Comparative Study of Bite Force Controls in Healthy Dentate Individuals and Complete Denture Wearers

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Abstract
This study compared the control of bite force in healthy dentate individuals and complete denture wearers. Forty subjects with natural dentition (20 males, 20 females; mean age 23.7 years) and 17 edentulous subjects wearing well-fitting complete dentures (8 males, 9 females; mean age 72.6 years) volunteered to participate in this study. Electromyographic activity of the temporalis and masseter muscles (bilaterally) was recorded under maximum voluntary contraction and during both light and strong biting as perceived by subjects. Subjects were also required to record perceived bite force on a visual analog scale. Consequently, visual analog scale assessments of light and strong biting by healthy dentate individuals and complete denture wearers were virtually equal at 20–25 and approximately 75, respectively. However, temporal and masseter muscle activity during light biting was 16.1% maximum voluntary contraction and 10.3% in the healthy dentate group, and 29.1% and 28.2% in the complete denture group. Temporal and masseter muscle activity levels during strong biting were 68.7% and 58.0%, respectively, in the healthy dentate group and 48.6% and 49.7%, respectively, in the complete denture group. Significant intergroup differences were observed between temporal and masseter muscle activity levels during light and strong biting. The study findings revealed a disparity between the two groups in perceived bite force and actual muscle activity, suggesting that compared to healthy dentate individuals, complete denture wearers have a narrow regulatory range and reduced flexibility in controlling bite force.

Keywords:
bite force, complete denture, natural dentition, subjective control, biting magnitude

Introduction
Bite force is an important indicator of masticatory efficacy, and has been evaluated along with electromyography (EMG) of masticatory muscles in several previous studies (1–7). It is widely known that the maximum bite force varies in healthy dentate individuals and complete denture wearers, and this variation can be explained by the presence or absence of mechanoreceptors in the periodontal membrane (PDMs) (8). The absence of sensory input from PDMs in edentulous patients results in reduced masticatory forces and distorted spatial control of jaw movements during chewing (9, 10). Accordingly, sensorimotor function in edentulous patients is reportedly subject to central neural processing based on information from mechanoreceptors in the muscles, temporomandibular joints (TMJs), mucosa, and periosteum (11).

The majority of studies on masticatory function in complete denture wearers have evaluated masticatory efficiency using maximum bite force, test food and artificial test food (2, 5, 12) or mandibular movement with a focus on chewing cycle (13, 14). To our knowledge, no studies have addressed the difference between dentate individuals and complete denture wearers in regulation of bite force; the actual state of this regulation is a matter of interest. The aim of the present study was to clarify the
discrepancy between perceived biting force and actual masticatory muscle activity, and the regulation of bite force in dentate individuals and complete denture wearers.

**Materials and Methods**

**Subjects**

Forty individuals with natural dentition, 20 males and 20 females (age, 21–26 years; mean age, 23.7 years), were recruited from among students of our dental school. All had complete natural dentition and their teeth were not periodontally involved. Seventeen edentulous subjects wearing well-fitting complete dentures (8 males, 9 females; age, 54–85 years; mean age, 72.6 years) volunteered to participate in this study.

Previous studies have shown that patients with newly fabricated complete dentures experience difficulty chewing immediately after denture delivery, although their masticatory function improves with time (15, 16). Based on these findings, subjects with a good outcome after wearing the denture for at least 3 months were recruited in this study. Moreover, complete denture wearers with a significantly resorbed residual ridge, Class IV in the classification system of the American College of Prosthodontists, were excluded (17).

Experiments were performed with the consent of each subject after adequate explanation of the purpose and protocol of this study. The study was approved by the Ethics Committee of Nihon University School of Dentistry at Matsudo (Approval No. EC09-009) and was conducted in full accordance with ethical principles, including the World Medical Association Declaration of Helsinki.

**Electromyography**

The masticatory muscles evaluated were the anterior bundle of the left and right temporal muscles and the central area of the superficial masseter muscles. Electrodes were placed parallel to muscle fibres at a site 10 mm posterior to and parallel to the anterior border of the anterior lobe of the temporal muscles, and in the central portion of the superficial masseter muscle parallel to its anterior rim. Muscle activity was measured using a multi-telemeter system (WEB-5000, Nihon Kohden, Tokyo, Japan) and Ag–AgCl bipolar surface electrodes (5 mm in diameter) with subjects in the sitting position. Measurement was performed with the high cut frequency turned off, a time constant of 0.03 seconds, and sensitivity (SENS) of 0.5 mV/diV. EMG signals were recorded at a sampling frequency of 1 kHz and transferred to wave analysis software (PowerLab, AD Instruments, Sydney, Australia).

**Task and measurement**

Occlusal loading while in intercuspal position was achieved in the subjects by requesting them to perform what they perceived to be a light bite and a strong bite. Each bite was repeated 3 times and maintained for 3 seconds. Subjects were also instructed to perform maximum voluntary contraction (MVC) 3 times; the mean muscle activity was regarded as 100% bite force of the temporal and masseter muscles. EMG analysis was performed by selecting the amplitude value from the final second of the 3-second EMG wave pattern recording and calculating the average root mean square (RMS) value of each muscle. The relative activity compared with the maximum voluntary contraction of the temporal and masseter muscles was calculated from the obtained RMS value. Subjective measurement of light and strong bite force was also performed after measuring muscle activity by instructing subjects to record their perceived intensity of each bite on a visual analog scale (VAS), wherein a score of 0 represented minimal force and 100 represented maximum force. MVC was measured by having the subjects bite a pressure-detecting sheet (Prescale, Fuji Film, Tokyo, Japan) and determining the bite force using a specialized analytical system known as a dental occlusion pressure graph (Occluzer FPD-707, Fuji Film, Tokyo, Japan).

The procedure and reliability of this method were previously reported (18, 19).
Statistical analysis

Differences between healthy dentate individuals and complete denture wearers in % MVC of temporal and masseter muscles and VAS scores were each analysed using the Student’s t-test. A significance level of 5% was adopted for all analyses. In addition, a correlation analysis (Pearson product–moment correlation coefficient) was performed to examine the relation between % MVC and VAS scores.

Results

Figures 1 and 2 show muscle activities (% MVC) and VAS scores of healthy dentate individuals and complete denture wearers during strong and light biting. Table 1 indicates the maximum bite force, and Table 2 shows the correlation between % MVC and VAS scores.

Table 1. Maximum biting force (Newtons)

<table>
<thead>
<tr>
<th></th>
<th>Bite-Force (SD)</th>
<th>Total mean (SD)</th>
<th>n</th>
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</thead>
<tbody>
<tr>
<td>Healthy dentate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>912.1(214.5)</td>
<td>800.1(232.6)</td>
<td>20</td>
</tr>
<tr>
<td>F</td>
<td>658.3(172.5)</td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>Complete denture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>412.6(121.3)</td>
<td>332.3(149.6)</td>
<td>8</td>
</tr>
<tr>
<td>F</td>
<td>252.3(136.7)</td>
<td></td>
<td>9</td>
</tr>
</tbody>
</table>

Table 2. Correlation between % MVC and VAS Score

<table>
<thead>
<tr>
<th></th>
<th>r</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Healthy dentate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strong biting</td>
<td>0.097</td>
<td>0.550</td>
</tr>
<tr>
<td>Temporalis</td>
<td>0.108</td>
<td>0.507</td>
</tr>
<tr>
<td>Masseter</td>
<td>0.162</td>
<td>0.317</td>
</tr>
<tr>
<td>Light biting</td>
<td>0.173</td>
<td>0.286</td>
</tr>
<tr>
<td>Temporalis</td>
<td>-0.325</td>
<td>0.203</td>
</tr>
<tr>
<td>Masseter</td>
<td>-0.303</td>
<td>0.237</td>
</tr>
<tr>
<td>Complete denture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strong biting</td>
<td>0.180</td>
<td>0.488</td>
</tr>
<tr>
<td>Temporalis</td>
<td>0.118</td>
<td>0.650</td>
</tr>
<tr>
<td>Masseter</td>
<td>-0.325</td>
<td>0.203</td>
</tr>
<tr>
<td>Light biting</td>
<td>-0.303</td>
<td>0.237</td>
</tr>
</tbody>
</table>

r; correlation coefficient  p; probability

Fig. 1. Light biting: Muscle activity and VAS scores of healthy dentate individuals and complete denture wearers during light biting.

Fig. 2. Strong biting: Muscle activity and VAS scores of healthy dentate individuals and complete denture wearers during strong biting.
Muscle Activities

1) Light biting

In the healthy dentate individuals, the mean % MVC during light biting was 16.1% (standard deviation: 6.4) in the temporal muscles and 10.3% (S.D.: 4.0) in the masseter muscle. Meanwhile, in the complete denture wearers, the mean values were 29.1% (S.D.: 16.0) and 28.2% (S.D.: 12.1), respectively.

2) Strong biting

In the healthy dentate individuals, the mean % MVC during strong biting was 68.7% (S.D.: 14.5) in the temporal muscles and 58.0% (S.D.: 18.5) in the masseter muscle. In the complete denture wearers, the mean values were 48.6% (S.D.: 10.4) and 49.7% (S.D.: 11.9), respectively.

VAS assessment

The mean VAS scores during light and strong biting were 25.1 (S.D.: 10.0) and 74.9 (S.D.: 5.4), respectively, in the healthy dentate individuals, and 21.3 (S.D.: 9.7) and 74.2 (S.D.: 7.4), respectively, in the complete denture wearers.

Maximum bite force

The mean maximum bite force of healthy dentate individuals was 912.1 Newtons (S.D.: 214.5) for men, 658.3 N (S.D.: 172.5) for women, and 800.1 N (232.6) for the entire group. For complete denture wearers, the maximum bite force was 412.6 Newtons (S.D.: 121.3) for men, 252.3 N (S.D.: 136.7) for women, and 332.3 N (149.6) for the entire group.

Statistical analysis

The temporal muscle activity of healthy dentate individuals during strong biting was significantly higher than the masseter muscle activity of the same group as well as both the temporal and masseter activity of the complete denture wearers. On the other hand, temporal and masseter muscle activity of healthy dentate individuals during light biting was significantly lower than that of the complete denture wearers.

No significant intergroup differences were observed between the VAS scores for light and strong biting (Figs. 1 and 2).

There was hardly any correlations between % MVC and VAS score except for a weak negative correlation for light biting in complete denture wearers (Table 2).

Discussion

Maximum bite force of complete denture wearers has been measured using a variety of methods, but differences in measurement techniques and positions have also led to varied results. Based on these studies, the maximum bite force of complete denture wearers is generally recognized as between 1/2 to 1/6 that of healthy dentate individuals. Alajbeg et al. (6) reported that the temporal and masseter muscle activity of complete denture wearers is approximately 40% that of younger dentate subjects and approximately 60% that of older dentate subjects. Two previous studies (18, 20) conducted on healthy dentate individuals in the same age demographic and using the same measurement techniques as the present study reported mean maximum bite forces of between approximately 780 N (22 males and 8 females) and 1,180 N (9 males and 3 females). The mean maximum bite force for the 20 males and 20 females recruited in this study was 800 N, which lies within the range of the above-mentioned findings. Multiplying this by the 40% ratio suggested by Alajbeg et al. gives a maximum bite force of 320 N, which is almost equivalent to the present study’s mean maximum bite force of 332 N observed in male and female complete denture wearers.

The subjective VAS assessments of light and strong biting indicated that conscious bite force in terms of central neural processing was evaluated almost equally by healthy dentate individuals and complete denture wearers for both light and strong bites. In other words, both groups recorded about 20 –25 for light biting and approximately 75 for strong biting, and there were no significant intergroup differences in the respective VAS scores.

In contrast, the findings from the actual temporal and masseter muscle activity during strong and light biting suggest that unlike their healthy dentate coun-
terparts, edentulous individuals have a narrow regulatory range and lack flexibility in terms of bite force control. This narrow regulatory range was also reported in a study by Fontijn-Tekamp et al. (4). They had adopted ‘as when chewing’ as the biting condition while determining the force level, and observed that the unilateral molar bite force was 120 N relative to a maximum bite force of approximately 400 N in the young natural dentition group, and 50 N relative to a maximum bite force of approximately 100 N in the denture wearing group. Kiliardis et al. (21) reported the bite forces in the premolar region of subjects with advanced occlusal wear who were instructed to perform ‘light biting’. According to this study, light biting generated a bite force of 74 N compared to a maximum bite force of 651 N in men, and a bite force of 42 N versus a maximum bite force of 556 N in women. This is equivalent to a % MVC of 11% and 8%, respectively, which is similar to the temporal muscle % MVC of 16% and masseter muscle % MVC of 10% recorded during light biting in the healthy dentate group of the present study. Comparison of muscle activity results indicates that, compared to their healthy dentate counterparts, the actual muscle activity of complete denture wearers falls short of their perceived level when intending to bite strongly, and exceeds their perceived level when intending to bite lightly. Perhaps when eating hard food, the central nervous system of a complete denture wearer determines that it is incapable of exerting adequate masticatory force. In contrast, when eating soft foods, the complete denture wearer may be exerting more masticatory force than is actually required. These sensory variations manifest as differences in the chewing cycle of dentate individuals and complete denture wearers. Veyruno et al. (14) evaluated the EMG of the masseter muscle from mastication to deglutition of a test food (gumdrops) by dentate subjects and complete denture wearers, and observed a marked difference in their respective EMG readings in the 15 seconds immediately prior to deglutition. While muscle activity declined gradually in the dentate subjects, it continued almost unabated until deglutition in the complete denture wearers. The findings of the present study also revealed differences in the level of temporal and masseter muscle activity of dentate subjects and complete denture wearers. While dentate subjects had a significantly higher amount of temporal muscle activity during both strong and light biting, complete denture wearers did not exhibit any differences in temporal and masseter muscle activity during strong and light biting. Manns et al. (22) asserted that mechanoreceptors of the anterior teeth (i.e., canines) are involved in bite force control. The difference between temporal and masseter muscle activity observed in dentate subjects in the present study occurred because the temporal muscles are involved not only in occlusion but also in backward and forward movement of the mandible. The present study also revealed that the actual muscle activity during strong biting was below the perceived level in both the dentate and complete denture groups. This mechanism whereby the perceived bite force takes precedence over the actual bite force may be a central nervous system function aimed at protecting the teeth and periodontal tissue.

Furthermore, it is worthy of note that 50% MVC in complete denture wearers is consciously perceived by the subjects as a strong bite equivalent to 75%. In dentate patients, a perception of 75% was approximately 70% MVC in the temporal muscles and 60% MVC in the masseter muscle. The fact that both dentate subjects and complete denture wearers indicated subjective VAS scores of 20–25 for a light bite and approximately 75 for a strong bite suggests that VAS may serve as a potential indicator when discussing bite force. However, this implies that in complete denture wearers, even if a subjective VAS score of ≥75 is regarded as a strong bite, an MVC of ≥50% must also be regarded as a strong bite.

The study findings reveal a discrepancy between perceived bite force and actual muscle activity, suggesting that compared to healthy dentate individuals, complete denture wearers have a narrow regulatory range and reduced flexibility when it comes to controlling bite force.
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