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Factors associated with self-assessed masticatory ability among community-dwelling elderly Japanese

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Self-assessed masticatory ability has been shown to be significantly related to general health among elderly persons. ***Objective:*** To identify oral factors associated with the self-assessed masticatory ability. ***Basic research design:*** Cross-sectional study. ***Participants:*** A total of 736 community-dwelling elderly persons. ***Main outcome measures:*** Data on background factors and the self-assessed masticatory ability were collected by questionnaire. An intraoral examination examined the pattern of posterior occluding pairs of natural teeth (POPs), the WHO Community Periodontal Index of Treatment Needs (CPI) and denture-related factors such as use of dentures, pain when using dentures and stability and retention of dentures. Chi-squared tests examined the relationships between the self-assessed masticatory ability and the background factors and oral conditions. Ordinal regression models were constructed with the self-assessed masticatory ability as the dependent variable and oral conditions as the principal independent variables, to adjust for the potential confounding variables. ***Results:*** Self-assessed impairment of masticatory ability was associated with lost POPs ($p<0.001$) and CPI ($p=0.012$). In the participants with lost POPs, self-assessed impairment of masticatory ability was associated with not using dentures and pain when using dentures ($p<0.001$). In the totally edentulous subjects, impairment of masticatory ability was not associated with stability and retention of dentures ($p=0.070$). ***Conclusions:*** Factors affecting self-assessed masticatory ability include the pattern of POPs, periodontal status, denture use and pain when using dentures.

Key words: *mastication, dentition status, community periodontal index of treatment needs, periodontal status, dentures, Japan*

Introduction

In many developed countries, the elderly population continues to increase and maintaining their general health is a concern. Therefore, it is necessary to identify factors influencing their health conditions.

Among the elderly, calorie-adjusted nutrient intake decreases with progressively impaired dentition and masticatory function is positively correlated with intake of dietary fibre, most vitamins and minerals (Krall *et al*., 1998). Self-assessed masticatory ability is related to general health conditions, including muscle strength, balance function and 9-year mortality among elderly persons (Moriya *et al*., 2009; Nakanishi *et al*., 2005). Further it has been shown that functional occlusion might prevent falls in elderly persons with dementia (Yoshida *et al*., 2005), suggesting better mastication ability may be associated with improved general health. Masticatory ability is considered an important indicator of general health among the elderly.

It has been shown that self-assessed impairment of masticatory ability was related to poor dental status (Nakanishi *et al*., 1999; Österberg *et al*., 1996). The existence occluding pairs of natural teeth has been shown to be a key factor in preserving masticatory function (Yamashita *et al*., 2000). However, it is still necessary to elucidate oral factors other than dental status associated with the self-assessed masticatory ability.

The aim of the present study was to identify oral factors associated with the self-assessed masticatory ability in detail, focused on the pattern of posterior occluding pairs of natural teeth (POPs), periodontal status and denture-related factors among community-dwelling elderly persons.

Materials and Methods

Dental health examinations were carried out on 882 independently residing persons aged 65 or over and were sponsored by public offices in 2 rural communities (Tomamae and Iwanai) in Hokkaido, the northernmost prefecture of Japan. Full details of the study design, recruitment and procedures were shown previously (Moriya *et al*., 2009). After exclusion of 38 persons aged 85 or over, 843 persons aged 65-84 remained. Those aged 85 or over were excluded from the survey, because we judged that the whole interview and examination could not be performed due to age-related declines in physical strength and their participation was limited to the intraoral examination.

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Ethical approval was secured from the ethical committee of the Hokkaido University Graduate School of Dental Medicine and written informed consent was obtained from each participant. Questionnaires on background factors and the self-assessed masticatory ability were sent via mail prior to the survey and the responses confirmed by the examiners on the day of the examination.

The questions about background factors included age, gender, current employment (working or not working), type of household (alone or with other family members), educational background (<10 years or ≥10 years of school education), social interaction (participating or not) including participation in groups gathering for social service, sports and hobbies, further about chronic systemic diseases (presence or absence of one or more chronic complaints such as hypertension, cardiac complaints, diabetes, cerebrovascular complaints, respiratory tract complaints, renal complaints, articular rheumatism, hepatic diseases and history of malignant tumour). The self-assessed masticatory ability was assessed by the question "Can you chew all kinds of food?" and the four alternative responses: "Yes, all kinds of food" (Good); "Yes, fairly hard food" (Fair), and "Only soft food" or "Only pureed food" (Poor) (Moriya *et al*., 2009).

Data collected by intraoral examination included the pattern of POPs, periodontal status and denture related factors. Intraoral examinations were performed by four dentists of the Graduate School of Dental Medicine, Hokkaido University and calibration was conducted to get close agreement in the assessments of dental status, periodontal status and the quality of dentures prior to the survey. The pattern of POPs was classified according to the presence or absence of POPs in the bilateral premolar and molar regions: 1, tooth contact in all of the bilateral premolar and molar regions; 2, tooth contact at least in one region except 1; or, 3, an absence of tooth contact (lost POPs). Periodontal status was evaluated by using the WHO Community Periodontal Index of Treatment Needs (CPI) and it was examined for all participants with at least one recordable sextant. Each participant was classified according to the maximum CPI code: code 0-2; code 3; or, code 4. Denture-related factors were evaluated based on use of dentures when eating and pain when using dentures for the participants with lost POPs and denture base fit for those using full upper and lower dentures. According to Kapur (1967) denture base fit of the totally edentulous was scored separately for its stability and retention, respectively, on 3- (0-2) and 4- (0-3) point-scales then summed for upper and lower dentures to range from 0 to 10. A sum >8 was characterised as clinically good dentures, 6-8 as fair dentures and <6 as poor dentures (Kapur, 1967). The assessment of denture base fit was not applied to the participants using partial dentures, because any standardised assessment tool for partial dentures suitable for an epidemiological survey was not available to our limited knowledge.

The chi-squared test was used to examine the relationships between the self-assessed masticatory ability and the background factors and oral conditions. Further, ordinal regression models were constructed with the self-assessed masticatory ability as the dependent variable; the background factors and oral conditions as the independent variables. These models present the estimated coefficient of ordinal regression (β) which reflects how changes in the independent variables affect the dependent variables and its 95% confidence interval (95% CI) for the self-assessed masticatory ability. The concordance of measurements between the examiners was evaluated according to the Kappa statistic. Only p-values <0.05 were considered significant. Analyses were performed using SPSS PASW® Statistics Base v18.0.

Results

After excluding participants with missing data from the 843 participants, there were 736 participants in the study (411 females, mean age 73.0 (sd 5.3) years, 325 males, 73.1 (sd 5.0) years). The relationships between the self-assessed masticatory ability and the background factors are shown in Table 1. The distributions of the participants by the self-assessed masticatory ability were related to age, gender, type of household, employment status, degree of social interaction and hypertension. Renal diseases and articular rheumatism were not included in the analysis because too few participants (6 and 5 respectively) had these diseases. The relationships between the self-assessed masticatory ability and oral conditions are shown in Table 2. The CPI could be assessed for 540 persons and use of dentures when eating was assessed for 428 persons who had no POPs. Of the 428 participants, 270 were partially edentulous and 158 were totally edentulous. After exclusion of 32 participants who did not use any dentures when eating from the 428 participants having no POPs, 396 participants using dentures could be included in the assessment of pain when using dentures. Of the 158 totally edentulous participants, 8 participants using no dentures were excluded and finally 150 could be evaluated for stability and retention of dentures. The distributions of the participants by the self-assessed masticatory ability were significantly related to the pattern of POPs (p<0.001), CPI (p=0.025), use of dentures (p<0.001), pain when using dentures (p<0.001) and stability and retention of dentures (p=0.049) (Table 2). Kappa values of each item were more than 0.80 for inter assessor agreement.

The results of ordinary regression analysis for the self-assessed impairment of masticatory ability are shown in Tables 3 and 4. Educational background and systemic diseases other than hypertension were not included in these models because no significant relationship was established in the univariate analysis. Five ordinal regression models were constructed for all participants (model 1), for those of CPI (model 2), for those who had no POPs (model 3), for those who had no POPs but used dentures when eating (model 4) and for the totally edentulous participants using both upper and lower dentures when eating (model 5). In model 1, self-assessed impairment of masticatory ability was associated with living alone status (p=0.020), non-working status (p=0.040), low social activity status (p=0.012) and lost POPs (p<0.001). In model 2, an association was established with code 4 of CPI (p=0.012). In model 3, self-assessed impairment of masticatory ability was associated with not using dentures when eating (p<0.001). In model 4, an association was established with pain when using dentures (p<0.001). In model 5 for the totally edentulous participants us-

Table 1. Relationships between the self-assessed masticatory ability and background factors

Background factors		*n*	*Self-assessed masticatory ability (%)*			*p-value*
			Good	*Fair*	*Poor*	
Age	65-74 years	447	68.9	25.3	5.8	
	75-84 years	289	58.5	35.6	5.9	**0.009**
Gender	Female	411	59.9	32.1	8.0	
	Male	325	71.1	25.8	3.1	**0.001**
Household	Living with others	561	68.3	27.1	4.6	
	Living alone	175	53.7	36.6	9.7	**0.001**
Employment	Working	561	62.0	31.0	7.0	
	Not working	175	73.7	24.0	2.3	**0.007**
Social interaction	Yes	324	70.1	26.5	3.4	
	No	412	60.7	31.6	7.7	**0.007**
Educational background	≥10 years	207	67.2	28.0	4.8	
	<10 years	529	63.9	29.9	6.2	0.631
Hypertension	Absence	382	68.8	26.7	4.5	
	Presence	354	60.5	32.2	7.3	0.038
Diabetes	Absence	650	63.7	30.0	6.3	
	Presence	86	73.3	24.4	2.3	0.139
Cardiac disease	Absence	618	66.0	28.3	5.7	
	Presence	118	58.5	34.7	6.8	0.290
Cerebrovascular disease	Absence	699	64.9	29.5	5.6	
	Presence	37	62.2	27.0	10.8	0.415
Liver disease	Absence	713	65.4	28.7	5.9	
	Presence	23	47.8	47.8	4.4	0.142
Respiratory tract disease	Absence	714	64.6	29.4	6.0	
	Presence	22	72.7	27.3	0.0	0.454
Malignant tumour	Absence	716	64.7	29.4	5.9	0.886
	Presence	20	70.0	25.0	5.0	

Table 2. Relationships between the self-assessed masticatory ability and oral conditions

Oral conditions		*n*	*Self-assessed masticatory ability (%)*			*p-value*
			Good	*Fair*	*Poor*	
The pattern of POPs	All regions	139	90.6	8.6	0.8	
n=736	At least one region	169	82.2	15.4	2.4	**<0.001**
	Absence	428	49.5	41.6	8.9	
CPI	Code 0-2	116	79.3	17.3	3.4	
n=540	Code 3	239	72.4	24.3	3.3	**0.025**
	Code 4	185	62.2	32.4	5.4	
Dentures use	Yes	396	51.3	42.2	6.5	
n=428	No	32	28.1	34.4	37.5	**<0.001**
Pain when using dentures	No	278	59.7	37.1	3.2	
n=396	Yes	118	30.5	55.1	14.4	**<0.001**
Stability/retention of dentures	Good/Fair	76	64.5	28.9	6.6	
n=150	Poor	74	44.6	45.9	9.5	**0.049**

POPs: Posterior occluding pairs of natural teeth, CPI: The maximum WHO Community Periodontal Index of Treatment Needs of each participant. Use of dentures was evaluated for the participants having no POPs. Pain when using dentures was evaluated for the participants having no POPs but using dentures (partial dentures: 246 persons, full upper and lower dentures: 150 persons). Stability and retention of dentures were evaluated for the totally edentulous participants wearing both upper and lower dentures.
All regions: tooth contact in all of the bilateral premolar and molar regions
At least one regions: tooth contact at least in one region, except the participants of all regions
Absence: an absence of tooth contact in premolar and molar regions (lost POPs)

Table 3. Results of the ordinal regression analysis for the self-assessed impairment of masticatory ability (1)

Independent variables		*Self-assessed masticatory ability (dependent variable) **			
		Model 1 (n=736)		*Model 2 (n=540)*	
		β (95%CI)	*p-value*	*β (95%CI)*	*p-value*
Age	65-74 years	0.00		0.00	
	75-84 years	-0.15 (-0.49,0.20)	0.409	-0.12 (-0.56,0.32)	0.592
Gender	Female	-0.20 (-0.54,0.14)	0.245	-0.06 (-0.49,0.37)	0.799
	Male	0.00		0.00	
Household	With others	0.00		0.00	
	Alone	-0.60 (-0.98,-0.22)	**0.020**	-0.37 (-0.83,0.89)	0.113
Employment	Working	0.00		0.00	
	Not working	-0.44 (-0.86,-0.02)	**0.040**	-0.25 (-0.78,0.27)	0.344
Social interaction	Yes	0.00		0.00	
	No	-0.43 (-0.76,-0.09)	**0.012**	-0.60 (-1.02,-0.18)	0.012
Hypertension	Absence	0.00		0.00	
	Presence	-0.31 (-0.64,-0.02)	0.068	-0.32 (-0.73,0.09)	0.125
Pattern of POPs	All regions	0.00		0.00	
	At least one region	-0.56 (-1.27,0.14)	0.116	-0.52 (-1.23,0.19)	0.154
	Absence	-2.24 (-2.85,-1.62)	**<0.001**	-2.16 (-2.81,-1.52)	**<0.001**
CPI	Code 0-2			0.00	
	Code 3			-0.20 (-0.78,3.80)	0.499
	Code 4			-0.76 (-1.35,-0.16)	**0.012**

Model 1 was constructed for all participants and Model 2 was constructed for the participants of CPI.
β: coefficient of ordinal logistic regression, CI: confidence interval
* Dummy variables of the self-assessed masticatory ability were created as: Good=2, Fair=1 and Poor=0.

Table 4. Results of the ordinal regression analysis for the self-assessed impairment of masticatory ability (2)

Independent variables		*Self-assessed masticatory ability (dependent variable) **			
		Model 3 (n=428)		*Model 4 (n=396)*	
		β (95%CI)	*p-value*	*β (95%CI)*	*p-value*
Age	65-74 years	0.00		0.00	
	75-84 years	-0.15 (-0.54,0.24)	0.409	-0.21 (-0.63,0.21)	0.335
Gender	Female	-0.41 (-0.81,-0.11)	**0.044**	-0.31 (-0.74,0.12)	0.156
	Male	0.00		0.00	
Household	With others	0.00		0.00	
	Alone	-0.61 (-1.06,-0.17)	**0.007**	-0.59 (-1.07,0.10)	**0.017**
Employment	Working	0.00		0.00	
	Not working	-0.64 (-1.13,-0.14)	**0.012**	-0.72 (-1.24,-0.19)	**0.008**
Social interaction	Yes	0.00		0.00	
	No	-0.36 (-0.75,-0.03)	0.067	-0.19 (-0.61,0.22)	0.353
Hypertension	Absence	0.00		0.00	
	Presence	-0.17 (-0.56,0.22)	0.387	-0.25 (-0.66,0.16)	0.238
Denture use when eating	Yes	0.00			
	No	-1.55 (-2.28,-0.82)	**<0.001**		
Pain when using dentures	No			0.00	
	Yes			-1.28 (-1.73,-0.84)	**<0.001**

Model 3 was constructed for the participants having no POPs and Model 4 was constructed for the participants having no POPs but using dentures (partial dentures: 246 persons, full upper and lower dentures: 150 persons).
β: coefficient of ordinal logistic regression, CI: confidence interval
*: Dummy variables of the self-assessed masticatory ability were created as follows: Good=2, Fair=1 and Poor =0.

ing dentures (n=150), there were also associations with pain when using dentures (β=-1.33, 95% CI -2.06,-0.60, $p<0.001$), but not with stability and retention of dentures (β=-0.64, 95% CI -1.33, 0.51, $p=0.070$) (data not shown).

Discussion

We have shown previously that the self-assessed masticatory ability was significantly related to physical performance among community-dwelling elderly persons (Moriya *et al*., 2009). The findings here identified factors associated with the self-assessed masticatory ability. Our study has several limitations that should be recognised. The study population was considered to be representative of a rural elderly population in Japan but not a nationally representative sample and the study was cross-sectional in design (Moriya *et al*., 2009). Nevertheless, the findings here added data for the detailed relationships between the self-assessed masticatory ability and oral conditions such as dental status, periodontal status and denture-related factors, to prior studies in this area (Nakanishi *et al*., 2005; Österberg *et al*., 1996).

The self-assessed masticatory ability was associated with the type of household, employment and social interaction in model 1 and these findings are consistent with those of earlier studies (Nakanishi *et al*., 2005; Österberg *et al*., 1996). It is not possible to show any causation of these relationships here, but a theoretical mechanism of the relationships can be explained by a number of hypotheses. First, living with others, working and reporting high social activity may have a positive effect on oral hygiene and consequently contribute to the preservation of the self-assessed masticatory ability. Elsewhere, life style related factors have been significantly related to oral hygiene in a rural population in Japan (Harada *et al*., 2005).

Second, a perception of masticatory ability may be influenced by psychosocial status, i.e., positive affect, defined as emotional contentment and happiness that has been associated with social activity (Kurland *et al*., 2006). Finally, it has been shown that masticatory ability was associated with physical performance and higher level functioning capacity (Moriya *et al*., 2009; Takata *et al*, 2008) and consequently the self-assessed masticatory ability may contribute to participating in work and the high social activity status.

A number of studies have found no clinical significant differences between subjects with shortened dental arches (SDA) of 3 to 5 occlusal units and complete dental arches regarding variables such as masticatory ability, signs and symptoms of temporomandibular disorders and oral comfort (Witter *et al*., 1994a, 1994b). Partially lost POPs (at least one region) was not related to the self-assessed impairment of masticatory ability in the present study. These findings suggest that occluding pairs of natural teeth may play an important role in oral functions, especially masticatory ability.

Lost POPs was significantly and closely related to the self-assessed impairment of masticatory ability here. These findings are in agreement with earlier studies, which have suggested that fewer functional tooth units and extremely shortened dental arches are associated with the perceived impairment of chewing ability (Sarita *et al*., 2003). The pattern of POPs has been significantly associated also with an objective masticatory performance based on particle size measures of a test food (Yamashita *et al*., 2000). Therefore, POPs may influence subjective and objective assessments of masticatory ability. These relationships may be accounted for through the stability of jaw relation, degree of support of dentures due to lost POPs and afferent signals arising from dentoalveolar ligaments, which have been shown to modulate masticatory behaviour in the laboratory (Inoue *et al*., 1989).

The findings of the present study showed that the advanced periodontal status (code 4 of CPI) was associated with self-assessed impairment of masticatory ability ($p=0.012$). It is thought that advanced periodontal conditions would cause biting pain, mobile teeth and a decline in biting force during mastication and consequently lead to an impairment of masticatory ability. Mobile teeth have been associated with eating difficulties in an old Chinese population (Zeng *et al*., 2008). No correlation has been found between periodontal status and biting force in persons with slightly reduced periodontal tissue support (Morita *et al*., 2003), but significant correlations have been established in persons with moderately to severely reduced periodontal tissue support (Takeuchi *et al*., 2008). It has been suggested that maximal occlusal force positively correlates with the masticatory performance (Okiyama *et al*., 2003).

The results of the data for dentures suggest that the masticatory ability may be impaired by not using dentures and pain when using dentures. Pain when using dentures is thought to be dependent chiefly on discordance of occlusal relationships of dentures and ill-fitting dentures. The absence of relationships between the self-assessed masticatory ability and denture adhesion ($p=0.070$) could be explained by several mechanisms; psychological factors may also influence the acceptance of dentures (Ozdemir *et al*., 2006), individuals wearing ill-fitting dentures may modify their chewing habits to optimise masticatory performance with such dentures (Demers *et al*., 1996), masticatory ability with dentures is thought to be influenced by factors other than denture adhesion such as occlusal relationships, the motion of the soft tissues and denture-supporting tissues.

The present study suggests that self-assessed masticatory ability may be influenced by dentition status, periodontal status and denture-related factors, providing a possibility that masticatory ability could be improved by dental interventions among community-dwelling elderly persons.

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References

Demers, M., Bourdages, J., Brodeur, J.M. and Benigeri, M. (1996): Indicators of masticatory performance among elderly complete denture wearers. *Journal of Prosthetic Dentistry* **75**, 188-193.

Harada, S., Akhter, R., Kurita, K., Mori, M., Hoshikoshi, M., Tamashiro, H. and Morita, M. (2005): Relationships between lifestyle and dental health behaviors in a rural population in Japan. *Community Dentistry and Oral Epidemiology* **33**, 17-24.

Kanno, T. and Carlsson, G.E. (2006): A review of the shortened dental arch concept focusing on the work by the Kayser/Nijmegen group. *Journal of Oral Rehabilitation* **33**, 850-862.

Kapur K.K. (1967): A clinical evaluation of denture adhesives. *Journal of Prosthetic Dentistry* **18**, 550-558.

Krall, E., Hayes, C. and Garcia, R. (1998): How dentition status and masticatory function affect nutrient intake. *Journal of the American Dental Association* **129**, 1261-1269.

Kurland, B.F., Gill, T.M., Patrick, D.L., Larson, E.B. and Phelan, E.A. (2006): Longitudinal change in positive affect in community-dwelling older persons. *Journal of the American Geriatrics Society* **54**, 1846-1853.

Inoue, T., Kato, T., Masuda, Y., Nakamura, T., Kawamura, Y. and Morimoto, T. (1989): Modifications of masticatory behavior after trigeminal deafferentation in the rabbit. *Experimental Brain Research* **74**, 579-591.

Moriya, S., Tsukasa, M., Tei, K., Nakamura, K., Muramatsu, M., Notani, K. and Inoue, N. (2009): Relationships between oral conditions and physical performance in a rural elderly population in Japan. *International Dental Journal* **59**, 369-375.

Morita, M., Nishi, K., Kimura, T., Fukushima, M., Watanabe, T., Yamashita, F., Zhou, R., Yang, J. and Xu, X. (2003): Correlation between periodontal status and biting ability in Chinese adult population. *Journal of Oral Rehabilitation* **30**, 260-264.

Nakanishi, N., Hino, Y., Ida, O., Fukuda, H., Shinsho, F. and Tatara, K. (1999): Associations between self-assessed masticatory disability and health of community-residing elderly people. *Community Dentistry and Oral Epidemiology* **27**, 366-371.

Nakanishi, N., Fukuda, H., Takatorige, T. and Tatara, K. (2005): Relationship between self-assessed masticatory disability and 9-year mortality in a cohort of community-residing elderly people. *Journal of the American Geriatrics Society* **53**, 54-58.

Okiyama, S., Ikebe, K. and Nokubi, T. (2003): Association between masticatory performance and maximal occlusal force in young men. *Journal of Oral Rehabilitation* **30**, 278-282.

Österberg, T, Carlsson, G.E., Tsuga, K., Sundh, V. and Steen, B. (1996): Associations between self-assessed masticatory ability and some general health factors in a Swedish population. *Gerodontology* **13**, 110-117.

Ozdemir, A.K., Ozdemir, H.D., Polat, N.T., Turgut, M. and Sezer, H. (2006): The effect of personality type on denture satisfaction. *International Journal of Prosthodontics* **19**, 364-370.

Sarita, P.T., Witter, D.J., Kreulen, C.M., Van't, Hof, M.A. and Creugers, N.H. (2003): Chewing ability of subjects with shortened dental arches. *Community Dentistry and Oral Epidemiology* **31**, 328-334.

Takata, Y., Ansai, T., Soh, I., Akifusa, S., Sonoki, K., Fujisawa, K., Yoshida, A., Kagiyama, S., Hamasaki, T., Nakamichi, I., Awano, S., Torisu, T. and Takehara, T. (2008): Relationship between chewing ability and high-level functional capacity in an 80-year-old population in Japan. *Gerodontology* **25**; 147-154.

Takeuchi, N. and Yamamoto, T. (2008): Correlation between periodontal status and biting force in patients with chronic periodontitis during the maintenance phase of therapy. *Journal of Clinical Periodontology* **35**, 215-220.

Witter, D.J., de Haan, A.F., Käyser, A.F. and van Rossum, G.M. (1994a): A 6-year follow-up study of oral function in shortened dental arches. Part I: Occlusal stability. *Journal of Oral Rehabilitation* **21**, 113-125.

Witter, D.J., de Haan, A.F., Käyser, A.F. and van Rossum, G.M. (1994b): A 6-year follow-up study of oral function in shortened dental arches. Part II: Craniomandibular dysfunction and oral comfort. *Journal of Oral Rehabilitation* **21**, 353-366.

Yamashita, S., Sakai, S., Hatch, J.P. and Rugh, J.D. (2000): Relationship between oral function and occlusal support in denture wearers. *Journal of Oral Rehabilitation* **27**, 881-886.

Yoshida, M., Morikawa, H., Kanehisa, Y., Taji T., Tsuga, K. and Akagawa, Y. (2005): Functional dental occlusion may prevent falls in elderly individuals with dementia. *Journal of the American Geriatrics Society* **53**, 1631-1632.

Zeng, X., Sheiham, A. and Tsakos, G. (2008): Relationship between clinical dental status and eating difficulty in an old Chinese population. *Journal of Oral Rehabilitation* **35**: 37-44.