with the sum OHIP-14. It should be considered that financial dissatisfaction and lower education could be related to other variables remaining in the logistic model thus contributing to their lack of significance independently. With regard to financial status, the majority of these elders were middle class or higher. Japan has a national health insurance system for all citizens that includes dental care. These facts may have contributed to the lack of a significant association between OHIP-14 and financial status. Additionally, other studies which showed a significant relationship with financial status used measures of actual income as related to a determined poverty status[16,17] rather than our measure of self-perceived satisfaction with financial status. The subjective nature of how we measured finances coupled with the relatively small numbers of persons who reported dissatisfaction with their finances might be related to the lack of significant association with the OHIP-14.

Our results found that self-assessed poor general health had a significant independent association with oral health related quality of life. As a cross-sectional study, these findings cannot determine cause and effect in terms of relationship between general health and oral health. However, the findings do suggest that our Japanese elderly who reported impaired general health also reported more oral problems. This association has been previously observed in other populations[18].

When our OHIP SC data was compared with that of other countries, the items were ranked similarly (Table 6). It was interesting that the two top items most frequently reported in all countries except for Hong Kong were the subdomains of physical pain or psychological discomfort[6,19]. Although the items were ranked similarly, the perceived magnitude of the problems were quite different in different populations[7]. The Osaka elders reported less impacts than did NC blacks or elders in Hong Kong,

Table 6 International comparisons using the OHIP SC.

	Adelaide[a] *n = 670 (74)*		*Mt Gambier*[a] *n = 266 (72)*		*NC White*[a] *n = 225 (75)*		*NC Black*[a] *n = 202 (74)*		*Toronto*[a] *n = 164 (70)*		*Rural Ontario*[a] *n = 115 (70)*		*Hong Kong*[b] *n = 586 (73)*		*Osaka n = 942, (66)*	
Characteristic	%	*Rank*	%	*Rank*	%	*Rank*	%	*Rank*	%	*Rank*	%	*Rank*	%	*Rank*	%	*Rank*
Functional limitation																
Trouble pronouncing words	2.2	6	1.1	6	0.5	6	4.6	9	3.0	7	0.0	12	8.0	4	4.4	6
Taste worse	2.2	7	0.8	9	0.5	6	11.3	3	4.6	3	2.7	3	11.8	2	4.5	4
Physical pain																
Painful aching	3.4	4	2.6	5	1.1	4	7.2	7	6.8	2	8.3	1	3.4	8	4.5	4
Uncomfortable to eat	6.5	1	5.3	2	4.8	1	11.9	2	2.9	10	1.3	6	16.4	1	8.1	1
Psychological discomfort																
Self-conscious	5.6	2	6.0	1	3.2	2	14.0	1	8.2	1	4.0	2	3.4	8	5.2	2
Tense	4.4	3	3.0	3	0.5	6	9.8	4	3.7	4	1.3	6	3.9	7	4.9	3
Physical disability																
Diet unsatisfactory	0.7	11	0.4	11	0.5	6	4.0	10	3.7	4	1.3	6	4.7	5	3.9	7
Interrupt meals	1.7	8	0.8	9	0.0	10	4.0	10	2.2	11	1.3	6	10.2	3	1.4	10
Psychological disability																
Difficult to relax	1.4	10	1.1	6	1.0	5	7.3	6	3.0	7	1.3	6	2.4	10	2.1	8
Been embarrassed	2.9	5	3.0	3	2.1	3	7.8	5	3.7	4	2.6	4	4.4	6	2.1	8
Social disability																
Irritable with others	0.7	12	0.0	13	0.0	10	2.6	12	1.5	12	1.4	5	1.0	12	0.7	12
Difficulty doing jobs	0.5	13	0.4	11	0.0	10	1.3	14	1.5	12	0.0	12	0.5	14	0.5	13
Handicap																
Life unsatisfying	1.7	9	1.1	6	0.0	10	4.7	8	3.0	7	1.3	6	2.4	10	1.2	11
Unable to function	0.2	14	0.0	13	0.0	10	2.0	13	1.5	12	0.0	12	0.9	13	0.5	13
OHIP-14 SC	0.34		0.26		0.14		0.93		0.49		0.27		0.73		0.44	

n, number of people and the values given in parenthesis are median age in years.
[a]Slade *et al.*, 1996[6].
[b]Wong *et al.*, 2002[19].

but more often than NC whites, while they were generally similar to elders in Adelaide and Toronto in terms of both ranking and yearly occurrence.

The differences compared with previous OHIP studies may be explained in a number of ways: they may be differences in the conceptual and linguistic equivalence of translated items (delicate shades of meaning of the question), or differences in the social security system, the health insurance system, national character (optimistic or pessimistic), or true differences in the perceived severity of oral health across cultures[7]. However, physical pain and psychological discomfort tended to be reported more frequently than social disability and handicap, which is similar to the other studies[8]. Our results provide additional support for Locker's theoretical model of oral health indicating that social disability and handicap are less frequent and measure the most comprehensive impact on quality of life[10].

In conclusion, the Japanese version OHIP-14 had a high internal reliability overall ($\alpha = 0.95$) and comparable ranking for items when compared with studies from other countries. Poor self-assessed general health, using a removable denture, and reporting a need for dental treatment were all independent variables, which were related to having a higher level of oral problems or impacts. The strong association of these dental health variables with the sum OHIP 14 precluded financial status and education level as independent variables. Neither age, gender, marital status, nor living companion status had an association with the OHIP measurement. However, generalisation of the specific variables, which had an association in this study should be viewed with caution and not considered representative for the general elderly Japanese as our study population was a convenience non-randomly-selected sample. The findings of this study do suggest that the culturally adapted OHIP-14 version may be a good research instrument to consider for use in measuring the impact of oral problems on the quality of life in a Japanese population.

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Association of bite force with ageing and occlusal support in older adults

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KEYWORDS
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Summary *Objectives.* The purpose of this study was to investigate the effect of ageing, occlusal support and TMJ condition and general health status on bite force in older adults.

Methods. The study sample consisted of 850 independently-living people over the age of 60 years. Bilateral maximal bite force in the intercuspal position was measured with pressure sensitive sheets. TMJ noise by palpation and limitation of mouth opening (less than 40 mm) were assessed. Subjects were grouped into three categories by occlusal support according to the Eichner Index.

Results. A multiple logistic regression analysis showed that whether participants had low bite force or not was significantly associated with gender, age, self-rated general health and occlusal support, but not TMJ noise or mouth opening limitation. Overall bite force showed a statistically significant but weak negative Spearman's correlation with age ($r=-0.24$, $p<0.001$). However, there was no significant correlation between age and bite force in the Eichner C group for males or in any of the Eichner classification for females.

Conclusions. Decline of occlusal support and general health might translate into reduction of bite force with ageing in older adults. Since tooth loss is not physiological ageing but pathological ageing, it cannot be shown that reduction of bite force is a natural effect of ageing.

Introduction

A primary reason for dental treatment is to restore oral function, especially mastication. Bite force shows a positive relationship with masticatory performance and dietary selection,[1-4] which is closely related to quality of life. Therefore, bite force has often been used as a variable for objectively evaluating masticatory function.

Factors reported to affect masticatory performance include age,[5] dental status,[6,7] salivary flow,[5] temporomandibular joint (TMJ) disorder[8] and/or orofacial pain.[9]

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Skeletal muscle atrophy, declining strength, and physical frailty are generally accepted as inevitable concomitants of ageing.[10] The muscle mass of old animals, as compared with young ones, is reported to have decreased by 30-40%, and strength to an even greater extent.[11] Bite force for individuals of 75 years and over was reported to be 40% lower than that for those of 35-44 years.[5] The main reason for the reduced bite force is thought to be atrophy of the jaw-closing muscles. The cross-sectional areas of the masseter and medial pterygoid muscle showed a significant reduction with age, with those in edentulous subjects showing a greater decrease than in dentate subjects.[12] In addition, masticatory ability is reported to relate to general health.[13] Indeed, elderly people are likely to have more compromised dentition and individually diverse health status than any other generation, although some people maintain good dental status and masticatory performance. There has previously been no investigation of potential explanatory variables (e.g. loss of occlusal support, ageing masticatory muscles, TMJ disorder, or decline of general health) associated with bite force in a large population of older adults.

The purpose of this study was to investigate the effects of ageing, occlusal support, TMJ condition and general health on bite force in independently-living older adults. We hypothesised that healthy older adults could maintain their bite force if the occlusion was also maintained, in spite of the ageing process.

Methods

Subjects

The subjects in this study were 1,738 students of the Senior Citizens' College of Osaka prefecture who attended the program from 1999 to 2001. The study sample consisted of community-dwelling, independently-living people over the age of 60 years who attended lectures once a week. This college is one of the adult education systems supported by the government of Osaka prefecture which enrolls volunteers for a period of one year. This course focused not only on health topics but also on other topics of interest to elderly people, such as finances or culture.

At the end of a lecture on oral health issues, the purpose and procedures of this study were explained to the audience, and volunteers were solicited to participate in filling out a questionnaire and volunteering to return for a dental examination on another day. After informed consent was obtained, subjects were given the opportunity to ask questions while completing the questionnaires; subjects could refuse to participate in the oral examination portion of the study. The final study population which voluntarily participated in the dental as well as the oral examination included 850 persons (460 men and 390 women). The participation rate was 48.9% of the total subjects, and their mean age was 66.6 ± 4.3 years. The mean age and the proportion of each gender were quite similar to those who did not volunteer for the dental examination ($n=888$).

Procedures

Informed consent was obtained from each participant, and the protocol was approved by the Institutional Review Board of Osaka University Graduate School of Dentistry. Comprehensive dental examinations were conducted by six calibrated dentists. Self-rated general health condition was estimated by the answer to the question: 'How do you rate your general health at the present time?' The volunteers were asked to respond with 'good', 'fair', or 'poor'.

Maximal bite force

Bilateral maximal bite force was measured with pressure sensitive sheets, the thickness of which was 97 micrometers (Dental Prescale 50 H R type, Fuji Film Co., Tokyo, Japan). The subjects performed maximal clenching in the intercuspal position with a pressure-sensitive sheet placed between the maxilla and the mandibular dental arch. Removable denture wearers bit the sheets with their dentures. Thirty subjects who had a partially edentulous arch without a replacement or who complained of a toothache or irritation of the denture-bearing tissues were excluded from the study population.

The occlusal force was measured by colour development in a pressure-sensitive film with special analytical equipment (Occluzer FPD703, Fuji Film Co.). The uses, limitations, validity, and reliability of this method have been discussed and reported previously.[14,15] Shiga et al. have shown that the bite force with this system has a significant positive correlation to real pressure values ($r=0.990$, $p<0.01$) and displayed 98-100% of the true values for pressures between 20 and 80 N on 1 mm^2.[16]

Temporomandibular joint dysfunction (TMD)

Signs and symptoms of TMD, which included TMJ pain, noise by palpation and limitation of mouth opening (less than 40 mm), were assessed.

Because only 10 subjects had TMJ pain, it was excluded as an explanatory variable in the analyses.

Occlusal support

Because the edentulous population was very small ($n=32$, 3.9%), and dentate status was strongly confounded with occlusal support, we used occlusal support, that is, the Eichner Index, to indicate dental status in this study.

Occlusal supports were recorded according to the Eichner Index.[17] The molar and premolar contacts of the residual teeth define the classification: class A contacts four support zones, class B one to three zones or contact in the anterior area only, and class C has no support zone at all, although a few teeth can still remain.

Statistical analysis

The data analyses were done using SPSS Version 11.0 for Windows (SPSS Inc., Chicago, IL, USA). Since the bite force was not normally distributed, non-parametric tests of both the Mann-Whitney U test and the Kruskal-Wallis test were used to examine differences in bite force with regard to each of the individual explanatory variables.

The Kruskal-Wallis test was used for age, self-assessed general health and Eichner classification, and the Mann-Whitney U test otherwise. *P*-values ≤ 0.05 were considered to be statistically significant. Pairwise comparisons were made by means of the Mann-Whitney U tests with Bonferroni correction only following significant results of Kruskal-Wallis tests. Results were considered significant at $\alpha=0.017$ for three categories.[18]

A stepwise multiple logistic regression analysis was carried out to test each explanatory variable's relationship with the outcome variable after controlling for the other factors. The dichotomised outcome variable was whether participants had low bite force or not. There is no established cut-off value for the definition of low bite force. Yeh et al. divided their study participants into four groups[5] and identified low bite force as less than the 25th percentile, medium low bite force as the 25-50th percentile, medium high bite force as the 50-75th percentile, and high bite force as more than the 75th percentile.[5] We adopted this classification to decide whether participants had low bite force or not using the lowest 25th percentile as the cut-off value.

For this analysis, explanatory variables were scored as dichotomies as follows: males=0, females=1; self-rated general health: good=0, fair/bad=1; TMJ noise: without=0, with=1; mouth open limitation: 40 mm and over=0, less than 40 mm=1. For occlusal support, class A was set equal to 0 and Classes B and C equal to 1. Age was left as a continuous explanatory variable. Explanatory variables were entered into the model by the forward stepwise method with the significance level set at 0.05.

Spearman correlation coefficients were used to evaluate the relationship between age and bite force for all subjects and also for subjects stratified by gender, and by gender and Eichner classification.

Results

Bite force was not normally distributed (Fig. 1). The median value was 426 N, and the 25th and 75th percentiles were 238 and 669 N, respectively.

The bite force was significantly associated with gender, age, self-rated general health, and occlusal

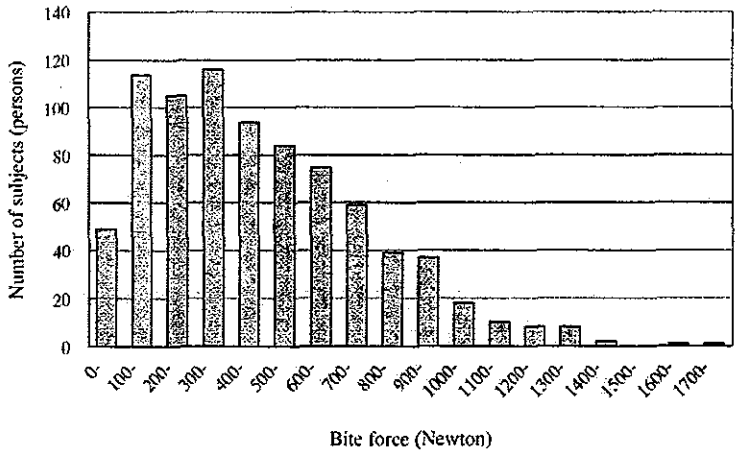

Fig. 1 Distribution of bite force ($n=820$).

Table 1 Frequency of demographic and oral variables and mean, standard error (SE), median, interquartile range of the bite force.

	n	Mean (N)	SE (N)	Median (N)	Interquartile range (N)		*P*-value
Gender							
Male	444	511.7	15.1	468.5	447.8		0.003
Female	376	442.4	14.2	382.0	397.8		
Age							
60-64	295	549.1	18.2	515.0	413.0	A	<0.001
65-69	326	470.9	16.6	418.5	442.6	B	
70+	199	392.2	18.7	333.0	395.5	C	
Self-assessed general health							
Good	451	525.0	14.9	470.0	430.2	A	<0.001
Fair	297	428.3	15.8	382.9	413.8	B	
Poor	72	410.9	31.9	345.3	471.5	B	
Eichner classification							
A	389	617.6	15.2	591.3	417.4	A	<0.001
B	297	417.8	14.4	369.0	329.5	B	
C	134	218.0	14.3	180.5	168.1	C	
TMJ noise							
no	591	478.0	12.5	423.0	434.2		0.631
yes	229	484.9	19.5	439.4	420.1		
Mouth open limitation							
40 mm and over	766	485.3	11.0	428.1	428.1		0.065
less than 40 mm	54	403.4	36.0	326.5	404.0		
Total	820	479.9	10.5	425.7	431.3		

The Kruskal-Wallis test was used for age, self-assessed general health and Eichner classification, the Mann-Whitney U test for others. Pairwise comparisons were made using Mann-Whitney U tests with Bonferroni correction ($\alpha=0.017$), where results were significant in Kruskal-Wallis tests. Pairs of values with different letters (A,B,C) are significantly different.

support, but not with TMJ noise or mouth opening limitation (Table 1). Males, younger persons, and subjects in good health had significantly stronger bite force than their counterparts. Participants in the Eichner A group had the highest median bite force among three groups ($p<0.01$).

A stepwise multiple logistic regression analysis showed that whether participants had low bite force or not, it was significantly associated with gender, age, self-rated general health and occlusal support (Table 2). The Nagelkerke R^2 of the model was 0.313, showing about 31% of the variation in the outcome variable could be statistically explained by this model. The overall accuracy of the model in predicting subjects having low bite force was 80.7%. Sensitivity was 93.5% and specificity was 43.5%.

The odds ratio was the highest for occlusal support. The Eichner B group compared to the A group was 3.6 times more likely to have low bite force, and the Eichner C group compared to the A group was 19.4 times more likely to have low bite force.

Overall bite force showed a statistically significant but weak negative correlation with age ($r=-0.24$, $p<0.001$)(Table 3). In the groups made up of the same gender and Eichner class, Spearman correlation coefficients between age and bite force in males, where significant, were very weak in the Eichner A group ($r=-0.15$, $p<0.05$) and in the Eichner B group ($r=-0.22$, $p<0.01$). There was no significant correlation in the Eichner C group for males or in any of the Eichner groups for females.

Table 2 Stepwise logistic regression analysis for the bite force.

	B	SE	*P*-value	Odds ratio	95% CI	95% CI
Gender	0.550	0.194	0.006	1.70	1.16	2.49
Age	0.036	0.022	0.038	1.05	1.00	1.09
General health	0.403	0.186	0.016	1.56	1.09	2.25
Eichner classification			<0.001			
B	1.673	0.223	<0.001	3.63	2.35	5.63
C	3.209	0.268	<0.001	19.44	11.50	32.86

Age: continuous variable; Gender: males=0, females=1; Self-rated general health: good=0; fair/bad=1; Eichner classification: class A was set equal to 0 and classes B and C equal to 1.

Discussion

This cross-sectional study evaluated a sample of functionally independent older urban adults who had volunteered for an education program. Most previous studies had evaluated a wider age range of patients from dental schools, hospitals or nursing homes. However, this study focused only on older adults and covered a larger number of subjects than former studies. How representative these individuals are of elderly Japanese is not precisely known. However, in Japan, most elderly people (95.5% of those 75-79 years, 90.8% of those 80-84 years, and 79.1% of those 85 years and over) are functionally independent and have no limitations in their daily activities.[19] The disability-adjusted life expectancy, the so-called 'healthy life expectancy' of the Japanese, is 74.5 years, which is the highest in the world. Therefore, it is important to know about the oral health of these independent elderly people who appear to represent a majority of the elderly Japanese population.

Table 3 Spearman correlations between bite force and age.

	Nimber of subjects	rs	*P*-value
Overall	820	−0.238	<0.001
Male	444	−0.324	<0.001
Eichner A	208	−0.150	0.030
Eichner B	164	−0.219	0.005
Eichner C	72	−0.217	0.067
Female	376	−0.210	<0.001
Eichner A	181	−0.105	0.160
Eichner B	133	−0.105	0.230
Eichner C	62	−0.071	0.585

In the present study, we evaluated the bilateral bite force in the intercuspal position, which is involved in several critical stages of food breakdown. We also examined gender, age, self-rated general health, occlusal support, and TMJ condition, as was done in previous studies. Factors investigated previously, which were associated with bite force, were income or educational level.[7] It has been reported that edentulous rates were negatively related to levels of education and income.[20-22] But in Japan, asking questions about educational or income level, especially of older people, is impolite and may result in a refusal to participate in the study. Therefore, we did not use these questions in our questionnaire.

The average of bite force is quite similar to what was found in previous studies using the same measuring device.[14,23] We found the bite force stronger in men (512 N) than in women (443 N), echoing the findings from previous studies.[23,24] This might be a result of difference in muscle strength.

Individuals with various TMD were reported to show a decrease in bite force,[8,9,25-27] although this has not been found by others.[28] We did not find an association of TMD with bite force. One possible reason is that a major contributing factor to TMD in our older subjects was not pain but TMJ noise or mouth opening limitation. In addition, our sample population was older than those of the other studies and seemed to be functionally adapted to the internal derangement of TMJ.

Self-rated general health was significantly associated with bite force independently of the other variables. It is well known that self-assessed health status well describes the objective health condition in geriatric persons. Subjective health conditions have been reported as important health status indicators, synthesizing objective health states and predicting physical condition and mortality.[29-31] The direction of cause and

effect is not clarified by this analysis; however, this suggests that elderly persons with impaired general health experienced more impact on oral function.

The bite forces of the Eichner class B and C groups were 68 and 35% of the class A group, respectively. As predicted, occlusal support of the residual teeth was suggested to be the most important variable for determining the bite force. The previous studies with varied measuring methods indicated that maximal bite force was 5-6 times greater in the dentate subjects than in the denture wearers.[32] It suggested directly that stronger occlusal force needs natural teeth supported with periodontal tissue, and artificial teeth over mucous membrane of residual ridge is not sufficient for the recovery of bite force. In addition, it suggested indirectly that occlusal contacts between maxillary and mandibular teeth activate oral function by masticatory muscles and temporomandibular joints, and so on. The cross-sectional area of both masseter and medial pterygoid muscles in edentulous subjects showed a greater decrease than in dentate subjects throughout the age range.[12] Significant correlation was found between masseter and medial pterygoid cross-sectional size and bite force.[33] Apart from the effects of tooth loss and muscle atrophy, the bite force in removable denture wearers might be limited because denture-bearing tissue is more subject to discomfort, compression, and denture shifting.[8,34]

Bite force was reported to decrease with increasing age after 25 years in women and after 45 years in men.[35] It also was reported that the direct effect of age on bite force was statistically significant but relatively small between 37 and 80 years (mean 58.5), excluding removable denture wearers.[36] In this study, overall age had a significant correlation with the bite force after controlling for other variables; however, in the groups of the same gender and occlusal support, correlation coefficients were very weak or not significant. Therefore tooth loss is supposed to be the most significant factor on reduction of bite force rather than ageing itself. In other words, oral function might be well preserved with advancing age if dentition is maintained in good condition.

Conclusions

Decline of occlusal support and general health might translate into reduction of bite force with ageing in older adults. Since tooth loss is not physiological ageing but pathological ageing, we cannot show that reduction of bite force is a natural effect of ageing. Maintaining a reasonable number of healthy natural teeth and occlusal support is the best guarantee for good masticatory ability with increasing age.

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