Effect of complete denture occlusal schemes on masticatory performance and maximum occlusal force

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Statement of purpose. Masticatory performance and maximum occlusal force may be different, depending on the occlusal schemes of the complete dentures used.

Purpose. The purpose of this study was to evaluate the effect of 2 complete denture occlusal schemes on masticatory performance and maximum occlusal force.

Material and methods. Two complete denture occlusal schemes, bilateral balanced occlusion and neutrocentric occlusion, were delivered to 10 participants who were completely edentulous (6 men and 4 women; mean age, 67.3 years). Masticatory performance was evaluated with the multiple sieve method and maximum occlusal force with pressure-sensitive films. The 2 occlusal schemes were interchanged on the participants’ denture bases. Two-way repeated-measures ANOVA was used to examine the differences between the occlusal schemes and chewing strokes and their interactions. The paired t test was used to compare the maximum occlusal force of the 2 occlusal schemes (α=.05).

Results. No difference was found in masticatory performance (P=.07) or maximum occlusal force (P=.31) between the occlusal schemes. For both schemes, a significant difference was found in masticatory performance (P<.001) with increased numbers of chewing strokes.

Conclusions. Complete dentures with bilateral balanced occlusion and neutrocentric occlusion found no significant differences in masticatory performance and maximum occlusal force. However, more chewing strokes resulted in better masticatory performance. (J Prosthet Dent 2014;112:1337-1342)

Clinical Implications
Neutrocentric occlusion, advocated for patients with dental arch incompatibility when accurate centric relation records are difficult to obtain, provides the same masticatory performance and maximum occlusal force as bilateral balanced occlusion. Complete denture wearers should be instructed to use more chewing strokes.

Several countries, including developing countries, have aging populations. The number of patients who are edentulous has increased, with many people requiring complete dentures to restore their speech, appearance, and chewing ability. Complete denture occlusal schemes promote denture retention, stability, and support, which increases the patient’s psychological comfort and denture longevity.1,2 Various approaches to the design of complete denture occlusion have been taken, including bilateral balanced occlusion, neutrocentric occlusion, and linguinalized occlusion.2 Bilateral balanced occlusion provides multiple contact points during excursive movement.

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and creates horizontal forces. Patients who present with jaw relationships other than ideal Class I relationships may encounter problems in obtaining fully bilateral balanced occlusion. DeVan proposed neurocentric occlusion with zero-degree teeth to balance the incline, centralize the masticatory force, and overcome the difficulty in obtaining accurate jaw relations. Moreover, zero-degree teeth generate less pressure transmission than cusped teeth.

Chewing ability is defined as the ability to break down foods and can be evaluated by either the subjective or the objective method. The subjective method uses a questionnaire to evaluate chewing ability. Masticatory performance is evaluated objectively and is defined as the median particle size calculated from the percentage ratio of test food size distribution caused by comminution at a certain number of chewing strokes. The sieve used in previous studies was either single or had multiple sieve sizes. Maximum occlusal force, another objective evaluation of denture quality and performance, is evaluated by registering the masticatory force on pressure-sensitive sheets (Dental Prescale). Used to evaluate chewing ability and directly related to masticatory performance, dental prescale does not require a specific armamentarium. The thin pressure-sensitive sheets do not alter the vertical dimension that could affect occlusal force.

Patients who are edentulous experience a decrease in chewing ability compared with individuals with dentate. Age, sex, personality type, denture experience, denture quality, and occlusal schemes also affect chewing ability. Masticatory performance is generally comparable with those between 35 and 75 years old, and sex has no significant effect on masticatory performance and maximum occlusal force in complete denture wearers. Denture experience improves chewing ability. Improvement in denture quality significantly affects masticatory performance, occlusal force, and patient satisfaction in complete denture wearers. Compared with natural dentition, the masticatory performance and the maximum occlusal force of partial removable dental prosthesis were lower, and those of complete denture wearers were even lower.

Several investigators have studied the effect of occlusal schemes on chewing ability, both objectively and subjectively. Some concern has been expressed about the lack of appropriate controls for various participant groups. Some studies compared 2 participant groups independently, with each group using only 1 occlusal scheme. Results of studies have shown different results for different study designs, which have led to controversy in the outcomes. Uncontrolled factors in previous studies include the intaglio surface of complete dentures and the altered vertical dimension with different denture bases. A few intra-individual studies with the same denture base have also been performed. These studies reported that dentures with 20-degree teeth provided better masticatory performance than dentures with zero-degree teeth. A study that used the sieve method of different cuspal angulations in 5 participants with the same denture base found no significant difference in masticatory performance. Another study that used the sieve method with lingualized occlusion and 33-degree teeth also found no significant difference in masticatory performance.

In Thailand, bilateral balanced occlusion and neurocentric occlusion are often used to fabricate complete dentures. However, the type of occlusal scheme that provides the best chewing ability for complete denture wearers remains unclear. The aim of the present study was to compare the effect of bilateral balanced occlusion and neurocentric occlusion on masticatory performance and maximum occlusal force by using the same denture bases in the same individual. The null hypothesis of this study was that different complete denture occlusal schemes do not affect masticatory performance or maximum occlusal force.

MATERIAL AND METHODS

Ten participants (6 men and 4 women; mean age, 67.3 years) classified as The American College of Prosthodontics (ACP) classifications I and II completely edentulous were recruited for this study. They were referred to the graduate prosthodontics clinic at the Faculty of Dentistry, Chulalongkorn University. The study protocol was approved by the research ethical committee of Chulalongkorn University, Faculty of Dentistry (no. 021/2011). Written informed consent was obtained from each participant after a detailed explanation of the study. Two occlusal schemes, bilateral balanced occlusion and neurocentric occlusion, were evaluated with the same patient with the same denture bases. The first occlusal scheme was delivered, and the second occlusal scheme followed.

Before the test, each denture was evaluated and scored separately by using the Kapur method. Scores for retention and stability ranged from 0 to 5. A score of 0 corresponded to no retention, 1 represented slight resistance to vertical pull, 2 represented moderate resistance to vertical pull, and 3 represented maximum resistance to vertical pull. For stability, a score of 0 corresponded to no stability, 1 represented moderate rocking on the supporting structures under pressure, and 2 represented slight or no rocking on the supporting structures under pressure. The sum score of maxillary and mandibular dentures on both retention and stability of 6 or more was considered as clinically acceptable for this study. Masticatory performance was evaluated with the multiple sieve method with 20, 40, and 60 chewing strokes. Masticatory performance was evaluated 2 months after denture delivery; then, the other occlusal scheme was placed on the same denture base by modifying the Khamis and Hussein method. Participants underwent the same test procedures after denture delivery.

When the artificial denture teeth arrangement for the first occlusal scheme was completed, remounting
occlusal indices for the maxillary and mandibular teeth were made. The maxillary and mandibular posterior teeth then were removed from the trial bases and collected in the remounting occlusal indices, which left only maxillary and mandibular anterior teeth on the trial bases. The posterior denture teeth for the other occlusal scheme were arranged on the trial bases, processed, and finished conventionally. After evaluations for masticatory performance and maximum occlusal force, the posterior teeth were removed, and the first posterior denture teeth were repositioned by using the remounting occlusal indices. The dentures were then processed and finished conventionally.

Evaluation of masticatory performance with the multiple sieve method

A number of studies evaluated masticatory performance with multiple sieve method\(^9,12,22\) The participant was placed in an upright position in the dental chair. Each participant was provided with 3 g of roasted peanuts and instructed to chew for 20 strokes using his or her whole mouth. This was done twice more with a 1-minute rest between each attempt. The chewed peanuts were collected in a cup. Tests with 40 and 60 chewing strokes were performed in the same manner. The 3 specimens of collected food for each chewing parameter were pooled and dried for 24 hours in an incubator at 37°C. Masticatory performance was calculated as median particle size. The median particle size is determined by the sieve through which 50% of the comminuted food can pass. Therefore, a smaller median particle size indicates better masticatory performance.

The dried test food was placed on 12 standard progressively smaller sieves (Test sieve; Retsch Technology GmbH): 5.6, 4.75, 4, 3.55, 3.35, 3.15, 2.8, 2, 1.4, 1, 0.5, and 0.25 mm in diameter. The dried test food on the sieve was shaken with a vibratory sieve shaker (AS 200 digit; Retsch Technology GmbH) at 70 Hz for 3 minutes. The material that passed through the sieve was collected and used to calculate the cumulative weight percentage:

Cumulative weight percentage of each sieve = \(1 - \left[\text{cumulative of mass retained on that sieve and previous sieves}/\text{total sample mass}\right] \times 100\)

The cumulative weight percentages of comminuted food on each sieve were plotted. The median particle size (the sieve size through which 50% of the comminuted food can pass) was calculated by linear regression from the plot.

Maximum occlusal force

Maximum occlusal force\(^9-11\) was measured with horseshoe-shaped, pressure-sensitive film (Dental Prescale 50H R type; Fujiﬁlm) (Fig. 1). Variation in the color of each pressure point on the film was a measure of the amount of applied pressure within a range of 5 to 120 MPa. Each participant was positioned in an upright position in a dental chair. The participant was instructed to clench maximally in the intercuspal position for 5 seconds on the pressure-sensitive film, which had been positioned on the occlusal surfaces between the maxillary and mandibular complete dentures. This procedure was performed 3 times. The imprint of occlusion on the film was analyzed with a computerized image scanner (Occluzer FPD705; Fujiﬁlm). The system analyzed maximum occlusal force by measuring the density of the color. The 3 readings were averaged for each participant. The data were analyzed with a statistics package for the social sciences (SPSS program v17.0; SPSS). The Shapiro-Wilk test was used to confirm the normality of masticatory performance data because the sample size was fewer than 30. The masticatory performance data were analyzed with statistical software (SigmaStat v2.03; Systat Software) (\(z = .05\)).

Two-way repeated-measures ANOVA was used to detect the significance of masticatory performance on the 2 measured effects of the different occlusal schemes (bilateral balance occlusion and neurocentric occlusion), the number of chewing strokes, and intraindividual interactions. One-way repeated-measure ANOVA was used to detect significant differences in the chewing strokes for each occlusal scheme. The Tukey honestly significant difference test was used for post hoc multiple comparisons. The paired t test was used to compare the mean maximum occlusal force between bilateral balance occlusion and neurocentric occlusion within participants.

RESULTS

The means (standard deviations) for the median particle sizes are shown in Figure 2. Bilateral balanced occlusion resulted in a similar median particle size to neurocentric occlusion. Increased

![Dental Prescale 50H, R type, Fujifilm.](image)
numbers of chewing strokes resulted in a smaller median particle size. The 2-way repeated-measures ANOVA between the groups determined a statistically significant difference only in chewing strokes \( P < .001 \) (Table I). The complete denture with bilateral balanced occlusion found no statistically significant differences compared with the complete denture with neurocentric occlusion when the number of chewing strokes was the same \( (P = .310) \). Multiple comparisons with the Tukey honestly significant difference test found a statistically significant difference between 20 and 30, and between 30 and 40 chewing strokes. \( (P < .001) \) (Table II). The means (standard deviations) for maximum occlusal force are shown in Figure 3. The paired \( t \) test found no statistically significant differences in maximum occlusal force between the bilateral balanced occlusion and neurocentric occlusion \( (P = .706) \).

### DISCUSSION

No statistically significant differences in masticatory performance were detected between bilateral balanced occlusion and neurocentric occlusion in this study (Table I). This finding is consistent with those of previous studies. \(^{29,30}\) However, the sample size in the present study was less than the suggested sample size determined by power analysis. Most clinical studies of this type that seek to control most of the confounding factors have similar limitations. In this study, only patients in ACP classifications I and II were selected, and all of the procedures were performed by a single prosthodontist (N.W.). Moreover, this might also result from the high score of the Kapur evaluation, which indicated good denture quality in terms of retention and stability. The interchangeable teeth technique used to fabricate the complete dentures by replacing posterior teeth in the same denture base did not change either the vertical dimension or the maxillomandibular relationship. Therefore, with this limitation, analysis of our data did not support rejection of the null hypothesis. That is, different complete denture occlusal schemes do not affect masticatory performance or maximum occlusal force, which suggests that, although the occlusal scheme may change, the chewing pattern, tone of masticatory muscle, and preparation of the food bolus on the occlusal surfaces of the denture teeth do not change and may be specific to each individual.

In this study, masticatory performance was selected to evaluate the effectiveness of chewing ability with 2 different occlusal schemes. Roasted peanuts were selected because the comminution of particles was easily done during chewing. The absorbed water could be easily eliminated, and the agglomerate of comminuted particles could be readily separated by sieving. \(^{28}\) Other natural test foods may vary in consistency because of the preparation of food and because of seasonal and geographical influences. Moreover, this study performed intra-individual evaluations at different time points.

Interesting results were observed when we compared masticatory performance with the different numbers of chewing strokes. Statistically significant

### TABLE I. Two-way repeated-measures ANOVA, showing results of effect of occlusal schemes, chewing strokes, and interaction on masticatory performance

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Squares</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occlusal schemes</td>
<td>0.192</td>
<td>1</td>
<td>0.192</td>
<td>4.150</td>
<td>.072</td>
</tr>
<tr>
<td>Chewing strokes</td>
<td>9.333</td>
<td>2</td>
<td>4.666</td>
<td>158.898</td>
<td>.001</td>
</tr>
<tr>
<td>Occlusal schemes × chewing strokes</td>
<td>0.011</td>
<td>2</td>
<td>0.0053</td>
<td>0.354</td>
<td>.706</td>
</tr>
</tbody>
</table>

### TABLE II. Results of multiple comparisons of masticatory performance on different chewing strokes

<table>
<thead>
<tr>
<th>Comparison of Masticatory Performance*</th>
<th>( P ) (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 vs 40</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>20 vs 60</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>40 vs 60</td>
<td>&lt; .001</td>
</tr>
</tbody>
</table>

*No of chewing strokes.

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2 Means (standard deviations) of median particle size in each occlusal scheme and chewing strokes.

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![2 Way ANOVA showing results of effect of occlusal schemes, chewing strokes, and interaction on masticatory performance.](image-url)
differences in masticatory performance were noted with increasing numbers of chewing strokes (Table II). In both bilateral balanced occlusion and neutrocentric occlusion, an increase in the number of chewing strokes yielded demonstrably improved masticatory performance, although the recommended number of chewing strokes for evaluating masticatory performance with roasted peanuts was 20.7 In this study, both bilateral balanced occlusion and neutrocentric occlusion provided higher masticatory performance as the number of chewing strokes increased from 20 to 60. The peanuts were comminuted until they could not be further processed into fragments. Analysis of the results suggests that complete denture wearers should use more chewing strokes. The dental prescale is a pressure-sensitive, thin film that registers occlusal contact forces. In contrast to other methods, minor changes in vertical dimension during clenching due to the thickness of the prescale sheet do not affect occlusal force.10,13,14 The maximum occlusal forces obtained from the occlusal table of denture teeth were observed. No significant difference was noted in maximum occlusal force between occlusal schemes detectable with the dental prescale.

Although other studies that used subjective methods to evaluate chewing ability between different occlusal schemes reported inconsistent results,23-26,28 in this study, the patients’ preferences for an occlusal scheme could not be related to masticatory performance when measured objectively. The present study evaluated the masticatory performance and maximum occlusal force objectively. Additional objective studies concurrent with subjective studies would be beneficial in evaluating masticatory performance and patient preference. We hypothesize that the masticatory performance and maximum occlusal force of the complete dentures as proposed by ACP classifications I and II were not significantly different, regardless of the 2 occlusal schemes, because of the retention and stability of the well-constructed complete dentures. The limitation of sample size might obscure significant differences. Thus, further larger sample size studies are suggested.

CONCLUSIONS

Within the limitation of this study, the following conclusions were drawn. For ACP classifications I and II completely edentulous with good denture quality (Kapur score ≥6), no significant difference was noted on masticatory performance and maximum occlusal force between bilateral balanced occlusion and neutrocentric occlusion. With either bilateral balanced occlusion or neutrocentric occlusion, 60 chewing strokes provided better masticatory performance than 20 or 40 chewing strokes.

### REFERENCES

Noteworthy Abstracts of the Current Literature

Influence of full-contour zirconia surface roughness on wear of glass-ceramics

Luangruangrong P, Cook NB, Sabrah AH, Hara AT, Bottino MC

**Purpose.** The purpose of this study was to evaluate the influence of full-contour (Y-TZP) zirconia surface roughness (glazed vs. as-machined) on the wear behavior of glass-ceramics.

**Materials and Methods.** Thirty-two full contour Y-TZP (Diazir®) specimens (hereafter referred to as zirconia sliders) (φ = 2 mm, 1.5 mm in height) were fabricated using CAD/CAM and sintered according to the manufacturer’s instructions. Zirconia sliders were embedded in brass holders using acrylic resin and then randomly assigned (n = 16) according to the surface treatment received, that is, as-machined or glazed. Glass-ceramic antagonists, Empress/EMP and e.max/EX, were cut into tabs (13 × 13 × 2 mm(3)), wet-finished, and similarly embedded in brass holders. Two-body pin-on-disk wear testing was performed at 1.2 Hz for 25,000 cycles under a 3 kg load. Noncontact profilometry was used to measure antagonist height (m) and volume loss (mm(3)). Qualitative data of the zirconia testing surfaces and wear tracks were obtained using SEM. Statistics were performed using ANOVA with a significance level of 0.05.

**Results.** As-machined yielded significantly higher mean roughness values (Ra = 0.83 μm, Rq = 1.09 μm) than glazed zirconia (Ra = 0.53 μm, Rq = 0.78 μm). Regarding glass-ceramic antagonist loss, as-machined zirconia caused significantly less mean height and volume loss (68.4 μm, 7.6 mm(3)) for EMP than the glazed group (84.9 μm, 9.9 mm(3)), while no significant differences were found for EX. Moreover, EMP showed significantly lower mean height and volume loss than EX (p < 0.0001). SEM revealed differences on wear characteristics between the glass-ceramics tested.

**Conclusion.** e.max wear was not affected by zirconia surface roughness; however, Empress wear was greater when opposing glazed zirconia. Overall, surface glazing on full-contour zirconia did not minimize glass-ceramic wear when compared with as-machined zirconia.

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