Original Article

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Subjective and objective masticatory function and their associated factors in complete denture wearers

Kanokporn Wongcharee[1], Chaivut Prunkgnamphan[2], Rajda Chaichit[3], Jarin Paphangkorakit[4]

[1] *Residency Training Program in Prosthodontics, Faculty of Dentistry, Khon Kaen University, Thailand*
[2] *Department of Prosthodontics, Faculty of Dentistry, Khon Kaen University, Thailand*
[3] *Department of Preventive Dentistry, Faculty of Dentistry, Khon Kaen University, Thailand*
[4] *Department of Oral Biomedical Science, Faculty of Dentistry, Khon Kaen University, Thailand*

Objective: The agreement between subjective and objective assessments of masticatory function in complete denture patients remains controversial, thereby complicating the selection of the appropriate assessment tool. The present study aimed to re-examine their association and factors related to both assessments.

Materials and Methods: Thirty-three complete denture patients, having regularly worn complete dentures for up to 10 years, were recruited. Years of usage, Functional Assessment of Dentures (FAD), chewing ability (using a 9-item questionnaire), masticatory performance (5-color scale and ΔE using color-changeable chewing gum), maximum bite force (MBF), area of occlusal contact and near contact (ACNC), Oral Impact on Daily Performance (OIDP), and Mini Nutritional Assessment (MNA) were also determined for each patient. Any associations between years of usage and the above variables, between chewing ability and masticatory performance, and between any two variables were analyzed using Spearman rank correlation.

Results: Years of usage was significantly correlated with ACNC (rho = 0.50) but not with chewing ability and masticatory performance. Masticatory performance (ΔE) was positively correlated with MBF (rho = 0.55; $p = 0.001$) and ACNC (rho = 0.39; $p = 0.025$) whereas chewing ability was inversely correlated with OIDP (rho = -0.49; $p = 0.003$) and positively correlated with MNA (rho = 0.34; $p = 0.05$). Chewing ability was not correlated with masticatory performance.

Conclusion: While the objective masticatory assessment was associated with MBF and ACNC, the subjective assessment was associated with the quality of life and nutritional status of the patients. With some limitations in the present study, the agreement between subjective and objective masticatory function could not be demonstrated in complete denture wearers.

Keywords: aging, complete denture, mastication, objective assessment, quality of life, subjective assessment.

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Introduction

Despite modern dental technologies available for treating fully edentate patients, complete dentures are still widely prescribed worldwide, especially in low to middle-income countries. Regaining masticatory function is one of the most important requirements of complete dentures. The evaluation of masticatory function can be conducted using both subjective and objective methods. Subjective assessment, often referred to as 'chewing ability', utilizes questionnaires either concerning chewing difficulty of various food items or chewing satisfaction perceived by the subject. Objective assessment or 'masticatory performance' is based on the actual measurement of food particle size, the mixing of two-colored chewing gum or the color change using color-changeable chewing gum [1]. The agreement between both assessments in complete denture wearers has been inconsistent. Hirai *et al.* [2]

Corresponding author: Jarin Paphangkorakit
Division of Oral Biology, Department of Oral Biomedical Science, Faculty of Dentistry, Khon Kaen University
123 Mittraphap Rd., Muang, Khon Kaen 40002, Thailand
Tel: +668 1717 3515 Email: jarin@kku.ac.th
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and Limpuangthip *et al.* [3] found a significant relationship between the results from a questionnaire used to evaluate chewing quality and masticatory performance. On the other hand, many studies did not demonstrate such correlations [4, 5]. The discrepancy was presumably due to the types of questionnaires used, whether food chewing difficulty [2], oral impact on eating [3], or chewing satisfaction [6, 7] being assessed. Masticatory performance has been shown to decrease whereas chewing ability increases 3 months after the replacement of old dentures [8], indicating that although the new dentures were well accepted, patients required more time to effectively use them to comminute foods.

Factors associated with both masticatory assessment methods could also be different. Occlusal contact area and maximum bite force (MBF) have been shown to be associated with masticatory performance [9, 10] but very few studies have investigated the direct association between these occlusal factors and chewing ability [11]. Regarding the effect on general health, correlations between the loss of occluding teeth and reduced oral-health related quality of life have been consistently demonstrated [3, 12, 13], indicating that both masticatory performance and chewing ability could affect the quality of life. The correlation between masticatory function and nutritional status, on the other hand, seems inconclusive [14, 15], possibly due to other factors acting as confounders in food choice.

The present study primarily aimed to comprehensively investigate factors associated with masticatory performance and chewing ability, specifically subjective (quality of life) and objective determinants (years of usage, MBF, occlusal contact area), and secondarily assess the association between masticatory performance and chewing ability in a group of Thai complete denture patients. The understanding could assist the selection of methods used to assess masticatory function in dental practice.

Materials and Methods

This cross-sectional study was approved by the Center for Ethics in Human Research, Khon Kaen University (HE642113). Two-hundred and fifty patients treated with complete dentures from the Department of Prosthodontics, Faculty of Dentistry, Khon Kaen University between 2015-2021, were contacted by phone, of which 33 patients were willing to participate in the study, partly due to health concerns during the post-COVID-19 period. All patients were previously treated by undergraduate dental students under the supervision of certified prosthodontists. The inclusion criteria were those who (a) regularly used the same set of dentures for at least 5 days a week for no more than 10 years until the day of the examination, (b) did not have any airborne transmitted diseases, (c) were not allergic to chewing gum, (d) had no pain during mastication and swallowing, and (e) had no oral lesions (except those caused by the use of dentures) during the past 2 weeks. Years of denture usage were categorized in round numbers, i.e. 1 year (0.5-1.4 years), 2 years (1.5-2.4 years), 3 years (2.5-3.4 years), 4 years (3.5-4.4 years) and 5 years (4.5-5.4 years). Those who wore their dentures for more than 5.4 years were grouped as one, i.e. 6-10 years, due to the small number of patients.

Data collection was performed using questionnaires including assessments of (a) denture quality using FAD (Functional Assessment of Dentures) index [16] encompassing the assessment of occlusion, denture adherence and stability (full score of 10), (b) the quality of life using the Oral Impact on Daily Performance (OIDP) in which physical, psychological and social impacts related to oral health were assessed (full score of 200), (c) chewing ability using a questionnaire modified from Peršić *et al.* [17]

and Hirai *et al* [2] to suit Thai patients (Figure 1) (full score of 5) and (d) nutritional level using the Mini Nutritional Assessment (MNA) (cut-off point at 17). In addition, masticatory performance was assessed using a color-changeable chewing gum (Xylitol®, Lotte, Tokyo, Japan), chewed for 80 cycles habitually. The chewed gum was pressed into a 2-mm thick sheet and the change in color was determined both using a colorimeter (NR110/3NH, Shenzhen 3NH Technology, China) and a 5-color shade scale. The area of occlusal contact and near contact (ACNC) was measured by asking the patient to clench firmly on the occlusal recording material (O-Bite®, DMG, USA) after which the impression was photographed on a view box (Cannon, EOS REBEL T7i/ EOS 800D, Thailand). The images were imported and the area of light transmitted region was measured using ImageJ (version 1.46r). Reference thicknesses of 50, 100, 150, 200, 250, 300, and 350 microns were fabricated from the same material and the summed area of these thicknesses on the bite record was used to determine ACNC. Finally, the maximum bite force (MBF) was recorded by asking the patients to bite as hard as possible for 3 seconds on the Occlusal Force-Meter (GM-10®, Nagano Keiki, Tokyo, Japan) placed between the upper and lower molar teeth on the preferred chewing side while the other side of the jaw was stabilized with a silicone jig to prevent the dislodgement of the denture similar to Shala *et al*. [18]. The measurement was repeated 3 times with 1-minute resting periods in between and the maximum value was used as MBF.

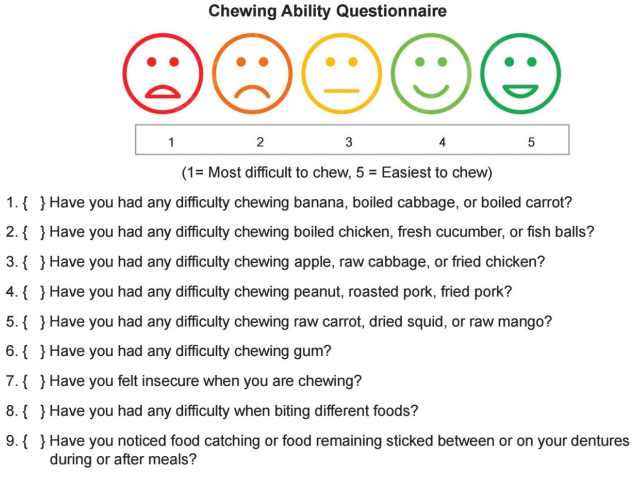


Figure 1 The questionnaire used to assess chewing ability in the present study (conducted in Thai language), adapted from Hirai *et al* [1] and Persic *et al*. [22]

Statistical analysis

Medians and interquartile ranges of all variables were described for years 1, 2, 3, 4, 5, and years 6-10 whereas means and standard deviations were described for the whole subjects. The correlations between all study variables and years of usage, between chewing ability and masticatory performance, and between any two variables were tested with Spearman rank correlation (SPSS version 21.0) with a statistical significance level of 0.05.

Results

Among 33 patients, 27 (81.8%) had been wearing the denture for less than 5 years. The mean duration of denture usage among our samples was 3.7 ± 2.0 years. Mean FAD, OIDP, and MNA scores were 5.6 ± 2.4, 3.2 ± 7.3, and 26.2 ± 2.7 respectively. 54.5% of the patients reported their dentures were asymptomatic. Intact denture, normal soft tissue, and good denture adaptability were seen in 75.8%, 90.9%, and 45.5% of the patients respectively. The mean chewing ability score was 4.5 ± 0.7 whereas masticatory performance (ΔE), masticatory performance (5-color scale), MBF, and ACNC were 41.7 ± 10.1, 3.3 ± 0.9, 117.6 ± 73.0 N, and 145.8 ± 67.6 mm^2 respectively. The descriptive values of each variable by year are presented in Table 1.

Table 1 Medians and interquartile ranges (in brackets) of study variables, organized by years of usage, in complete denture wearers

Variables \ Years of usage	1 year (n=6)	2 years (n=5)	3 years (n=5)	4 years (n=5)	5 years (n=6)	6-10 years (n=6)	Grand mean
1. Age	69.0 (59.5 - 76.5)	65.0 (61.0 - 66.5)	70.0 (66.0 - 77.0)	72.0 (62.0 - 77.5)	74.5 (67.0 - 80.5)	72.5 (64.25 - 84.5)	70.4 ± 8.2
2. FAD	3.5 (2.75 - 7.75)	7.0 (7.0 - 8.5)	7.0 (5.0 - 8.0)	5.0 (3.5 - 5.5)	4.5 (2.75 - 8.0)	5.0 (3.25 - 8.50)	5.6 ± 2.4
3. OIDP	0 (0 - 8)	0 (0 - 0)	0 (0 - 0)	0 (0 - 12.5)	0 (0 - 11.75)	2.5 (0 - 8.0)	3.2 ± 7.3
4. MNA	26.5 (22.4 - 27.4)	27.5 (27.3 - 29.0)	27.0 (24.5 - 28.3)	27.0 (25.8 - 27.8)	27.0 (21.8 - 28.6)	25.0 (21.5 - 28.6)	26.2 ± 2.7
5. ACNC (mm^2) *	95.8 (65.0 - 137.9)	120.2 (107.0 - 145.4)	173.3 (112.2 - 209.8)	130.8 (21.3 - 182.8)	178.8 (147.8 - 218.7)	191.6 (120.7 - 247.2)	145.8 ± 67.6
6. MBF (N)	94.5 (65.8 - 143.5)	145.0 (76.5 - 184.0)	74.0 (63.5 - 236.0)	67.0 (41.5-156.0)	108.50 (63.0 - 143.5)	114.0 (49.5 - 195.8)	117.6 ± 73.0
7. Chewing ability	4.4 (3.6 - 4.7)	5.0 (4.9 - 5.0)	4.8 (4.0 - 4.8)	4.9 (3.5 - 4.9)	4.7 (4.3 - 4.8)	4.6 (4.2 - 4.9)	4.5 ± 0.7
8. Performance (ΔE)	47.1 (40.5 - 51.7)	42.4 (31.8 - 45.9)	46.3 (38.7 - 48.8)	40.4 (24.7 - 46.7)	46.5 (38.9 - 50.0)	41.3 (24.9 - 50.7)	41.7 ± 10.1
9. Performance (5-color)	3.3 (2.4 - 4.6)	3.0 (2.5 - 3.5)	3.0 (2.8 - 4.0)	2.5 (1.8 - 3.3)	3.5 (3.3 - 4.0)	3.0 (2.1 - 3.5)	3.1 ± 0.9

FAD = Functional Assessment of Dentures index, OIDP = Oral Impacts on Daily Performance, MNA = Mini Nutritional Assessment, ACNC = Area of occlusal contact and near contact, MBF = Maximum bite force, Performance (ΔE) = Masticatory performance as measured by color-changeable chewing gum using a colorimeter, Performance (5-color) = Masticatory performance as measured by color changeable chewing gum using a 5-color shade scale

* Significant correlation with years of usage (rho = 0.50, $p = 0.003$)

Bivariate analyses showed that years of usage were significantly correlated with ACNC (rho = 0.50, p = 0.003). When the correlations between masticatory function and all variables were tested, it was found that chewing ability was significantly inversely correlated with OIDP (rho = -0.49, p = 0.003) and positively correlated with MNA (rho = 0.34; p = 0.05), whereas masticatory performance was significantly correlated with MBF (rho = 0.55, p = 0.001) and ACNC (rho = 0.39, p = 0.025), but not with OIDP. Furthermore, OIDP was inversely correlated with FAD (rho = -0.40, p = 0.023) and MNA scores (rho = -0.49, p= 0.004). Chewing ability was not significantly correlated with masticatory performance, either assessed by the 5-color scale or ΔE (Table 2).

Discussion

Some values of parameters studied in the present study were comparable to those in previous reports. The mean FAD score of 5.6 ± 2.4 indicated that complete dentures worn by our patients were in relatively good condition, similar to the value of 5.7 reported by Cerutti-Kopplin *et al.* [19]. This could be partly attributed to the fact that these dentures were fabricated in a dental school setup. The low mean OIDP score of 3.2 ± 7.3 which indicated that patients had a low impact on their daily life appeared to be consistent with the denture quality. The value was lower than the mean value of 17.6 in community-dwelling elderly whose occlusion was categorized as Eichner group C (with no occluding pairs of teeth) [20]. The mean MNA of 26.2 ± 2.7 also indicated good nutritional status, comparable to the mean value of 25.9 ± 2.9 for a group of complete denture wearers (31 women and 16 men, mean age 70.1 ± 8.1) treated in a dental hospital [21]. The mean chewing ability score of 4.5 ± 0.7 (out of 5) indicated that patients were quite satisfied with their dentures. This seemed to be in accordance with the mean masticatory performance (ΔE) of 41.7 ± 10.1 (out of 70) [22]. The mean ΔE in our patients was similar to the value of 41.8 in a group of the elderly with a mean age of 75.4 years reported by Kugimiya *et al*. [23] The masticatory performance, determined by the 5-color scale, of 3.1 ± 0.9 was also comparable to the values of 3.5 - 3.8 in the elderly wearing complete dentures in a Japanese survey [24], though slightly lower. Mean MBF was 117.6 ± 73.0 N which was comparable to the range of 77 - 135 N previously reported [25] and also to the mean value of 13.11 kgF reported by Moura *et al.* [26]. The relatively good masticatory function in our patients could also be explained by the fact that most of the patients (81.8%) were those who have worn dentures for less than 5 years, as recommended for functional dentures by the American College of Prosthodontists (ACP) [27]. Mean ACNC in the present study of 145.8 ± 67.6 mm^2 on both sides of the jaw was relatively small compared to that in dentate subjects reported by Owens *et al.* [28] (177.6 ± 18.4 mm^2 on the left and 179.8 ± 21.5 mm^2 on the right side). Since the percentages of patients with intact dentures, normal soft tissue, and good denture adaptability were different from the percentage of asymptomatic patients, combined rather than individual factors probably explained the symptoms associated with their dentures.

Among all variables tested, only ACNC was significantly associated with years of denture usage, showing an increase over time. This finding aligned with previous studies showing greater wear, including occlusal wear, in dentures worn for a long time, depending on materials used [29].

Table 2 Correlation coefficients and *p*-values (in brackets) obtained from the bivariate analysis of all study variables (n = 33)

	Years of usage	FAD	OIDP	MNA	ACNC	MBF	Chewing ability	Performance (ΔE)	Performance (5-color)
Years of usage	1								
FAD	-0.09	1							
	(0.61)								
OIDP	0.23	-0.40	1						
	(0.21)	*(0.02)**							
MNA	-0.06	0.03	-0.49	1					
	(0.73)	*(0.85)*	*(0.004)**						
ACNC	0.50	0.15	0.11	-0.13	1				
	*(0.003)**	*(0.39)*	*(0.55)*	*(0.46)*					
MBF	-0.04	0.24	-0.01	0.13	0.60	1			
	(0.84)	*(0.19)*	*(0.97)*	*(0.46)*	*(0.001)**				
Chewing ability	-0.01	0.32	-0.49	0.34	-0.05	0.04	1		
	(0.97)	*(0.07)*	*(0.003)**	*(0.05)**	*(0.80)*	*(0.82)*			
Performance (ΔE)	-0.12	0.05	-0.08	0.05	0.39	0.55	-0.06	1	
	(0.51)	*(0.78)*	*(0.67)*	*(0.76)*	*(0.025)**	*(0.001)**	*(0.73)*		
Performance (5-color)	-0.08	0.01	0.02	-0.11	0.35	0.31	-0.12	0.70	1
	(0.66)	*(0.98)*	*(0.90)*	*(0.56)*	*(0.048)**	*(0.08)*	*(0.50)*	*(0.001)**	

FAD = Functional Assessment of Dentures index, OIDP = Oral Impacts on Daily Performance, MNA = Mini Nutritional Assessment, ACNC = Area of occlusal contact and near contact, MBF = Maximum bite force, Performance (ΔE) = Masticatory performance as measured by color-changeable chewing gum using a colorimeter, Performance (5-color) = Masticatory performance measured by color changeable chewing gum using a 5-color shade scale

* Statistically significant at $p = 0.05$

The rate of wear could not be determined in the present study due to its cross-sectional design but the significant correlation even in the independent group of patients suggested a strong link between the two variables. The increased ACNC is presumably due to the occlusal wear of denture teeth over time. Nevertheless, it might be premature to suggest when a denture needs to be replaced since the extent of wear that would affect jaw functions is not known. It would therefore be interesting to further investigate when such wear would negatively affect jaw functions as well as the occlusal vertical dimension of the patients. On the other hand, chewing ability, masticatory performance, and MBF were not correlated with years of usage. Such an insignificant association could be attributed to the small sample size and the patients' adaptation to the denture. A previous study showed that MBF tended to decrease with the initial replacement of complete dentures but increased after 6 months [30]. Similarly, Garrett *et al*. evaluated the masticatory performance in patients with complete dentures 3 months after using a new denture and found that their satisfaction increased, whereas masticatory performance (assessed by the sieving method) tended to decrease [8]. These seemed to support a different time-dependent nature of both assessments. In addition, the lack of association between ODIP and years of usage found in this study could be explained by differences in satisfaction levels with dentures. Those who were highly satisfied were likely to show greater improvement in terms of their quality of life [31]. The negative correlation between FAD and OIDP shown in the present study seems to support the significant association between denture quality and functional outcomes, such as eating difficulties or food choices [16, 32].

Masticatory performance was not significantly correlated with chewing ability in the present study. Until now, the association between subjective and objective assessments of masticatory function remains inconclusive. A strong positive correlation between subjective and objective assessments using the mixing ability of two-colored chewing gum was reported in the elderly with natural teeth or fixed partial dentures [33], in patients with removable partial dentures [34] and in complete denture wearers [3, 35]. In contrast, Pedroni-Pereira *et al*. found a lack of agreement between objective and subjective measures in the evaluation of masticatory function [5]. The insignificant correlation could be due to the fact that the subjective assessment like chewing ability, based on the patient's assessment of chewing difficulty, might not reflect the actual ability to pulverize food chunks but rather the preference and adaptation to a particular food type.

Factors associated with subjective and objective masticatory assessments seemed to differ. Masticatory performance was associated with ACNC and MBF in the present study. Such associations were in agreement with previous studies [9, 10, 36, 37]. Increased occlusal contacts and bite force together explained about 70% of the variance in the masticatory performance [38]. Not many studies have investigated the association between masticatory performance and oral health-related quality of life. Moderate correlations have been reported between masticatory performance (using a multiple sieve method of chewed peanuts) and OIDP in complete denture wearers [3]. Another study [13] in a mixed group of denture wearers has also shown a significant correlation between chewing efficiency based on the mixing ability of two-colored chewing gum and

oral-health related quality of life based on SC-GOHAI. In complete denture patients, Yamamoto and Shiga [39] only found a significant correlation between masticatory performance (using a hard gummy jelly) and the functional limitation component of OHIP-J49 in patients after complete denture treatment. The present study, however, cannot demonstrate the association between masticatory performance and OIDP. This could be attributed to the small sample size. However, It should be noted that the less discriminative ability using hard food in the masticatory performance test, as opposed to the mixing ability test, in dentally compromised patients like complete denture wearers [40] might enhance the correlation between masticatory performance and the quality of life. In contrast, a significant correlation between chewing ability and OIDP was demonstrated in the present study. This was consistent with previous findings which demonstrated a moderate correlation between perceived chewing ability and oral-health related quality of life both in partially dentate patients [12] and in a mixed group of elderly wearing removable dentures [13]. The correlation between OIDP and chewing ability, but not with masticatory performance found in the present study, suggested that the ability to chew foods into fine particles did not always reflect patients' satisfaction in their oral functions including chewing, speaking and socializing. Moreover, chewing ability, not masticatory performance, was also correlated with MNA score, suggesting that the nutritional status was affected by the subjective assessment of one's own chewing capability, hence, their food choice.

Some limitations were encountered in the present study. Firstly, the relative changes in all parameters could not be determined since it was a cross-sectional study. Secondly, due to our limited sample size, the power of the test might not be reached for all analyses. However, our post-hoc power analyses have shown that some insignificant relationships observed in the bivariate analyses have an acceptable power (>= 0.8), i.e. those between MBF and OIDP, chewing ability and ACNC and between masticatory performance and chewing ability. Future studies with multivariate analysis using a larger sample size are therefore suggested. Thirdly, since the patients in the present study tended to be those with good masticatory function, it could be argued that this could be attributed to some selection bias. It was speculated that the patients who were wiling to travel to the dental clinic during the post-COVID-19 period would have been those having problems with their dentures. Contrary to this expectation, most patients had moderately-functioning dentures. Moreover, the mean and range of the values of masticatory performance among our subjects were comparable to those reported in the Japanese studies [23, 24] suggesting that our findings, to some extent, could be generalized. Despite the limitations mentioned above, the present study possessed some strength in that several variables were collected from each individual, allowing for the comprehensive assessment of factors potentially related to masticatory function.

Conclusions

The present study did not find any association between masticatory function and the duration of denture usage, except for ACNC, in a group of denture wearers. Also, it could not demonstrate the association between subjective and objective masticatory assessments in

this group of patients. The study further showed that factors associated with subjective and objective masticatory assessments tended to differ. While ACNC and MBF were significant determinants of masticatory performance, they did not appear to be associated with chewing ability and quality of life. Chewing ability appeared to be more suitable than masticatory performance in predicting health outcomes such as the quality of life and nutritional status affected by complete dentures. Dentists should, therefore, be aware of selecting the methods to evaluate the performance of complete dentures. However, due to the limited sample size, further investigations with multivariate analyses using a larger sample size will provide a better understanding of this subject.

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Conflict of Interest

The authors have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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