h	0.88
Item 8: Rice ^s	0.89
Item 9: Nabak ^h	0.88
Item 10: Foul ^s (cooked brown fava beans)	0.89
Item 11: Corn on the cob ^h	0.88
Item 12: Cooked potatoes ^s	0.90
Item 13: Tomatoes ^s	0.89
Item 14: Turmus ^h	0.88
Item 15: Ripe bananas ^s	0.90
Cronbach's α of all items	0.89
95% Lower confidence limit	0.89

^s soft food, ^h hard food

food; 4 = have to use special or specially prepared food; 5 = other complaints such as pain or discomfort during chewing (15). Participants with a score of 1 and above were categorized as having CCs.

Clinical examination

Five calibrated dentists including the lead author carried out the clinical examinations. The extent to which the dentition was affected by dental caries was recorded using the decayed missing filled teeth index (DMFT). A full mouth recording for 32 teeth was performed (20). A visually present carious lesion confirmed by a community periodontal index (CPI) probe was recorded as decay. Teeth extracted because of cavities were recorded as missing due to caries. Periodontal health was evaluated by the CPI (20).

An index that uses partial recording of the 12 upper and lower anterior teeth was used to examine tooth wear. The same index was used in the survey of Oral Health of

Table 2 Test-retest reliability, as measured by intraclass correlation coefficients (ICCs) of perceived difficulty of chewing (PDC) index

PDC		ICC ^a	95% CI
Item 1: Peanuts ^h	Single measures ^b	0.78	0.60-0.61
	Average measures ^c	0.80	0.64-0.89
Item 2: Lugma (stiff porridge) ^s	Single measures ^b	0.85	0.65-0.88
	Average measures ^c	0.96	0.75-0.96
Item 3: Meat ^h	Single measures ^b	0.80	0.72-0.82
	Average measures ^c	0.84	0.82-0.94
Item 4: Kisra (thin sheets of traditional bread) ^s	Single measures ^b	0.88	0.64-0.89
	Average measures ^c	0.91	0.74-0.95
Item 5: Raw carrots ^h	Single measures ^b	0.89	0.71-0.93
	Average measures ^c	0.92	0.73-0.96
Item 6: White bread ^s	Single measures ^b	0.84	0.82-0.89
	Average measures ^c	0.88	0.85-0.90
Item 7: Dates ^h	Single measures ^b	0.94	0.85-0.94
	Average measures ^c	0.95	0.87-0.97
Item 8: Rice ^s	Single measures ^b	0.85	0.79-0.87
	Average measures ^c	0.88	0.85-0.89
Item 9: Nabak ^h	Single measures ^b	0.87	0.81-0.91
	Average measures ^c	0.94	0.85-0.97
Item 10: Foul ^s (cooked brown fava beans)	Single measures ^b	0.85	0.83-0.88
	Average measures ^c	0.86	0.83-0.92
Item 11: Corn on the cob ^h	Single measures ^b	0.90	0.86-0.94
	Average measures ^c	0.92	0.89-0.95
Item 12: Cooked potatoes ^s	Single measures ^b	0.87	0.82-0.88
	Average measures ^c	0.87	0.83-0.90
Item 13: Tomatoes ^s	Single measures ^b	0.83	0.79-0.83
	Average measures ^c	0.86	0.82-0.87
Item 14: Turmus ^h	Single measures ^b	0.84	0.79-0.86
	Average measures ^c	0.89	0.84-0.90
Item 15: Ripe bananas ^s	Single measures ^b	0.83	0.77-0.87
	Average measures ^c	0.89	0.81-0.92

^aThe degree of consistency among measurements, ^bEstimates the reliability of single ratings, ^cEstimates the reliability of averages of k ratings.

Irish Adults 2000-2002 (21) and the Adult Dental Health Survey in the United Kingdom 1998 (22). Functional tooth units (FTUs) were assessed using articulating paper. Anterior teeth were considered functional if they met in protrusive or lateral eccentric positions (7,23), and the maximum possible number of anterior FTUs was 6. Posterior teeth were considered functional if they met in centric relation, and the maximum number of posterior FTUs was 10. The number of FTUs of natural teeth and artificial teeth of fixed or removable prostheses was determined (23,24,).

The clinical examination procedures and calibration were performed by trained investigators, and inter-examiner reliability was checked using intra-class correlation coefficients (ICCs). This was assessed in 20 patients at the beginning and during the survey, on clinical measures of CPI, DMFT, tooth wear, and FTUs with an interval of 2 to 3 weeks. According to Fleiss (25), the ICC for the CPI ranged from fair to good; that for DMFT was excellent; that for tooth wear ranged from fair to good (17); and that for FTUs was excellent at the start 0.88 (95% CI, 0.80-0.91) and during the survey 0.89 (95% CI, 0.84-0.93).

The main investigator performed field checks during the survey and acted as the gold standard. Data were entered in standardized proformas, and then onto a spreadsheet for analysis. Random checking was implemented to verify the correctness of data entry.

Data analysis

The statistical software package STATA Release 9 (Stata Statistical Software 2005, StataCorp LP, College Station, TX, USA) was used to analyse the data. For validity of the PDC index, its relationship to CCs and OHIP-14 was analysed, and its internal consistency reliability (Cronbach's α) and test-retest reliability (ICC) were investigated.

Data were subjected to frequency distribution analysis. Bivariate analysis was carried out using Pearson's χ^2 test. Categorical dependent or outcome variables were reduced to binary variables, such as no CCs (0) and having CCs (1), as well as no perceived difficulty of chewing common Sudanese foods (0) and having perceived difficulty of chewing (1).

Independent factors used in multivariate logistic regression modelling were socio-demographic variables (gender, ethnic group, occupation, monthly household income, and education level achieved); behavioural variables (frequency of dental visits, tobacco use, and frequency and type of dental hygiene); medical variables (how often mouth feels dry, had surgery, and presence of

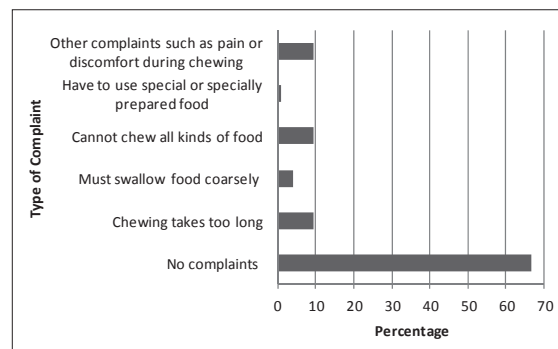


Fig. 1 Distribution of responses to chewing complaints.

disease); clinical variables (21+ teeth [0] and 0-20 teeth [1]; no missing teeth [0] and 1 or more missing teeth; <18 and ≥ 18 sound untreated natural teeth; 0 and ≥ 1 decayed teeth; no tooth wear and tooth wear; healthy periodontal tissues and those with periodontal pockets ≥ 4 mm; with or without prosthodontic replacement; all six anterior FTUs present [0] and reduced [0-5] anterior FTUs [1]; all 10 posterior FTUs present [0] and reduced [0-9] posterior FTUs [1]); and psychosocial variables (OHIP impacts: impacts occasionally, fairly often, and very often taking a value of 1, and never/hardly taking a value of 0). Global questions of perceived need for dental treatment with response categories 'no', 'yes', and 'don't know', as well as self-perceived oral and general health, with responses provided on ordinal scales 'good', 'fair', and 'poor', were also included.

Results

Descriptive statistics

From interviews

In all, 1,888 adults were included in the study, and the participants were divided into seven age groups: 16-24, 25-34, 35-44, 45-54, 55-64, 65-74, and 75+ years. Women represented 59% of the sample. The characteristics of this group of adults have been described in more detail in previous reports (17,26).

Up to one fifth (19.3%) of individuals reported that their mouths felt dry occasionally or more frequently, with 3.5% to the point of being xerostomic.

Several (40%) rated their oral health as good, while even more (69%) rated their general health as good. Many (89%) reported a need for dental treatment.

More than half of the participants reported that oral disorders affected quality of life when the OHIP-14s-ar was used to investigate the impacts of selected oral disorders on OHRQoL (27).

With respect to CCs, a sizeable number of the whole sample (33.5%) presented with some form of complaint (Fig. 1). Responses regarding perceived difficulty of

Table 3 Distribution of responses to perceived difficulty of chewing common Sudanese foods

	Very easy (%)	Minor problems, adapted (%)	Minor problems, not adapted (%)	Difficult but not avoided (%)	Very difficult but not avoided (%)	Very difficult and avoided (%)	Never used that food (%)
Hard foods							
Peanuts	78.3	4.7	1.0	2.0	1.9	7.5	4.8
Meat	73.9	7.7	1.7	3.0	7.4	4.4	1.9
Raw carrots	74.0	4.6	1.1	1.6	2.4	9.6	6.7
Dates	66.6	6.1	1.7	1.7	5.0	12.1	6.8
Nabak	81.5	2.6	0.7	0.7	0.9	7.0	6.6
Corn on the cob	77.5	3.2	0.6	0.9	1.2	7.6	9.0
Turmus	84.8	2.4	0.5	0.7	0.7	5.1	5.7
Soft foods							
Lugma	98.3	0.5	0.1	0.3	0.2	0.3	0.3
Kisra	97.1	0.6	0.1	0.3	0.3	0.4	1.2
White bread	93.1	2.9	0.7	0.7	0.8	0.8	1.0
Rice	96.1	1.0	0.2	0.2	0.4	1.0	1.2
Foul	95.6	1.3	0.5	0.3	0.2	0.7	1.4
Cooked potatoes	97.9	0.5	0.2	0.2	0.1	0.4	0.8
Tomatoes	96.7	1.0	0.5	0.6	0.2	0.4	0.6
Ripe bananas	98.5	0.4	0.1	0.2	0.2	0	0.6

Table 4 Characteristics associated with chewing ability in Sudanese adults as assessed by Pearson's χ^2 test

Characteristic	PDC <i>P</i> value	CC <i>P</i> value
Age group	0.000*	0.000*
Gender	0.000*	0.000*
Ethnic group	0.180	0.943
Occupation	0.990	0.127
Income	0.014*	0.422
Education	0.000*	0.005*
Dental visits	0.000*	0.000*
Reason for visiting the dentist	0.000*	0.001*
Tobacco use	0.372	0.522
Dental hygiene		
Tooth brushing	0.150	0.281
Mouth rinse	0.075	0.625
Cleaning between teeth	0.056	0.029*
Use of medication	0.000*	0.003*
How often mouth feels dry	0.000*	0.000*
Suffering from disease	0.000*	0.000*
<18 sound teeth, >18	0.000*	0.000*
Tooth wear	0.198	0.799
Tooth loss (missing 1+)	0.000*	0.000*
21+ / 0-20 teeth	0.000*	0.000*
Prosthetic status	0.002*	0.027*
Periodontal status	0.801	0.100
Decay	0.000*	0.000*
Self-rated oral health	0.000*	0.000*
Self-rated general health	0.000*	0.000*
Self-perceived need for dental treatment	0.000*	0.000*
OHIP	0.000*	0.000*
Perceived difficulty of chewing foods		0.000*
Chewing complaints	0.000*	
FTU anterior	0.000*	0.033*
FTU posterior	0.000*	0.006*

* $P < 0.05$, Pearson's χ^2 test.

chewing common Sudanese foods established that 15.2-33.4% of people had perceived difficulty of chewing common Sudanese hard foods, whereas only 1.5-6.9% had perceived difficulty of chewing common Sudanese soft foods (Table 3).

From clinical examination

The results showed that in all age groups, 41.4% had healthy periodontal tissues and the percentage of the population with decayed, missing, or filled teeth was 95.5%. Caries prevalence was 87.7% of decayed untreated teeth. The mean number of decayed teeth was 3.5 (SD 3.2) and that of missing teeth was 3.6 (SD 4.9), while the mean number of filled teeth was 0.2 (SD 0.8).

The mean number of teeth was 28.4 (SD 4.9), and that of FTUs was 12.20 (SD 3.70).

Over one third (35.5%) of participants had anterior tooth wear that involved at least some dentine.

Descriptive statistics and bivariate associations of chewing ability

Associations between chewing ability and the range of categorical variables were assessed using Pearson's χ^2 test (Table 4). The variables were entered in 2×2 tables to examine the relationship between chewing ability, that is, CCs and perceived difficulty of chewing, and various variables (sociodemographic, behavioural, medical and clinical).

Socio-demographic variables (except ethnic group and occupation), behavioural variables (dental visits, reason for visiting the dentist and cleaning between teeth),

Table 5 Likelihood of an adult with chewing complaints or perceived difficulty of chewing certain foods (odds ratios from logistic regression)

Characteristic	Odds of having chewing complaints	Odds of having perceived difficulty of chewing certain foods
Use of medication		
No	1	
Yes	0.46* (CI = 0.11-0.81)	
How often mouth feels dry		
Never	1	
Occasionally	2.27* (CI = 0.76- 3.77)	
Frequently	7.57* (CI = -5.93-21.07)	
Dental status		
<i>Having teeth</i>		
More than 21	1	1
Less than 20	2.13* (CI = 0.56-3.70)	3.35** (CI = 1.02-5.68)
<i>Sound teeth</i>		
More than 18		1
Less than 18		1.65+ (CI = 0.49-2.81)
<i>Decay</i>		
No decay	1	
More than 1 tooth decayed	2.40+ (CI = 0.28-4.52)	
Self-rated oral health		
Good	1	
Poor	2.33** (CI = 0.84-3.82)	
Self-rated general health		
Good		1
Fair		1.64+ (CI = 0.78-2.50)
Poor		4.67** (CI = -0.05-9.40)
Perceived difficulty of chewing foods		
No	1	
Yes	19.56** (CI = 8.15-31.0)	
OHIP		
Never/hardly ever	1	1
Occasionally/fairly often/very often	2.33** (CI = 1.15-3.51)	3.47** (CI = 1.98-4.96)
FTU anterior		
Full (6)	1	
Reduced (0-5)	0.56* (CI = 0.25-0.87)	

+ $P < 0.10$; * $P < 0.05$; ** $P < 0.01$. Estimates are reported as significant exponentiated coefficients (OR), with 95% Confidence Interval (CI) given in parentheses. Some cells are left blank because only characteristics with statistically significant outcomes are shown.

medical variables (use of medication, occurrence of dry mouth, and suffering from disease), clinical variables (18 sound untreated natural teeth, tooth loss/decay, prosthetic status, anterior and posterior FTUs), and self-reported oral and general health and perceived need for dental treatment were all significantly associated with perceived difficulty of chewing and/or CCs. Perceived difficulty of chewing and CCs were also significantly associated with each other. Only the significant variables ($P < 0.05$) were included in the multivariate logistic regression model.

Multivariate logistic regression findings

Characteristics associated with CCs

Table 5 shows the likelihood of adults with certain characteristics having CCs or perceived difficulty of chewing. The odds ratio represents the number of times

more likely it is that a particular type of person will have CCs or perceived difficulty of chewing in comparison to another. The “other” person in this table is the one whose odds are 1.00. For example, people presenting frequently with dry mouth were 7.57 times more likely to have CCs. Only characteristics that were statistically associated with the outcome variable are shown in the model, which included use of medication, how often mouth feels dry, dental status (0-20/21+ teeth; no decay/1+ decayed tooth surface), self-rated oral health, perceived difficulty of chewing, OHIP, and anterior FTUs.

The likelihood of CCs was higher in people who had dry mouth occasionally (odds ratio [OR], 2.27) and frequently (OR, 7.57) among those with less than 20 teeth (OR, 2.13), those with tooth decay (OR, 2.40), those who rated their oral health as poor (OR, 2.33),

those with perceived difficulty of chewing (OR, 19.56), and those with higher OHIP scores (OR, 2.33). People on medication (OR, 0.46) as well as those with reduced anterior FTUs (OR, 0.56) were less likely to have CCs.

Characteristics associated with perceived difficulty of chewing

Again, only the characteristics that increase the odds of predicting perceived difficulty of chewing common Sudanese foods at statistically significant levels are shown in the model (Table 5), which included dental status (0-20 / 21+ teeth; <18 / ≥18 sound untreated natural teeth), self-rated general health, and OHIP scores.

Individuals with less than 20 teeth (OR, 3.35), those who rated their general health as poor (OR, 4.67), and those with higher OHIP scores (OR, 3.47) were all more likely to have perceived difficulty of chewing certain foods.

Discussion

In this study, factors affecting chewing ability, which is a significant aspect of oral health, were investigated. Detection of oral health problems related to chewing ability can help to assist oral health care providers in preventing and addressing chewing difficulties by identifying the factors associated with impaired oral function.

Although chewing ability was assessed in people who actually sought dental care, the results of our study are probably not a gross overestimate of the general population because only a few of those who presented had sought treatment for teeth replacement.

The mean number of total FTUs was relatively high, with very few participants wearing artificial FTUs (from fixed or removable prostheses), which is in accord with the findings from the Oral Health Survey (17) conducted on the same population, wherein only very few people (4.3%) wore an upper bridge or denture and had prosthodontic appliances (1.7%) in the lower jaw (26). This gives some indication of the limited level of prosthodontic care in Khartoum State. Conversely, dentists carrying out the survey reported that the need for prosthetic treatment was high, with over one-third of the participants requiring prosthodontic replacement of teeth in the upper jaw, and nearly half of the participants requiring it in the lower jaw (26).

Approximately one third (33.5%) of the participants under investigation had CCs. Previous studies (6) have reported a similar prevalence (40%) of problems with chewing at least one common Tanzanian food item. From the Florida Dental Care Study (23), 23% of dentate participants aged 45 had difficulty chewing one or more

food items. A point to be noted is that the chewing indices of these studies were different, and thus the results should be compared with caution.

Although several factors were found to be significant in the bivariate analysis, only a subset of these measures was significant when other factors were taken into account. This might be due to factors exerting influences on chewing ability by producing differences in other aspects of oral health.

This study, like a previous study (1), identified significant associations between the number of teeth and chewing ability; that is, people with less than 21 teeth had more chewing problems. As recommended by the WHO and according to our results, we recommend a natural and functional dentition of more than 21 teeth to help maintain a healthy diet. Tooth loss results in a poor diet due to the avoidance of nutritious foods, which strengthens the need for treatment strategies to maintain healthy teeth. Observations from a previous study (9) revealed that edentulous participants had a lower intake of vegetables, lower intake of fibre and carotene, and higher intake of cholesterol, saturated fat, and calories than participants with 25 or more teeth. The importance of teeth and their association with a healthy diet rich in fruit and vegetables, satisfactory nutritional status, and acceptable body-mass index has also been highlighted (28).

It has been theorized that the functional arrangement of teeth would be more discriminatory of masticatory ability than the mere number of teeth. Therefore, we examined the association between FTUs and chewing ability using multivariate analysis. Unexpectedly, the distribution of FTUs (opposing tooth pairs) did not play as important a role as hypothesized, whereas the fact that tooth loss increased the likelihood of chewing problems supports the discriminatory validity of the PDC index. Given the limited infrastructure for oral health care service delivery in Khartoum, the patients presented with a large number of un-restorable teeth and roots, which, though not classified as functionally opposing/meeting teeth, might be easier to chew with than edentulous ridges.

According to our findings as well as the results of other studies (4,29), individuals presenting with oral dryness were more likely to have problems with eating or chewing certain foods. This implies that treatment of dry mouth, which may be caused by medication, disease, or other factors, may help to improve chewing ability. The relationship between dry mouth and chewing difficulty is not surprising given the importance of saliva in chewing and bolus formation. Likewise, a study by Shinkawa et al. (30) revealed the association of poor chewing ability

with lower mucosal moisture in elderly individuals. The authors evaluated oral dryness objectively by measuring the water content in the oral epithelium as well as subjectively by self-assessed oral dryness.

Significant associations were observed between chewing ability and self-reported measures of oral and general health, as well as OHIP scores, and these findings highlight the importance of oral health and chewing ability for general well-being. These self-reported measures as well as the significant associations between CCs and perceived difficulty of chewing in the Pearson (Table 4) and multivariate analyses (Table 5) support the validity of the measures. There is always a downside to the use of a new measure owing to lack of established validation. Previous studies using new measures have recommended the use of other measures along with a new measure to ensure and validate the quality of the scale.

The finding that those who rate their oral health as poor are more likely to have CCs is again comparable to the results of similar studies (6). The findings of the current study suggest that some characteristics influence how patients' perceived impaired chewing ability is related to overall perceived oral health.

A striking finding from this study is that those who rated their general health as poor were nearly five times more likely to have perceived difficulty of chewing certain foods, suggesting that Sudanese adults consider oral health important. One has to remember that the WHO has defined health as 'a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity'. This is in accord with the results of other studies (1) showing that reduced chewing ability was more frequently reported by people who considered their general state of health to be impaired than by healthy participants. The effect, if any, of perceived difficulty of chewing on the perception of one's general health should be taken into account when developing programmes to improve OHRQoL, because altered food choices have been implicated in an increased risk of cancer and cardiovascular disease (9).

This study confirmed that individuals' perception of chewing ability is significantly related to OHRQoL, in that those with higher OHIP scores were more likely to report having chewing problems and perceived difficulty of chewing. This is not very surprising, because OHIP-14 includes three questions directly related to chewing, such as 'discomfort eating foods', 'interrupted meals', and 'poor diet'. This result also supports the validity of the PDC scores.

The Oral Impacts on Daily Performance scale (6) showed that people who were dissatisfied with their

chewing ability reported more impairment of daily performance. This was also reported in another study (7), which established a significant association between chewing ability and OHRQoL as measured by OHIP-14 in a population-based sample. Therefore, evidence from our own study as well as that from studies with different settings and populations supports the hypothesis that chewing ability seems to have a consistently significant impact on OHRQoL. The high prevalence of chewing difficulty in this population constitutes an important public health issue, and appropriate care is recommended to prevent overtreatment.

In conclusion, impaired chewing ability was rather highly prevalent among Sudanese adults. As a result, individuals might develop a tendency to omit essential foods from the diet. Patients' perception of their chewing ability was significantly related to their OHRQoL. Chewing ability is an important dimension of oral health; in addition to being associated with OHRQoL, it was associated with self-rated oral and general health, dry mouth, tooth loss, and decay. These relationships support the construct validity of chewing ability as a valid measure of an important oral health outcome.

Acknowledgments

We express our gratitude to Dr. Isam M. Ahmed and the Ministry of Health, Khartoum for supporting this research.

References

1. Agerberg G, Carlsson GE (1981) Chewing ability in relation to dental and general health. Analysis of data obtained from a questionnaire. *Acta Odontol Scand* 39, 147-153.
2. Hildebrandt GH, Dominguez BL, Schork MA, Loesche WJ (1997) Functional units, chewing, swallowing, and food avoidance among the elderly. *J Prosthet Dent* 77, 588-595.
3. Heath MR (1982) The effect of maximum biting force and bone loss upon masticatory function and dietary selection of the elderly. *Int Dent J* 32, 345-356.
4. Locker D (1993) Subjective reports of oral dryness in an older adult population. *Community Dent Oral Epidemiol* 21, 165-168.
5. Hatch JP, Shinkai RS, Sakai S, Rugh JD, Paunovich ED (2001) Determinants of masticatory performance in dentate adults. *Arch Oral Biol* 46, 641-648.
6. Kida IA, Aström AN, Strand GV, Masalu JR (2007) Chewing problems and dissatisfaction with chewing ability: a survey of older Tanzanians. *Eur J Oral Sci* 115, 265-274.
7. Brennan DS, Spencer AJ, Roberts-Thomson KF (2008) Tooth loss, chewing ability and quality of life. *Qual Life Res* 17, 227-235.
8. Chauncey HH, Muench ME, Kapur KK, Wayler AH (1984) The effect of the loss of teeth on diet and nutrition. *Int Dent J* 34, 98-104.

9. Joshipura KJ, Willett WC, Douglass CW (1996) The impact of edentulousness on food and nutrient intake. *J Am Dent Assoc* 127, 459-467.
10. Krall E, Hayes C, Garcia R (1998) How dentition status and masticatory function affect nutrient intake. *J Am Dent Assoc* 129, 1261-1269.
11. Sheiham A, Steele J (2001) Does the condition of the mouth and teeth affect the ability to eat certain foods, nutrient and dietary intake and nutritional status amongst older people? *Public Health Nutr* 4, 797-803.
12. Dawson-Hughes B, Dallal GE, Krall EA, Harris S, Sokoll LJ, Falconer G (1991) Effect of vitamin D supplementation on wintertime and overall bone loss in healthy postmenopausal women. *Ann Intern Med* 115, 505-512.
13. Willett WC (1994) Diet and health: what should we eat? *Science* 264, 532-537.
14. Manly RS, Braley LC (1950) Masticatory performance and efficiency. *J Dent Res* 29, 448-462.
15. Sarita PT, Witter DJ, Kreulen CM, Van't Hof MA, Creugers NH (2003) Chewing ability of subjects with shortened dental arches. *Community Dent Oral Epidemiol* 31, 328-334.
16. Hirai T, Ishijima T, Koshino H, Anzai T (1994) Age-related change of masticatory function in complete denture wearers: evaluation by a sieving method with peanuts and a food intake questionnaire method. *Int J Prosthodont* 7, 454-460.
17. Khalifa N, Allen PF, Abu-bakr NH, Abdel-Rahman ME, Abdelghafar KO (2012) A survey of oral health in a Sudanese population. *BMC Oral Health* 12, 5.
18. Elsharif MM (2006) Prosthodontic treatment need in military hospital. MS Thesis, University of Khartoum, Khartoum, 1-112.
19. Ali MY (2009) Prosthodontic treatment need among adult dental patients attending the federal state hospitals and health centers in Khartoum State. MS Thesis, University of Khartoum, Khartoum, 1-75.
20. World Health Organization (1997) Oral health surveys: basic methods. 4th ed, WHO, Geneva, 36-47.
21. Whelton H, Crowley E, O'Mullane D, Woods N, McGrath C, Kelleher V et al. (2007) Oral health of Irish adults 2000-2002. Department of Health and Children, Dublin, 1-224.
22. Kelly M, Steele J, Nutall N, Bradnock G, Morris J, Nunn J et al. (2000) Adult dental health survey: oral health in the United Kingdom 1998. The Stationery Office Books, London.
23. Foerster U, Gilbert GH, Duncan RP (1998) Oral functional limitation among dentate adults. *J Public Health Dent* 58, 202-209.
24. Ueno M, Yanagisawa T, Shinada K, Ohara S, Kawaguchi Y (2008) Masticatory ability and functional tooth units in Japanese adults. *J Oral Rehabil* 35, 337-344.
25. Fleiss J (1986) The design and analysis of clinical experiments. Wiley, New York, 17-28.
26. Khalifa N, Allen PF, Abu-bakr NH, Abdel-Rahman ME (2012) Factors associated with tooth loss and prosthodontic status among Sudanese adults. *J Oral Sci* 55, 303-312.
27. Khalifa N, Allen PF, Abu-bakr NH, Abdel-Rahman ME (2013) Psychometric properties and performance of the Oral Health Impact Profile (OHIP-14s-ar) among Sudanese adults. *J Oral Sci* 55, 123-132.
28. Marcenes W, Steele JG, Sheiham A, Walls AW (2003) The relationship between dental status, food selection, nutrient intake, nutritional status, and body mass index in older people. *Cad Saude Publica* 19, 809-816.
29. Gilbert GH, Heft MW, Duncan RP (1993) Mouth dryness as reported by older Floridians. *Community Dent Oral Epidemiol* 21, 390-397.
30. Shinkawa T, Hayashida N, Mori K, Washio K, Hashiguchi K, Taira Y et al. (2009) Poor chewing ability is associated with lower mucosal moisture in elderly individuals. *Tohoku J Exp Med* 219, 263-267.