Transient Pain Following Orthodontic Fixed Appliances Induces Sensitization of Gingival and Periodontal Tissues

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Aims: To evaluate the transient effects of orthodontic treatment on the mechanical detection threshold (MDT) and mechanical pain threshold (MPT) of the buccal attached gingiva and the pressure pain threshold (PPT) of the buccal attached gingiva and of the teeth in two directions (perpendicular and parallel). **Methods:** A total of 20 patients (15 females and 5 males) aged 18 to 30 years participated in the study. Perceived pain on a 0- to 10-cm visual analog scale (VAS) and MDT, MPT, and PPT scores were evaluated at two time points at the masseter muscle, gingiva, teeth, and hand (control) prior to orthodontic treatment (T_0) and 24 hours after the first archwire placement (T_1). Mean values and SEMs were calculated for all continuous variables. The differences between T_0 and T_1 of MDT, MPT, and PPT were analyzed by means of a paired Student *t* test. **Results:** The pain intensity as assessed on the VAS was 4.2 ± 1.8 cm. No significant changes in MDT or MPT were found at the hand and buccal attached gingiva ($P > .06$). The PPTs at the buccal attached gingiva of teeth 21, 23, 24, and 34, at teeth 21, 23, 24, and 34 (perpendicular) and at teeth 21 and 23 (parallel) were lower (ie, more sensitive) at T_1 compared with T_0 ($P < .04$). **Conclusion:** This study indicates for the first time that pain following insertion of an archwire causes sensitization to blunt-pressure stimuli both in the attached gingiva and in the periodontal ligament. Quantitative assessment of mechanical sensitivity may provide more insights into procedural pain and allow for better monitoring and evaluation of the effects of orthodontic treatment in the future. *J Oral Facial Pain Headache 2016;30:228–233. doi: 10.11607/ofph.1646*

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Patients undergoing orthodontic therapy frequently experience varying degrees of discomfort and pain with the placement of initial separators, archwires, elastomerics, spring-type steel separators, and latex elastics.[1–4] Indeed, pain induced by orthodontic treatment is one of the main reasons for patients wanting to discontinue treatment.[5]

It is known that orthodontic pain is part of an inflammatory reaction in response to the compression and tension of the periodontal ligament.[6–8] This reaction is also known to release various chemical mediators that elicit a hyperalgesic response. The hyperalgesia is related to prostaglandins, which make the periodontal ligament sensitive to other released algogens and neuroactive substances such as prostaglandin E, histamine, bradykinin, serotonin, and substance P.[9]

To study and evaluate orthodontic pain and interview patients, questionnaires such as the McGill Pain Questionnaire (MPQ) and ratings with visual analog scales (VAS) or verbal rating scales (VRS) have been widely used in clinical and research settings.[10,11] However, algometry has not commonly been applied in the assessment of orthodontic pain.[12]

The pressure-pain threshold (PPT) can be defined as the minimum amount of pressure capable of inducing a just barely perceptual sensation of pain; ie, the transition point from a nonpainful mechanical sensation to a painful sensation. Previous studies[13–16] have shown PPT differences at different sites and at different load-rates, suggesting both good reliability and validity of PPT measurements in the oral mucosa and gingiva for clinical and research investigations.

In contrast to PPT assessments of deep pain sensitivity and mucosal sensitivity, mechanical detection thresholds (MDT) and mechanical pain thresholds (MPT) can distinguish between sensations evoked by different types of fibers such as A-beta, A-delta, and C-fibers.[12] Different neural mechanisms have been shown to underlie different types of mechanical hyperalgesia.[15] Therefore, there is a need to apply different types of mechanical stimuli to the mucosa of orthodontic patients in order to provide a comprehensive assessment of mechanical somatosensory function and orthodontic pain. The authors have recently developed a new technique for application of pressure algometry directly to the crowns of the anterior and posterior teeth, thereby indirectly activating receptors in the periodontal ligament in both a perpendicular direction (perpendicular to the labial surface of the teeth) and a parallel direction (parallel to the tooth axis).[17] Importantly, this technique was shown to have excellent test-retest reliability (intraclass coefficients > .87) and was therefore included in this study as a measure of mechanical sensitivity changes in the periodontal ligament following orthodontic pain. Therefore, the specific aim of this study was to evaluate the transient effects of orthodontic treatment on the MDT and MPT of the buccal attached gingiva and the PPT of the buccal attached gingiva and teeth in two directions (perpendicular and parallel).The hypothesis was that even a transient painful input from the periodontal ligament due to the orthodontic treatment would be sufficient to trigger site-specific mechanical sensitization of the orofacial tissues, but not in the hand, which served as an extratrigeminal control site.

Materials and Methods

Participants

A total of 20 patients (15 females and 5 males) scheduled for fixed orthodontic treatment and aged 18 to 30 years participated in the study. All participants were recruited from the Institute of Stomatology of Nanjing Medical University and gave informed consent to the procedures, which were approved by the ethical committee of Nanjing Medical University and followed the guidelines from the Helsinki Declaration II. The inclusion criteria in this study were: *(1)* have orthodontic treatment with bonding of self-ligating brackets (American Orthodontics) only in the maxillary arch; *(2)* have a complete natural dentition; *(3)* have no intraoral or extraoral devices such as a flat plate or facebow; *(4)* have no history of periodontal disease or dysesthesia in the oral cavity or facial pain; and *(5)* have not received dental or periodontal treatment during the last 6 months.

Experimental Design

The experiment was performed at a steady temperature (20°C to 23°C) in a quiet room. The participant was positioned horizontally in a dental chair and was told to relax throughout the procedure. In the experimental session, VAS, MDT, MPT, and PPT were recorded in a sequential order. All data were collected at two time points by a single investigator (D.L.): prior to orthodontic treatment (T_0) and 24 hours after the first archwire placement (T_1).

Test Sites

Seven sites were selected for MDT and MPT examinations: the dorsum of the left hand (as a control) and the buccal attached gingiva of teeth 21, 23, 24, 31, 33, and 34. A total of 18 sites were selected for the PPT test; these included the thenar of the left hand (as a control), the masseter muscle (the left side), the buccal attached gingiva of teeth 21, 23, 24, 31, 33, and 34, and perpendicular to the buccal surface of the crown of these teeth, and parallel to the axis of teeth 21, 23, 31, and 33 (Table 1).

Visual Analog Scale

A 0-cm to 10-cm VAS was used to measure orofacial pain intensity during orthodontic treatment. The VAS was represented by a line marked 0 (representing "no pain at all") on the left end-point and 10 ("worst pain I can imagine") on the right end-point.[10,18] The patients were carefully instructed to score the degree of pain before orthodontic treatment and 24 hours after the first archwire placement.

Measurement of MDT

The MDT was tested using a set of standardized Semmes-Weinstein monofilaments with 20 differently sized diameters (North Coast Medical).[19] Each different monofilament exerts a different force upon bending vertically and the force increases by a factor of 2 from one monofilament to the next sequentially in one set. Forces ranging from 0.008 to 300 g weight have been frequently applied for quantitatively assessing tactile sensitivity in the orofacial region. The terminal of each monofilament was covered with a small epoxy bead to make the contact area smooth. The sizes of all calipers were constant. Furthermore, all intraoral examination sites were dried with gauze before testing to prevent filament slippage. The MDT was assessed using a modified method of limits. Five threshold determinations were made with a series of ascending and descending stimulations.[13] The final threshold was the geometric mean of these five series.

All participants were instructed to close their eyes during the procedure and to raise their hand as soon as they felt the stimulation at the test site. Mechanical

Table 1 Overview of Test Sites for Mechanical Detection Threshold (MDT), Mechanical Pain Threshold (MPT), and Pressure Pain Threshold (PPT) and the Definition of the Measuring Sites

Variable	Test sites
MDT	Dorsum of left hand (control) Buccal attached gingiva of teeth 21, 23, 24, 31, 33, and 34
MPT	Dorsum of left hand (control) Buccal attached gingiva of teeth 21, 23, 24, 31, 33, and 34
PPT	Thenar of left hand (control) Masseter muscle Buccal attached gingiva of teeth 21, 23, 24, 31, 33, and 34 Perpendicular to the labial surface of teeth 21, 23, 24, 31, 33, and 34 Parallel to the axis of teeth 21, 23, 31, and 33

stimulation with constant force stimulators requires that all stimulators are applied perpendicularly to the test surface and contact time was kept as 1 to 2 seconds. It is difficult to stimulate more posterior intraoral regions because of physical constraints.[12] Care was also taken each time that the instrument did not touch any other intraoral tissues (eg, lip or tooth). At each site, the test began with the number 1.65 filament. If the patient did not raise his or her hand, it was considered a negative response, and the filament one step higher (number 2.36 filament) was then applied. This procedure was repeated until the participant felt the stimulation (a positive response). The filament with a lower step was then applied again until the patient no longer felt the stimulation (another negative response). This procedure stopped after five positive and five negative responses were recorded. The geometric mean of the MDT was entered into the database.

Measurement of MPT

MPT was determined with the use of a set of seven punctuate mechanical stimulators. The contact area of each stimulator was flat and had a 0.2-mm diameter. The stimulators exerted forces ranging from 8 to 512 mN: 8, 16, 32, 64, 128, 256, and 512 mN.[16] Contact time was set at 2 seconds. The method of limits with ascending and descending stimulus intensities that was applied to determine the MDT was also used to determine the MPT.[15]

The stimuli were applied using the same method as for the MDT, except that the patients raised their hand as soon as they felt a pinprick pain in the test area rather than just a stimulation.

Measurement of PPT

PPT was defined as the amount of pressure that the participants first perceived to be painful. The PPT was measured to assess deep and superficial pain sensitivity, which are likely to be mediated through activation of C-fibers and/or A-delta fibers.[12] An electronic algometer (Medoc) with two sizes of probes was used to assess PPT: the probe with a diameter of 10 mm was used at extraoral sites and the probe with a diameter of 8 mm was used at the attached gingiva and teeth. The computer connected to the strain gauge showed the pressure (kPa) and the rate of pressure increase (kPa/s). In this study, the pressure was set to increase at a constant rate of 30 kPa/s. As soon as the participants felt the pressure stimulus as painful, they pressed a button to stop the recording.[13] The procedure was repeated three times for each site and with about a 1-minute interval between consecutive stimuli. The PPT was recorded as the mean of the three trials.[20]

The PPTs were measured at 18 sites (Table 1). PPTs of the teeth were measured in two directions: perpendicular and parallel. When PPT was tested on the thenar of the left hand, masseter muscle, gingiva, and teeth (perpendicular), the stimulator was applied perpendicularly to the test surface; when the stimulator was applied to the teeth (parallel), the stimulator was applied parallel to the axis of the tooth. The computer and algometer were positioned so that the participants were unable to see the algometer during the measurement procedure to minimize the possibility of bias.

Statistical Analyses

Mean values and SEMs were calculated for all continuous variables. Because the study failed to show normality for the VAS scores, the VAS scores were analyzed by means of nonparametric Wilcoxon-Pratt match pairs test. Since the hypothesis that MDT, MPT, and PPT were normally distributed could not be rejected, the differences between T_0 and T_1 of MDT, MPT, and PPT were analyzed by means of a paired Student *t* test. A 5% level of significance was used for these tests ($P < .05$). Spearman tests were used for the correlation analysis of VAS and MDT (also MPT and PPT) and $P < .05$ was considered to reflect statistical significance.

Results

VAS

All participants reported pain in their teeth at 24 hours after the archwire was placed. The mean pain intensity as assessed on the VAS was 4.2 ± 1.8 cm, ranging from 1.7 to 8.9 cm.

MDT and MPT

No significant time changes were found at the hand and buccal attached gingiva for MDT or MPT ($P > .06$) (Fig 1).

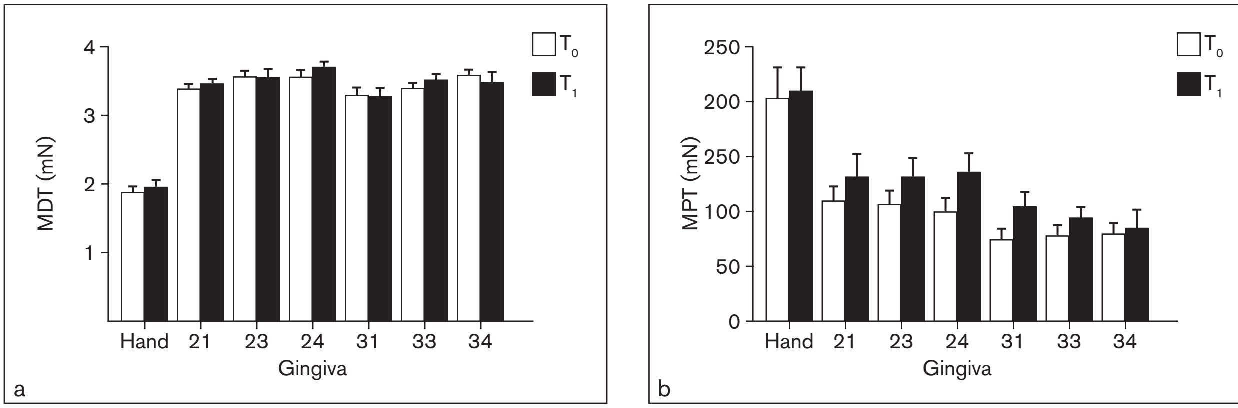

Fig 1 Mean and standard error of the mean (SEM) of **(a)** mechanical detection threshold (MDT) and **(b)** mechanical pain threshold (MPT) at the dorsum of the left hand (as the control site) and the buccal attached gingiva of teeth 21, 23, 24, 31, 33, and 34 at T_0 and T_1.

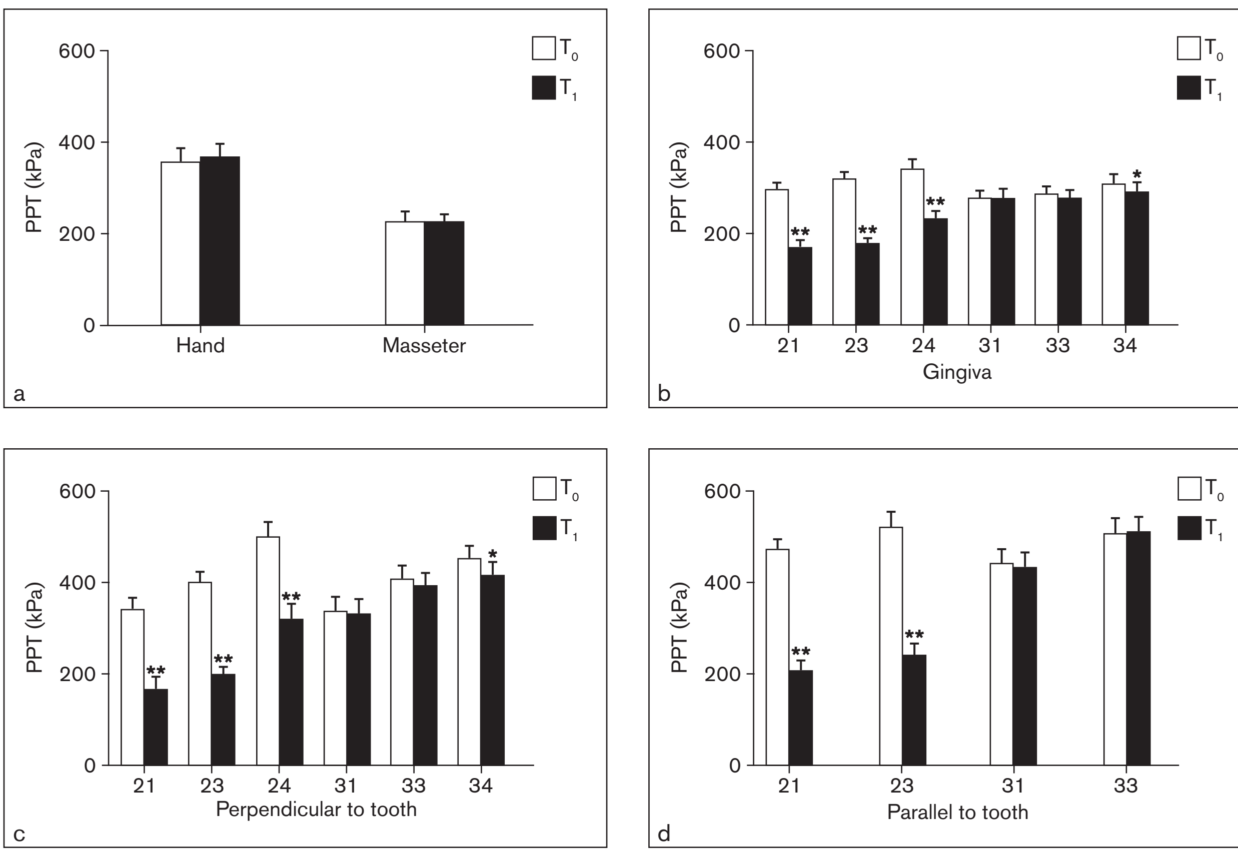

Fig 2 Mean and standard error of the mean (SEM) of PPTs at the hand and **(a)** masseter muscle, **(b)** buccal attached gingiva, and teeth in **(c)** perpendicular direction and **(d)** parallel direction. White bars = before treatment (T_0), black bars = after treatment (T_1). *Indicates significant difference between T_0 and T_1 ($P < .05$); **Indicates significant difference between T_0 and T_1 ($P < .01$).

PPT

The PPTs are shown in Fig 2. There were statistically significant differences in the PPTs between T_0 and T_1 for the maxillary dentition (21 gingiva, 23 gingiva, 24 gingiva, 21 perpendicular, 23 perpendicular, 24 perpendicular, 21 parallel, 23 parallel) ($P < .04$). PPTs at the masseter muscle and hand did not show any significant changes between T_0 and T_1 ($P > .38$).

There were no significant correlations between VAS and PPTs at the gingiva or teeth in the two directions ($P > .053$).

Discussion

Consistent with previous reports,[3,8,21,22] the results in this study suggest that the insertion of the first archwire on the maxillary dentition over a 24-hour period induces pain in the orofacial area, specifically related to the teeth. Although the pain was assessed at 24 hours after the application of orthodontic force in all patients, the amount of reported pain was variable. Some patients reported slight to moderate pain while others reported quite severe pain. Nevertheless, the transient pain appeared to be sufficient to trigger site-specific changes in mechanical sensitivity in the orofacial tissues, although no significant relationships between VAS pain intensity and PPT changes were observed.

Animal studies[23–25] of orthodontically induced tooth movements have shown some correlations with the time course of orthodontic pain in humans and these studies suggested that the orthodontically induced mechanical and thermal hypersensitivity may be helpful measurements of orthodontically induced pain.

Bakke et al[26] reported that prolonged overloading of the masticatory system does not affect PPTs of the jaw-elevator muscles in healthy subjects. Based on the VAS and PPT results in the masseter muscle in the present study, the hypothesis of muscle hyperalgesia induced by orthodontic treatment was not supported. However, a study[17] that aimed to evaluate the short-term effects of orthodontic pain on the PPT of the masseter muscle found a decrease in the PPT values. Nevertheless, it must be kept in mind that the pain was only transient and perhaps a longer-lasting nociceptive input would be needed in order to trigger changes in mechanical sensitivity of the jaw muscles.

The PPT of the attached gingiva of teeth 21, 23, 24, and 34 was lower at T_1 than T_0. This indicated that orthodontic treatment triggered changes in mechanical sensitivity of the mucosa adjacent to the teeth affected by the archwire and loading of the periodontal ligament. A surprising result was that the buccal gingiva of tooth 34, which was not included in the archwire, also was decreased at T_1. However, compared with the gingiva at tooth 24, which was decreased by 32%, the relative change in PPT value at the gingiva of tooth 34 was a decrease of only 6%. The reasons for this minor but statistically significant decrease in PPTs in the mandible are not known, but could perhaps be related to an acute effect of a supracontact induced by the movement of tooth 24.

Pressure algometry has been adapted for use on oral mucosa,[27] but few studies have reported its clinical application to teeth. In this study, consistent and significant changes were demonstrated in mechanical sensitivity of the periodontal ligament following insertion of the archwire. It would be interesting to see in future studies how these parameters develop over the whole orthodontic treatment period and whether it would be a completely reversible process.

All orthodontic treatment will create tension and compression zones in the periodontal ligament, resulting in pain for patients.[1] It is tempting to link the decrease of PPTs in the maxillary dentition with an acute inflammatory reaction in the periodontal ligament and sensitization of nociceptive afferent fibers. Again, it is surprising that perpendicular stimulation of tooth 34 was also associated with a significant PPT decrease at T_1; however, the relative change at tooth 34 was only 8% compared with 36% at tooth 24. Similar considerations may apply to the changes in PPT of the teeth as the PPT changes at the buccal gingiva in the mandible (see above). Thus, the change observed in the antagonist tooth was an interesting observation, and may be explained by the change in loading of the tooth during normal function. This needs further investigation.

The numbers of male and female participants included in this research were relatively small and did not allow for testing of possible robust gender differences in pain or somatosensory function. Further studies will be needed to address this in detail. Finally, a larger sample size would have allowed for examination of whether QST parameters could have predictive values for developing orthodontic pain.

Conclusions

This study indicates for the first time that transient pain following insertion of an archwire causes sensitization to blunt-pressure stimuli both in the gingiva and in the periodontal ligament. Quantitative assessment of mechanical sensitivity may provide more insights into procedural types of pain and allow for better monitoring and evaluation of the effects of orthodontic treatment in the future.

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