Masticatory muscle pain: Causes, consequences, and diagnosis

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Chapter 4

Provocation of delayed-onset muscle soreness in the human jaw-closing muscles

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ABSTRACT

Eccentric contractions of jaw-closing muscles are difficult to perform. This may explain why fatigue-inducing experiments performed so far suggest the jaw-closing muscles to be fatigue-resistant. Aim of this study was to construct an apparatus that can impose intense eccentric contractions to the jaw-closing muscles, and to test the hypothesis that eccentric contractions can provoke symptoms of delayed-onset muscle soreness (DOMS) in these muscles.

The provocation apparatus consists of two tungsten arms connected by a hinge axis on one end. Participants bite with their anterior teeth on biting plates located on the other end. Each time the experimenter gradually releases the compression force of the apparatus' rubber tubings, the mouth is forced open and the jaw-closing muscles perform an eccentric contraction. Six male participants performed eccentric contractions of their jaw-closing muscles in six sets of exercises, each lasting 5 minutes, and with one minute of rest in between. Each set consisted of 60 open-close movements. Before and after the exercises, and after 24 hours, 48 hours, and one week, feelings of fatigue and pain, the maximum mouth opening without pain, muscles' tenderness to palpation and the maximum voluntary bite force were recorded.

After 24 hours and 48 hours, the levels of fatigue and pain were elevated, the maximum mouth opening without pain was smaller, and five of the participants reported tenderness to palpation. The maximum voluntary bite force was also smaller after 24 hours. These findings indicate that this novel apparatus is successful in inducing DOMS in the jaw-closing muscles.

Key words: eccentric exercises, delayed-onset muscle soreness (DOMS), human jaw-closing muscles, jaw-muscle fatigue, jaw-muscle pain, visual analogue scale (VAS), maximum mouth opening, maximum voluntary bite force

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INTRODUCTION

Human jaw muscles are of vital importance for the biological and social well-being of humans. They act as a group of jaw closers or jaw openers and are important for functions like chewing, talking, drinking, and smiling, which are essential for the human race (Creanor and Noble, 1994).

Jaw-closing muscles are considered to differ in several aspects from muscles in other parts of the human body. Human jaw-closing muscles contain large, homogeneous groups of fibers. The diameter of the type I fibers are greater than those of type II fibers, but both are comparatively small. This contrasts strongly with the limb and trunk muscles, where there are mosaic-like, mixed fiber distributions, and where fiber diameter is correlated to histochemical type (Hannam and McMillan, 1994; van Eijden and Turkawski, 2001). Moreover, adult masseter muscles also contain neonatal myosin heavy-chain isozymes and alpha-cardiac myosin, which have not been described in normal limb muscles (Hannam and McMillan, 1994).

Intense dynamic (Farella et al., 2001) and isometric (Svensson et al., 2001) contractions have been successful in inducing short-lasting fatigue and pain in the jaw-closing muscles, which rapidly disappear after cessation of the exercise. A variety of protocols, like mimicking tooth-grinding activity (Arima et al., 1999) and resisted opening and closing mouth movements (Svensson and Arendt-Nielsen, 1995), have been used to provoke delayed-onset muscle soreness (DOMS) in the jaw-closing muscles. However, these protocols were only successful in provoking mild symptoms of DOMS in these muscles. From limb muscles, it is known that DOMS is especially provoked by intense eccentric contractions of the muscles involved (Cleak and Eston, 1992; Kroon and Naeije, 1991). During eccentric exercise, the contracting muscle is forcibly lengthened (Proske and Morgan, 2001). Due to the anatomy of the masticatory system, eccentric contractions of the jaw-closing muscles are difficult to perform. This may explain why the results of fatigue and pain inducing experiments performed so far suggest the jaw-closing muscles to be fatigue resistant (Arima et al., 1999; Svensson et al., 2001).

Therefore, the aim of the present study was to construct an apparatus capable of imposing intense eccentric contractions to the jaw-closing muscles, and to test the hypothesis that repetitive eccentric contractions can provoke symptoms of DOMS in the jaw-closing muscles.

MATERIALS AND METHODS

Provocation apparatus

The provocation apparatus (Figure 1) consists of two tungsten arms connected by a hinge axis on one end and with two biting plates on the other end. In each arm six grooves and five holes were drilled. Opposing grooves offer the possibility to place pieces of rubber tubing between the two arms. A lever, connected to a bolt which also connects the two arms

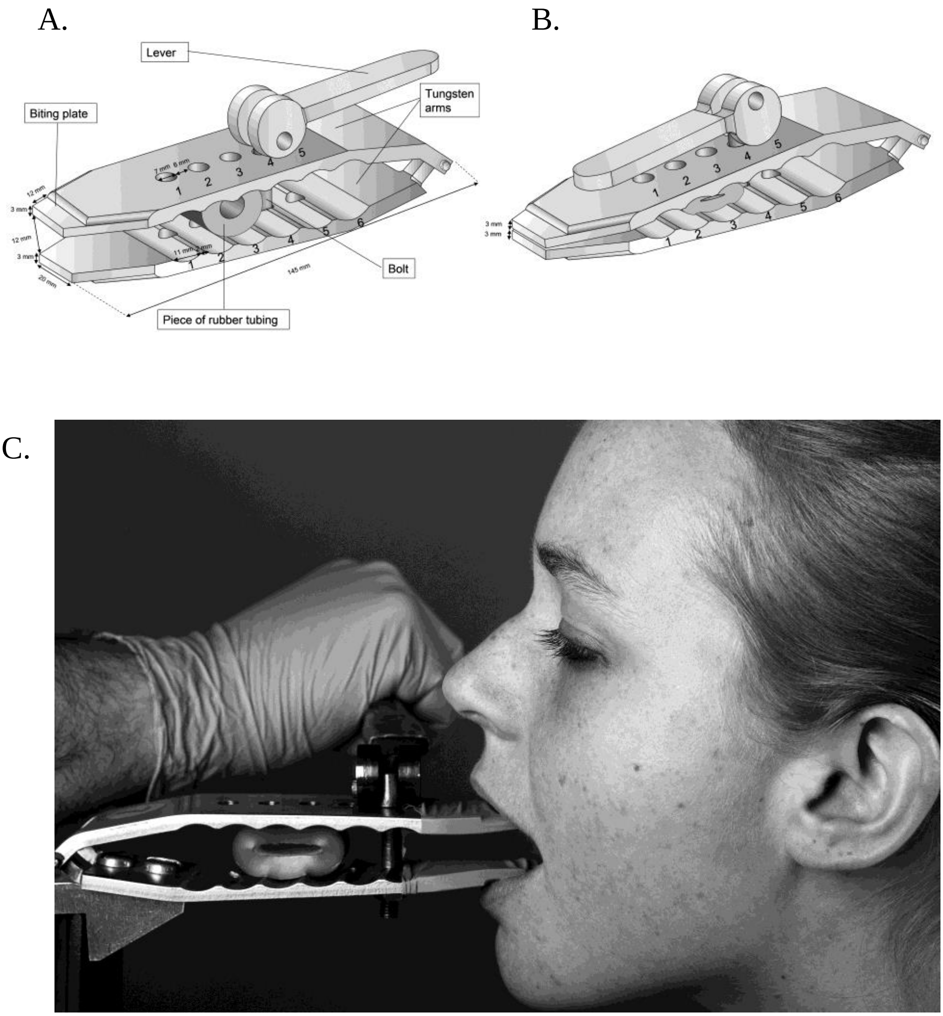

Figure 1. Eccentric Contraction Apparatus: A. Open and B. Closed. C. Participants placed their teeth on the upper and lower biting plates of the apparatus in the ‘closed’ position, and were instructed to continuously bite at a predetermined biting level. When the experimenter released the compressed tension of the rubber tubings, the contraction apparatus opened and the jaw-closing muscles were eccentrically contracting.

by its placement through two opposing holes, enables to vary the distance between the two biting plates. When the device is closed by rotating the lever by 180 degrees, an elastic force is built up in the rubber tubing. When the lever is gradually rotated backwards to its original position, this elastic force will urge the arms of the apparatus to open and to overcome the biting force exerted by the participant on the two biting plates. The jaw-closing muscles of the participant will therefore perform an eccentric contraction.

Dependent upon the biting force exerted by the participant, one or two pieces of rubber tubing are placed in opposing grooves closer or farther away from the hinge axis of the device. The thickness of each metal biting plate is 3 mm and, at maximum seperation, the two arms are 12 mm apart, thus yielding an interincisal distance of 18 mm.

Experimental protocol

The provocation apparatus was tested in an experimental protocol aimed at provoking DOMS in the human jaw-closing muscles. Sets of data were collected at baseline, immediately after the provocation, and 24 hours, 48 hours, and one week later on.

Each data set consisted of measurements of fatigue and pain in the jaw-closing muscles, of the maximum mouth opening without pain, of the tenderness to palpation of the jaw-closing muscles, and of the maximum voluntary bite force (MVBF).

Subjective feelings of fatigue and pain in the jaw-closing muscles were rated at two separate 100 mm visual analogue scales (VAS), with left anchor words “No fatigue/pain at all” and right anchor words “Fatigue/Pain as worse as it could be”. Participants were asked to draw a perpendicular line at the point representing their subjective feelings of fatigue and pain, respectively.

Maximum mouth opening was recorded by asking participants to open their mouths as wide as possible, without experiencing any pain. The distance between the incisal edges of the right upper central incisor and the right lower central incisor were added to the vertical overjet to come to the maximum mouth opening without pain (MMO without pain).

The major jaw-closing muscles, the masseter and temporalis, were manually palpated (Dworkin and LeResche, 1992). The temporalis was palpated on three points (its posterior, middle, and anterior part) and the masseter was palpated on its origin, body, and insertion.

MVBF was recorded by asking the participants to bite as hard as possible on a custom-made bite force transducer. Four efforts, lasting 10s each, were performed and the MVBF was the maximum value of these four efforts. During each effort, participants were verbally encouraged to increase their biting force gradually to its maximum, then to keep it at that level for approximately 3 seconds and then to relax. In order to protect the teeth from possible damage, individual impressions of both upper and lower teeth were made with a dental putty material (PROVIL® novo; Heraeus Kulzer, Hanau, Germany). In order to avoid muscle fatigue, the clenching efforts were separated by 2 minutes of rest.

Provocation part

During the provocation part, eccentric contractions of the jaw-closing muscles were performed in six sets of exercises, each lasting 5 minutes, and with one minute of rest in between. Each set of exercises consisted of about 60 open-close movements, each movement lasting about 5 seconds.

The provocation apparatus was mounted on a table with the fixed lower arm parallel to the floor of the experimental room. Participants were sitting upright in a chair with an adjustable height, so that they could comfortably bite with their central incisors on the biting plates of the apparatus. In order to protect the teeth from pain or possible fractures, participants were wearing soft acrylic mouth guards (Bioplast, Ref 3188.1, 4,0x125mm, clear, Scheu Dental Technology, Am Burgberg 20, 58642 Iserlohn, Germany), made on individual plaster casts of both dental arches. Two pieces of rubber tubing were used between the two metal arms throughout the provocation. The release of the lever was done at a steady pace controlled by the experimenter, under the guidance of a silent metronome.

During the open-close movements, participants were constantly biting at a level of 30% of the baseline maximum electromyographic (EMG) activity of their right masseter muscle. The root mean square values of the EMG activity were displayed to the participant through visual feedback with the use of a voltmeter. Custom-made, bipolar surface electrodes made of silver amalgam (diameter: 4 mm) were placed over the belly of the right masseter muscle after thorough cleaning of the skin with alcohol. The electrodes were placed parallel to the muscle fibres and with their centres approximately 15 mm apart. The EMG signals were filtered (bandwidth 5-1000 Hz), amplified (1000 times), and sampled (2000 Hz). An isolated metal common electrode held in the palm of the hand served as a reference electrode.

Participants

Six healthy male participants (mean age ± SD = 35,67 ± 13,49 years) with no history of temporomandibular disorders (TMD) or chronic orofacial pain complaints participated in the study. Before the start of the experiment, they gave a written informed consent. The study was conducted according to the Helsinki declaration and the protocol was approved by the University of Adelaide Human Research Ethics Committee.

Statistical analysis

The mean VAS scores, the mean MMO without pain, and the mean MVBF values were analysed with repeated measures analysis of variance (ANOVA) with time as a within-participants factor with five levels (before, after, after 24 hours, after 48 hours, after one week). Pair-wise comparisons were performed with simple contrast analysis and the first (before) level as reference.

RESULTS

Immediately after the provocation part, participants reported significantly elevated levels of fatigue and pain ($p<0.01$ for both) that remained elevated at the follow-up appointments after 24 and 48 hours ($p<0.05$). After one week, fatigue and pain VAS values did not differ anymore from baseline (Figure 2).

The MMO without pain was significantly decreased at the appointments 24 hours ($p<0.01$) and 48 hours ($p<0.05$) after the provocation part when compared with baseline (Figure 3), indicating a restricted range of movement of the mandible.

Regarding the response to manual palpation of the jaw-closing muscles, three participants developed painful reactions on at least one palpated point immediately after the provocation part, while five participants showed painful reactions at the follow-up measurements 24 hours and 48 hours later on. At baseline and one week after the exercises, no painful palpation points were found (Figure 4).

Compared to baseline, the MVBF was significantly decreased at the follow-up appointment 24 hours after the provocation part ($p<0.05$) (Figure 5).

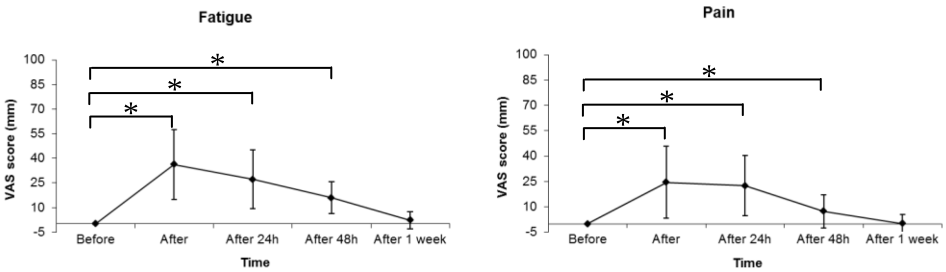

Figure 2. Mean values ± SD regarding the subjective feelings of fatigue and pain, rated at two separate 100-mm VAS, at baseline, immediately after the provocation, and 24 hours, 48 hours, and one week later on (*: $p<0.05$; **: $p<0.01$).

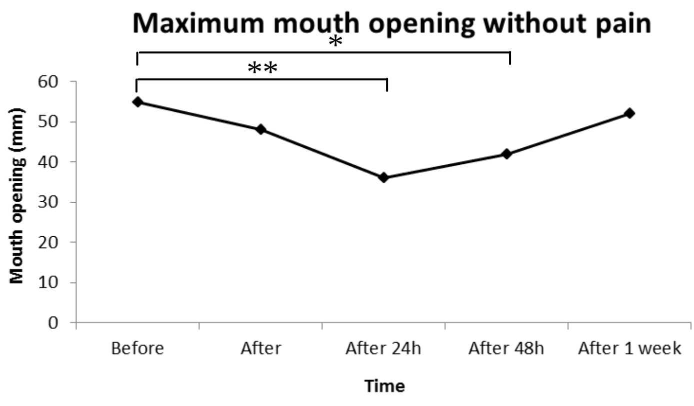

Figure 3. Mean values ± SD of the maximum mouth opening without pain, recorded at baseline, immediately after the provocation, and 24 hours, 48 hours, and one week later on (*: $p<0.05$; **: $p<0.01$).

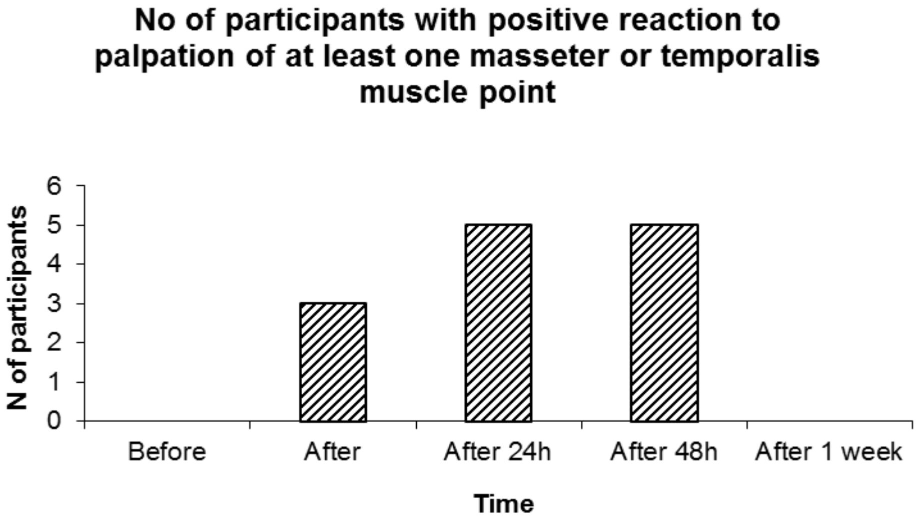

Figure 4. Number of participants with at least one painful reaction to manual palpation of the masseter and temporalis muscles, recorded at baseline, immediately after the provocation, and 24 hours, 48 hours, and one week later on.

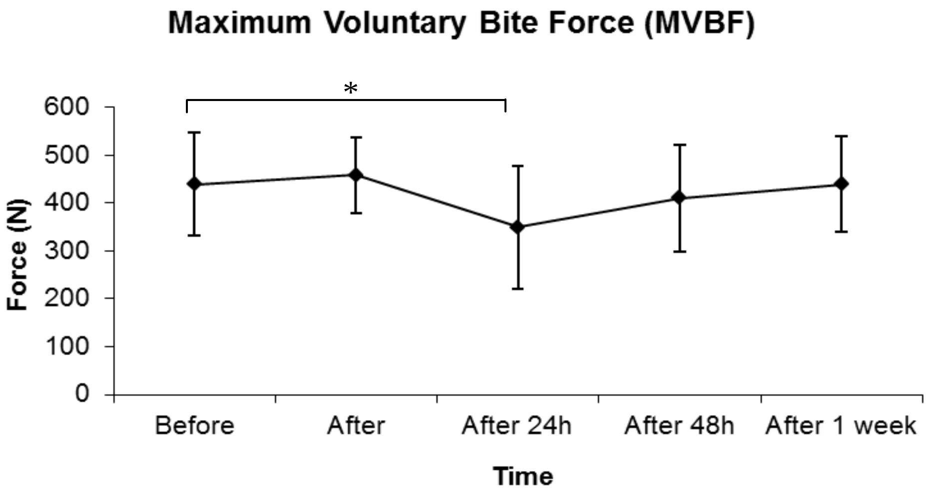

Figure 5. Mean values ± SD of the maximum voluntary bite force (MVBF), recorded at baseline, immediately after the provocation, and 24 hours, 48 hours, and one week later on (*: $p<0.05$).

DISCUSSION

In this study, an apparatus was presented which is capable of imposing intense eccentric contractions upon the jaw-closing muscles, and the hypothesis was tested that repetitive eccentric contractions imposed by this apparatus, can provoke symptoms of DOMS in the jaw-closing muscles.

Eccentric contractions can generate DOMS in limb muscles (Cheung et al., 2003; Proske and Morgan, 2001). It is characteristic for DOMS that it is experienced in the first 12-48 hours following intense eccentric exercise. DOMS presents with a variety of symptoms that include increased perceived muscle pain or soreness, reports of pain upon muscle palpation, a reduced maximum voluntary muscle force, and a limited range of motion (Prasartwuth et al., 2005). Although there is no consensus regarding the underlying mechanisms of DOMS (Clarkson and Sayers, 1999), inflammatory processes (Jones et al., 1986; Round et al., 1987), muscle fibre degeneration (Friden et al., 1983; Newham et al., 1983), and necrosis (Friden and Lieber, 1998; Nosaka and Clarkson, 1996) are typically suggested.

In the present study, signs and symptoms, typical for DOMS, could also be provoked in the jaw-closing muscles. This suggests that the conclusion drawn from pain and fatigue inducing experiments performed so far, viz., that the jaw-closing muscles are rather fatigue resistant (Arima et al., 1999; Svensson et al., 2001), may be due to difficulties imposing eccentric contractions to these muscles. The apparatus presented in this study has overcome this problem since it induces only eccentric contractions of the jaw-closing muscles and not combination of concentric and eccentric ones like a previous protocol (Svensson and Arendt-Nielsen, 1995). Its use in a DOMS provocation protocol has indicated that even though jaw-closing muscles differ from other skeletal muscles, they respond similarly to intense eccentric exercise.

The characteristics of DOMS are similar to the signs and symptoms of patients suffering from a myofascial temporomandibular disorder (TMD) pain. The aetiology of myofascial TMD pain is still unclear (Suvinen et al., 2005). Although bruxing habits, such as frequent clenching and grinding, are thought to play an important role in this respect, not every myofascial TMD patient is a frequent bruxer, indicating that other factors are involved as well (Lobbezoo and Lavigne, 1997). That myofascial TMD-like symptoms can be provoked in an experimental setting offers the possibility to gain more insight into the onset and aetiology of myofascial TMD pain.

In conclusion, the apparatus described in the present paper can successfully provoke DOMS in the jaw-closing muscles of healthy volunteers. This opens the possibility to further study the onset and aetiology of myofascial TMD pain.

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