

Comparison of the Masticatory Performance in Mixing and Comminuting Food in Complete Denture Wearers

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Abstract

The aim of our study was to analyze masticatory performance as measured with gummy jelly and color-changeable chewing gum between complete denture wearers and dentate patients, and to analyze the correlation between masticatory performance with other factors such as age, gender, body mass index, salivary flow rate, saliva pH, chewing time, and swallowing threshold. 40 complete denture wearers and 40 fully dentate subject participated in this study. Two test foods were used to evaluate masticatory performance: gummy jelly and color-changeable chewing gum. Subject was instructed to chew on the color-changeable chewing gum in 30, 45, and 60 strokes, and to chew gummy jelly in 10, 20, and 30 strokes. We also measure subjects swallowing threshold with gummy jelly. There was significant differences ($p < 0.05$) between masticatory performance as measured with gummy jelly and color-changeable chewing gum in dentate subjects and complete denture wearers, which the first group had a better result. There was correlation between the measurement using both test foods. Masticatory performance in complete denture wearers is inferior compared to natural dentition subjects. There is correlation between masticatory performance measurement using gummy jelly and color-changeable chewing gum.

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Introduction

Mastication is the process of chewing food to form a bolus that is readily swallowed and digested. The masticatory performance and digestive system play an essential role in maintaining general health and normal body functions. When mastication is disturbed, digestive organs are required to perform an extra amount of work for which they are unfit. This struggle can cause digestive disorders, health problems, and the onset of illness, and affect the life expectancy of a person.^{1,2} Patients with poor mastication tend to prefer soft food rather than food that is hard to chew.^{3,4} In children, poor

mastication is associated with being underweight or childhood obesity.⁴

In elderly patients, masticatory performance is related to a their quality of life.⁵ Without tooth loss, masticatory performance is said to decrease with age.⁶ A study conducted by Kimura *et al.* in Japan found that elderly patients with decreased masticatory performance had a high risk of depression, decreased cognitive function, decreased ability to perform daily activities, and decreased nutritional intake.³ According to the results of the 2007 Indonesia Basic Health Research, 4.5% of Indonesians wear dentures, while 79.6% of patients have experienced tooth loss.⁷ These data may be because the patient is unaware of the need to replace missing teeth with artificial teeth and the consequences arising from tooth loss, especially the decline in mastication function.⁷

Patients with complete dentures are said to have poor masticatory performance compared with those with partial dentures and fully dentate patients.⁵ Patients with complete dentures have

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about 16–50% of the masticatory performance of dentate patients.² They adapt to this condition by chewing food longer, choosing easily chewable food, and swallowing food in larger chunks.⁸ Complete denture wearers with good masticatory performance can consume a more extensive variety of food.⁹

A patient's mastication can be evaluated objectively and subjectively. A questionnaire can be used to evaluate masticatory performance subjectively.^{2,10} There are several methods to objectively measure masticatory performance with relative ease, such as sieving test materials chewed within a number of strokes or within a certain amount of time, analyzing the particle size of test material using computer assistance, and indirectly examining masticatory performance by measuring the occlusal force.¹⁰ Occlusal force affects the strength of the patient to comminute the test material. Patients with high occlusal force have good masticatory performance and vice versa.¹¹ The test material used to evaluate masticatory performance varies from paraffin wax,^{12–15} natural food test substances,^{12–14} artificial test food substances (Optosil, Optocal^{15–17}, and gummy jelly^{5,14,18–21}), two-color chewing gum,^{16,22} to color-gum.^{23–28}

The process of mastication itself consists of the ability to comminute food and mix food to be ready for swallowing. No single method of measuring masticatory performance can measure all these aspects.^{15,16} An examination using several methods can give a complete picture of masticatory performance.²⁴ Testing masticatory performance in comminuting food is typically measured using natural or artificial food, such as beans, Optosil, Optocal, or gummy jelly. Evaluating the particle size of chewed gummy jelly is considered a standard in evaluating masticatory performance. Masticatory performance in mixing food can be evaluated using paraffin wax or chewing gum. The chewed material can be examined with a device or visually. A device is used more often at research institutions, whereas visual means can be used more generally, thus facilitating the evaluation of prosthodontic treatment in patients.^{12–28}

Research by Van der Bilt *et al.*¹⁶ and Speksnijder *et al.*¹⁵ suggests that measuring masticatory performance in mixing food is suitable for patients with compromised mastication. For example, in patients who have undergone mandibulectomy and those wearing complete

dentures, wax, or chewing gum can imitate the formation of a food bolus that is easily manipulated. Measuring masticatory performance in comminuting food is less suitable when applied to patients with low masticatory performance because the test material requires substantial chewing strength, good posterior tooth contact, and the test material forms particles of smaller size instead of a bolus.^{15,16}

Patients with complete loss of teeth are said to have the worst masticatory performance compared with partial denture wearers and fully dentate patients. Masticatory performance can be evaluated by food comminuting and mixing food abilities. Both these can be objectively measured with different test materials, such as gummy jelly to measure comminuting food capability, and color-changeable chewing gum to measure mixing food ability. Measuring mixing food ability is said to be more suitable for patients with compromised masticatory performance (e.g., those wearing complete dentures). Measuring comminuting food ability is less suitable for these patients because the test material is difficult to manipulate. This study evaluated the masticatory performance in mixing food and comminuting food using color-changeable chewing gum and gummy jelly by those wearing complete dentures and compared it with the masticatory performance of dentate patients. This study also evaluated the relationship between the two materials.

Methods

Ethics statement

All experimental procedures were approved by the Ethical Committee of the Faculty of Dentistry, Universitas Indonesia (No. 27/Ethical Approval/FKGUI/VII/2016). Informed consent was obtained from all subjects after they received an explanation about the study.

Subjects

A consecutive sampling was performed on 40 fully dentate patients (15 males and 25 females; age between 21 – 38 years; average age 26.48 years) at the Dental Teaching Hospital, Faculty of Dentistry, Universitas Indonesia. Forty patients (23 males and 17 females; age 54 – 79 years; average age 67.18 years) wearing conventional complete dentures were examined at the Dental Teaching Hospital, Faculty of

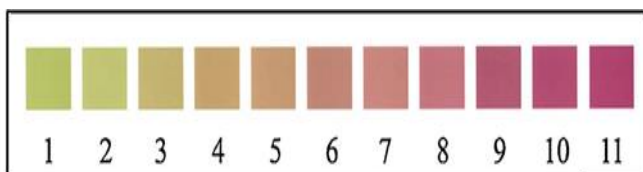
Dentistry, Universitas Indonesia, and Ajiwaras Dental Clinic, Cilandak. The group of complete denture wearers could not have had complaints about their dentures. The other inclusion criteria applied were (1) willingness and ability to give consent to participate in the study, (2) non-Muslim because of the porcine ingredient in the gummy jelly, (3) and no history of temporomandibular disorders.

Recording methods

Masticatory performance in mixing food



Figure 1. Masticatory performance evaluating gum, Xylitol.²³



ΔE 0 7 14 21 28 35 42 49 56 63 70

Figure 2. Color scale of color-changeable chewing gum.²³

The test food was color-changeable chewing gum (Figure 1; Masticatory Performance Evaluating Gum Xylitol, Lotte Co. Ltd., Saitama, Japan). The subjects were asked to chew the color-changeable gum in 30, 45, and 60 strokes to measure the masticatory performance in mixing food. They chewed the gum at an average speed of 1 stroke per second with the help of a metronome mobile application. The chewed gum then was flattened to 1.5 mm thickness by compressing it between two glass plates and an acrylic plate and then measured using the color scale (Figure 2).

Masticatory performance in comminuting food

The test food was gummy jelly (Figure 3; Uha Mikakuto Co., Ltd., Osaka, Japan). To

measure the masticatory ability in comminuting food, the subjects were asked to chew gummy jelly in 10, 20, 30 strokes, and their swallowing threshold stroke. The chewed pieces were spat out by subjects into a paper cup covered by gauze. The chewed particles were rinsed in flowing water for 30 s, and then measured using the gummy jelly visual score (Figure 4).

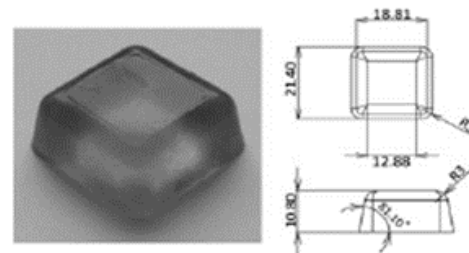


Figure 3. Gummy Jelly.¹⁹

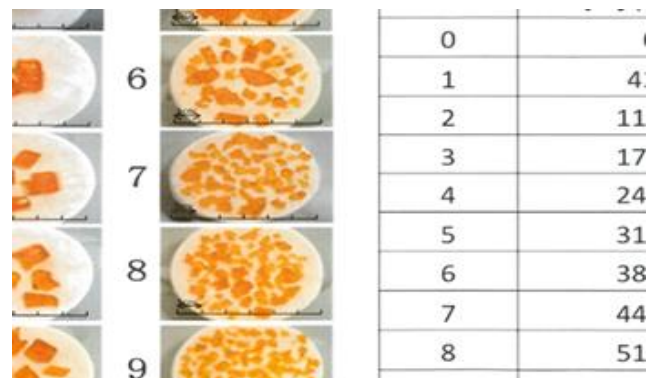


Figure 4. Visual score of gummy jelly.¹⁹

The time the subjects needed to chew the gummy jelly and their convenience in swallowing the particles in every stroke measured were also calculated.

Statistical analysis

Statistical analysis was performed using SPSS software (IBM, USA). The Mann–Whitney U test was used to analyze the differences between the two groups of subjects. The Spearman rank correlation coefficient was used to analyze the correlation between the chewing gum and gummy jelly measurements and the correlation between the masticatory performance measurement and other factors that may influence the masticatory performance.

Results

The masticatory performance in dentate patients was significantly better than that in

complete denture wearers in both measurements using color-chewing gum and gummy jelly. Superior results were achieved by complete denture wearers when using color-changeable chewing gum for measurements (Table 1). The median scores for 30, 45, and 60 strokes of the color-changeable chewing gum in the dentate group were 3, 6, and 8, respectively, with the highest score being 9 (Fig. 2). In the group of complete denture wearers, the median scores with the same strokes were 2, 3, and 5, respectively. The highest score achieved was 8 with 60 strokes, which was achieved by one subject.

Color-changeable chewing gum	CDW Median (Min–Max)	Dentate Median (Min–Max)	p-value
30 Strokes	2 (1–3)	3 (2–4)	0.00*
45 Strokes	3 (1–5)	6 (3–8)	0.00*
60 Strokes	5 (2–8)	8 (5–9)	0.00*

Mann–Whitney U analysis, $p < 0.05$; CDW: complete denture wearers.

Table 1. Color-changeable Chewing Gum Scores in Complete Denture Wearers and Dentate Patients.

Complete denture wearers had difficulty in chewing the gummy jelly (Table 2), and the scores were zero for all strokes. These scores indicate that the gummy jelly was still intact after being chewed by complete denture wearers. If the complete denture wearers were given more time to chew the gummy jelly, they could eventually comminute it. The median scores in the dentate group were 3, 6, and 8 for 10, 20, and 30 strokes, respectively.

The average time the subjects needed to chew gummy jelly and the visual analog scale of convenience to swallow it can be seen in Table 3. In the swallowing threshold measurement, complete denture wearers needed an average time of 55.15 s to chew the gummy jelly before it could be swallowed. That time was for an average of 71 strokes. On the contrary, dentate subjects needed only 26.51 s and 30.48 strokes to chew the gummy jelly before it could be swallowed.

There was a correlation between the measurement of masticatory performance in mixing and comminuting food in complete denture wearers at every mastication cycle. However, in the dentate subjects, only a few significant correlations were found (Table 4).

Color-changeable chewing gum	CDW Median (Min–Max)	Dentate Median (Min–Max)	p-value
10 Strokes	0 (0–1)	3 (0–5)	0.00*
20 Strokes	0 (0–3)	6 (3–7)	0.00*
30 Strokes	0 (0–5)	8 (4–9)	0.00*
Swallowing Threshold	3 (1–7)	7 (4–9)	0.00*

Mann–Whitney U analysis, $p < 0.05$; CDW: complete denture wearers.

Table 2. Gummy Jelly Scores in Complete Denture Wearers and Dentate Patients.

Gummy jelly	Chewing time (second)		VAS swallowing	
	CDW Mean \pm SD	Dentate Mean \pm SD	CDW Median (min–max)	Dentate Median (min–max)
10 Strokes	9.17 \pm 1.34	9.58 \pm 0.84	1 (0–5)	3 (0–7)
20 Strokes	17.63 \pm 2.34	18.30 \pm 1.74	2 (0–7)	5 (3–9)
30 Strokes	25.92 \pm 2.61	26.44 \pm 2.93	3 (0–9)	8 (7–10)
Swallowing threshold	55.15 \pm 17.08	26.51 \pm 4.92	6 (2–9)	9 (7–10)

CDW: complete denture wearers; VAS: visual analog scale.

Table 3. Chewing Time and Visual Analog Scale Convenience in Swallowing.

Groups	Gummy jelly 10 (r)	Gummy jelly 20 (r)	Gummy jelly 30 (r)
	Chewing gum 30	CDW 0.345*	0.454*
	Dentate 0.347*	0.240	0.379*
Chewing gum 45	CDW 0.321*	0.427*	0.609*
	Dentate 0.151	0.171	0.258
Chewing gum 60	CDW 0.313*	0.458*	0.552*
	Dentate 0.166	0.113	0.293

Spearman's analysis, $p < 0.05$; CDW: complete denture wearers.

Table 4. Correlation Coefficients Between Masticatory Performance in Mixing and Comminuting Food.

Discussion

Masticatory performance between complete denture wearers and dentate subjects

Previous studies have confirmed that the lowest masticatory performance was with conventional complete denture wearers and the highest masticatory performance was with dentate patients. Even rehabilitation with dental implants cannot restore masticatory performance as well as that in fully dentate patients.¹⁰ This study evaluated the masticatory performance between complete denture wearers and fully dentate patients by simultaneously using two measurement instruments. There was a

significant difference in the measurement of masticatory scores using gummy jelly and color-changeable chewing gum between complete denture wearers and fully dentate patients. The masticatory performance of complete denture wearers was lower than that of fully dentate patients. Rehabilitation to replace tooth loss with artificial teeth cannot restore the efficiency of a complete original tooth. Although artificial teeth can function to break down food, the efficiency is different in fully dentate patients.^{5,10}

Measuring the masticatory performance in comminuting food in complete denture wearers using gummy jelly yielded a median score of zero for the mastication cycle of 10, 20, and 30 strokes and a score of 3 for the swallowing threshold. This score is lower than that in fully dentate patients, who achieved scores of 3, 6, 8, and 7 for the mastication cycle of 10, 20, 30 strokes and the swallowing threshold stroke, respectively. Complete denture wearers have difficulty in chewing gummy jelly. This difficulty is illustrated by a measurement score of zero, indicating that the gummy jelly was still intact at the end of each mastication cycle. Gummy jelly describes the masticatory performance of comminuting food.

According to previous studies, occlusal force plays a significant role in the process of comminuting a food bolus.^{11,29} The occlusal force in complete denture wearers was five to six times lower than that in fully dentate patients.^{1,6} Unfortunately, in this study, the occlusal force was not measured to confirm that theory.

The hardness factor of the gummy jelly test material can also influence the measurement results. Okiyama *et al.* found that masticatory performance can be better when using softer gummy jelly.²⁹ Subjects complained that the gummy jelly was hard in consistency, making it difficult to chew for those who wore complete dentures. Several research subjects in the fully dentate group complained of similar issues, most of whom were female subjects. The authors concluded that gummy jelly is less suitable to measure the masticatory ability in comminuting food in patients with compromised masticatory performance, especially those with low occlusal force. The gummy jelly used in this study was full size. Half-size gummy jelly could be used for further research to measure the masticatory performance in comminuting food in complete denture wearers.

In measuring the masticatory performance in mixing food using color-changeable chewing gum, the score in complete denture wearers remained lower than that in fully dentate patients. Interestingly, complete denture wearers could chew the gum test material. One of the advantages of color-changeable chewing gum versus gummy jelly is that the chewing gum can simulate the formation of a food bolus, and does not form small particles like gummy jelly that can be tucked between artificial teeth and oral mucosa.² This is consistent with a study by Van der Bilt *et al.*, which states that for complete denture wearers, it is more appropriate to use masticatory measurements in mixing food rather than measuring the ability of comminuting food.¹⁶

Thirty strokes was the ideal number of strokes with gummy jelly and 60 strokes was ideal for the color-changeable chewing gum. For lower stroke cycles in each measurement method, the results were not satisfactory, although the measurements were taken in fully dentate patients who were assumed to have an ideal masticatory performance. A higher number of strokes resulted in a similar situation, where masticatory performance could not be differentiated among the groups.

The measurement scores of the color-changeable chewing gum and gummy jelly in fully dentate patients in this study can be used as a reference value of masticatory performance scores. However, the masticatory performance score of complete denture wearers cannot be used as a reference. In this study, no control of denture quality was used, but it was based on the subjective assessment of the patient who felt that the dentures could still be used. In addition, the results of the measurement scores with gummy jelly in complete denture wearers were found to be zero in all cycles of mastication.

In addition to the visual scores of chewed test materials, we also examined the time of mastication required by the subjects to perform the number of gummy jelly chewing cycles. The complete denture wearers took less time to perform the same number of strokes than fully dentate patients. These results are interesting because the results of the visual scores were meager in the complete denture wearers. The complete denture wearers had difficulty in chewing gummy jelly and therefore tended to chew faster. The fully dentate patients required an average of 26.51 s and an average of 30.48

strokes to chew gummy jelly until they felt it was ready to swallow. This result is consistent with a study by Fontijn-Tekamp, who obtained a 30.9 stroke result to chew Optosil before it was perceived as being ready to swallow.³⁰ However, in complete denture wearers, the chewing time and number of masticatory strokes took about two times longer before subjects were ready to swallow the gummy jelly. This result is consistent with the literature that says patients with poor masticatory performance adapt to chew more and longer before swallowing food. In addition, it also aligns with a study by Fontijn-Tekamp *et al.*, which mentions that patients with poor masticatory performance tend to swallow food in larger sizes.^{1,6,30}

The relationship between masticatory performance in mixing and comminuting food in complete denture wearers and fully dentate subjects

The Spearman rank correlation coefficient test was performed to evaluate the relationship between the measurement of mastication ability in mixing food and comminuting food in complete denture wearers and fully dentate patients using color-changeable chewing gum and gummy jelly. There was a low positive correlation in fully dentate patients between 30 strokes of color-changeable chewing gum measurements with 10 strokes of gummy jelly ($r = 0.347$) and 30 strokes of gummy jelly ($r = 0.379$). In other measurements, this relationship was insignificant. Therefore, it can be interpreted that the measurement of mastication ability in mixing food and comminuting food in fully dentate patients has no significant correlation with the measurement of comminuting food and was more suited for fully dentate patients.

There was a significant correlation between measurements using color-changeable chewing gum and gummy jelly with complete denture wearers in all masticatory cycles. Nevertheless, the correlation coefficients obtained were mostly weak or moderate. This result is consistent with other studies, which found a correlation between the ability of comminuting food and mixing food. The scores of the measurements with gummy jelly in complete denture wearers were mostly zero. A higher variety of values were obtained in measurements using color-changeable chewing gum. Therefore, we conclude that measuring the mastication

ability in complete denture wearers who are considered to have a compromised mastication ability should be carried out using color-changeable chewing gum.

The results of the correlation test in this study were consistent with a study by Van der Bilt *et al.*, which compared the mastication ability of young and elderly research subjects with Optosil–Optocal and two-colored chewing gum. Measurements of comminuting food ability (using Optosil and Optocal) were better at measuring the differences between young and elderly subjects compared with the measurement of the mixing ability of foods with two-colored chewing gums. Significant correlations were found between the measurements of comminuting food and mixing food in older subjects. On the contrary, they were not found in younger groups. The results of the two-colored chewing gum measurements showed similar results in younger groups, so they were unable to show the difference in mastication ability. A higher variety of results were obtained with the Optosil–Optocal measurements in younger groups. The measurement of comminuting food was suitable for the group of patients with good mastication ability. Chewing Optosil requires precision in manipulating food particles between molar teeth on each mastication stroke, which is difficult for denture wearers, while chewing gum can form a bolus that is relatively easy to manipulate by a denture wearer. There can be differences where the subjects can have a lower score in comminuting and a higher score in the ability to mix food. Van der Bilt concluded that measurements of mastication ability in mixing food are more suitable for subjects with limited mastication ability than for denture wearers.¹⁶

Similar results were proposed by Speksnijder *et al.*, who evaluated mastication abilities in fully dentate patients, conventional complete denture wearers, and patients with implant-supported complete dentures. In measuring the mastication ability in mixing food using paraffin wax, patients with implant-supported complete dentures had a better score than the conventional complete denture wearers. There was no difference between the two groups in the measurement of comminuting food using Optosil–Optocal. Speksnijder *et al.* concluded that measuring the mixing food ability was more appropriate in patients with compromised mastication ability.¹⁵

Shibuya *et al.* evaluated the mastication ability in patients who had undergone mandibulectomy using color-changeable chewing gum and gummy jelly and found a significant correlation between the two. Nevertheless, they suggested that measuring the mastication ability in patients who have undergone mandibulectomy was more suitable using color-changeable chewing gum.²⁸ However, Ono *et al.* evaluated the mastication ability in post-maxillectomy patients using gummy jelly and stated that measuring comminuting food using gummy jelly could be performed in patients with compromised mastication ability.²¹

Conclusion

The masticatory performance in complete denture wearers is inferior compared with fully dentate patients as determined through an objective measurement method. There is an association between the measurement of masticatory performance using color-changeable chewing gum and gummy jelly. Therefore, both test materials can represent an evaluation of masticatory performance. Color-changeable chewing gum can be used to measure masticatory performance in all patient groups, including complete denture wearers. While gummy jelly is not optimal when used in patients who have compromised masticatory performance, as in complete denture wearers, it can be used in dentate patients. The reference scores of mastication measurement using color-changeable chewing gum with 30, 45, and 60 strokes are 3, 6, and 8, respectively; whereas the reference scores of masticatory performance using gummy jelly with 10, 20, and 30 strokes are 3, 6, and 8, respectively. These reference scores were obtained from the group of fully dentate patients who are considered to have good masticatory performance.

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Conflict of Interest

No conflicts of interest are declared.

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