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The effect of various factors on the masticatory performance of removable denture wearer

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Abstract. An individual's masticatory performance concerns his/her ability to break down food in order to facilitate digestion, and it therefore plays an important role in nutrition. Removable dentures are used to rehabilitate a loss of teeth, which could jeopardize masticatory performance. Further, there exist various other factors that can affect masticatory performance. The objective of this research is to analyze the relationship between various factors and masticatory performance. Thirty-four removable denture wearers (full dentures, single complete dentures, or partial dentures) participated in a cross-sectional study of masticatory performance using color-changeable chewing gum (Masticatory Performance Evaluating Gum Xylitol®). The volume of saliva was evaluated using measuring cups, while the residual ridge heights were measured using a modified mouth mirror no. 3 with metric measurements. The residual ridge height and removable-denture-wearing experience exhibited a significant relationship with masticatory performance. However, age, gender, saliva volume, denture type, and the number and location of the missing teeth did not have a statistically significant association with masticatory performance. The residual ridge height influences the masticatory performance of removable denture wearers, since the greater the ridge height, the better the performance. The experience of using dentures also has a statistically significant influence on masticatory performance.

1. Introduction

An individual's ability to masticate has an important impact on his/her quality of life due to its key role in providing nutrition. According to the studies conducted by Okada *et al*. and Smith *et al*., masticating ability is closely related to general health as measured by anthropometric factors, especially in senior citizens. Therefore, the presence of a disturbance in the masticatory system may lead to a nutritional deficiency [1,2]. The mastication process breaks down food into smaller particles, blends it with saliva, and ends with swallowing. Masticatory performance thus concerns the ability of an individual to break down food into smaller particles by means of a number of masticatory movements [3]. Tooth loss may result in the loss of the ability to chew certain foods, especially food with a hard texture. However, the rehabilitation of mastication can be achieved with removable dentures; although not all dentures are able to facilitate good masticating forces. There are numerous factors that influence the masticating abilities of a denture, including the anatomical structure of the supporting tissues, duration of removable denture function, experience during removable denture function, occlusal scheme of the denture, and saliva conditions of the patient. The most frequent reason for complaints of lost masticatory performance among removable denture wearers is a decrease in the denture's stability and retention. The quality of a removable denture will decrease over time,

most commonly after between four and eight years of wear, which causes many patients with removable dentures to complain of a loss of masticatory performance [4].

Masticatory performance is also closely related to the saliva conditions in the mouth. The role of saliva during mastication is to lubricate and soften the food, as well as to collect the food particles into a bolus that can then be swallowed [5]. Ikebe found that hyposalivation may significantly decrease masticatory performance in subjects who wear removable dentures, especially subjects with full dentures [5]. The decrease in masticatory performance is also thought to be influenced by age, although aging itself does not directly influence the loss of masticatory performance, especially in patients with occlusion in their posterior teeth [5]. Physiological changes such as tooth loss, a decrease in saliva quantity and quality, changes in blood pressure, and a decrease in general health typically occur as a person ages [5]. It can therefore be said that an individual's mastication is affected by the physiological changes related to aging.

There are several methods available to evaluate masticatory performance, one of which involves filtering the end product of mastication and then directly evaluating it. This is the most commonly used method of evaluation. The filtering process uses a filter with a specific density and then, after filtering, the product is dehydrated and weighed. This method is considered to be the "gold standard" for evaluating masticatory performance, although it does have some weaknesses, including the amount of time needed to conduct the test and the relative complexity of the test in clinical practice [6,7]. Liedberg *et al*. developed a new, simple, and more practical method of evaluating masticatory performance using two-colored chewing gum [6,8]. This method is able to evaluate bolus formation, while the rate of mixing of the two colors serves as an indicator of masticatory performance. Validity and reliability studies of the mixing test have shown that this test represents a viable alternative to the conventional masticatory performance test [9]. However, masticatory evaluation using the mixing test has not yet been widely applied. This study will therefore evaluate masticatory performance using chewing gum by observing the color changes in the gum after mastication, as well as analyzing its relation to several of the factors mentioned above, including residual ridge height, age, sex, type of removable denture, experience with removable dentures, amount of tooth loss, and salivary flow rate.

2. Materials and Methods

This cross-sectional study involved subjects selected using a non-probability consecutive sampling method. The inclusion criteria are patients with ten or more missing teeth; who wear a partial removable denture, complete denture, or single complete denture; who have visited the dentist for the third control after insertion of the denture; who have no systemic diseases; and who are able to communicate. Informed consent to participate in the study was obtained from each patient who met the inclusion criteria. Information concerning the patients and the results of their oral examinations were recorded. The conducted examinations were as follows. First, the residual ridge height was measured using a no. 3 mouth mirror modified with metric measurements on its surface. The measurement was divided into three regions, namely the anterior, left posterior, and right posterior. If a region was toothless, then no measurement was performed. All the measurements were accumulated and the mean was calculated. Second, the salivary flow rate was measured. The subjects were instructed to swallow their remaining saliva, and they were then asked to eject their saliva periodically for five minutes. The saliva volume was divided by five (ml/minute). Saliva foams were excluded from the measurement [5,10]. Third, each patient's masticatory performance was tested. The subjects are instructed to chew color-changeable chewing gum (Xylitol®). The partial removable denture wearers and single complete denture wearers were required to chew for 60 seconds, while the complete denture wearers were asked to chew for 100 seconds. The subjects were then instructed to stop and the operator collected the gum with dental tweezers [11]. The chewed gum was flattened with a plate in order to achieve a homogenous thickness and its color was evaluated using the five-color scale printed on the chewing gum packet [12].

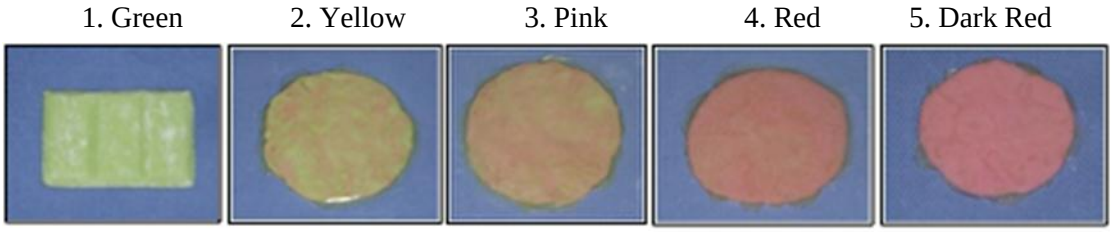

Figure 1. An example of each potential color result of the chewing gum test, as based on the five-color scale printed on the chewing gum packet [12]

3. Results and Discussion

3.1 Results

The total number of subjects involved in this study was 34. This number was lower than that indicted by the sample size calculations, although it was still clinically significant because the proportion difference was greater than the minimal size effect (20%), which is 0.28. This means that the results of the present study are clinically significant, but not statistically significant. To achieve a power above 80%, the subject number has to match the non-paired categorical analysis sample formula, which in this case was 64 subjects.

Table 1. Subject distribution based on age, sex, experience with removable dentures, type of denture, and number of teeth lost

Variable	Frequency	%
Age		
<60 years old	14	41.2
≥60 years old	20	58.8
Gender		
Male	12	35.3
Female	22	64.7
Experience with dentures		
No experience	15	44.1
Experience	19	55.9
Removable denture type		
Partial removable denture	15	44.1
Complete denture	11	32.4
Single complete denture	8	23.5
Number of teeth lost		
10–22	19	55.9
>22	15	44.1

Table 1 presents the subject distribution based on age, sex, experience with dentures, and amount of tooth loss. The age range in this study was 40–78 years, with the majority of participants being aged over 60 years. There were almost twice as many female subjects as male subjects (22 and 12 subjects, respectively). The number of subjects with and without denture wearing experience was similar (19 and 15 subjects, respectively). The partial removable denture wearers comprised the largest group in this study (15 subjects), followed by the complete denture wearers (n=11) and the single complete denture wearers (n=8). More subjects had lost 10–22 teeth than had lost more than 22 teeth (19 and 15 subjects, respectively).

Table 2. Relationship between age, sex, experience with removable dentures, type of removable denture, amount of tooth loss, and masticatory performance

	Poor masticatory performance (1–3) N (%)	Good masticatory performance (4–5) N (%)	p-value
Age			
<60	9 (64.3)	5 (35.7)	1.000
≥60	13 (65)	7 (35)	
Sex			
Male	7 (58.3)	5 (41.7)	0.711
Female	15 (68.2)	7 (31.8)	
Experience with dentures			
No experience	7 (46.7)	8 (53.3)	0.050
Experience	15 (78.9)	4 (21.1)	
Removable denture type			
Partial removable denture	8(53.3)	7(46.7)	0.218
Complete denture & Single complete denture	14(73.7)	5(26.3)	
Tooth loss amount			
10–22	10 (52.6)	9 (47.4)	0.097
>22	12 (80)	3 (20)	

Table 2 shows that the majority of the chi-square and Fisher's exact test results were statistically insignificant ($p>0.05$). Only the experience with dentures variable demonstrated a significant difference.

Table 3. Difference in residual ridge height and salivary flow rate based on masticatory performance

Variable	Mean	p-value
Residual ridge height		
Poor masticatory performance	5.942	0.003*
Good masticatory performance	7.175	
Salivary flow rate		
Poor masticatory performance	0.600	0.400
Good masticatory performance	0.729	

Tests were conducted to determine the differences in the residual ridge height and salivary flow rate variables based on masticatory performance (Table 3). A non-paired t-test was conducted on the residual ridge height variable, with a result of $p=0.003$ ($p<0.05$). This means that there is a statistically significant difference in the residual ridge height of subjects with poor masticatory performance and those with good masticatory performance. A Mann-Whitney U test was performed on the salivary flow rate variable due to it exhibiting a non-normal distribution. The result was 0.400 ($p>0.05$), which means that there was no statistically significant difference in the salivary flow rates of subjects with poor masticatory performance and those with good masticatory performance.

3.2 Discussion

This study found that there is no relationship between masticatory performance and age. This finding is supported by the results of previous studies, which found that age does not influence masticatory performance when posterior occlusion contact is achieved [5]. The subjects in this study completed the

chewing gum test using their dentures with all occlusion contacts achieved, especially posterior contact. The relationship between sex and masticatory performance was also found to be statistically insignificant (0.417, $p>0.05$). This might be due to the unequal numbers of female and male subjects, with there being almost twice as many female subjects as male. Statistically speaking, the number of subjects based on gender did not exhibit a normal distribution. Previous studies such as that conducted by Hatch *et al*. found that sex does not influence masticatory performance [13]. Their study stated that the number of functioning teeth has the greatest effect on masticatory performance [13]. The variations in the subjects' teeth condition were believed to be a confounding factor in the study by Hatch *et al*. [13]. In addition to the relatively low number of subjects, the present study also featured a variation in teeth conditions, which may have resulted in statistical insignificance. Another contradictory study stated that there does exist a difference in masticatory performance between males and females [14]. However, that study involved homogenous subjects with no tooth loss except for the third molar [14].

According to this study, the residual ridge height does have a significant effect on masticatory performance ($p=0.003$, $p<0.05$). The residual ridge height is a factor that determines the success of removable denture treatment, especially in the case of complete dentures, because it provides retention and stability, which helps in achieving mastication efficiency [15]. The average height of the residual ridge in the subjects with poor masticatory performance was 5.942 mm, while the average height in the subjects with good masticatory performance was 7.175 mm. This finding is different to the results of previous studies. Koshino *et al*. observed different elements of the residual ridge (e.g., width, height, and volume) and determined which had the greatest effect on mastication efficiency [15]. The results of their study showed that the surface area of the basal bone has the greatest effect on masticatory efficiency in cases of complete denture [15]. In another study, Shoxia *et al*. concluded that the residual ridge height does not influence patient satisfaction concerning removable dentures [16]. Further, a study by Kimoto and Garret showed that in patients with a short mandibular residual ridge, masticatory performance can be enhanced if the conventional removable denture is replaced with an implant-supported overdenture [17]. This finding is similar to the present study, which showed that there does exist a relationship between the residual ridge height and masticatory performance. In terms of the patient's perception of using a new complete denture, no difference was found between patients with a low residual ridge and those with a moderate or high ridge [18]. Thus, it can be objectively concluded that the residual ridge height is able to influence masticatory performance, although subjectively it exhibits no significant difference.

The influence of saliva on masticatory performance in this study showed no statistical significance (0.400, $p>0.05$). The subjects who exhibited poor masticatory performance had a salivary flow rate average of 0.600 ml/min, while those who exhibited good masticatory performance had an average of 0.729 ml/min. Hence, the subjects with a relatively high salivary flow rate showed good masticatory performance, while those with a relatively low flow rate showed poor performance. This finding is similar to that of the study by Ikebe *et al*., who found that the salivary flow rate significantly influences masticatory performance [5,19]. However, the influence of saliva is only significant when the patient has tooth loss, whether or not they wear dentures [5,19]. It must be recognized that a contradictory study did find the correlation between saliva and the masticating parameters to be insignificant [20]. The use of removable dentures, especially when newly inserted, is believed to significantly increase both the stimulated and unstimulated salivary flow rate [21-23]. A prior study found that the increase in saliva mimics that of a young and healthy individual [21]. The increase occurs two days after the insertion of the dentures and it decreases after three weeks, although it is still higher than prior to the use of removable dentures [23]. This means that the use of removable dentures may provide an inaccurate result in terms of the saliva volume after chewing gum, as well as potentially influencing the subject's masticatory performance.

An individual's masticatory performance is related to that individual's oral stereognostic ability, which is the ability to recognize the shape, size, surface texture, and temperature of an object inside the mouth [24]. The removable denture insertion process may possibly interrupt the sensory function

of a patient, which may make it difficult for the patient to adapt to the dentures [25]. The experience of a denture wearer eases as the patient adapts to the new denture, which also serves to accelerate the patient's stereognostic ability. The experience of a patient with dentures is one of the variables that exhibited an almost statistically significant difference in this study (0.051, $p>0.05$). When studied further, patients with denture-wearing experience demonstrated a lower mastication performance. This may be due to the average time of data collection being during the third control or one to two weeks after insertion, when the patient may not yet have fully adapted to the new denture. This is similar to the results of the study by Amarasena *et al*., which showed a significant increase in stereognostic ability after one month of using the new dentures, while no statistically significant difference was found between patients with or without experience of wearing dentures [25].

The subjects in this study varied from partial removable denture wearers to complete denture wearers. Of the 34 subjects, 15 used partial removable dentures (PRD), 11 used complete dentures (CD), and eight used single complete dentures (SCD). The results showed no significant difference between the type of denture and the chewing gum score (0.218, $p>0.05$). The masticatory performance of the CD wearers was mostly poor, with ten subjects exhibiting poor performance and one exhibiting good performance, while the masticatory performance of the PRD and SCD wearers was almost similar whether poor or good. It has been established that the use of dentures may decrease mastication efficiency by up to 1/6 of the efficiency of a healthy individual with complete real teeth [26]. According to the studies by Mendoca et al. and Neves *et al*., using a complete denture may only restore 31% and 21% of mastication performance, respectively [27,28]. Thus, the real figure determined for this study's subjects shows similarities with the findings of previous studies. However, when compared statistically, the result of this study is contradictory to those of previous studies. This may be due to the relatively low number of subjects in this study, which might have led to a biased number.

The number of teeth lost also showed a statistically insignificant difference (0.097, $p>0.05$). Among the subjects who had lost 10–22 teeth, ten of them demonstrated poor masticatory performance and nine had good masticatory performance, while in the subjects who had lost more than 22 teeth, 12 demonstrated poor masticatory performances and three had good masticatory performance. It can therefore be concluded that the majority of subjects who had lost more than 22 teeth exhibited poor masticatory performance. The statistical insignificance is caused by the subjects' use of dentures when chewing the gum. Many previous studies have found that the occlusion contact of teeth, especially the posterior teeth, has a significant influence on masticatory performance [5,19,29]. Yet, it must be remembered that the subjects in those studies had worn their dentures for a long time and had therefore adapted to their dentures.

4. Conclusion

The residual ridge height influences the masticatory performance of removable denture wearers, whereby the greater the ridge height, the better the performance. Experience of using dentures also had a statistically significant influence on masticatory performance. The masticatory performance of denture wearers who had prior experience of wearing dentures was better than that seen in first time wearers. The salivary flow rate, age, sex, type of denture, and number of teeth lost had no influence on masticatory performance.

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