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Original Article

An observational study of oral functions in patients aged from 20 to 49 years

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Abstract

Purpose: The purpose of this study was to analyze oral functions (MOF: maximum occlusal force; MTP: maximum tongue pressure; and MF: masticatory function) in Eichner A subjects aged from 20 to 49 years.
Methods: The data of three oral functions in Eichner A patients aged from 20 to 49 years were extracted. The mean values, subjects with lower values than the thresholds, and the differences among ages, and between sexes were investigated retrospectively.
Results: Although the mean values of these oral functions in 183 subjects were higher than the thresholds, the numbers of the subjects with lower values than the thresholds were 30 in MTP, 19 in MOF, and only three in MF. No significant effects of ages on all oral functions were identified and all functions in males were significantly higher than those in females. The subjects whose two functions were lower than the thresholds were nine females, eight of whom were associated with malalignment.
Conclusion: Although the mean values of oral functions were higher than the thresholds, some patients showed lower values, especially in MOF and MTP, even though they were unaware of any inconvenience. Patients with malalignment might be associated with declined oral functions.

Keywords: malalignment, masticatory function, maximum occlusal force, maximum tongue pressure, middle-aged population, young adulthood

Introduction

Dental status and oral functions are integral to general health. These factors have been reported to be associated with systemic condition [1,2], oral health-related quality of life [3], nutrient acquisition [4], psychosocial status [5] and cognitive function [6,7]. These backgrounds have led to a large number of publications, especially focusing on the elderly population. In 2018, the concept of "oral hypofunction" was proposed globally [8] and oral functions to diagnose "oral hypofunction" have been increasingly investigated [9-12]. Above all, maximum occlusal force (MOF) using a pressure-sensitive sheet, maximum tongue pressure (MTP) created by tongue elevation and masticatory function (MF) defined by glucose concentration obtained from crushed gummy jelly particles were major functions, and assessment fees are covered by the Japanese medical insurance system. Considerable evidence regarding these functions has been reported and interactions among them have been elucidated [13-15].

Regarding decline or deterioration of oral functions in the elderly population, aging itself can be one of the main reasons, although these phenomena could not be explained by aging alone [16-19]. To prevent oral hypofunction in this generation, the development and management of oral functions throughout life stages are important [20-24]:

1) Normal maxillofacial and dental development in childhood;
2) Dental interventions for dental diseases, malalignment, malocclusion and unfavorable habits in adolescence and young adulthood;
3) Dental and functional managements in adulthood.

In childhood, they visit dentists to receive dental care and treatment with parents or guardians, and their functions can be cared for since they are growing and developing. However, few young adult patients complain about their oral functions because they are growing with present conditions throughout their lives, even if they have some potential structural and functional problems. To reveal the current problems in oral functions in young adulthood and middle-aged generations, it is important to evaluate oral functions in these generations and to prevent potential oral hypofunction when they get older.

The purpose of this observational study was to analyze the data of oral functions (MOF, MTP, and MF) in Eichner A subjects aged from 20 to 49 years retrospectively. Oral functions were evaluated using the method for the diagnosis of oral hypofunction, and the threshold values in this concept were also adopted [8,25]. The hypothesis of this study was that there were some subjects with declined functions even in young adulthood and middle-aged populations with Eichner A dental arches, and there were some factors which affected the impairment of oral functions in this generation.

Materials and Methods

Study subjects and data collection

Study subjects were patients who had visited a private dental clinic in Fukuoka City, Japan from April 2020 to November 2022. Most patients in this clinic were aged less than 50 years old and this study was designed to focus on oral functions in patients aged from 20 to 49 years.
The inclusion criteria were as follows:

1) The patients who were aged from 20 to 49;
2) The patients who had completed dental treatment (dental maintenance was not included);
3) The patients who were classified into Eichner A group. Eichner A was defined as dental arches with occlusal supports in all premolar and molar support zones [26]. In this study, the patients had occlusal supports including pontics without any implant-supported prostheses and/or any removable dental prostheses;
4) The patients whose MOF, MTP, and MF after dental treatment had been evaluated.

The exclusion criteria were as follows:

1) The patients who were not aged from 20 to 49;
2) The patients who were under dental treatment;
3) The patients who were classified into Eichner B, C, or Eichner A group with implant-supported prostheses and/or removable dental prostheses;
4) The patients whose MOF, MTP, and MF had not been evaluated.

Patients' profiles were checked carefully and the patients who met the inclusion criteria were enrolled as subjects. The data of age, sex, remaining teeth for Eichner classification, three oral functions' measurement values, reasons for visiting and the history of dental treatment were extracted from the patients' medical charts.

Measurements of oral functions

Maximum occlusal force (MOF)

MOF was measured using a pressure-sensitive sheet (Dental Prescale II; GC Corp., Tokyo, Japan). The subjects were asked to clench the sheet with maximum force in the intercuspal position for 3 s. The sheets were analyzed with

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the dedicated software (Bite Force Analyzer, GC Corp.) and MOF values were calculated. The threshold value of MOF using this system was 500 N [25].

Maximum tongue pressure (MTP)

MTP was calculated with a specific device (TPM-01, JMS Co., Ltd., Hiroshima, Japan). Briefly, the inflated balloon connected with this device was pressed by the elevation of the forefront of tongue and the pressure was recorded. The threshold value of MTP using this system was 30.0 kPa [8,25].

Masticatory function (MF)

MF was defined by the concentration of glucose in 10 mL of water after voluntary chewing (20 s) of gummy jelly (Glucoram, GC Corp.). The concentration was determined using a specific device (Gluco Sensor GS-II, GC Corp.) and the threshold value of MF using this system was 100 mg/dL [8,25].

Data analyses

First, statistical analysis was performed using the Shapiro-Wilk normality test. The extracted data were described as the mean values and standard deviations (SDs), and/or the median values and interquartile ranges (IQRs), depending on the normality of the distribution. The number of the subjects who did not exceed the threshold value in each oral function was counted. Additionally, the subjects whose multiple oral functions were lower than the threshold values were picked up and the profiles of these subjects were also examined.

Statistical comparisons of each oral function among age groups (20-29, 30-39 and 40-49) were performed (analysis of variance [ANOVA] and/or Kruskal-Wallis test followed by a *post hoc* comparison [Tukey or Steel-Dwass test]). Due to the limited number of subjects, the standardized effect sizes (ESs) were also calculated. In addition, to evaluate the effect of sex on each oral function, the measurement values of respective oral functions were compared between males and females using Student *t* test and/or Welch's test after *F*-test of equality of variances, and/or Wilcoxon rank sum test and ESs were also calculated. Statistical analyses were conducted using JMP Pro 17.0.0 (SAS Institute, Cary, NC, USA). A *P*-value less than 0.05 was considered to be statistically significant.

Results

Subjects' profiles and oral functions

Totally, the number of patients who were enrolled as subjects were 183 (male: 50, female: 133) (Table 1). They visited the clinic due to mild pain attributed to tooth hypersensitivity or caries, dental cleaning, dental check-up, mild periodontal problems, or concern with their appearance (teeth discoloration or poor teeth alignment). Few subjects complained about their oral functions. All subjects could be regarded as systemically healthy, although nine female subjects had taken medication: antiasthmatic (three females), iron preparation (two females), thyroid hormone preparation (two females), antihistamine and hypolipidemic agent (one female, respectively). The distribution of the number of residual teeth was also described and all groups did not show normal distributions ($P < 0.05$, Shapiro-Wilk normality test). Statistical analyses showed that there were no significant differences among the three groups ($P = 0.07$, Kruskal-Wallis test).

All other data showed normality ($P > 0.05$, Shapiro-Wilk normality test) and equal distribution ($P > 0.05$, *F*-test of equality of variances) and were statistically analyzed using parametric methods as described above. The data of oral functions are described in Tables 2-4. The number of the subjects who did not exceed the threshold value of each oral function was also described. The highest number of subjects with lower values than the threshold values was identified in MTP (30, 16.4%: three males and 27 females) (Table 3), followed by MOF (19, 10.4 %: one male and 18 females) (Table 2). Only three showed declined values in MF (1.6 %: three females) (Table 4). The number of the subjects whose two functions were lower than threshold values was nine female subjects: six in MOF and MTP, two in MOF and MF, and one in MTP and MF, respectively. All subjects with lower MF showed another lower value in MOF (two) or MTP (one). No subjects showed declined values in all oral functions.

Table 1 Subjects

Age group	Number (male, female)	Age mean ± SD		Number of residual teeth (IQR)
20-29	58 (11, 47)	total	25.1 ± 2.8	28 (28-28)
		male	25.9 ± 2.8	
		female	25.0 ± 2.8	
30-39	71 (20, 51)	total	33.9 ± 2.7	28 (28-28)
		male	34.5 ± 2.4	
		female	33.7 ± 2.8	
40-49	54 (19, 35)	total	43.5 ± 2.5	28 (27-28)
		male	43.1 ± 2.8	
		female	43.7 ± 2.3	
Total	183 (50, 133)	total	34.0 ± 7.7	28 (28-28)
		male	35.8 ± 7.1	
		female	33.2 ± 7.8	

SD: standard deviation; IQR: interquartile range

Table 2 Data of MOF

Age group (number of subjects)	MOF (N) mean ± SD	Number of subjects lower than threshold value (male, female)	*P*-value (*ANOVA)
Total (183)	1117.5 ± 505.7	19 (1, 18)	
20-29 (58)	1044.1 ± 483.2	9 (1, 8)	$P = 0.32$ (not significant)
30-39 (71)	1179.5 ± 521.4	5 (0, 5)	
40-49 (54)	1114.9 ± 507.1	5 (0, 5)	

MOF: maximum occlusal force; SD: standard deviation; ANOVA: analysis of variance (*comparison among 20-29, 30-39, and 40-49)

Table 3 Data of MTP

Age group (number of subjects)	MTP (kPa) mean ± SD	Number of subjects lower than threshold value (male, female)	*P*-value (*ANOVA)
Total (183)	37.4 ± 8.0	30 (3, 27)	
20-29 (58)	37.5 ± 7.7	8 (1, 7)	$P = 0.94$ (not significant)
30-39 (71)	37.1 ± 8.1	14 (1, 13)	
40-49 (54)	37.6 ± 8.4	8 (1, 7)	

MTP: maximum tongue pressure; SD: standard deviation; ANOVA: analysis of variance (*comparison among 20-29, 30-39, and 40-49)

Table 4 Data of MF

Age group (number of subjects)	MF (mg/dL) mean ± SD	Number of subjects lower than threshold value (male, female)	*P*-value (*ANOVA)
Total (183)	249.1 ± 70.9	3 (0, 3)	
20-29 (58)	230.9 ± 66.4	2 (0, 2)	$P = 0.06$ (not significant)
30-39 (71)	255.7 ± 78.4	1 (0, 1)	
40-49 (54)	259.7 ± 62.5	0 (0, 0)	

MF: masticatory function; SD: standard deviation; ANOVA: analysis of variance (*comparison among 20-29, 30-39, and 40-49)

Table 5 Comparisons of three oral functions between males and females

Oral function	Male (50 subjects) mean ± SD	Female (133 subjects) mean ± SD	*P*-value (student *t* test)
MOF (N)	1444.9 ± 471.0	994.4 ± 463.1	$P < 0.01$ (r = 0.40)
MTP (kPa)	42.0 ± 7.7	35.7 ± 7.5	$P < 0.01$ (r = 0.34)
MF (mg/dL)	278.2 ± 67.0	238.1 ± 69.5	$P < 0.01$ (r = 0.26)

SD: standard deviation; MOF: maximum occlusal force; MTP: maximum tongue pressure; MF: masticatory function; r: effect size

The effect of age and sex on each oral function

Each oral function was statistically compared among the three generations (20-29, 30-39, and 40-49) (Tables 2-4) and between males and females (Table 5). The statistical analyses showed that there were no significant differences among the three generations in all functions ($P > 0.05$, ANOVA). It was confirmed that there were no significant differences among the three groups in all oral functions. Although a limited number of subjects and the differences between the number of males and females were confirmed, all functions in males were significantly higher than those in females in this study. The calculation of ESs revealed that moderate effects were found in MOF and MTP, although a small effect was found in MF (Table 5).

Table 6 Profiles of the subjects with lower values than the thresholds in two oral functions

Declined functions	Age	MOF (N)	MTP (kPa)	MF (mg/dL)	RFV	OT
MOF and MTP	22	368.6	21.4	323.0	dental check-up	post-OT
	24	470.6	18.6	142.0	small caries	no OT
	27	297.1	29.1	136.0	dental check-up	post-OT
	30	442.8	24.9	199.0	discoloration	post-OT
	42	455.6	26.7	154.0	hypersensitivity	post-OT
	43	362.9	23.3	257.0	caries	post-OT
MOF and MF	20	171.9	44.5	99.0	dental check-up	post-OT
	21	134.6	42.5	96.0	esthetic concern (DA)	pre-OT
MTP and MF	36	561.7	27.4	92.0	esthetic concern (DA)	pre-OT

MOF: maximum occlusal force; MTP: maximum tongue pressure; MF: masticatory function; RFV: a reason for visit; DA: dental arch; OT: orthodontic treatment

Features of subjects with declined oral functions

Totally, the number of subjects who presented with declined oral functions in at least one function was 43 (four males and 39 females) in this study, and nine females showed declined values in two functions (Table 6). As mentioned above, no subjects complained about any problems in their oral functions subjectively. All three subjects with lower MF showed another lower function (two in MOF and one in MTP). No subjects with lower values in all three functions were identified. Their profiles (age, the measurement values of their oral functions, reason of visit, and the associations with orthodontic treatment) were shown in Table 6. Six of them had completed their orthodontic treatment (post-orthodontic treatment) and two were considering orthodontic treatment (pre-orthodontic treatment).

Discussion

The critical roles of oral functions in systemic conditions have been recognized widely [1,2,6,7]. Since the concept of oral hypofunction was proposed in 2018 [8], the measurements of oral functions have been conducted proactively and studies which included the term “oral hypofunction” in the titles have been increasing [9-12]. However, most of these studies evaluated oral functions in the elderly population. Decline or deterioration of oral functions are generally attributed to aging, dental or oral diseases and inadequate dental treatment and management. Meanwhile, maxillofacial and dental development in childhood and adolescence are associated with oral functions in younger generations and will affect their oral functions in the future (adulthood). In other words, oral functions should be observed and managed throughout the life course. However, detailed investigations of oral functions in young adulthood and middle-aged population have been lacking compared to childhood, adolescence, and elderly. This study aimed to evaluate and analyze oral functions in these generations and to investigate factors related to declined oral functions.

Most of the patients in the dental clinic in this study were younger patients, aged from 20 to 49 years, which made it a favorable situation to analyze oral functions in these generations. Therefore, this study focused on three major oral functions, MOF, MTP and MF in the subjects aged from 20 to 49 years, and these oral functions were measured using the methods to diagnose “oral hypofunction” [8,25]. These methods were appropriate in this study because the threshold values were set clearly, although these values were usually adopted in the elderly population [8,25]. Whereas the mean value of each oral function in this study was higher than the threshold value, some subjects showed lower values than the threshold values. Interestingly, the number of subjects who showed lower MTP values was 30 (16.4%: three males and 27 females), the greatest number in the three functions, followed by MOF (19, 10.4 %: one male and 18 females). The number of subjects with lower MF was only three (1.6 %: three females). These results suggested that some subjects in young adulthood and middle-aged population with Eichner A dentitions might show lower oral functions, especially MTP, although lower MF population was considerably limited.

In this study, the study subjects were limited to Eichner A patients without any implant-supported prostheses and/or any removable dental prostheses. It is well-known that tooth loss and occlusal supports are associated with oral functions [10,13,14], and Eichner B and C patients who had been rehabilitated with some dental prostheses might present a wide variety of oral conditions depending on their teeth location, occlusal status, and dental prostheses. It was considered that the exclusion of these factors would be reasonable for analyses. In addition, the patients who visited this dental clinic (research institution) were mostly classified into Eichner A, especially in the younger generation. They visited the clinic due to tooth hypersensitivity, caries, dental cleaning, dental check-up, mild periodontal problems, or concern with their appearance including orthodontic problems. Whereas nine female subjects had taken medication, these medications did not prevent any dental interventions and suggested that most of the candidates could be assumed to be healthy and this limitation was adopted as one of the inclusion criteria to make the analyses convenient in all subjects. Although it was understandable that the data from only Eichner A patients could be a limitation of this study, it should be noted that it is meaningful to delete diversity in oral and dental status or potential influential factors for the analyses in these populations.

Regarding MOF and MTP, both functions were closely associated with some perioral muscles [8,27-29]. The development of these muscles in childhood, and sex differences are also associated with MOF and MTP in these generations [17,30,31]. This study compared MOF and MTP among three generations and between males and females. Based on previous studies, the hypotheses in this study were that there were no significant differences among these generations in these three oral functions [16,18,19]. The present study found that no effects of age on these oral functions were identified. The potential reasons were the limitations of the subjects in this study, which were the patients aged from 20 to 49 and Eichner A patients, meaning that they were younger and had healthy oral conditions compared to previous studies [9-19]. Previous studies suggested that the declines of these oral functions were identified in the subjects older than 60 or 70 years [16,18,19]. However, as this study presented, some younger subjects showed lower values than the thresholds in MOF (19 subjects, <500 N) and MTP (30 subjects, <30 kPa), and some factors such as maxillofacial and dental development, lifestyles and unfavorable habits in childhood and adolescence might be associated. Future studies are needed to examine these associations longitudinally. In the analyses of MF, previous studies showed the significant associations of MF with MOF, MTP and the number of residual teeth [13,14] and MF were generally regulated by multiple factors [8,13,14,18]. Previous studies reported that the values of MF tend to be maintained regardless of aging compared to other functions [10,16,18] and the present study showed a similar result. As described above, the inclusion criteria in this study which limited Eichner A patients aged from 20 to 49 years might be related to this result.

This study also evaluated the differences of three oral functions between males and females statistically. All oral functions in males were significantly higher than those in females, although ESs were moderate in MOF and MTP, and small in MF. The subjects were Eichner A patients and systemically healthy, and the hypotheses were that there were limited differences between males and females. As described, the values of these oral functions were associated with perioral muscle strength [8,27-29]. The previous study showed that some oral functions in males were significantly higher than those in females [17]. Previous studies analyzed oral functions in elderly patients, and the dental arches were various [9-19]. The subjects in this study were limited to Eichner A patients, meaning similar dental arches, and significant differences were identified in the three oral functions. Based on previous reports [8,27-29], the differences of perioral muscle strength might be related to these results. Previous studies reported the associations of muscle strength including grip strength, and systemic condition including body mass index with oral functions [13,14], and further studies to investigate the associations of these factors with oral functions in males and females. Additionally, this study could not compare the three oral functions between similar numbers of males and females, and ESs were smaller than expected. This is a limitation of this study, although multiple studies were reported using fewer males and more females [9-14,16-23]. A study using a nearly equal number of male and female subjects is required.

This study found nine female subjects who showed lower measurement values in two oral functions. As described above, it was assumed that maxillofacial and dental development in childhood was associated with declined functions in younger generation. The previous review suggested the association between primary development and malocclusion [32], and in this study, the history of orthodontic treatment was also evaluated. Totally, the number of subjects who completed or were considering orthodontic treatment were 17 or 11 respectively. Interestingly, of nine

female subjects with declined functions, six completed orthodontic treatment and two were considering treatment. In addition, another three (one male and two female) and one female who completed orthodontic treatment showed lower MTP and MOF, and four female subjects who were considering orthodontic treatment showed lower values in one function (two in MOF and two in MTP). The effects of malalignment, malocclusion and orthodontic treatment on oral functions are still lacking, although there were some previous studies that analyzed oral functions before and after orthodontic treatment [33-36]. Unfortunately, in this study, it was impossible to compare these oral functions between before and after orthodontic treatment because they were not recorded, and most of the subjects who were associated with orthodontic treatment showed normal oral functions. One narrative review that noted oral dysfunction as a cause of malocclusion was found [37]. And it was suggested that the subjects might have lower values in these oral functions before orthodontic treatment. Although some previous studies reported that orthodontic treatment could improve some functions [33-36], few studies proposed the necessity for oral rehabilitation based on the threshold values. Even though the concept of oral hypofunction was basically proposed to evaluate seven oral functions in the elderly population mainly [8,25], it would be necessary to evaluate these oral functions, and if necessary, oral rehabilitation to enhance their oral functions would be expected. Although this study could not show any associations between malalignment, malocclusion or orthodontic treatment and oral functions, it would be meaningful to propose this clinical question. Longitudinal studies with orthodontists would be favorable to analyze these oral functions before and after orthodontic treatment.

Lastly, the additional limitations of this study and future perspectives should be presented. As described above, this study enrolled subjects using strict inclusion criteria (Eichner A patients without any implants). This dental status meant healthy patients. Although there were some studies that analyzed oral functions in various generations [16-19], few studies compared oral functions among multiple generations with various dental and oral status. Especially, few studies compared oral functions among middle-aged populations with various dental and oral status. The dental and oral status in middle-aged population can directly influence oral conditions in the elderly population, although such studies are still lacking. This study evaluated oral functions in multiple generations with healthy dental arches, but the necessity for a longitudinal study was considered to elucidate the process of decline of oral functions. Furthermore, oral functions in the patients with or without malalignment, malocclusion or orthodontic treatment, and the effects of these interventions on oral functions should be examined and it would be better to suggest the interventions to improve oral functions, especially in the younger generation.

Ethical Statements

Ethical approval for this study was obtained from the institutional review board for clinical research in Kyushu University (approval number: 22214-01). This study was conducted in accordance with Declaration of Helsinki and Strengthening the Reporting of Observational Studies in Epidemiology (STROBE).

Conflicts of Interest

The authors have no conflicts of interest to declare.

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References

1. Iwasaki M, Hirano H, Motokawa K, Shirobe M, Edahiro A, Ohara Y et al. (2021) Interrelationships among whole-body skeletal muscle mass, masseter muscle mass, oral function, and dentition status in older Japanese adults. BMC Geriatr 21, 582.
2. Nishi T, Ohta M, Takano T, Ogami K, Ueda T, Sakurai K (2022) Oral function is associated with the body and muscle mass indices of middle-aged dental patients. Clin Exp Dent Res 8, 217-224.
3. Gerritsen AE, Allen PF, Witter DJ, Bronkhorst EM, Creugers NH (2010) Tooth loss and oral health-related quality of life: a systematic review and meta-analysis. Health Qual Life Outcomes 8, 126.
4. Nishi K, Kanouchi H, Tanaka A, Nakamura M, Hamada T, Mishima Y et al. (2021) Relationship between Oral Hypofunction, and Protein Intake: a cross-sectional study in local community-dwelling adults. Nutrients 13, 4377.
5. Su N, van Wijk A, Visscher CM (2021) Psychosocial oral health-related quality of life impact: a systematic review. J Oral Rehabil 48, 282-292.
6. Nakamura T, Zou K, Shibuya Y, Michikawa M (2021) Oral dysfunctions and cognitive impairment/dementia. J Neurosci Res 99, 518-528.
7. Galindo-Moreno P, Lopez-Chaichio L, Padial-Molina M, Avila-Ortiz G, O'Valle F, Ravida A et al. (2022) The impact of tooth loss on cognitive function. Clin Oral Investig 26, 3493-3500.
8. Minakuchi S, Tsuga K, Ikebe K, Ueda T, Tamura F, Nagao K et al. (2018) Oral hypofunction in the older population: Position paper of the Japanese Society of Gerodontology in 2016. Gerodontology 35, 317-324.
9. Nakamura M, Hamada T, Tanaka A, Nishi K, Kume K, Goto Y et al. (2021) Association of oral hypofunction with frailty, sarcopenia, and mild cognitive impairment: a cross-sectional study of community-dwelling Japanese older adults. J Clin Med 10, 1626.
10. Onuki W, Magara J, Tsujimura T, Ito K, Sakai H, Kulvanich S et al. (2021) Survey of oral hypofunction in older outpatients at a dental hospital. J Oral Rehabil 48, 1173-1182.
11. Yoshida M, Hiraoka A, Takeda C, Mori T, Maruyama M, Yoshikawa M at al. (2022) Oral hypofunction and its relation to frailty and sarcopenia in community-dwelling older people. Gerodontology 39, 26-32.
12. Onuki W, Magara J, Ito K, Ita R, Kawada S, Tsutsui Y et al. (2023) Evaluating the effect of management on patients with oral hypofunction: a longitudinal study. Gerodontology 40, 308-316.
13. Morita K, Tsuka H, Kato K, Mori T, Nishimura R, Yoshida M et al. (2018) Factors related to masticatory performance in healthy elderly individuals. J Prosthodont Res 62, 432-435.
14. Maruyama M, Morita K, Kimura H, Nishio F, Yoshida M, Tsuga K (2020) Association between masticatory ability and oral functions. J Clin Exp Dent 12, e1011-e1014.
15. Nishizaki H, Iida T, Tanaka Y, Morimoto Y, Hayashi M, Mikuzuki L et al. (2022) Effect of masticatory training using confectioneries on oral function in elderly patients – a randomized controlled trial. J Dent Sci 17, 1480-1486.
16. Iyota K, Mizutani S, Oku S, Asao M, Futatsuki T, Inoue R et al. (2020) A cross-sectional study of age-related changes in oral function in healthy Japanese individuals. Int J Environ Res Public Health 17, 1376.
17. Kim S, Doh RM, Yoo L, Jeong SA, Jung BY (2021) Assessment of age-related changes on masticatory function in a population with normal dentition. Int J Environ Res Public Health 18, 6899.
18. Hatanaka Y, Furuya J, Sato Y, Uchida Y, Shichita T, Kitagawa N et al. (2021) Associations between oral hypofunction tests, age, and sex. Int J Environ Res Public Health 18, 10256.
19. Shiga H, Komino M, Yokoyama M, Sano M, Arakawa I, Nakajima K et al. (2023) Relationship between age and occlusal force in adults with natural dentition. Odontology 111, 487-492.
20. Taylor KR, Kiyak A, Huang GJ, Greenlee GM, Jolley CJ, King GJ (2009) Effects of malocclusion and its treatment on the quality of life of adolescents. Am J Orthod Dentofacial Orthop 136, 382-392.
21. Kim SY, Kim JE, Kim HN, Jun EJ, Lee JH, Kim JS et al. (2018) Association of self-perceived oral health and function with clinically determined oral health status among adults aged 35-54 years: A cross-sectional study. Int J Environ Res Public Health 15, 1681.
22. Sörensen C, Lemberger M, Larsson P, Pegelow M (2022) Comparing oral health-related quality of life, oral function and orofacial aesthetics among a group of adolescents with and without malocclusions. Acta Odontol Scand 80, 99-104.
23. Nakata H, Masaki Y, Watanabe Y, Ohkubo M, Sugiyama T, Kobayashi K (2022) Relationship between knowledge and attitude toward oral function in middle-aged and older adults. Int J Dent 2022, 3503644.
24. Hama Y, Hosoda A, Kubota C, Guo R, Soeda H, Yamaguchi K et al. (2023) Factors related to masticatory performance in junior and senior high school students and young adults: a cross-sectional study. J Prosthodont Res 67, 424-429.
25. Iwasaki M, Hirano H (2022) Decline in oral function and its management. Int Dent J. 72, S12-S20.
26. Murata T, Arai K, Kashiwagi K, Baba S (2020) Relationship between the number of occlusal supporting and medical cost: analysis using large claims database from employee health care insurance in Japan. J Health Econ Outcomes Res. 24, 1-9.
27. Nakamori M, Imamura E, Fukuta M, Tachiyama K, Kamimura T, Hayashi Y et al. (2020) Tongue thickness measured by ultrasonography is associated with tongue pressure in the Japanese elderly. PLoS One 15, e0230224.
28. Namiki C, Hara K, Yanagida R, Nakagawa K, Yamaguchi K, Okumura T et al. (2022) Association between tongue pressure and jaw-opening force in older adults. Int J Environ Res Public Health 19, 9825.
29. Niwa K, Takahashi N (2023) Elucidation of the relationship between masticatory muscle activity and masticatory movement. Report 1. Mechanism of occlusal force generation. Clin Exp Dent Res 9, 472-480.
30. Usui T, Uematsu S, Kanegae H, Morimoto T, Kurihara S (2007) Change in maximum occlusal force in association with maxillofacial growth. Orthod Craniofac Res 10, 226-234.
31. Fujita Y, Maki K (2018) Association of feeding behavior with jaw bone metabolism and tongue pressure. Jpn Dent Sci Rev 54, 174-182.
32. Vig KW, Fields HW (2000) Facial growth and management of orthodontic problems. Pediatr Clin North Am 47, 1085-1123.
33. Sultana MH, Yamada K, Hanada K (2002) Changes in occlusal force and occlusal contact area after active orthodontic treatment: a pilot study using pressure-sensitive sheets. J Oral Rehabil 29, 484-491.
34. Ngom PI, Diagne F, Aïdara-Tamba AW, Sene A (2007) Relationship between orthodontic anomalies and masticatory function in adults. Am J Orthod Dentofacial Orthop 131, 216-222.
35. Lambrechts H, De Baets E, Fieuws S, Willems G (2010) Lip and tongue pressure in orthodontic patients. Eur J Orthod 32, 466-471.
36. Zanon G, Contardo L, Reda B (2022) The impact of orthodontic treatment on masticatory performance: a literature review. Cureus 14, e30453.
37. D'Onofrio L (2019) Oral dysfunction as a cause of malocclusion. Orthod Craniofac Res 22 Suppl 1, 43-48.