Headache as a referred pain from the masticatory muscular system

Kazuhiko Hara

Nihon University School of Dentistry,
Department of Oral Diagnostic Sciences
(Directors: Prof. Yoshiki Imamura and Assis. Prof. Takahiro Shinozaki)

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This thesis is based on the following article with additional new unpublished data on teeth contact ratio of the norm (Fig.4):

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ABSTRACT

The temporal association between temporomandibular disorders (TMD)-related symptoms and headache during TMD treatment was studied in patients who fulfilled the diagnostic criteria for headache attributed to TMD (HATMD) specified in the Diagnostic criteria for TMD (DC/TMD) and International classification of headache disorders (ICHD)-3 beta was studied.

Methods: The study enrolled 13 healthy volunteers and 34 patients with HATMD induced by masticatory myofascial pain but not by temporomandibular arthralgia. Facial pain intensity, the pressure pain threshold of pericranial muscles, and maximum unassisted opening of the jaw were assessed at an initial examination and before and after physical therapy. The intensity and frequency of headache episodes were also recorded before and after the intervention. Further, the tooth contact ratio was analyzed both in patients and controls.

Results: Headache intensity and frequency significantly decreased, and these reductions were temporally related to improvements in facial pain intensity, maximum unassisted opening, and pressure pain threshold during TMD treatment. Linear regression analysis showed significant correlations between facial pain intensity and headache intensity and between tooth contact ratio (TCR) and pressure pain threshold, although TCR did not show any differences between patients and controls.

Conclusion: Among patients who fulfilled the DC/TMD and ICHD-3 beta diagnostic criteria for HATMD, headache improved during TMD treatment,

and the improvement was temporally related to amelioration of TMD symptoms.

INTRODUCTION

Many studies have shown an association between masticatory myofascial pain (MMP) and headache, [1–6] although there is disagreement regarding their similarities and comorbidity. [7–10] Recently, the diagnostic criteria for temporomandibular disorders (DC/TMD) included a new classification, headache attributed to TMD (HATMD), [11] which suggests that myalgia and temporomandibular joint (TMJ) arthralgia are associated with headache. In contrast, the International Classification of Headache Disorders, Third Edition beta (ICHD-3 beta) describes headache and facial pain due to problems in the TMJ, masticatory muscles, and/or associated structures as secondary headache.[12] Nevertheless, the headaches described in these two classifications probably refer to the same condition: secondary headache induced by masticatory myalgia and TMJ arthralgia. These classifications clearly delineate the diagnostic criteria for HATMD; thus, the important questions are now differentiation of HATMD from primary headache and its optimal treatment. The DC/TMD diagnostic criteria should be used in evaluating the location of usual headaches and the history of pain modification with jaw movement, along with identification of actions that induce or exacerbate headache during palpation of the temporal muscle and extensive jaw movement.[11] As defined in the DC/TMD, confirmation of a myofascial trigger point (MTrP), where palpation evokes the familiar pain, suggests that headache originates from the MTrP and that myofascial pain does not originate from intracranial structures. The ICHD-3 beta recommends checking the temporal relation between headache and TMD in onset, development, and/or improvement. [12]

The International Headache Society recommends "headache improving in temporal relation to improvement of the presumed causative disorder" as a criterion in the standardized general diagnostic criteria for secondary headaches.[13] However, this criterion is not included in the abovementioned classifications. Although it is controversial whether response to treatment of a presumed causative condition should be included in the diagnostic criteria for secondary headache, response to treatment is of particular interest for clinicians who treat secondary headache. Further, understanding the temporal relation between the responses of HATMD and TMD to standard treatment may add to our understanding of HATMD pathophysiology. Physical therapy, ie, stretching and massaging the masticatory and cervical muscles, is supported by systematic reviews as an evidence-based treatment for TMD and was used as the intervention in the present study.[14–16] The temporal association between TMD-related symptoms and headache during TMD treatment was investigated in patients fulfilled the diagnostic criteria for HATMD specified in the DC/TMD and ICHD-3 beta.

METHODS

A self-controlled, time series trial was conducted to investigate the temporal association between TMD-related symptoms and headache during TMD treatment for patients with HATMD. The observation period was 2 to 4 weeks before, and after, the intervention (depending on patient compliance, as described below, in the section on data collection).

1. Participants (inclusion and exclusion criteria)

The participants were recruited from among healthy volunteers who had no history of systemic diseases and no symptoms on their masticatory muscles and temporomandibular joints or headaches, and patients who were referred to the Orofacial Pain Clinic at Nihon University Dental Hospital for treatment of chronic facial pain. All patients underwent a medical interview followed by extra- and intra-oral examinations and additional X-ray examinations. After ruling out dental pain, patients who complained of referred pain in response to masticatory muscle palpation were diagnosed as having MMP and underwent an additional interview and examinations regarding facial pain and headaches, which were classified according to the DC/TMD[11] and ICHD-3 beta criteria.[12] To simplify the study design, only patients with MMP but no TMJ arthralgia were included. Patients who met the criteria for arthralgia and/or intra-articular TMD were excluded. Thus, HATMD represents MMP with referral in this study, and any reduction in jaw opening distance was caused by muscular pain instead of TMJ problems. Healthy volunteers who complained of tenderness during muscle palpation were excluded. Forty-two patients who met the criteria for HATMD but not those for arthralgia or intra-articular TMD and thirteen controls were included in this study. This study was conducted in accordance with the Declaration of Helsinki and was approved by the Nihon University Dental Hospital Ethics.

2. Data collection

The examinations were performed at the initial visit, and before and after instruction on the intervention. Patients were interviewed on the nature and history of facial pain and headache and were physically examined at the initial visit to collect information on their signs and symptoms. During the first 2 weeks, baseline data on headache (intensity and frequency: patients) and tooth contact ratio (TCR: patients and controls) were collected by means of a diary designed for this study. If data were not collected, this period was extended by 2 weeks. All the following chair-side measurements were repeated three times and an averaged value was used to represent the individual data. The effects of the intervention were then evaluated, using data obtained during the subsequent 2 weeks, and compared with baseline. The timeline of the study is shown in Fig 1.

1) Tooth contact ratio

Persistent nonfunctional jaw activity precipitates and perpetuates jaw symptoms.[16] Involuntary tooth contact is one of the most typical parafunctions and is observed more frequently in TMD patients than in healthy controls.[17,18] Instructing patients to avoid daytime jaw parafunction by encouraging a mandibular resting position, with upper and lower teeth separated, reduces unnecessary masticatory muscular activity, which results in pain reduction in TMD patients.[16] This study was started by assessing patients' daytime jaw parafunction. All patients and controls were requested to mark symbols in a diary to indicate if their upper and lower teeth were in contact with each other during the daytime, except during meals and conversations (Fig. 2). They were asked to wear a reminder (a rubber band on the wrist, an artificial nail, or whatever they thought suitable for the purpose) and, when they saw the reminder, to mark an open circle ("○") or an "X" in the diary, to indicate the contact status of the upper and lower teeth. They were suggested to mark the symbols immediately after checking the status of tooth contact, and not to delay. An open circle was marked if the upper and lower teeth were completely apart, and an "X" was marked if there was any contact. The ratio of "X" marks to the total number of marks for TCR was used to represent the frequency of involuntary muscle contraction. It was specified that the timing of these self-assessments should not be scheduled or decided upon in advance. No devices to notify patients of the time point of self-assessments were used in this study, although some previous studies used such devices to help patients record involuntary tooth contact.[5,17,19] Patients were asked to record tooth contact status in the diary and to bring the diary to the clinic at every appointment. Before starting treatment (ie, the second visit, for most patients), no information was given to patients on how tooth contact might affect their signs and symptoms or what represented optimal contact status. When symbols had been recorded at fixed intervals or too frequently, the symbols were regarded as unrepresentative of involuntary tooth contact. Additional instruction was then given to the patient, and tooth contact status was monitored again during the subsequent 2-week period.

2) Intensity of facial pain and headache

After diagnosing HATMD in accordance with DC/TMD and ICHD-3 beta criteria, the following data sampling was performed. The palpation points and pressure applied were set to highlight tenderness in various muscles and joints in Japanese persons[20] and were thus not identical to those specified in DC/TMD.[11] Patients were asked to use a 100-mm visual analog scale (VAS) to express the magnitude of facial pain they felt at rest and during palpation of masticatory and cervical muscles. Palpating pressure was standardized with a pressure algometer (Nagano Keiki, Ueda, Japan), which generated a 2-kg force. The palpation points included (A) the anterior portion of the temporal muscle, (B) the superficial belly of the masseter muscle, (C) the lateral pole of the condyle, (D) the upper portion of the trapezius muscle, and (E) the middle of the brachioradial muscle. Each palpation point in the muscle was first examined with the examiner’s finger, to detect the tender point in the designated area. The VAS scores for facial pain (F-VAS) at rest and during palpation of the most intense tender point were recorded at every visit. Patients were also asked to rate their worst daily headache intensity on a VAS (H-VAS). Average VAS scores during each observation period (2 weeks) were calculated for each individual. Headache frequency (H-Freq), defined as days with a headache during the previous 2 weeks, was also obtained. These data were used to represent headache magnitude and frequency and were statistically analyzed.

3) Pressure pain threshold

The algometer had a 1-cm^2 tip with a disk-shaped flat head, which was applied to masticatory and cervical muscles and joints bilaterally. The tip was placed on each point so that it was perpendicular to the skin overlaying a tender point, which allowed application of uniform pressure at all points of contact. Patients were asked to press a button when they first felt pain. The force at that moment was automatically recorded as the pressure pain threshold (PPT).

4) Maximum unassisted opening

A caliper was used to measure maximum unassisted opening (MUO), with and without pain, between the upper and lower incisal edges. Every MUO measurement was adjusted to the overbite distance. No patient exhibited an open bite. Patients were first asked to occlude their upper and lower teeth and open their mouth until they first felt pain (MUO from the intercuspal position). The distance at this point was defined as

MUO without pain. Then, patients were asked to open their mouth further until the pain became intolerable. This was defined as MUO with pain.

3. Intervention

1) Overall treatment course

It is believed that myofascial pain occurs by immobilization of fascia, which induces sensitization of free nerve endings. Stretching of the fascia, including MTrP by massage and passive stretching, is believed to improve fascial mobility and relieve pain. Massage of temporal and masseter muscles were recommended to stretch the fascia that included MTrPs.[21,22] Patients received an explanation of their possible occlusal habits, after validation of their baseline data (usually at the second visit). Later, they received instruction regarding the intervention. The exercise regimen instructions were repeated until the techniques were mastered by the patients. All patients received a booklet of instructions for home physical therapy, and performance quality was evaluated at every visit, to ensure standardization. The first two weeks were used to collect baseline data. Patients were observed for changes in pain intensity and jaw function, without receiving treatment. Jaw parafunctions were also monitored during this period.

2) Muscle massage and stretching

After assessing the parameters described in the data collection section, patients received instruction on a set of exercises for stretching and massaging their muscles. In addition, they were asked to mark their diary when they stretched these muscles. The patients were instructed to perform muscle-stretching sessions five times a day: after getting up, before or after every meal, and before going to bed.

Massage

Patients were instructed to massage their symptomatic muscles by placing their bilateral hypothenars at the tender point in the muscle (nearly mirrored sites) and then pressing them firmly with fine vibration. They were advised to massage the tender points for 30 seconds each, five times a day, along with the muscle stretching exercises (Fig. 3a & 3b).

Muscle stretching

Lifting temporal muscles

Patients were told to place their fingers perpendicularly to the temporal scalp, while keeping them apart from each other. They were instructed to place their bilateral little fingers at the temporal fossa and their index fingers on the temporal scalp posterosuperior to the auricle. The middle and annular fingers were placed apart between them. Patients were then instructed to lift the scalp with temporal muscles bilaterally and keep it stretched for 5 seconds and relaxed for the next 5 seconds. They were told to repeat this cycle of muscle stretching and relaxing ten times in a session (Fig. 3c).

Pulling down the mandible

Patients were instructed to keep their neck in a slightly extended position and to open their mouth to the MUO position. They were told to place their right annular, middle, and index fingers on the lower incisal edge and to pull their jaw down with their fingers so that their mouth was open as widely as possible, even if they felt pain. Participants were instructed to keep the muscles relaxed while opening the jaw and to not try to open the mouth actively; the mouth was opened passively (maximum assisted opening: MAO). Patients were instructed to keep the jaw in the MAO position for 5 seconds and relaxed for the next 5 seconds. This stretching and relaxing cycle was also to be repeated ten times in a session (Fig.3d).

Post-treatment evaluation was conducted after a 2-week period of stretching.

4. Data presentation and statistical analysis

To evaluate differences between groups, all data (except those for H-Freq) were expressed as mean ± SEM and analyzed with either the paired *t*-test (headache intensity, headache frequency, and TCR) or one-way ANOVA followed by the Tukey test for post-hoc analysis (facial pain intensity at rest and during palpation, PPT in pericranial muscles, and MUO with/without pain). Change in H-Freq was analyzed with the Wilcoxon signed-rank test. Linear regression analysis was used to investigate correlations between variables. SPSS statistics 20 software for

Windows (IBM, Tokyo, Japan) was used for these analyses, and a *p* value of less than 0.05 was considered to indicate statistical significance.

RESULTS

Forty-two patients and thirteen healthy volunteers were informed of the purpose and protocol of this study, and 38 patients and 13 healthy controls gave their oral and written informed consent for participation. It was also explained that they were entirely free to withdraw their consent at any time during the study. These patients and controls were asked to report any need for new dental or medical treatment, regardless of the body site. After starting the observation, no patients and controls withdrew their consent, although four patients were excluded from this study because they could not be followed up as scheduled. Consequently, 34 patients (4 men and 30 women) and 13 controls (9 men and 4 women） completed the research protocol. All patients and controls refrained from taking new drugs and receiving other treatment while participating in this study. The average ages of the analyzed patients and controls were 48.5 ± 2.8 and 25.2 ± 1.2 years, respectively.

Changes in signs and symptoms

Tooth contact ratio

The involuntary tooth contact ratio (TCR) was defined as the ratio of “X” marks to all marks in the diaries and represents the frequency of masticatory muscle contraction. The TCR was 57.9 ± 4.0% before instruction and 53.8 ± 4.3% after instruction. Contrarily, the TCR of controls was 52.8 ± 0.1%. These values were slightly higher than those previously reported. [18,19] The TCR did not show any significant difference between patients and controls before instruction, further it did not change even after patients started stretching and massaging pericranial muscles (Fig.4).

Intensity of headache and facial pain

Eleven of the 34 patients rated the magnitude of headache as 0 mm on the VAS at the initial visit, although they experienced headache episodes during the subsequent 2 weeks. The average headache intensity for the first and second visits was 29.5 ± 4.2 mm. This value represents headache intensity before the intervention. The intensity significantly decreased, to 15.2 ± 3.4 mm, after stretching and massage ($p < 0.001$) (Fig. 5a). The median value for headache episode frequency (number of days with headache during the previous 2 weeks) significantly decreased, from 5 (interquartile range, 3–7) days to 1.5 (0–7) days after home physical therapy ($p = 0.001$) (Fig. 5b). In addition, pain intensity in masticatory muscles at rest was 35.4 ± 3.8 mm at the first visit and 33.7 ± 3.1 mm at the second visit (before instruction), which was not a significant change. However, it significantly decreased, to 15.7 ± 3.1 mm, after exercise ($p = 0.034$ vs before instruction). Pain intensity during palpation was 61.7 ± 3.5 mm at the first visit and 61.1 ± 3.2 mm at the second visit. This value significantly decreased, to 37.1 ± 3.4 mm, after exercise ($p < 0.001$ vs both first visit and before instruction; Fig. 6).

Pressure pain threshold

The changes in PPT for the pericranial muscles on the symptomatic (more intense) side are shown in Figure 6. There were significant increases in PPT in all pericranial muscles (masseter, temporal, and trapezius muscles) after exercise (p < 0.001 for all). Although no significant change was seen in the brachioradial muscle, there was a tendency toward an increase. No patients complained of spontaneous pain in the area near the TMJ at their first visit. However, PPT significantly increased after exercise (p = 0.001 vs first visit; p < 0.001 vs before instruction; Fig. 7).

Maximum unassisted opening

In all patients, MUO without pain did not differ between the first visit and before instruction (40.1 ± 1.5 mm and 39.6 ± 1.6 mm, respectively), although it significantly improved after exercise (45.3 ± 1.1 mm, p = 0.034 vs first visit; p = 0.020 vs. before instruction). MUO with pain showed a tendency to increase after exercise, although it did not significantly change at any time point (43.8 ± 1.4 mm at the first visit, 44.1 ± 1.3 mm before instruction, and 46.5 ± 1.1 mm after exercise; Fig. 8).

Correlations between variables

Linear regression analysis revealed significant correlations between some variables representing magnitude of changes in signs and symptoms, before and after home physical therapy. Increase in PPT was significantly correlated between pericranial muscles. A significant inverse correlation between TCR and PPT was observed for both the masseter and trapezius muscles. Headache intensity (after vs before physical therapy) was significantly positively correlated with both facial pain at rest ($p < 0.001$) and during palpation ($p = 0.026$; Fig. 9).

DISCUSSION

Headache intensity and frequency decreased in conjunction with improvement in MMP signs and symptoms during physical therapy designed for TMD. These signs and symptoms included intensity of facial pain at rest and during palpation, range of jaw movement without pain, and pain sensitivity of pericranial muscles to pressure. As compared with baseline, signs and symptoms significantly improved after physical therapy, although no significant changes were observed between the first and second visits, when no intervention was provided. Although facial pain and jaw opening distance were reported to spontaneously improve as part of the long-term natural course of TMD,[23,24] physical therapy for both MMP and TTH was reported to be effective after a shorter time period.[25–27] Taken together, the present findings suggest that simultaneous improvement in the signs and symptoms of facial pain and headache was a result of home physical therapy. Although we used a time series trial to observe simultaneity in the response to the intervention in signs and symptoms of facial pain and headache, future studies using a blinded and controlled design with random sampling might provide additional information.

Involuntary nonfunctional tooth contact is believed to be an important cause of TMD and headache.[17,18] TCR is reportedly higher in patients with MMP[18] and headache[5] than in normal adults. In the current study, the TCR in patients was 57.9 ± 4.0% before instruction in physical therapy, and 52.8 ± 0.2% in controls. There was no significant difference between these data. Contrarily, linear regression showed a significant inverse correlation between TCR and PPT in both the masseter and trapezius muscles in patients. These data suggest that involuntary nonfunctional tooth contact was a possible contributing factor for MMP. The TCR after 2 weeks of home physical therapy was 53.8 ± 4.3%, which suggests that stretching and massage alone do not significantly improve tooth contact habits. In addition, the intensity of facial pain and headache significantly decreased without a reduction in TCR. Glaros et al. reported that splints and pagers were useful in alleviating MMP in patients with involuntary nonfunctional tooth contact, although they did not report whether these devices reduced the frequency of nonfunctional tooth contact.[19] The findings obtained in this study indicate that muscle stretching and massage designed for TMD alleviate signs and symptoms of HATMD without correcting parafunctional habits. Because we attempted to evaluate the response of HATMD to a standardized home physical therapy, the importance of correcting parafunctional habits during HATMD treatment should be investigated elsewhere.

Many previous studies have described the effectiveness of physical therapy for MMP,[25,28–31] although some reviews concluded that stretching of masticatory muscles did not have a significant effect on pain intensity in TMD patients.[16] This study showed a significant improvement in both facial pain and headache. The most apparent difference in the stretching regimen in this study from that described in reviews reporting an equivocal effect was employment of the passive stretching of masticatory muscles of the resistance of fabrics .[32] Some patients reported slight muscle soreness after the start of the instructed physical therapy, which resolved within several days of repeated stretching. Alleviation of masticatory muscle tenderness was significantly correlated with elevation of PPT, and elevated PPT was observed not only in masticatory muscles but also in trapezius and brachioradial ($p < 0.05$) muscles after the physical therapy. Some studies have reported decreased pain thresholds in the extremities of TMD patients.[33,34] These findings suggest that exercise and massage may elevate the threshold of peripheral nociceptors in the affected muscles that generate nociceptive inputs [35] and may have suppressed pain processing and/or have facilitated pain modulation in the central nervous system.

Signs and symptoms of HATMD were significantly improved by physical therapy, and these improvements were temporally related to improvements in TMD signs and symptoms. The trigeminal and cervical nervous systems are intricately involved in generating craniofacial pain,[36] and chronic contraction of masticatory and cervical muscles can cause referred pain in cranial and facial structures.[37] Studies have revealed that pain referral results from a barrage of noxious inputs from these muscles, [38,39] a process that induces central sensitization. Furthermore, previous animal studies suggest the involvement of glial cells in orofacial pathological pain conditions. Noxious or neuropathic inputs from the trigeminal nerve territory induce activation of glial cells in the extended areas beyond the trigeminal subnucleus caudalis, which further results in excitation of second-order neurons in the cervical spinal dorsal horn.[40–42] The results of this study showed lowered PPT in masticatory muscles and the TMJ, as well as in the muscles of the extremities of MMP patients. A significant decrease in PPT was observed in intra- and extra-territorial structures of innervation that cover the original pain region in persons with TMD [33,43,44] and painful knee osteoarthritis. [45] These findings are also likely due to induction of central sensitization. This pain mechanism may explain simultaneous excitation of second-order neurons in distance induced by noxious or neuropathic inputs from head and neck neuromuscular structures. [40,41,46]

The present results have increased our understanding of secondary headache, although this study does have limitations that warrant mention. First, it is unclear whether (1) parafunctional muscle contraction or other factors (eg, occlusal interference) were the main contributor to induction of MMP and HATMD and (2) whether the present physical therapy regimen led to recovery of plasticity of the central nervous system. Future studies should investigate correction of parafunction and occlusal therapy including appliances, as well as long-term outcomes.

Conclusion

Data show that headache in patients with HATMD according to the DC/TMD and ICHD-3 beta criteria was successfully alleviated, in temporal relation to TMD symptoms, by physical therapy designed for TMD. These results suggest a possible causative mechanism for HATMD, namely, TMD-induced sensitization in the central and peripheral nervous systems.

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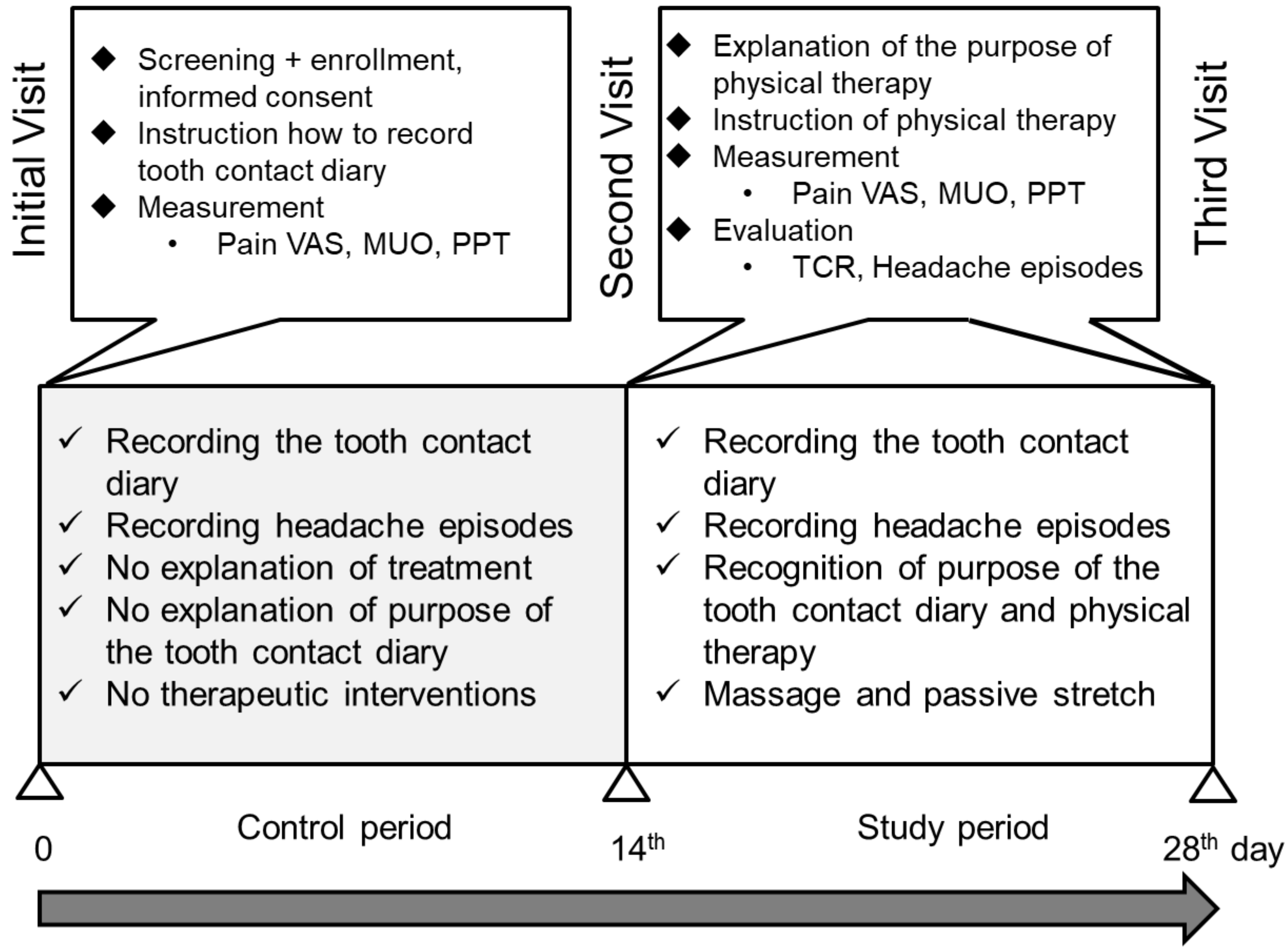

Fig. 1. The study timeline
In the control period, baseline data of tooth contact ratio (TCR), frequency of headaches (H-Freq) and intensity of headache episodes (H-VAS) were collected without any treatments or explanations of causes and contributing factors of facial pain and headache.

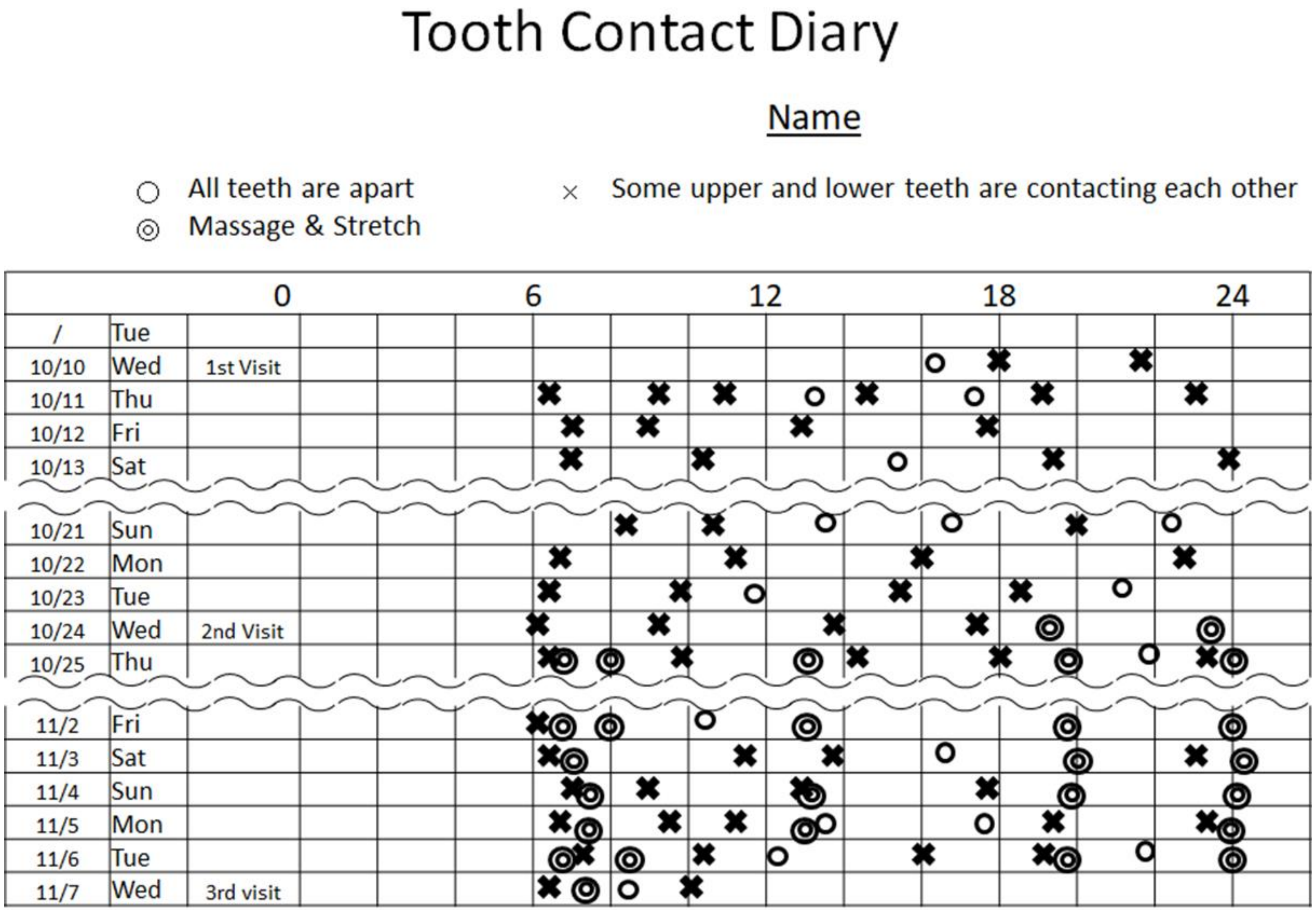

Fig. 2. An example of a tooth contact diary

: Upper and lower teeth are totally separated

: Upper and lower teeth are in contact at some part of the jaw

: Muscle stretching and massage were performed

TCR=Number of `×` / (Number of `×` + Number of `○`) × 100 (%)

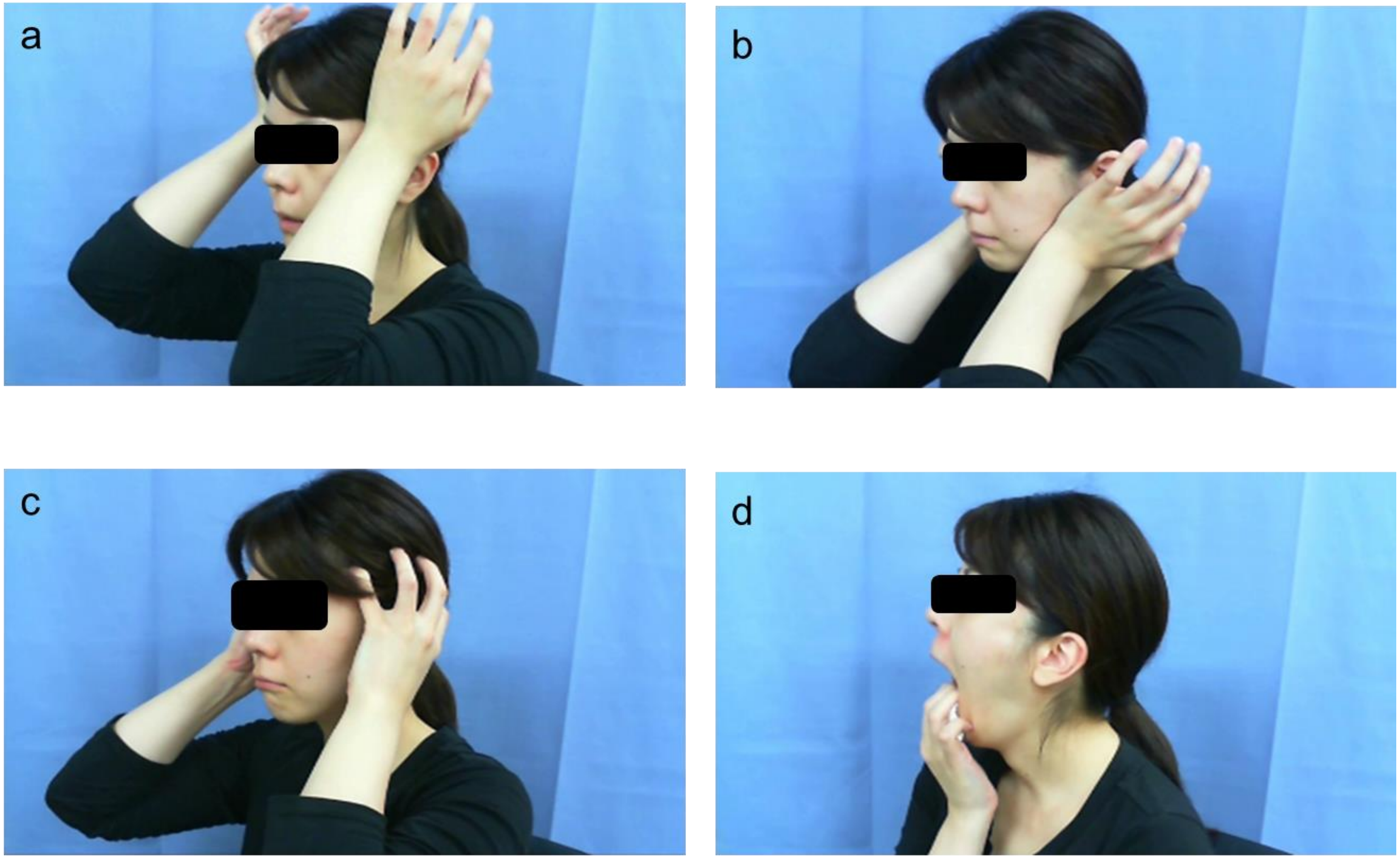

Fig.3 Physical therapy (massage and stretching)
Participants were strongly encouraged to perform the set of physical therapy consisting of the muscle massage (a: the temporal muscle, b: the masseter muscle) at specific tender points and the muscle stretch (c: the temporal muscle, d: the masseter, temporal, and medial pterygoid muscles) for five sessions a day.

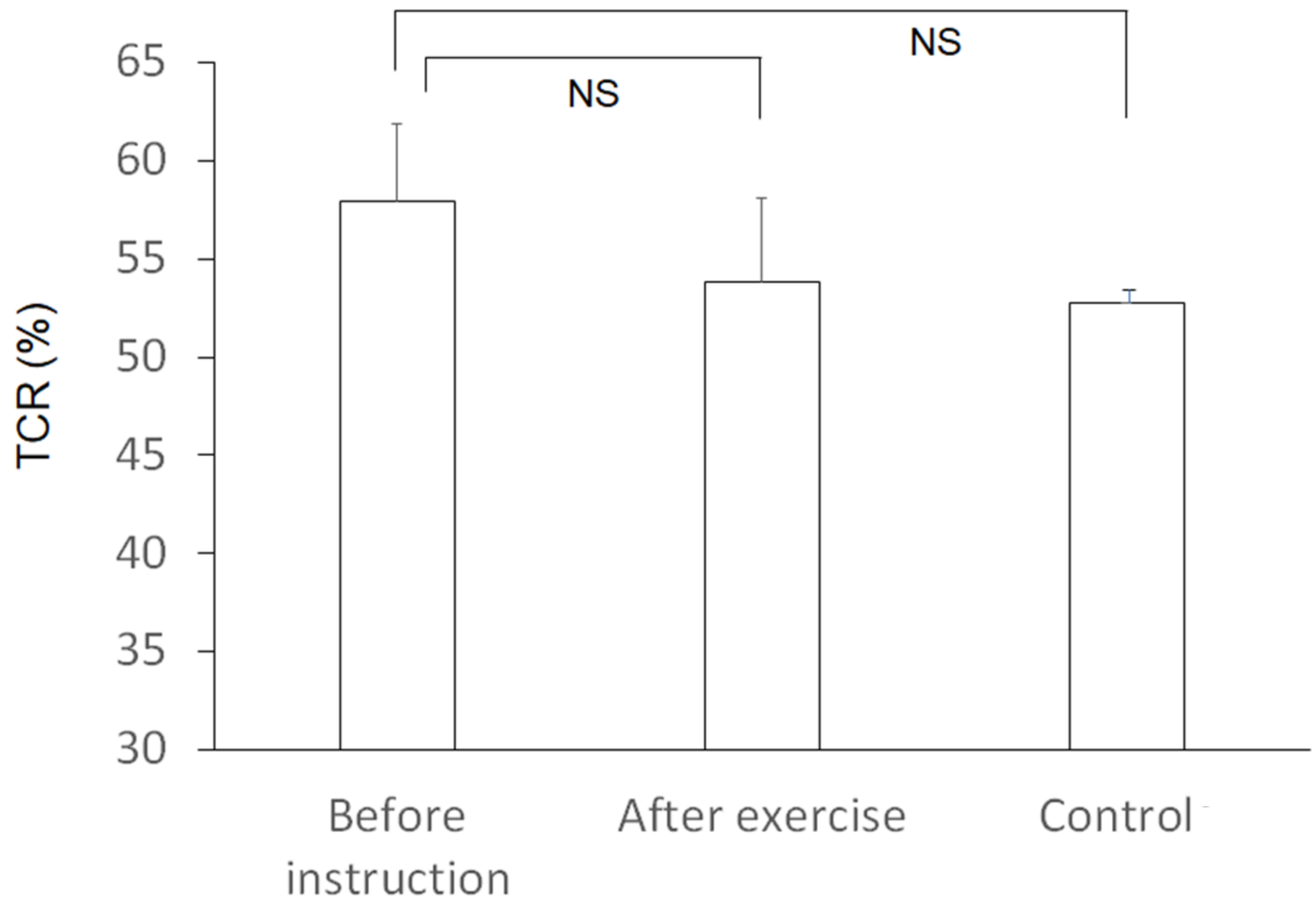

Fig. 4 Change in TCR

TCRs were calculated with the formula shown in Fig.2. There were no significant differences in the TCR between before and after the exercise in TMD patients and between TMD patients and control.

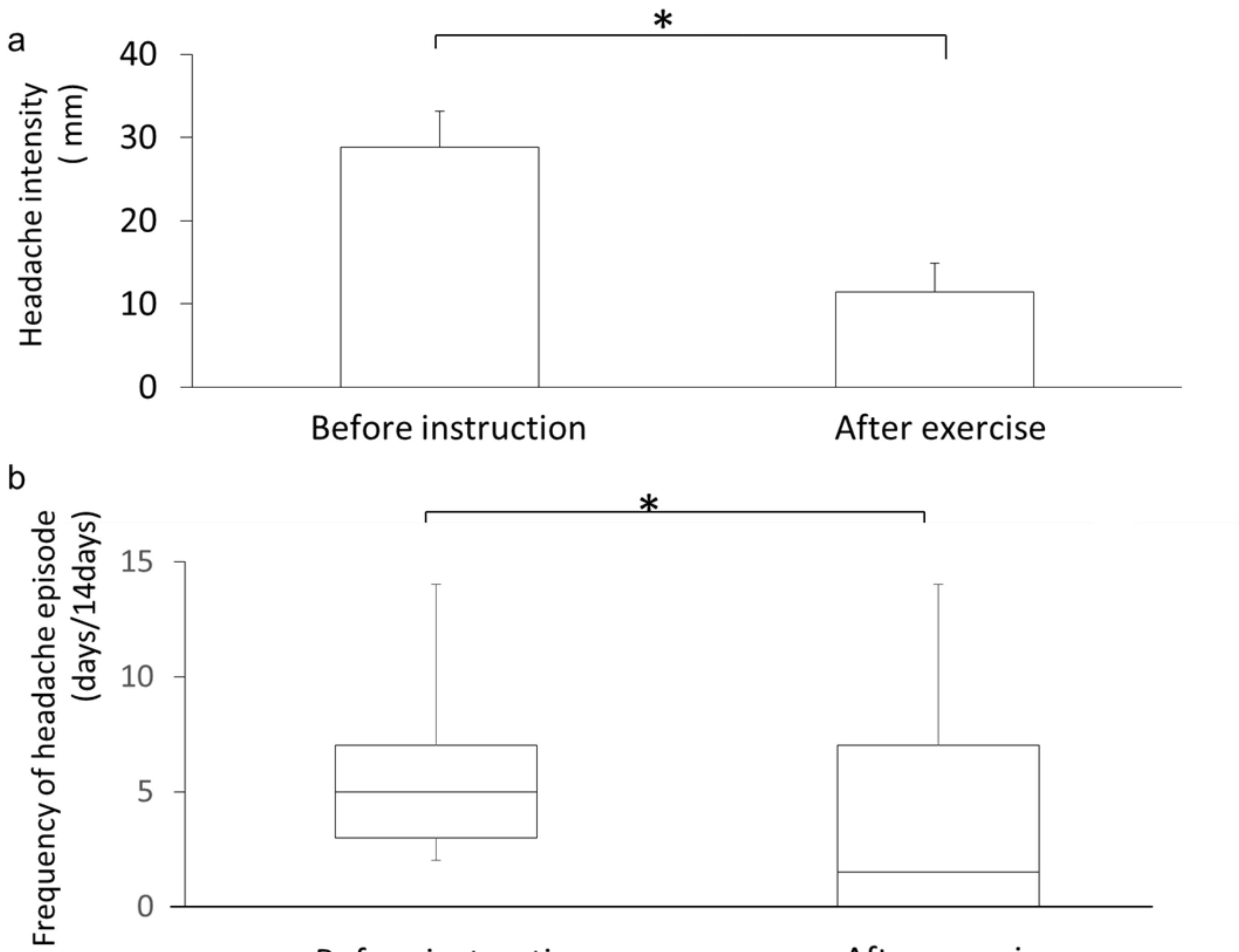

Fig.5

Fig. 5 Changes in headache intensity and frequency

a: intensity (VAS) b: frequency

* $p < 0.01$

Headaches were diagnosed according to DC/TMD and ICHD-3beta. Both headache intensity and frequency significantly decreased after exercise.

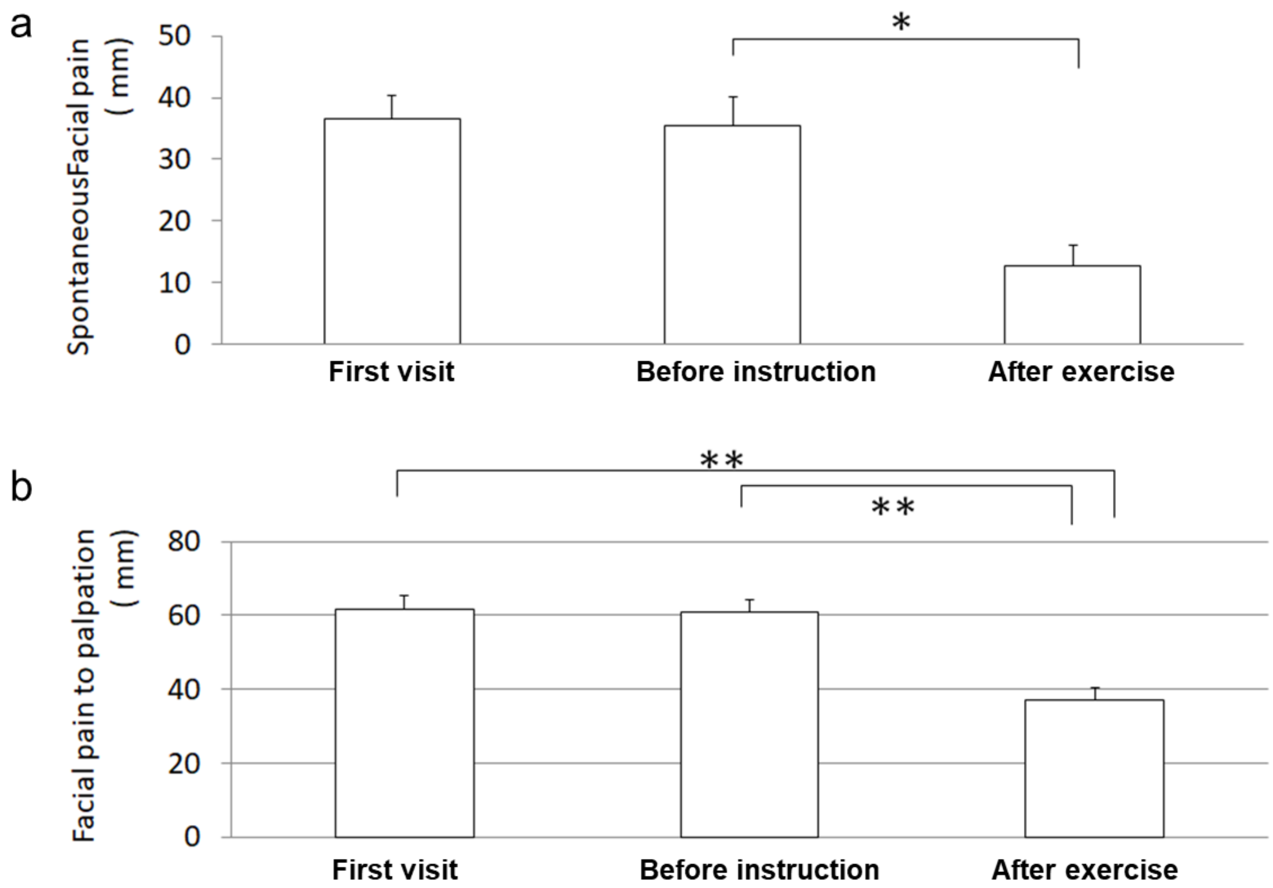

Fig. 6 Changes in facial pain at rest and during palpation

a: at rest b: to palpation *$p < 0.05$ ** $p < 0.01$

Both spontaneous facial pain and tenderness during palpation (the most tender point among masticatory muscles) showed a significant reduction in pain intensity after exercise. There were significant differences in pain intensity between the second and the third visits but not between the first and the second visits suggesting that the physical therapy including muscle massage and stretch induced the pain relief.

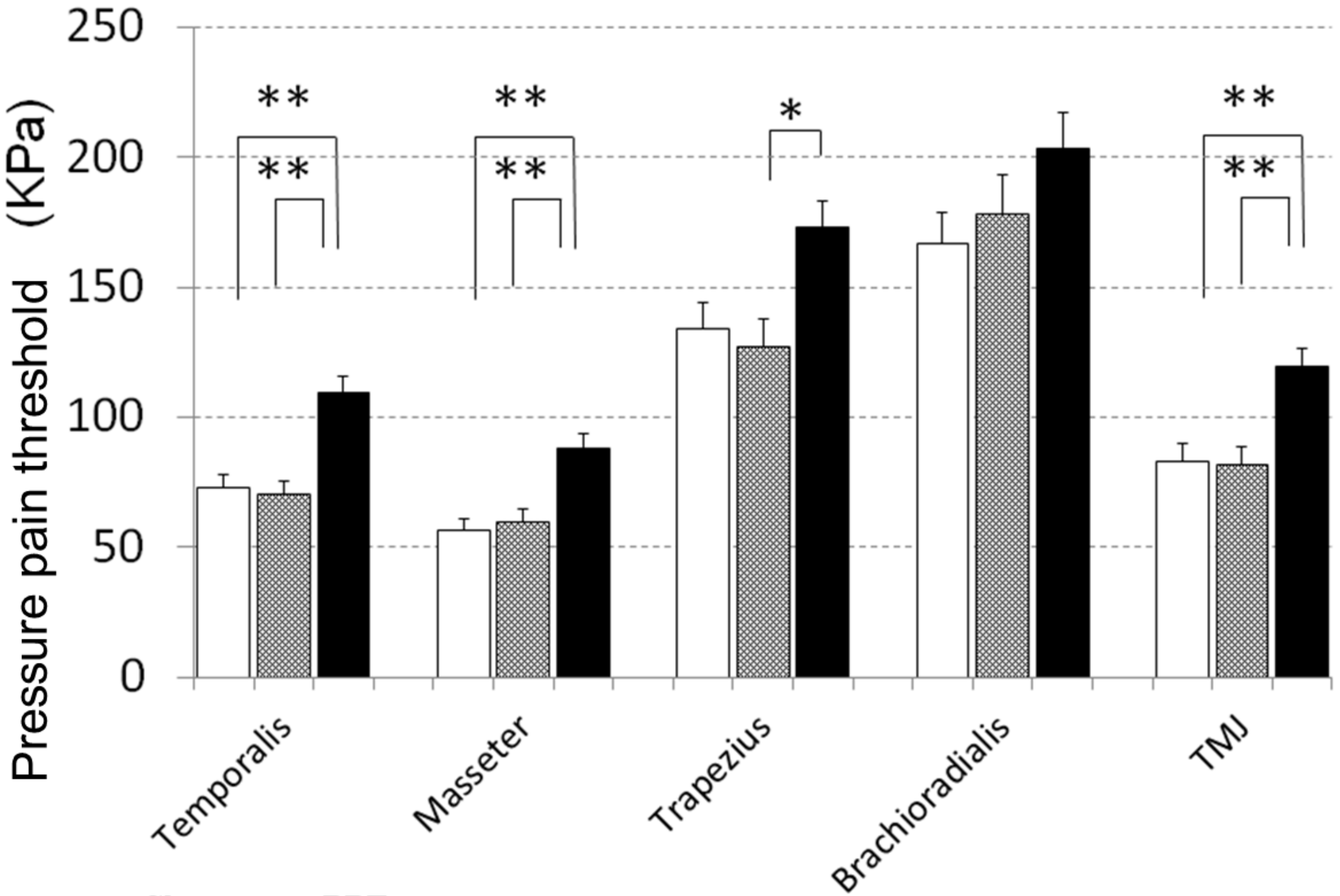

Fig.7 Changes in PPT

First visit Before instruction After physical therapy

* $p < 0.05$ ** $p < 0.01$

Pressure pain threshold (PPT) showed a significant elevation after the physical therapy.

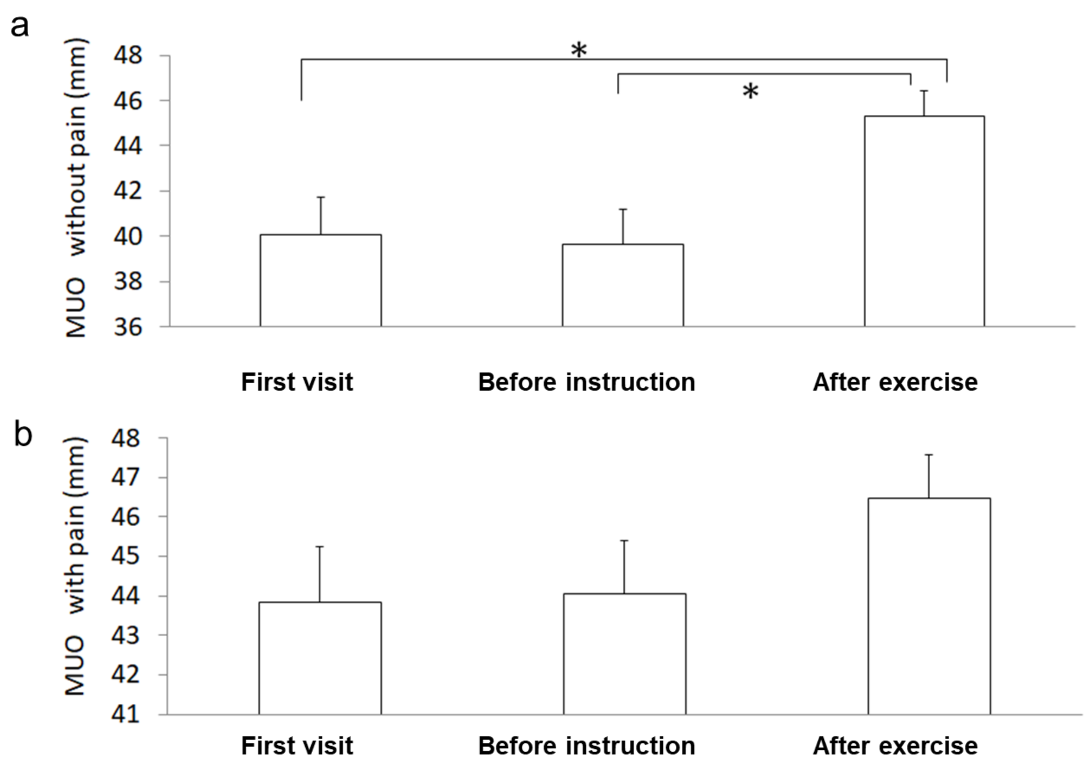

Fig.8 Changes in jaw range of motion

a: MUO without pain b: MUO with pain ＊ $p < 0.05$

Maximal unassisted jaw opening distance (MUO) without pain significantly increased after exercise. However, MUO with pain just showed a tendency towards an increase but not a significant change, which suggested that the main cause of the jaw opening limitation was pain.

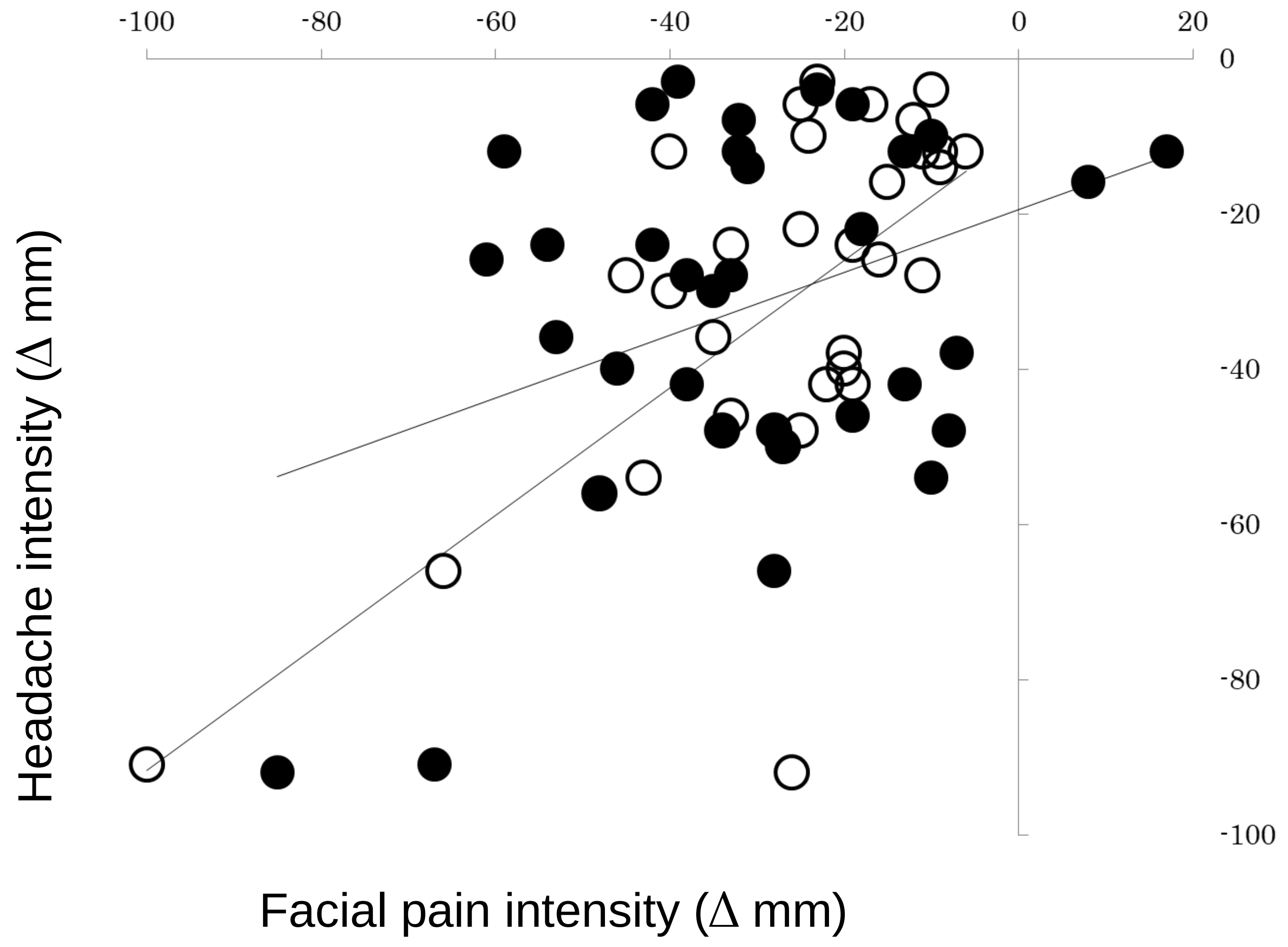

Fig.9 Correlation between intensity of headache and facial pain
Open circle + dashed line: headache vs facial pain at rest
Filled circle + solid line: headache vs facial pain during palpation