Influence of mouthguard on temporomandibular joint

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The aim of this study is to examine whether wearing a mouthguard (MG) has an influence on temporomandibular joint (TMJ) components (i.e., the condyle and the articular disk) and whether clenching with a resilient MG has an effect on the same components. Twenty-six healthy volunteers (15 females, 11 males) with an age range of 26–42 years old (median 28 years) participated in this study. Among all 52 joints in the 26 subjects, anterior disk displacement (AntDD) was recognized in 15. Thus, we classified the 52 joints into two groups, the AntDD group and the Normal group. Resilient thermoplastic materials were used to fabricate two types of MG, one that raised the vertical dimension height by 3 mm and another that raised it by 6 mm. Subjects were scanned with/without two types of MG with/without clenching by magnetic resonance imaging (MRI). The movement of the condylar head and articular disk was measured in the magnetic resonance images using the special subtraction technique. Wearing the MG without clenching did not have a negative influence on the TMJ and clenching in the Normal group. In the AntDD group, however, the relationship between the disk and condyle was affected by clenching and the degree of disk displacement was worsened by clenching with the thicker MG. From our results, we recommend that athletes with an internal derangement of the TMJ not wear the thicker MG and attention should be paid to its setting. And the subtraction technique using MRI was thought as a good tool for detecting a slight change in the TMJ.

A mouthguard (MG) is widely used by athletes, especially those participating in contact sports, with the main purpose of protecting the teeth from traumatic injury (Newsome et al., 2001; Labella et al., 2002). In some contact sports, MG usage is mandatory (Holmes, 2000). Although the frequency of tooth fracture is decreased by wearing such a device, we have encountered many athletes complaining of pain and dysfunction in the temporomandibular joint (TMJ) after using an MG.

The number of patients with TMJ dysfunction has been increasing (Larheim et al., 2001), with the chief cause found to be anterior disk displacement (AntDD), which is brought about by occlusion disturbances (Westersson & Rohlin, 1984). Patients with TMJ dysfunction always complain of the clicking noise, pain at TMJ region, and the disturbance of the mouth opening. Furthermore, in many cases that have no symptoms or signs in the TMJ region, disk displacement has been found incidentally during an unrelated examination, such as with magnetic resonance imaging (MRI) (Nebbe & Major, 2000; Larheim et al., 2001).

An MG is mounted onto the teeth; thus, occlusion will change and may affect the TMJ by changing the condylar and disk position. Furthermore, if the wearer clenches with a resilient MG, the relationship between the condyle and disk could change. However, it was very difficult for imaging to detect slight differences of TMJ components between before and after wearing or while clenching an MG.

Recently, MRI has been utilized for examinations of the oral and maxillofacial region (Lenz et al., 2000), and it has shown to be advantageous because of the optional tomographic planes and greater tissue contrast without exposure to ionizing radiation (Murakami et al., 1992). The TMJ is considered to be the best target for MRI in the oral and maxillofacial region (Murakami et al., 1992; Larheim et al., 2001), and a digital subtraction method has been introduced to detect slight differences among states (Molloi et al., 1998; Remonda et al., 2002). In the dental field, measurement of distances below 0.1 mm has been reported to be very useful (Sato et al., 1998).

In the present study, we employed MRI using the subtraction method to determine if wearing an MG
has an influence on TMJ components (i.e., the condyle and disk) and whether clenching with a resilient MG has an effect on the same components.

Subjects and methods

Twenty-six healthy volunteers (15 females, 11 males) with an age range of 26-42 years old (median 28 years) participated in this study. None showed any symptoms or signs of problems in the TMJ on either side. The study protocol was approved by the ethics committee of our university and written informed consent was given by all subjects.

Impressions of both the upper and lower dental arches were taken in the upright position. For determining individual vertical dimensions, two points for inter-marking distance (IMD) were marked as references on the midline of a plaster model. Silicone rubber squash bites were taken at the centric occlusion (CO) in the upright position (IMD = 0 mm). The MG was made using a pressure-lamination machine (Druformat, Pfalzgrafenweiler, Germany), which utilizes a heating element and up to 10 atmospheres of pressure to obtain a better form and more intimate adaptation to a plaster model. Resilient thermoplastic materials of the ethylene vinyl acetate (Erkosoft®, Erkodent, Pfalzgrafenweiler, Germany) were used to fabricate two types of MG, one that raised the vertical dimension height by 3 mm (MG1; IMD = 3 mm) and another that raised it by 6 mm (MG2; IMD = 6 mm). The surface of MG was finished according to the opposing occlusion in order to make an even bite.

For MRI imaging, a 1.5 T superconductive-type scanner (Signa LX, GE Medical Inc., Milwaukee, Wisconsin, USA) was used with a TMJ exclusive coil for signal receiving. Each subject was placed in a supine position so that the Frankfort plane agreed with the horizontal laser beam pointer of the scanner. The head was fixed as firmly as possible during 1-min scanning.

First, a horizontal plane around the TMJ was taken as a localizer. Using this horizontal plane, we obtained a parasagittal plane perpendicular to the long axis of the condylar head. Image sequencing was performed at a fast spin echo and imaging parameters included TR of 2000, TE of 19, and ETL of 16. The field of view (FOV) was 8 cm and the matrix size was 512 × 512. Para-sagittal images were taken at five different mandibular positions as follows: (1) CO, (2) wearing MG1, (3) clenching with MG1, (4) wearing MG2, (5) clenching with MG2. As for the clenching, we asked subjects to clench as strongly as possible during 1-min scanning.

Image data were transferred to a workstation (ADW 3.1, GE Medical Inc.) online and analysis was performed digitally. Vertical and horizontal differences between the CO and MG, and the MG and clenching were measured using a subtraction method, in which the value of a pixel was zero when it was black on the image, indicating no change between the first and second phase. When a change was detected, the pixel had a value and showed white on the image. The number of white pixels was counted along the Frankfort plane and along the line perpendicular to the Frankfort plane.

Among all 52 joints in the 26 subjects, AntDD was recognized in 15. Thus, we classified the 52 joints into two groups, the AntDD group (n = 15) and the Normal group (n = 37).

Results

The first scan, as a localizer, took 3 s and the subsequent four scans of the TMJ required 64 s to complete. The FOV was 8 cm × 8 cm and the matrix size was 512 × 512; therefore, the size of one pixel was 0.156 mm.

Results of the subtraction method are shown in Fig. 1, while Fig. 1(c) shows MG1 findings and Fig. 1(f) shows those of MG2. The changes were slight; however, they were confirmed as white pixels on the subtracted image (Fig. 1).

The mean of the vertical joint space at CO was 2.65 mm (SD; 1.14 mm, maximum; 4.6 mm, minimum; 0.7 mm). Wearing the MG widened the vertical joint space in all joints, with those with MG2 being statistically larger than those with MG1 (Table 1). All condyles moved forward horizontally, and movements with MG2 were statistically larger than those with MG1 (Table 1). The disks also moved forward, and disk movement in the AntDD group was statistically larger than those in the Normal group with MG2 (Table 1).

During clenching of the MG, condyles and disks moved upward and backward, while vertically the condyles moved upward. The movements were larger with MG2 than with MG1 (Table 2). Horizontally, the condyles moved backward, and movement in the AntDD group was statistically greater than that with MG1, though there was no statistical difference for disk movement between the Normal and AntDD groups.

Discussion

Methodology

It has been reported that the occlusal height of the freeway space is <3 mm and masticator muscles are activated at 6 mm of occlusal height (Williams et al., 1983; Wood et al., 1986). In the present study, two kinds of MG were made, MG1 with an occlusal height of 3 mm and MG2 with that of 6 mm. To determine optimal MG thickness, various MG thicknesses will need to be studied; however, that was not the objective of this study. And we had better examine other MGs with greater occlusal heights because there are many athletes with bigger body size and they might have bigger jaws.

There is no clear consensus regarding the best materials to use for construction of an MG, though we utilized resilient materials, because that type is most often used in Japan. During our experiments, a resilient MG was simply mounted and imaging was performed. When clenching was not performed, the MG material had no influence; however, when the subjects were asked to clench with their maximum bite force, occlusal force varied. For a study to determine the optimum materials of an MG, individual occlusal force will need to be measured and a variety of materials tested. Two of
the present subjects complained of temporary dull pain in the masseter muscle region caused by clenching.

There is no ionizing radiation exposure associated with MRI; thus, examinations are repeatable. Furthermore, use of an optional tomographic plane is very useful for TMJ imaging. One of the weak points of our protocol is that each examination time was long (approximately 1 min), even though we used a fast spin echo sequence.

A digital subtraction method was used to detect slight changes in condyle and disk movement, which has recently also been used for studies of the brain, as slight changes can be demonstrated. When applied for dentistry studies, the measurement unit is \( \text{mm} \). For our subjects, the head was fixed firmly, and slight changes in the condyle and disk were measured. Because the FOV was 8 cm and the matrix size was 512, one pixel became 0.156 mm. These were analyzed on a workstation.

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**Fig. 1.** Para-sagittal magnetic resonance (MR) images of the temporomandibular joint (TMJ). (a) centric occlusion, (b) mouthguard (MG)1 wearing, (c) subtracted image (b–a), (d) MG2 wearing, (e) clenching with MG2, (f) subtracted image (e–d). HD, horizontal difference; VD, vertical difference.

**Table 1. Change of condyle and disk on MG wearing**

<table>
<thead>
<tr>
<th></th>
<th>Total (n = 52)</th>
<th>Normal (n = 37)</th>
<th>AntDD (n = 15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertically (downward)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Condyle</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MG1</td>
<td>1.15 ± 0.79</td>
<td>1.10 ± 0.77</td>
<td>1.25 ± 0.89</td>
</tr>
<tr>
<td>MG2</td>
<td>2.10 ± 1.48</td>
<td>1.79 ± 1.11</td>
<td>2.76 ± 2.02</td>
</tr>
<tr>
<td>Horizontally (forward)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Condyle</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MG1</td>
<td>1.17 ± 0.55</td>
<td>1.00 ± 0.80</td>
<td>1.26 ± 0.39</td>
</tr>
<tr>
<td>MG2</td>
<td>2.33 ± 1.11</td>
<td>2.28 ± 0.86</td>
<td>2.35 ± 1.24</td>
</tr>
<tr>
<td>Disk</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MG1</td>
<td>0.22 ± 0.52</td>
<td>0.03 ± 0.09</td>
<td>0.62 ± 0.80</td>
</tr>
<tr>
<td>MG2</td>
<td>0.62 ± 1.78</td>
<td>0.11 ± 0.36</td>
<td>1.73 ± 1.29</td>
</tr>
</tbody>
</table>

Notation is the average ± SD (standard deviation) and unit is millimeter. Plus quantity means the change downward and forward. AntDD, anterior disk displacement; MG, mouthguard.

**Table 2. Change of condyle and disk on clenching with MG**

<table>
<thead>
<tr>
<th></th>
<th>Total (n = 52)</th>
<th>Normal (n = 37)</th>
<th>AntDD (n = 15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertically (upward)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Condyle</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MG1</td>
<td>0.08 ± 0.75</td>
<td>0.02 ± 0.12</td>
<td>0.21 ± 1.38</td>
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<tr>
<td>MG2</td>
<td>1.33 ± 1.45</td>
<td>1.09 ± 1.21</td>
<td>1.84 ± 1.87</td>
</tr>
<tr>
<td>Horizontally (backward)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Condyle</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MG1</td>
<td>1.15 ± 0.42</td>
<td>0.45 ± 1.03</td>
<td>1.33 ± 0.78</td>
</tr>
<tr>
<td>MG2</td>
<td>1.28 ± 1.11</td>
<td>1.16 ± 1.93</td>
<td>2.30 ± 1.27</td>
</tr>
<tr>
<td>Disk</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MG1</td>
<td>0.22 ± 0.32</td>
<td>0.00 ± 0.02</td>
<td>0.47 ± 0.65</td>
</tr>
<tr>
<td>MG2</td>
<td>0.62 ± 0.80</td>
<td>0.08 ± 0.36</td>
<td>0.71 ± 1.27</td>
</tr>
</tbody>
</table>

Notation is the average ± SD (standard deviation) and unit is millimeter. Plus quantity means the change upward and backward. AntDD, anterior disk displacement; MG, mouthguard.
For simplifying our analysis, measurements were carried out only in the top to bottom and front to back directions. However, as the condyle and disk can move medially and laterally as well, future measurements should also be performed three-dimensionally. Although statistical analyses were carried out by pixel, the results are expressed in millimeter units.

Significance of results

Effect of MG wearing on TMJ

With MG1, the condyle moved 1.15 mm downward and 2.10 mm forward, while with MG2, condyle movement was statistically larger. A separation was reported between the head of the condyle and the base of the skull by the MG wearing acted as a buffer so the force of the blow delivered to the lower jaw or chin will not be transferred to the base of the skull (Winters, 1997; Winters, 2001). And the separation was also confirmed in this study. A similar tendency was recognized for disk movement as well. The lateral pterygoid muscle is contracted with mouth opening, and the condyle and disk are also retracted forward by this muscle. In our subjects, their relative position scarcely changed.

None of our subjects had complaints regarding the TMJ; however, AntDD was found in 15 (28.8% of all joints), which agreed with previous reports (Nebbe & Major, 2000; Larheim et al., 2001). Although movement of the disk with MG was slightly greater in the AntDD group, the difference was not statistically significant, as a similar tendency was found for disk movement with both MG1 and MG2. These results suggest that when the thickness of the MG is <6 mm, MG wearing does not affect the TMJ components, not only in normal subjects but also in athletes with an internal derangement of the TMJ.

Effect of clenching with resilient MG on TMJ

When clenching the MG, the condyle moved backward and upward in nearly all of the subjects. In the Normal group, the disk also moved backward and upward; thus both the condyle and disk returned to the previous normal position in this group. However, in the AntDD group, the disk either did not move or moved forward, which occurred to a greater degree when clenching with the thicker MG2.

The direction of condyle movement during clenching was associated with the direction of the mouth closing muscles, i.e. the temporal, masseter, and lateral pterygoid muscles. In the Normal group, the disk returned to the previous position; therefore, we considered that the lateral pterygoid muscle, which had pulled the disk forward during mouth opening, released the disk, and allowed the posterior attachment to pull the disk backward.

In the AntDD group, the disk did not come back to the previous position. Thus, because the elasticity of the posterior attachment was reduced, the posterior attachment no longer pulled the disk backward during clenching. It was suggested that clenching with the thicker MG altered the relationship of the condyle and disk in the AntDD group.

Perspectives

Wearing the MG without clenching did not have a negative influence on the TMJ and clenching in the Normal group gave the same result. However, in the AntDD group, the relationship between the disk and condyle was affected by clenching and the degree of the disk displacement was worsened by clenching with the thicker MG. From our results, we recommend that athletes with an internal derangement of the TMJ not wear the thicker MG and attention should be paid to its setting.

In the present study, we measured and analyzed movement and change in only one plane by MRI. However, because the condyle and disk may move medio-laterally as well as vertically and horizontally, it is necessary to measure and analyze in three dimensions in future experiments.

Although a fast MR sequence was adopted, each examination required approximately 1 min to complete, which led to subject discomfort while clenching and two subjects complained of temporary pain in the masseter muscle region. As MRI methods improve, the examination time should be reduced.

Key words: mouthguard, MRI, clenching, sports dentistry, TMJ, TMJ dysfunction.

References


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