Mouth-opening Exercises Produce a Decrease in Pain Perception in Patients with Disk Displacement with Reduction

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Abstract: This study was intended to determine whether mouth-opening exercise reduces pain sensitivity in remote regions as well as in the trigeminal region. Seven female subjects with disk displacement with reduction were asked to perform a three-minute repetitive mouth opening and closing exercise (exercise A) and a three-minute continuous mouth opening exercise (exercise B) on two separate days. Sensory/nociceptive perception thresholds were measured at the point over the right masseter and the skin overlying the volar aspect of the right forearm immediately after exercises A and B, and were compared to data in which no exercise was performed (baseline). Significant elevation in the heat-induced pain threshold was seen as a result of both exercises in the cervical region and in the trigeminal region. Also, a significant elevation in the cold-induced pain threshold was seen after exercise B in the cervical region. Further, there was a tendency toward a higher warm sensation threshold after exercise A in the cervical region. These results indicate that mouth opening training produces non-segmental analgesic effects mediated by C fiber and A-delta fiber.

Key words: exercise, pain perception, analgesic effect, disk displacement with reduction

Introduction

A Japanese survey\(^1\) showed that 84.6% of patients with temporomandibular joint clicking primarily caused by placement of an anterior disk with reduction (ADDWR) but who do not experience any related pain expect some kind of treatment. Although the most standard therapy for clicking is to reposition the splint, the use of a repositioning splint may often develop occlusal problems and treatment for these patients is still controversial\(^1\).

Physical therapy falls within the domain of physical medicine, and various therapeutic exercises can be used for the treatment of temporomandibular disorders (TMD). These treatments can be performed in the office with the assistance of a dental clinician or physical therapist or at home by the patient. Decker et al. have classified therapeutic exercises for the masticatory systems regarding the possible mechanisms of action of exercises into five major categories: (1) range of motion (ROM) exercises to improve mobility by elongating soft tissue structures such as the muscle or joint capsule; (2) isometric exercises to
strengthen the muscles and improve coordination; (3) repetitive exercises to improve the biomechanics of joint and muscle function; (4) postural exercises to reduce muscle and joint strain; and (5) stretching exercises to increase joint ROM and lengthen soft tissue. Kemppainen et al. demonstrated that physical exercise using a cycle ergometer elevated dental pain thresholds, and they concluded that physical exercise produces a non-segmental, load-dependent decrease in pain and thermal sensitivity. Koltyn et al. also reported that analgesia was observed after an isometric handgrip exercise.

Mouth-opening exercises are often employed for TMD in clinical practice. Yoda et al. reported a new therapeutic exercise for clicking attributable to ADDWR, by which an actual change in intra-articular anatomic relationships is induced. However, the underlying mechanism was unknown and little attention has been given to the changes in pain sensitivity that result from the mouth-opening exercises. A non-invasive computer-based quantitative sensory testing device has been developed to measure thermal senses, and its reliability and validity have been proven in several scientific studies. Our study used this device in order to confirm whether or not two kinds of mouth-opening exercise change the threshold of cool sensation, warm sensation, cold-induced pain, and heat-induced pain in the trigeminally mediated region and in the cervically mediated region.

Materials and Methods

1. Subjects

Seven female subjects with anterior disk displacement with reduction were recruited for this study. All patients were selected from the outpatient clinic at the Department of Oral and Maxillofacial Surgery, Miyazaki Medical College Hospital. After a screening questionnaire, each subject was given a complete intraoral and extraoral examination for signs and symptoms of TMD. The criteria for inclusion were as follows: (1) reproducible painless joint noise occurring at variable positions during opening and closing mandibular movements; (2) mandibular deviation during movement coinciding with a click; (3) a lack of tenderness at the temporomandibular joints (TMJ), superficial masseter, deep masseter, anterior temporals, and middle temporals on either side; (4) a jaw-opening ability greater than or equal to 40 mm as measured by a calibrated ruler; (5) a full set of teeth, with the possible exception of third molars; (6) age between 18 and 39 years; (7) freedom from acute dental disease, migraines or vascular headaches; and (8) taking no analgesics, muscle relaxants, or antidepressants on the day of assessment. All subjects were clinically diagnosed as having anterior disk displacement with reduction. This study protocol was approved by an appropriate committee in our department (P2002-2). All of the subjects were informed of the purpose and procedures of the tests, and informed consent was obtained prior to the commencement of the study.

2. Procedures

The tests were performed on three separate days within two consecutive weeks, and the three experimental days were randomly assigned exercise A, exercise B, or no mouth-opening-exercise (baseline). On each test day, the subjects were seated comfortably in a chair without a headrest. Exercise A consisted of a three-minute repetitive mouth-opening exercise. In other words, subjects were asked to open their mouths to a width of three fingers for five seconds, then relax and close the jaw over five seconds, synchronized to the clicking sounds of a metronome. The opening-closing procedure was repeated for three minutes. Exercise B consisted of holding the mouth open at a width of three fingers continuously for three minutes with verbal encouragement.

At the baseline and immediately after exercises A and B, sensory/nociceptive perception thresholds were measured at the same point over the right masseter as well as on the skin overlying the volar aspect of the right forearm. The following order of stimuli was used in all subjects: cool sensation, warm sensation, cold-induced pain, and heat-induced pain. This order was selected because it proceeds from the lowest (cool sensation) to the highest (heat-induced pain) stimulus. Measurement
ment of the thresholds of the skin over the masseter muscle always preceded that at the forearm.

Thermal thresholds were measured with a computer-controlled contact thermal stimulator (The TSA-II NeuroSensory Analyzer, Medoc Advanced Medical Systems, Ramat Yishai, Israel). The thermal probe consisted of a square thermode measuring $30 \times 30$ mm that could either increase or decrease the temperatures depending on the direction of the current flow through the device. The subject was instructed to press a button on a computer mouse when a specified sensation was first perceived. In all measurements, the thermode baseline temperature was kept at 32.0°C. The rate of temperature change was kept constant at $1.0°C/s$ for the assessment of cool and warm sensations, with a rate of $1.5°C/s$ used for the cold-induced and heat-induced pain. The return rate of the stimulus to the baseline was $1.0°C/s$ for cool and warm sensations, and three times for cold-induced and heat-induced pain. The thresholds were taken as the means of these measurements.

Vital signs including blood pressure, pulse rate, body temperature, and blood oxygen saturation, as measured by a pulse oximeter, were measured at baseline and immediately after the exercises. The respective degrees of pain and unpleasantness caused by exercise A or exercise B were also evaluated using a 10-cm visual analog scale (VAS). The 10-cm VAS was scaled from 0, defined as no pain or unpleasantness, to 10, defined as the worst pain or unpleasantness the subject had ever experienced. Delayed onset muscle soreness was also confirmed after 24 to 48 hours.

3. Statistics

A paired t-test was performed to examine any differences in blood pressure, pulse rate, body temperature, and blood oxygen saturation between the data at baseline and corresponding data recorded immediately after the both exercises. A Mann-Whitney U test was used to compare VAS values between the two exercises. The null hypothesis that there were no differences among the data at baseline and those after exercises A or B in terms of vibratory sensation, cool sensation, warm sensation, cold-induced pain, and heat-induced pain was evaluated by paired t-tests. Bartlett tests were also performed to determine the homogeneity of variance before the t-test. If the data obtained did not show homogenous distribution, a Wilcoxon test was employed instead of the paired t-tests. All statistical analyses were carried out using Stat View software, version 5.1 for Macintosh (Abacus Concept, Inc., Berkeley, CA, U.S.A.). All tests were considered statistically significant at a level of 0.05. Statistical trends were defined as $0.05 < P < 0.1$.

Results

The vital signs of the seven participants at baseline and after mouth-opening exercise are shown in Table 1. There were no significant differences in terms of blood pressure, pulse rate, body temperature, and blood oxygen saturation. Table 2 shows the intensity of pain, unpleasantness, and occurrence of delayed onset muscle soreness resulting from the exercises. The VAS results for intensity of pain and unpleasantness were similar for the two exercises, and none of the subjects complained of delayed onset muscle soreness due to the exercises between 24 and 48 hours after completion of the tasks. Since all the data obtained were normally distributed in the Bartlett tests, paired t-tests were performed. The effects of the exercises on sensory and pain perception thresholds are shown in Figure 1. A significant elevation in the heat-induced pain threshold was seen with the exercises in the cervical region (baseline vs. exercise A: $P = 0.0327$, baseline vs. exercise B: $P = 0.0022$), and there was a statistical significance toward a higher threshold in the trigeminal region (baseline vs. exercise A: $P = 0.0351$, baseline vs. exercise B: $P = 0.0022$). In addition, a significant elevation in cold-induced pain threshold was seen after exercise B in the cervical region ($P = 0.0219$), and there was a tendency toward a higher warm sensation threshold after exercise A in the cervical region ($P = 0.0653$), compared to the baseline.
The most striking findings of this study are that both types of mouth-opening exercise elevated the heat-induced pain threshold not only in the trigeminal region but also in the remote region. These results indicate that mouth-opening exercises produce a non-segmental decrease in heat-induced pain sensitivity. This study also demonstrated that exercise A elevated the warm sensation threshold, and that exercise B elevated the cold-induced pain threshold in the cervical region. It is well established that (1) heat-induced pain is a mostly C fiber-mediated sensation, with some involvement of A-delta fibers, (2) warm sensation is a C fiber-mediated sensation, and (3) cold induced pain is mediated by a combination of both C and A-delta fibers\textsuperscript{7–9}. Accordingly, the mouth-opening exercises would produce some analgesic effects that are mediated by not only C fiber but also by A-delta fiber. On the contrary, cool sensation, which is mediated by A-beta fiber, did not show any significant changes in this study.

The underlying mechanisms of the mouth-opening exercises on the perceptional thresholds are still unknown. On the whole, pain is recognized as a significant subjective aspect of the illness experience. When nociceptive inputs reach the limbic system by which pain is perceived, certain emotions can be precipitated and represent protective actions in an attempt to move the individual away from the source of painful irritation\textsuperscript{10}. It is also well known that glucocorticoids released by the hypothalamo-pituitary-adrenocortical axis during pain response diminish inflammation and block the sensitization of nociceptors in injured tissue\textsuperscript{11}. However, we also surmised that the mouth-opening task was not as severe as events that produce stress-induced analgesia. In consideration of this experiment, there are at least two mechanisms that can explain their analgesic effects: diffuse noxious inhibitory controls (DNIC) and anti-nociceptive effects produced by arterial hypertension. DNIC are known to have inhibitory effects: a painful stimulus applied anywhere in the body, not necessarily in the same or an adjacent neuronal segment, can modify pain perception, probably due to endogenous opioids\textsuperscript{12}. There is considerable evidence that the analgesic effects caused by acupuncture and acupuncture-like stimulation are significantly reduced by systematic injection of naloxone\textsuperscript{13,14}. We previously reported that ischemic pain induced by a submaximal effort

### Table 1  Comparison of vital signs (baseline vs. exercises A, B)  
Means +/- standard deviations shown

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Exercise A</th>
<th>Exercise B</th>
<th>Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>102.3 ± 15.6</td>
<td>104.6 ± 19.4</td>
<td>106.9 ± 11.3</td>
<td>N.S.</td>
</tr>
<tr>
<td>Diastolic blood pressure (mmHg)</td>
<td>62.2 ± 5.9</td>
<td>62.9 ± 6.7</td>
<td>66.8 ± 4.1</td>
<td>N.S.</td>
</tr>
<tr>
<td>Pulse rate (/min)</td>
<td>74.7 ± 8.5</td>
<td>75.5 ± 9.4</td>
<td>73.4 ± 9.2</td>
<td>N.S.</td>
</tr>
<tr>
<td>Body temperature (°C)</td>
<td>36.6 ± 0.5</td>
<td>36.7 ± 0.3</td>
<td>36.6 ± 0.4</td>
<td>N.S.</td>
</tr>
<tr>
<td>O₂ saturation (%)</td>
<td>97.6 ± 0.5</td>
<td>97.4 ± 0.4</td>
<td>97.7 ± 0.5</td>
<td>N.S.</td>
</tr>
</tbody>
</table>

N.S.: Not significant

### Table 2  Comparison of the intensity of pain, unpleasantness and occurrence of delayed onset muscle soreness (exercise A vs. exercise B)  
Means +/- standard deviations shown

<table>
<thead>
<tr>
<th></th>
<th>Exercise A</th>
<th>Exercise B</th>
<th>Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAS of intensity of pain</td>
<td>0.4 ± 1.1</td>
<td>2.1 ± 0.7</td>
<td>N.S.</td>
</tr>
<tr>
<td>VAS of unpleasantness of pain</td>
<td>1.9 ± 1.7</td>
<td>5.4 ± 1.1</td>
<td>N.S.</td>
</tr>
<tr>
<td>Delayed onset muscle soreness</td>
<td>0/7</td>
<td>0/7</td>
<td>N.S.</td>
</tr>
</tbody>
</table>

N.S.: Not significant
tourniquet procedure increased the pressure pain thresholds\textsuperscript{15}, and consequently increased maximal, finger-pinch and handgrip forces\textsuperscript{16}. In this experiment, the results showed that significant elevation in the heat-induced pain threshold was only seen in the cervical region, not in the trigeminal region, suggesting that mouth-opening exercise has a marginal effect on reducing pain sensitivity in trigeminal region. These results support the view that physical exercise produces a non-segmental, load-dependent decrease of pain and thermal sensitivity, and that the cervical region might be more effective compared to the trigeminal region, at least in this test situation. It is also possible that elevations in arterial blood pressure produce analgesic effects. Several studies have shown the analgesic effects produced by arterial hypertension resulting from the stimulation of peripheral carotid sinus baroreceptors that engage central regulatory pathways\textsuperscript{17,18}. In the present study, however, we did not observe any substantial increase in blood pressure despite the fatigue involved in the tasks.

Fig. 1 Sensory and pain perception thresholds (baseline vs. exercise A, B) Means +/− standard deviations shown.
Clearly, additional studies are warranted to identify the underlying mechanisms responsible for the analgesic effects evoked by the mouth-opening exercises.

In the present study, we limited the subjects to patients with painless clicking, which is a common TMJ arthropathy. Such specification would be necessary to evaluate the underlying mechanisms of the exercises for TMD, since TMD is a collective term embracing a number of clinical problems, and different modalities of exercise are recommended for each specific problem. Also, we intentionally excluded patients with pain from this study, since typical treatment modalities for acute pain do not include exercise but rest in order to control swelling and muscle spasm, while gentle exercise is initiated within appropriate levels of pain tolerance for chronic pain.

In general, exercises for disk displacement with reduction are directed toward reducing muscle dysfunction and improving the biomechanics of the joint-disk complex with the aim of reducing joint noise. For example, Decker et al. noted that specific jaw exercises including “TMJ rotation exercise”, “repetitive short opening exercise”, and “rhythmic stabilization exercise” are recommended for patients with disk displacement with reduction. “TMJ rotation exercise” is a mouth opening-and-closing exercise in a shortened range while monitoring condylar rotation, maintaining the tongue on the roof of the mouth and placing the index finger over the TMJ. “Rhythmic stabilization exercise” involves holding the jaw in a neutral position, using the fingertips gently to resist opening and closing movement. “Repetitive jaw opening exercise” is a mouth opening and closing exercise in a shortened range, in which speed is gradually increase as tolerated. Yoda et al. reported a mouth opening-and-closing exercise to capture an anteriorly displaced disk. Although there is, thus, extensive clinical experience suggesting the beneficial effects of a variety of mouth opening exercises on disk displacement with reduction, specific indications for each exercise vary considerably in clinical practice, due to the lack of well-controlled clinical trials. In consideration of the above-mentioned discrepancies, we requested the subjects to carry out two kinds of tasks: exercise A as a dynamic exercise, and exercise B as a static exercise. However, it was difficult to find marked differences between the two types of exercise.

One limitation of the present study is that people are generally indifferent to day-to-day variations in pain. Although we randomly assigned three test days into exercise A, exercise B, and a baseline to minimize potential errors, the baseline test should be performed on the same day as Exercises A or B. The other limitation is that the displacement of the disks was not visually confirmed using an MRI. Indeed, the incidence due to ADDWR is very high in patients with clicking sound, and includes muscle incoordination, gross injury, deviation in form of the surface of the condyle or articular fossa (so-called eminence click). Afterwards, the disk position of two subjects was confirmed by MRI, and five subjects were clinically diagnosed as experiencing anterior disk displacement with reduction.

In summary, this study provides evidence that mouth-opening exercises produce a non-segmental decrease in some but not all types of pain perception, although the underlying mechanisms remain unknown.

References