journal of prosthodontic research 62 (2018) 432–435

Contents lists available at ScienceDirect

Journal of Prosthodontic Research

journal homepage: www.elsevier.com/locate/jpor

Original article

Factors related to masticatory performance in healthy elderly individuals

Koji Morita[a,*], Hiroki Tsuka[a], Kan Kato[a], Takahiro Mori[a], Rumi Nishimura[b], Mitsuyoshi Yoshida[a], Kazuhiro Tsuga[a]

[a] Department of Advanced Prosthodontics, Hiroshima University Graduate School of Biomedical & Health Sciences, Hiroshima, Japan
[b] Department of Oral Health Sciences Major, Hiroshima University Graduate School of Biomedical & Health Sciences, Hiroshima, Japan

ARTICLE INFO

Article history:
Received 10 November 2017
Received in revised form 25 March 2018
Accepted 29 March 2018
Available online 26 April 2018

Keywords:
Masticatory performance
Grip strength
Occlusal force
Oral diadochokinesis test
Physical/oral function

ABSTRACT

Purpose: Maintenance of natural dentition and/or prosthodontic rehabilitation is necessary for good masticatory function. Although other factors such as physical and oral functions are also important for masticatory performance, only a few studies have evaluated their roles. The aim of the current study was to assess factors associated with masticatory performance among elderly individuals, while maintaining and/or reconstructing all occlusal support areas.

Methods: The present study was designed and implemented as a cross-sectional study, involving a total of 262 participants (mean age: 74.2 ± 5.9 years) who participated in the Kyoto Elders Physical Fitness Measurement Research Project. Individuals with partial or complete edentulousness who did not use dentures were excluded from the study. The predictor variables included physical status (i.e., age, gender, body-mass index, and grip strength), oral conditions (i.e., number of present teeth, temporomandibular joint noise, and denture wearer), and oral functions (i.e., maximum voluntary occlusal force; occlusal contact area; cheek pressure; oral diadochokinesis test /pa/, /ta/, /ka/; and maximum voluntary tongue pressure). The variable outcome was masticatory performance. These variables among the participants using univariate and multivariate analyses were compared.

Results: Grip strength, number of present teeth, maximum voluntary occlusal force, occlusal contact area, oral diadochokinesis /ka/ /ta/, and maximum voluntary tongue pressure were significant factors for masticatory performance. Stepwise regression analysis showed that grip strength, maximum voluntary occlusal force, and diadochokinesis /ta/ significantly affected masticatory performance.

Conclusions: Masticatory performance was closely associated with grip strength, maximum voluntary occlusal force, and diadochokinesis /ta/ among healthy elderly participants.

1. Introduction

Masticatory function is important for feeding and swallowing, i.e., from ingestion of food to swallowing, and affects the quality of life (QOL) [1,2]. It was recently reported that masticatory deficiency, which causes soft-diet feeding, is a risk factor for the development of dementia [3]. Maintenance of the natural dentition and/or prosthodontic rehabilitation is necessary for good masticatory function. However, it was very difficult to evaluate the association between masticatory performance and prosthesis placement by quantifying retention, stability, and occlusal morphology. Therefore, the prevention of occlusal collapse was found to be important for the maintenance of masticatory performance [4]. Further, functional factors such as masticatory muscular strength have been found to be related to each other as well as to morphological problems, such as the occlusal relationship and the presence or absence of dentures [4–6]. Further, there is also an association between masticatory performance and oral functions, such as tongue pressure and cheek pressure, among young participants [5,7]. Moreover, if natural dentition was maintained in elderly participants, the masticatory performance did not differ with age [8]. Another report demonstrated a significant association between tongue pressure and mixing ability among elderly people with no occlusal support, because the tongue may compensate for the missing teeth in masticatory performance [9]. However, the relationships between such factors and masticatory performance among healthy elderly participants are still not well understood.

* Corresponding author at: Department of Advanced Prosthodontics, Hiroshima University Graduate School of Biomedical & Health Sciences, 1-2-3 Kasumi, Minami-Ku, Hiroshima,734-8553, Japan.
E-mail address: moritak@hiroshima-u.ac.jp (K. Morita).

https://doi.org/10.1016/j.jpor.2018.03.007
1883-1958/

Thus, the aim of the present study was to evaluate the association between masticatory performance and factors such as physical, oral, and occlusal states, among healthy elderly participants. It was hypothesized that any individual with a good masticatory performance would have particular physical, oral, and occlusal states. If true, it was postulated that this would allow us to address the maintenance of a sound masticatory system for older people, whose population is rapidly increasing worldwide.

2. Materials and methods

2.1. Study design and sample population

The present study included individuals who participated in the Kyoto Elders Physical Fitness Measurement Research Project to undergo physical fitness measurement. From among these participants, it was included the same participants who were included in another study that revealed the association between oral function and buccal mucosa ridge [10]. The study cohort consisted of individuals who presented at Kyoto Gakuen University on June 25 and 26, 2016. The participants who met the following criteria were included in the present study: (1) more than 60 years of age; (2) independent activity in daily life; and (3) no history of orthodontic treatment. The exclusion criteria were as follows: (1) severe periodontitis; (2) tooth pain; (3) orofacial pain; and (4) untreated missing teeth. Before the study was initiated, the purpose and the methodology of the study were explained to the participants, who provided informed consent prior to the enrolment in the study. The medical ethics committee of Kyoto Prefectural University of Medicine (No. E-382) approved this study. Further, the study conformed to the strengthening the reporting of observational studies in epidemiology (STROBE) guidelines [11] and was performed in compliance with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

2.2. Study variables and data collection methods

The predictor variables were the same as those in the previous study [10], i.e., physical status (age, gender, body-mass index, and grip strength (GS)), oral conditions (number of present teeth (NPT), temporomandibular joint noise (TJN), and denture wearer), and oral functions (maximum voluntary occlusal force (MVOF), occlusal contact area (OCA), cheek pressure (CP), oral diadochokinesis /pa/, /ta/, /ka/ (OD/pa/, OD/ta/, OD/ka/), and maximum voluntary tongue pressure (MVTP)). As described below, four dentists examined the participants. One interviewed the participants (T.M.); one performed oral examinations (M.Y.); one measured MVOF and OCA (K.M.); and one measured the CP and MVTP (M.M.).

All participants using an original questionnaire prepared based on the questionnaire recommended by the American Academy of Orofacial Pain (AAOP) regarding TJN were interviewed. The presence or absence of TJN was determined with the following question: “Have you or anybody ever noticed your own clicking or crepitus sound while opening or closing your jaw in the past 3 months?” [12–14].

Oral function was tested in the following manner: participants were asked to rest on chairs, such that their Frankfort horizontal planes were parallel to the horizontal plane. They were then asked to chew on the pressure measurement film (Dental Prescale 50H, GC, Tokyo, Japan) for 3 s with maximum voluntary effort. The pressure measurement film with ultrathin characteristics used in the present study measured each contact pressure and area of all occlusal contact sites [15]. Therefore, the MVOF was dependent on the all sites of the molars, premolars, and incisors. The MVOF and OCA from the three occlusal pressure measurements were measured, which were acquired using an occlusal force measuring system (Occluser 709, GC). The validity, reliability, and reproducibility of this method have been described previously [16]. Furthermore, the reliability of this occlusal force measuring system were reconfirmed elsewhere [17].

The oral diadochokinesis test evaluated the number of fastest repetitive /pa/, /ta/, /ka/ articulations per second, which was calculated with a measurement device (Kenko-Kun, Takei, Niigata, Japan) that counted the pronunciations within a period of 5 s without taking a breath [7]. The tasks of /pa/, /ta/ and /ka/ were used to evaluate the movement of lips, apex of the tongue, and posterior region of the tongue, respectively.

CP and MVTP were measured using the same devices. These were comprised of pressure measuring device and disposable balloon probe (TPM-01, JMS, Hiroshima, Japan). The probe comprised of a balloon (diameter: 18 mm) and a plastic cylinder for the participant to hold the probe at a prescribed position. To measure CP, the balloon in the space between mandibular first molar and buccal mucosa on the habitual masticatory side was positioned. The participants asked to close their lips and then press the balloon along the buccal surface of molars with maximal voluntary muscular effort for 7 s. The average of three measurements was used for analysis. The validity, reliability, and reproducibility of this method have been described previously [5]. The intra-class correlation (ICC) for CP showed excellent single agreement (ICC: 0.901, 95 % confidence interval [CI]: 0.875–0.921). To measure MVTP, the participants were asked to press the balloon of the probe onto their palate with maximum voluntary effort for 7 s. The average of three measurements for analysis was used. The validity, reliability, and reproducibility of this method have been described previously [18]. The intra-class correlation for MVTP showed good single agreement (ICC: 0.893, 95 % CI: 0.865–0.915).

The variable outcome was masticatory performance (MP). To measure MP, the concentration of dissolved glucose emitted by gummy jelly using a glucose measuring device (GLUCO SENSOR GS-II, GC) were measured. The participants were instructed to chew a gummy jelly from their habitual chewing side (left or right) for 20 s. After chewing, the participants were asked to include 10 ml of distilled water in their mouth and to spit the gummy jelly, distilled water, and saliva into a filter cup. Thereafter, the amount of glucose extraction during chewing of a gummy jelly was measured to obtain the MP. The validity, reliability, and reproducibility of this method have been described previously [19].

2.3. Data analyses

A Spearman’s rank correlation coefficient test to compare each variable for MP among the participants was used. Statistical significance was set at $P < 0.05$. In addition, the Spearman’s rank correlation coefficient was used to detect confounding factors related to the MP. After adjusting these confounding factors, the odds ratios and 95 % confidence intervals using stepwise regression analysis were calculated to determine the association between the predictor variables and the variable outcome. All statistical analyses were conducted using SPSS Statistics Version 19 for Windows (IBM Corp., Armonk, NY, USA).

3. Results

The participant cohort included 56 men and 206 women, with a mean age of 74.2 ± 5.9 years (60–89 years). Occlusal contacts were maintained with natural dentition in 161 participants, and partial and complete dentures were used in 85 and 16 participants, respectively. The means and standard deviations for MP and the variables representing physical and oral factors are shown in

Table 1
Average values and standard deviation for each variable.

Variable name	Average values ± standard deviation or *n* (%)
MP: masticatory performance (mg/dL)	170.7 ± 53.6
Age (yr)	74.2 ± 5.9
Male, *n* (%)	56.0 (21.4)
BMI: body-mass index	21.8 ± 2.5
GS: grip strength (kg)	25.0 ± 6.4
NPT: number of present teeth	22.8 ± 7.2
TJN: temporomandibular joint noise, *n* (%)	25 (9.5)
Denture wearer, *n* (%)	101 (38.5)
MVOF: maximum voluntary occlusal force (N)	471.8 ± 277.1
OCA: occlusal contact area (mm^2)	13.2 ± 8.5
CP: cheek pressure (kPa)	17.9 ± 4.0
OD/pa/: oral diadochokinesis test of /pa/	30.6 ± 3.9
OD/ta/: oral diadochokinesis test of /ta/	30.9 ± 3.9
OD/ka/: oral diadochokinesis test of /ka/	29.8 ± 3.9
MVTP: maximum voluntary tongue pressure (kPa)	30.9 ± 6.4

Table 2
Spearman's rank correlation coefficient for the association with outcome variable and predictor variables.

Variable name	MP: masticatory performance	
	ρ	*P* value
Age	0.030	0.626
Male	−0.049	0.427
BMI: body-mass index	0.115	0.064
GS: grip strength	0.152	0.014*
NPT: number of present teeth	0.375	< 0.001**
TJN: temporomandibular joint noise	0.016	0.793
Denture wearer	-0.005	0.939
MVOF: maximum voluntary occlusal force	0.277	< 0.001**
OCA: occlusal contact area	0.324	< 0.001**
CP: cheek pressure	0.067	0.280
OD/pa/: oral diadochokinesis test of /pa/	0.095	0.127
OD/ta/: oral diadochokinesis test of /ta/	0.144	0.020*
OD/ka/: oral diadochokinesis test of /ka/	0.122	0.050*
MVTP: maximum voluntary tongue pressure	0.130	0.036*

Data was presented as ρ or *P* value.
Spearman rank correlation coefficient test.
* $P < 0.05$.
** $P < 0.01$.

Table 1. Results of the Spearman's rank correlation coefficient test between MP as an outcome variable and all the predictor variables are shown in Table 2. Age, male gender, body mass index (BMI), TJN, denture wearer, CP, and OD/pa/ were not correlated with MP. In contrast, GS, NPT, MVOF, OCA, OD/ta/, OD/ka/, and MVTP were significantly positively correlated with MP ($P < 0.05$). Based on Spearman's rank correlation coefficient test for these items, NPT, OCA, and OD/ka/ were excluded as confounding factors from the predictor variables. NPT and OCA showed multicollinearity for MVOF (ρ: 0.333, *P*-value: < 0.001; and ρ: 0.941, *P*-value: < 0.00, respectively) and OD/ka/ showed multicollinearity for OD/ta/ (ρ: 0.770, *P*-value: < 0.001). Stepwise regression analysis revealed a significant relationship between MP, and GS, MVOF, and OD/ta/ ($P < 0.05$; Table 3).

4. Discussion

The results of the present study demonstrated that healthy elderly individuals with higher MP have a significantly higher GS and MVOF and faster OD/ta/. Although there are several methods to measure masticatory ability, a unified measurement does not exist. Many test foods, such as chewing gum, gummy jelly, rice, or adenosine triphosphate granules, are used. Among these, gummy jellies were used in the present study because this evaluating system can indicate masticatory performance objectively with glucose dissolved concentration [20]. Further, it is listed in the public insurance system in Japan. Therefore, the results in this study can indicate the participants' usual masticatory performance.

Table 3
Summary of regression model.

Outcome variable	Predictor variables	*F*	*t*	*P* value	VIF
MP	GS	8.245	2.871	0.004**	1.010
	MVOF	18.306	4.279	< 0.001**	1.010
	OD/ta/	3.609	2.564	0.011*	1.001

F:*F* statistic, *t*: *t*-statistic, VIF: variance inflation factor, MP: masticatory performance, GS: grip strength, MVOF: maximum voluntary occlusal force, OD/ta/: oral diadochokinesis test of /ta/.
A stepwise multiple logistic regression analysis.
* $P < 0.05$.
** $P < 0.01$.

MP was positively associated with GS in the current study. This result is consistent with past reports on elderly individuals [21]. GS is related to muscle power of whole body, independently from muscle mass. Thus, it can be concluded that masticatory performance is associated with the muscle power of the whole body. Although GS usually differs with gender, no remarkable differences in MP were found between the elderly male and female participants in the present study, which corroborated with results from a previous report [8]. Therefore, further validation is required, although it has been highlighted that a different mechanism is more likely to contribute to the relationship between MP and muscle strength.

MP was also positively associated with MVOF in the present study. Lower MVOF has been reported to increase the risk of development of frailty among elderly individuals [22,23]. In contrast, it has been reported that gum chewing exercises can strengthen masticatory muscles and increase MVOF in elderly individuals [24,25]. Another report found that MP was significantly associated with MVOF, regardless of the occlusal support areas [26]. Moreover, the velocity of mandibular movement during mastication was associated with MP, suggesting that faster mandibular movement leads to higher MP [20]. Although MP does not differ according to gender, it has also been reported that men have a higher MVOF than women [27,28]. Therefore, it has been suggested that women compensate for their low muscle strength by increased coordination of other motor and sensory functions [8]. This may be why masticatory performance did not different with gender. However, since it was not evaluated mandibular movement, this remains to be validated in the future.

MP was also positively associated with OD/ta/ in the current study. Pronouncing the syllables /pa/, /ta/, and /ka/ involves the use of the front (lips), middle (tip of the tongue), and back of the mouth (posterior tongue), respectively [29]. OD /pa/, /ta/, or /ka/ has been reported to be significantly associated with the ability to crush peanuts in young dentate adults [7]. Further, OD /ta/ was significantly correlated with the ability to mix food in elderly people [9]. It has also been reported that the improvement program for oral function has improved masticatory function and oral diadochokinesis [30]. These reports suggest the possibility of a relationship between masticatory function and oral diadochokinesis. The results of the present study indicate that the tip of tongue is largely involved in the masticatory movement.

In the current study, MP was not associated with MVTP in elderly people with occlusal support. However, another report demonstrated that MP was negatively correlated with MVTP in elderly people without occlusal support [9]. It was suggested that the use of prosthesis placement may reduce the use of the tongue

in elderly people with occlusal support; thus, the presence or absence of prosthesis placement as a factor affecting MVTP must be considered. Therefore, it may be suggested that increased tongue movement in elderly people without occlusal support can compensate for decreased mastication; although, this may not hold true for elderly people with occlusal support.

Unfortunately, the distribution of ages of the participants in this cohort was relatively wide, which lends uncertainty to this results, although reports suggest that age and gender do not affect masticatory performance among elderly people if natural dentition is maintained [8]. However, since denture use, which restricts mandibular movement, increases with aging, it may decrease masticatory performance. Well-designed longitudinal studies are needed in the future to evaluate the effect of oral function with and without dentures in masticatory performance.

5. Conclusion

The results of the present study demonstrated that participants with higher masticatory performance have a significantly higher grip strength, maximum voluntary occlusal force, and faster oral diadochokinesis /ta/. This might indicate that masticatory performance is affected by muscle power and muscle movement in independent elderly participants.

Funding

This research was performed without any special funding.

Author contributions

K. Morita contributed to study conception and design, data acquisition, analysis and interpretation, and drafting of the manuscript; H. Tsuka contributed to data analysis, and drafting of the manuscript; K. Kato contributed to study conception, data analysis and drafting of the manuscript; T. Mori contributed to study conception, data acquisition and analysis and drafting of the manuscript; R. Nishimura contributed to data analysis and interpretation; M. Yoshida contributed to study design, data acquisition, interpretation and critically revised the manuscript; K. Tsuga contributed to data analysis and interpretation and critically revised the manuscript.

Ethical approval

All procedures involving human participants performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent

Informed consent was obtained from all participants for this study.

References

[1] Isabel CA, Moysés MR, van der Bilt A, Gameiro GH, Ribeiro JC, Pereira LJ. The relationship between masticatory and swallowing behaviors and body weight. Physiol Behav 2015;151:314–9.
[2] Hama Y, Hosoda A, Komagamine Y, Gotoh S, Kubota C, Kanazawa M, et al. Masticatory performance-related factors in preschool children: establishing a method to assess masticatory performance in preschool children using colour-changeable chewing gum. J Oral Rehabil 2017;44:948–56.
[3] De Cicco V, Barresi M, Tramonti Fantozzi MP, Cataldo E, Parisi V, Manzoni D. Oral implant-prostheses: new teeth for a brighter brain. PLoS One 2016;11: e0148715.
[4] Ikebe K, Matsuda K, Kagawa R, Enoki K, Okada T, Yoshida M, et al. Masticatory performance in older subjects with varying degrees of tooth loss. J Dent 2012;40:71–6.
[5] Takahashi M, Koide K, Arakawa I, Mizuhashi F. Association between perioral muscle pressure and masticatory performance. J Oral Rehabil 2013;40:909–15.
[6] Fueki K, Igarashi Y, Maeda Y, Baba K, Koyano K, Sasaki K, et al. Effect of prosthetic restoration on masticatory function in patients with shortened dental arches: a multicentre study. J Oral Rehabil 2016;43:534–42.
[7] Yamada A, Kanazawa M, Komagamine Y, Minakuchi S. Association between tongue and lip functions and masticatory performance in young dentate adults. J Oral Rehabil 2015;42:833–9.
[8] Ikebe K, Matsuda K, Kagawa R, Enoki K, Yoshida M, Maeda Y, et al. Association of masticatory performance with age, gender, number of teeth, occlusal force and salivary flow in Japanese older adults: is ageing a risk factor for masticatory dysfunction? Arch Oral Biol 2011;56:991–6.
[9] Kikutani T, Tamura F, Nishiwaki K, Kodama M, Suda M, Fukui T, et al. Oral motor functions and masticatory performance in the community-dwelling elderly. Odontology 2009;97:38–42.
[10] Morita K, Mori T, Maruyama M, Hiraoka A, Higa C, Kuroki A, et al. Association between buccal mucosa ridging and oral or occlusal status among older people. Oral Dis 2018 [Epub ahead of print].
[11] von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. J Clin Epidemiol 2008;61:344–9.
[12] Panek H, Nawrot P, Mazan M, Bielicka B, Sumisławska M, Pomianowski R. Coincidence and awareness of oral parafunctions in college students. Community Dent Health 2012;29:74–7.
[13] Motghare V, Kumar J, Kamate S, Kushwaha S, Anand R, Gupta N, et al. Association between harmful oral habits and sign and symptoms of temporomandibular joint disorders among adolescents. J Clin Diagn Res 2015;9:ZC45–8.
[14] Jang JY, Kwon JS, Lee DH, Bae JH, Kim ST. Clinical signs and subjective symptoms of temporomandibular disorders in instrumentalists. Yonsei Med J 2016;57:1500–7.
[15] Choi TH, Kim BI, Chung CJ, Kim HJ, Baik HS, Park YC, et al. Assessment of masticatory function in patients with non-sagittal occlusal discrepancies. J Oral Rehabil 2015;42:2–9.
[16] Hidaka O, Iwasaki M, Saito M, Morimoto T. Influence of clenching intensity on bite force balance, occlusal contact area, and average bite pressure. J Dent Res 1999;78:1336–44.
[17] Morita K, Tsuka H, Shintani T, Yoshida M, Kurihara H, Tsuga K. Prevalence of torus mandibularis in young healthy dentate adults. J Oral Maxillofac Surg 2017;75:2593–8.
[18] Hayashi R, Tsuga K, Hosokawa R, Yoshida M, Sato Y, Akagawa Y. A novel handy probe for tongue pressure measurement. Int J Prosthodont 2002;15:385–8.
[19] Sugiura T, Fueki K, Igarashi Y. Comparisons between a mixing ability test and masticatory performance tests using a brittle or an elastic test food. J Oral Rehabil 2009;36:159–67.
[20] Uesugi H, Shiga H. Relationship between masticatory performance using a gummy jelly and masticatory movement. J Prosthodont Res 2017;61:419–25.
[21] Moriya S, Notani K, Murata A, Inoue N, Miura H. Analysis of moment structures for assessing relationships among perceived chewing ability, dentition status, muscle strength, and balance in community-dwelling older adults. Gerodontology 2014;31:281–7.
[22] Kamdem B, Seematter-Bagnoud L, Botrugno F, Santos-Eggimann B. Relationship between oral health and Fried's frailty criteria in community-dwelling older persons. BMC Geriatr 2017;17:174.
[23] Iwasaki M, Yoshihara A, Sato N, Sato M, Minagawa K, Shimada M, et al. A 5-year longitudinal study of association of maximum bite force with development of frailty in community-dwelling older adults. J Oral Rehabil 2018;45:17–24.
[24] Kiliaridis S, Tzakis MG, Carlsson GE. Effects of fatigue and chewing training on maximal bite force and endurance. Am J Orthod Dentofac Orthop 1995;107:372–8.
[25] Nakagawa K, Matsuo K, Takagi D, Morita Y, Ooka T, Hironaka S, et al. Effects of gum chewing exercises on saliva secretion and occlusal force in community-dwelling elderly individuals: a pilot study. Geriatr Gerontol Int 2017;17:48–53.
[26] Kosaka T, Ono T, Kida M, Kikui M, Yamamoto M, Yasui S, et al. A multifactorial model of masticatory performance: the Suita study. J Oral Rehabil 2016;43:340–7.
[27] Ohara Y, Hirano H, Watanabe Y, Edahiro A, Sato E, Shinkai S, et al. Masseter muscle tension and chewing ability in older persons. Geriatr Gerontol Int 2013;13:372–7.
[28] Oksuzyan A, Singh PK, Christensen K, Jasilionis D. A cross-national study of the gender gap in health among older adults in India and China: similarities and disparities. Gerontologist 2017 [Epub ahead of print].
[29] Hiramatsu T, Kataoka H, Osaki M, Hagino H. Effect of aging on oral and swallowing function after meal consumption. Clin Interv Aging 2015;10:229–35.
[30] Kumar A, Kothari M, Grigoriadis A, Trulsson M, Svensson P. Bite or brain: implication of sensorimotor regulation and neuroplasticity in oral rehabilitation procedures. J Oral Rehabil 2018;45:323–33.