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<td>Author(s)</td>
<td>Yanagisawa, K; Takagi, I; Sakurai, K</td>
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Influence of tongue pressure and width on tongue indentation formation

Keyword: tongue indentation, clenching, tongue pressure, tongue width, bruxism

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Summary

The purpose of this study was to clarify which physiological and anatomical factors were involved in the formation of tongue indentations, which are believed to be a clinical sign of clenching. Twenty-four dentulous subjects were investigated. They were divided into two groups, depending on the presence or absence of tongue indentations: (i) a tongue indentation group, and (ii) a no tongue indentation group. Intraoral appliances containing a small pressure sensor were placed at the lingual surfaces of the upper and lower right first molars. Lingual pressure on the lingual surfaces of the upper and lower right first molars was then recorded under different conditions. The tasks selected as physiological factors to be recorded were: (i) silent reading at rest for 10 min, (ii) maximum voluntary clenching (MVC) for 5 s, (iii) 10% of maximum voluntary clenching for 1 min, and (iv) swallowing. The results for all tasks were compared between groups. Tongue width and dental arch width were also measured as anatomical factors. No significant differences were found between groups during silent reading at rest, clenching, swallowing, or in tongue pressure integration during silent reading at rest. However, a significant difference was found in terms of tongue width ($P < 0.05$). These results indicate that neither volume of lingual pressure exerted on the lingual surface of the teeth during rest, clenching, nor swallowing are related to the formation of tongue indentations. The results do suggest, however, that tongue width at rest plays an important role in the formation of tongue indentations.

Introduction

Abnormal activity and hypertrophy of the masseter muscle, pain in the temporomandibular joint, abnormal dental wear, and abfraction, among others, are all believed to be clinical signs of bruxism (1-6). Buccal mucosa ridging and tongue indentations are considered to be the most reliable clinical signs of clenching among the various types of bruxism (7). However, in a recent study, Takagi et al. found that formation of buccal mucosa ridging was not related to clenching (8). Some studies have suggested that tongue indentations resulted from clenching (9-12), and they
have also been reported in patients with lingual habits such as sucking (13), and in those with macroglossia or amyloidosis (14, 15). However, as yet, there is no consensus on which factors are involved in the formation of tongue indentations.

The aim of this study was to clarify which physiological factors were involved in the formation of tongue indentations by recording lingual pressure on the lingual surface of the teeth during different activities. Tongue pressure integration was also calculated. In addition, tongue and dental arch differential width were measured as anatomical factors.

Materials and Methods

Subjects

Twenty four young adults in their twenties (15 male and nine female, mean age, 22 ± 2) with normal occlusion and complete natural upper and lower dentition participated in this study. All subjects were fully informed about the experimental procedures and gave their consent to participate in the study.

Intraoral examinations were carried out to assess presence of tongue indentations according to the following protocol and criteria: subjects were required to open their mouth slightly, but not allow their tongue to protrude. Indentations had to be located along the lateral border of the tongue where it lay alongside the premolars and molars. Furthermore, tongue indentations had to show no change throughout each day, or from day to day, during the course of the study.

Subsequently, the subjects were divided into two groups: (i) a group where all subjects had tongue indentations (seven male, one female), and (ii) a group where all the subjects had no tongue indentations (eight male and eight female).

Recording System

Impressions of the upper and lower arches were taken to obtain working casts for all subjects. A silicone impression material was used. The casts were obtained by pouring high-strength dental stone in the impressions taken.
Intraoral appliances, 1 mm in thickness, were made from cobalt-chrome alloy and placed in the upper and lower jaws. They were designed so as not to interfere with the subject’s intercuspal position. Since tongue indentations have been found in both the upper and lower portions of the tongue border, a small pressure sensor device was set in both the upper and lower experimental intraoral appliances, parallel to the tooth axis of the right first molar. (Fig.1) This allowed a measurement range of from 100 KPa as the maximum value to -100 KPa as the minimum value (PS-1KC, KYOWA, Tokyo, Japan). The sampling frequency selected in this study was 10 KHz. The pressure registered when the pressure sensor device was placed intraorally, without lingual contact, was assumed to be 0 Pa. Measurement data were downloaded onto a computer using an amplifier (ML112, BIO RESEARCH CENTER, Tokyo, Japan) and analyzed by means of a software program (Power Lab, BIO RESEARCH CENTER, Tokyo, Japan).

Recording Procedure

The subjects were required to perform the following activities: (i) silent reading at rest for 10 min, (ii) maximum voluntary clenching (MVC) for 5 s, (iii) 10% of MVC for 1 min, and (iv) swallowing. Tongue pressure integration was also measured and defined as the product of positive tongue pressure and pressure duration time during silent reading at rest. (Fig.2)

Tongue pressure integration = \( \text{product of positive tongue pressure} \times \text{duration of positive tongue pressure} \)

Recordings were carried out for the upper and lower jaws in two sessions.

An electromyographic (EMG) recording device was used to measure MVC and 10% of MVC, and the subjects were able to control muscle contraction strength through feedback from a monitor. The muscle selected for EMG measurement was the right side masseter muscle, with the recording site at the centre of the muscle. EMG activity was recorded by means of bipolar surface electrodes (NT-211U, NIHON KOHDEN, Tokyo, Japan) applied parallel to the main direction of the muscle fibres. Interelectrode distance was 25 mm, and the reference electrode was attached behind the ear. The sampling frequency selected was 10 KHz. Measurement data were downloaded onto a computer.
via a signal from a surface electrode using a high sensitivity amplifier (MEG-2100, NIHON KOHDEN, Tokyo, Japan) and analyzed by means of a software program (Power Lab, BIO RESEARCH CENTER, Tokyo, Japan).

Before commencing measurements, all the recordings were fully explained to all subjects and rehearsed sufficiently. To avoid subjects becoming fatigued, a relaxation time of approximately 2 min was set between recordings. All the recorded tasks were repeated three times, except for the silent reading at rest, which was performed only once. The mean value of the data obtained from the pressure sensor device was calculated for each recording task. The results obtained from each group were then compared.

Tongue width and dental arch width were also measured to obtain the differential width. To measure tongue width, a cast of each subject’s tongue was prepared. However, since it is difficult to fix a recording site using only a tongue cast, we also assembled mandible casts. This allowed us to establish a stable recording site. Prior to taking impressions, subjects were seated comfortably upright in a dental chair, keeping the Frankfort plane horizontal. They were asked to relax, hold their tongue in a resting position and refrain from moving the tongue during the impression-taking procedure. Custom trays were prepared for each subject using their mandible working casts as shown in Fig. 3. A silicone material was used for the impression (Fig. 4). After intraoral placement of the custom trays, the subjects were asked to close their mouth immediately. Once the impression material hardened, the custom trays were removed and placed over the mandible working casts. A high-strength dental stone was then poured into the space between the working cast and the custom tray with the tongue impression, as shown in Figure 5.

Tongue width was measured from the point at which the tongue’s lateral border overlaps the central pit of the mandible first molar on both sides using the cast made from the tongue impression taken at rest. Dental arch width was measured from the center of the lingual surface of the mandibular first molar from right to left using the mandible working cast. A digital caliper (CD-S15, Mitutoyo, Tokyo, Japan) was used to record the above mentioned measurements.
Tongue and dental arch differential width were calculated by subtracting dental arch width from tongue width. (Fig.6) The results obtained from each group were compared.

Data analysis

The results for each task were compared between groups using the Mann-Whitney test. The result of tongue and dental arch differential width was compared between groups using a test of homogeneity and then the Student’s t-test. Statistical significance was set at P < 0.05

Experimental Ethics

The study protocol was approved by the Ethics Committee of Tokyo Dental College (080). All the experiments were done in accordance with the Edinburgh Revision of the Helsinki Declaration.

Results

The results of the recordings of lingual pressure on the lingual surface of the upper first molar for each recording task are shown in Table 1. Tongue pressure (KPa/s) was calculated as the lingual pressure in KPa exerted on the lingual surface of the teeth per second.

The results of the recordings of lingual pressure during silent reading at rest for 10 min revealed that there was no significant difference between the two groups. The values obtained from recording lingual pressure during MVC for 5 s and 10% MVC for 1 min were similar to those obtained during silent reading at rest, and no significant differences between groups were found. The results of the recordings of lingual pressure during swallowing showed higher values than for the other tasks. However, as with the other three tasks, there was no significant difference between the two groups.

The results of the recordings of lingual pressure exerted on the lingual surface of the lower first molar are shown in Table 2. These were very similar to those obtained for the upper first molar.

The results of the recordings of tongue pressure integration during silent reading at rest for 10 min are shown in Table 3. Tongue pressure integration (KPa ∙ s) was calculated as the integration of positive tongue pressure and duration of pressure. These show that there were no significant
differences between the two groups for either the upper or lower jaws.

The results of the recordings of tongue and dental arch differential width are shown in Table 4. A comparison of tongue and dental arch differential width revealed significant differences between the groups (P < 0.05). In the group with tongue indentations, tongue and dental arch differential width was 1.96 ± 2.21 mm, while in the group without tongue indentations it was −3.56 ± 2.16 mm. In other words, in the group with tongue indentations, tongue width was larger than dental arch width.

Discussion

Within all the subjects assessed to participate in this study, based on the selection criteria for the detection of tongue indentations, only those who presented a remarkable expression of this condition were selected (mild conditions were not included). For most of them was difficult to get their agreement to participate in this study. Consequently the final number of participants was reduced to eight.

In the pre-experimental phase of this study, we measured tongue pressure on the right and left molars at rest in six subjects in order to determine whether there were any differences. Comparison of the results with the Student’s t-test revealed no differences between the two sides (Table 5).

Therefore, the right side first molar was selected as the recording site. Recordings for the maxilla and mandible were carried out in different sessions in order to avoid the subjects experiencing discomfort as a result of the intraorally placed experimental appliances.

To keep the tongue as close as possible to its normal position during the recording procedure, the intraoral appliances were designed so as not to interfere with the subjects’ intercuspal position, and their thickness was kept to a minimum to reduce any discomfort. Moreover, they were put in place one hour prior to commencement of measurements to allow the subjects to become accustomed to them. With regard to influence of thickness of intraoral appliance on measured value, a thickness of 1 mm was selected based on a previous study which reported that a thickness of below 2 mm
negated interference with measured value (16).

To investigate formation of tongue indentations, lingual pressure during rest, clenching, and swallowing were measured as physiological factors. Tongue width and dental arch width were also measured as anatomical factors to obtain the differential width for each subject. Lingual pressure on the lingual surface of the teeth during rest is believed to be possibly related to the formation of tongue indentations, because at rest the tongue stays in contact with the teeth over long periods. Therefore, we surmised that not only lingual pressure on the lingual surface of the teeth, but also the duration of that pressure might be associated with the formation of tongue indentations. To investigate this, tongue pressure integration, defined as the product of positive tongue pressure and pressure duration time during silent reading at rest, was also calculated.

During silent reading at rest, lingual pressure on the lingual surface of the teeth showed some variation during the recording session, with a positive pressure being recognized most of the time. In the tongue indentation group, a higher lingual pressure was observed than in the group without tongue indentations. However, no significant difference was found between the two groups. With regard to tongue pressure integration at rest, the maxilla showed higher values than those observed for the mandible (Table 3). This was because mean lingual pressure during silent reading at rest was higher for the maxilla than the mandible. As tongue pressure integration was calculated from lingual pressure at rest and pressure duration, the same tendency to be high was observed for the maxilla, too. However, when tongue pressure integration values from both groups were statistically compared, no significant difference was found. Therefore, we believe that neither level of lingual pressure at rest, nor duration of that pressure, have any relationship to the formation of tongue indentations.

Previous studies (7, 9) have reported that tongue indentations were caused by clenching. To assess the effect of clenching strength, 2 different tasks were recorded: MVC (17) and 10% of MVC (18). In this study, lingual pressure recorded during MVC was higher than that observed during 10% of MVC (Table 1, 2). However, it was found that lingual pressure on the lingual surface of the right
first molar showed no significant difference between groups, regardless of clenching strength. These results are contrary to those of previous studies, which concluded that tongue indentations were a result of clenching (7, 9), and suggest that tongue indentations do not result from level of lingual pressure of clenching.

In this study, experimental clenching was included as one of the tasks to be recorded in order to clarify which factors were involved in the formation of tongue indentations, but not to investigate the relationship between clenching and tongue indentation. Therefore, sleep-related bruxism and/or non-sleep clenching were not assessed. Further study will be required to determine the relationship between clenching (or other oral parafunctions) and tongue indentations. Such study will need to include not only a parafunction activity questionnaire, but also EMG recordings and intraoral assessment.

A previous study (8) reported that swallowing played an important role in the formation of buccal mucosa ridging. Therefore, we considered that the same might apply to tongue indentations. As described above, the lingual pressure on the lingual surface of the first molar measured during swallowing showed the highest value among the activities recorded (Table 1, 2). These findings concur with those of previous studies, which reported a lingual pressure of 8.3 KPa on the upper molar area and 7.2 KPa on the lower molar area (19, 20). However, in this study, no significant difference was found between the two groups. Based on these results, we believe that volume of lingual pressure during swallowing is not related to the formation of tongue indentations.

In the pre-experimental phase of this study, tongue width was measured throughout each day and on different days in order to ascertain whether any changes occurred. These measurements were carried out in four subjects. The results for tongue width were compared using a one-way ANOVA, which revealed no significant differences. Based on these results, we believe that the tongue impression method used was reliable enough to determine tongue width.

In terms of tongue width, a difference between the two groups was recognized, with tongue width being wider than dental arch width in the tongue indentation group, as shown in Table 4.
This suggests that tongue width, as an anatomical factor, plays an important role in the formation of tongue indentations. As previously mentioned, some clinical studies have reported that tongue indentations were observed in patients with macroglossia (15). Moreover, in oriental medicine, the condition called plump tongue is characterized by the presence of tongue indentations (21). In this condition, there is a decline in the metabolism of liquids, leading to an augmentation of tongue size. As a consequence, tongue indentations are recognized when this condition persists for a certain period of time. This condition may be regarded as a type of oedema. Moreover, as such tongue indentations often persist for a long time, it is believed that the viscoelasticity of the mucosa may also be implicated in their development.

The results of this study revealed that there were significant differences between the two groups in terms of tongue width. This suggests that individual tongue size, as well as tongue characteristics (mucosa elasticity, liquid retention, etc.), is related to the formation of tongue indentations.

These findings indicate that neither level of lingual pressure exerted on the lingual surface of the upper and lower teeth during rest, clenching, nor swallowing are responsible for the formation of tongue indentations. However, our results do suggest that tongue width plays an important role in the formation of tongue indentations.

Although the results of this study indicate that tongue width plays an important role in the formation of tongue indentations, we believe that there may also be other factors involved, including inclination of the lingual surface of the posterior teeth and overjet in the posterior teeth. Such occlusal factors may allow the tongue to come into contact with the lingual surface of teeth, leading to the formation of tongue indentations. Furthermore, levels of tongue pressure during swallowing showed no significant differences between the two groups. Therefore, we believe that neither level of pressure nor number of swallows plays a role in the formation of tongue indentations, bearing in mind that the tongue is in contact with the lingual surface of the teeth for only a short time during swallowing. Moreover, as the position of the tongue changes throughout
the different stages of swallowing, the duration of contact for any given area of tongue is very short. Therefore, we believe that this would not result in tongue indentations.

Furthermore, although the tongue is in contact with the lingual surface of the teeth for long periods during rest, the results obtained here for tongue pressure during silent reading at rest for 10 min showed no significant differences between the groups. This suggests that the position of the tongue during rest is not an important factor in the formation of tongue indentations.

References
10. Gray RJ, Davies SJ, Quayle AA. A clinical approach to temporomandibular disorders.


Acknowledgments

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Table 1: Lingual pressure (KPa/s) exerted on lingual surface of upper first molar in each task

<table>
<thead>
<tr>
<th>Tasks</th>
<th>Tongue indentation group</th>
<th>No tongue indentation group</th>
</tr>
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<tr>
<td></td>
<td>n=8</td>
<td>n=16</td>
</tr>
<tr>
<td>Mean ± s.d.</td>
<td>Mean ± s.d.</td>
<td>P-value</td>
</tr>
<tr>
<td>Silent reading at rest</td>
<td>3.14 ± 1.42</td>
<td>2.17 ± 1.63</td>
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<tr>
<td>MVC</td>
<td>3.53 ± 2.69</td>
<td>2.75 ± 2.24</td>
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<tr>
<td>10%MVC</td>
<td>2.48 ± 1.40</td>
<td>2.01 ± 1.26</td>
</tr>
<tr>
<td>Swallowing</td>
<td>7.62 ± 2.85</td>
<td>7.80 ± 3.08</td>
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MVC = maximum voluntary clenching
s.d. = standard deviation
### Table 2

<table>
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<tr>
<th>Tasks</th>
<th>Tongue indentation group</th>
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</tr>
</thead>
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<tr>
<td></td>
<td>n=8</td>
<td>n=16</td>
</tr>
<tr>
<td></td>
<td>Mean ± s.d.</td>
<td>Mean ± s.d.</td>
</tr>
<tr>
<td>Silent reading at rest</td>
<td>1.98 ± 0.84</td>
<td>1.74 ± 0.69</td>
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<tr>
<td>MVC</td>
<td>2.28 ± 1.03</td>
<td>2.04 ± 0.93</td>
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<tr>
<td>10%MVC</td>
<td>1.78 ± 0.99</td>
<td>1.70 ± 0.86</td>
</tr>
<tr>
<td>Swallowing</td>
<td>7.18 ± 2.92</td>
<td>7.89 ± 2.80</td>
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MVC = maximum voluntary clenching
s.d. = standard deviation

### Table 3

<table>
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<th>Measurement region</th>
<th>Tongue indentation group</th>
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<td>n=16</td>
</tr>
<tr>
<td></td>
<td>Mean ± s.d.</td>
<td>Mean ± s.d.</td>
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<tr>
<td>Upper first molar</td>
<td>1,887 ± 855</td>
<td>1,304 ± 806</td>
</tr>
<tr>
<td>Lower first molar</td>
<td>1,189 ± 505</td>
<td>1,118 ± 447</td>
</tr>
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</table>

s.d. = standard deviation
<table>
<thead>
<tr>
<th>Tongue indentation group</th>
<th>No tongue indentation group</th>
</tr>
</thead>
<tbody>
<tr>
<td>n=8</td>
<td>n=16</td>
</tr>
<tr>
<td>Mean ± s.d.</td>
<td>Mean ± s.d.</td>
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<tr>
<td>1.96 ± 2.21</td>
<td>- 3.56 ± 2.16</td>
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</table>

s.d. = standard deviation

* = Significant difference
Table.5

<table>
<thead>
<tr>
<th>Subject</th>
<th>Tongue pressure at left first molar Mean ± s.d. (KPa/s)</th>
<th>Tongue pressure at right first molar Mean ± s.d. (KPa/s)</th>
<th>P-value</th>
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<tr>
<td>1</td>
<td>0.82 ±0.02</td>
<td>0.81 ±0.03</td>
<td>0.61</td>
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<tr>
<td>2</td>
<td>0.91 ±0.17</td>
<td>0.88 ±0.19</td>
<td>0.28</td>
</tr>
<tr>
<td>3</td>
<td>1.18 ±0.97</td>
<td>1.19 ±0.14</td>
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<td>4</td>
<td>1.07 ±0.07</td>
<td>1.07 ±0.05</td>
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</tr>
<tr>
<td>5</td>
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<td>1.00 ±0.05</td>
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</tr>
<tr>
<td>6</td>
<td>0.70 ±0.15</td>
<td>0.69 ±0.13</td>
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s.d. = standard deviation

Figure 1: Experimental intraoral appliances

Intraoral appliances, 1 mm in thickness, were made from cobalt-chrome alloy for each subject.
Small pressure sensor was placed at right first upper and lower molar.

Figure 2: Tongue pressure integration

Tongue pressure integration was calculated by product of positive tongue pressure (KPa) and pressure duration time (s)
Figure 3: Custom tray for tongue impression

Individual trays for each subject were made using mandible working casts.

Figure 4: Tongue impression

Impressions of tongue were taken by means of silicone impression material.

Figure 5: Mandible and tongue casts

Tray containing impression of tongue was placed over mandible working cast. High-strength dental stone was poured into space between working cast and tongue impression.

Figure 6: Tongue and dental arch differential

Tongue width was measured from point at which lateral border of tongue overlaps central fossa of mandible first molar on both sides. Dental arch width was measured from center of lingual surface of mandibular first molar from right to left.
Fig. 1
Fig. 2

(KPa)

: Tongue pressure integration
Fig. 6