

Impact of Stress and Trait Anxiety on the Sensory and Jaw Motor Responses to a Tonic Orofacial Nociceptive Stimulus

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Aims: To investigate how trait anxiety and stress jointly affect the sensory and jaw motor responses to a tonic orofacial nociceptive stimulus. **Methods:** Orthodontic separators were placed between the first molars in 45 adults with low ($n = 14$), intermediate ($n = 17$), and high ($n = 14$) trait anxiety. Tooth pain, occlusal discomfort, tooth clenching (as a jaw motor behavior), and situational stress were measured three times a day for 5 days using visual analog scales. Mixed-effects regression models were used to evaluate the sensory and motor outcome measures. **Results:** Pain, discomfort, and frequency of tooth-clenching trajectories were affected by trait anxiety ($P = .007$, $P < .001$, and $P = .055$, respectively) and stress ($P < .001$, $P < .001$, and $P = .044$, respectively). Individuals with high anxiety reported their highest pain (17.7 ± 2.9 mm) and discomfort (35.2 ± 4.1 mm) 24 hours earlier than those with low anxiety (pain: 15.9 ± 2.6 mm, discomfort: 28.8 ± 3.7 mm). Tooth clenching decreased progressively in response to the stimulus ($P < .001$). **Conclusion:** A tonic orofacial nociceptive stimulus triggers an avoidance jaw motor behavior. Both trait anxiety and situational stress heighten the sensory response to such a stimulus, but weakly affect the motor response to it. *J Oral Facial Pain Headache* 2022;36:26–35. doi: 10.11607/ofph.3048

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Psychologically stressful events contribute to arousal¹ and state anxiety, a transitory state consisting of feelings of apprehension and nervousness,^{2,3} as the stress response. Trait anxiety, in contrast, is more enduring⁴ and is characterized by a general pattern of worry and physical dysregulation⁵ less tied to specific events. Both stress response and trait anxiety contribute to amplifying bodily sensations^{6–8} and pain sensitivity,^{9–12} and they favor bodily hypervigilance.^{7,13–17} In addition to both sensory and hypervigilance responses to nociceptive stimuli, the stress response and trait anxiety also affect jaw motor behaviors. For example, oral behaviors characterized by repetitive tooth-to-tooth contact or tooth clenching increase with stressful events^{18–21} and are more frequent in individuals with high trait-anxiety levels.^{22–25}

The sensory and motor systems interact to start a defensive response to nociceptive stimuli to prevent or limit tissue damage. Stress and trait anxiety may influence such a response. In the presence of an orofacial nociceptive stimulus, stress and trait anxiety may contribute to strengthening the sensory and hypervigilance responses.⁹ In addition, they could also contribute to increased jaw motor activities, such as oral behaviors involving tooth-to-tooth contact and clenching,^{26,27} in search of the source of the nociceptive drive; ie, the threat. Of importance, an increased jaw motor response could lead to sensitization of the masticatory muscles.^{28,29}

The placement of separators between molars is an orthodontic procedure that creates space between teeth before band placement. The separator compresses the periodontal ligament and causes inflammation, tooth movement, and pain (typically called orthodontic pain),³⁰ which peaks within 48 hours and resolves after 5 to 7 days.

Orthodontic pain has been reported to significantly reduce or slightly affect^{31–32} the activity of the masticatory muscles. These contrasting findings suggest that the jaw motor response to a tonic nociceptive stimulus may be dependent not only on the intensity and duration of the nociceptive input, but also on psychologic factors influencing the pain experience, such as stress and both state and trait anxiety.

In contrast to state anxiety, which is a transient reaction to an adverse situation, trait anxiety is a relatively stable personality disposition, which makes it suitable to investigate the effect of anxiety on jaw motor behaviors in the context of longitudinal behavioral studies. This longitudinal study aimed to determine how trait anxiety and stress affect the sensory and jaw motor response to an ecologically valid tonic orofacial nociceptive stimulus produced by orthodontic elastomeric separators. It was hypothesized that individuals with high trait anxiety would experience greater tooth pain, discomfort, and tooth-clenching frequency in response to an experimentally induced nociceptive stimulus compared to those with lower trait anxiety, and that the sensory and motor responses to such a stimulus would be influenced by situational stress. It was further hypothesized that individuals with high trait anxiety would develop masticatory muscle hyperalgesia.

Materials and Methods

Web Survey

A link to a web survey was included in posters describing the research study, which were displayed on public message boards at the St George Campus, University of Toronto. The survey included the trait (Y2) version of the State-Trait Anxiety Inventory (STAI) for adults,⁵ the Somatosensory Amplification Scale (SSAS),⁷ and the Temporomandibular Disorder (TMD) Pain Screener.³³ The survey also included demographic data. Participation was therefore university community-based. The web survey was open between October 2016 and February 2017.

The STAI-Y2 includes 20 items, such as “I feel pleasant,” “I feel nervous and restless,” “I feel like a failure,” and “I am calm, cool, and collected.” Participants rated how they generally feel using a 4-point ordinal rating scale of “almost never,” “sometimes,” “often,” or “almost always.” The total score ranges from 20 to 80, with a higher score indicating worse anxiety.

The SSAS assesses participants' sensitivity to somatic and visceral sensations based on 10 items, such as “I hate to be too hot or too cold” and “I am often aware of various things happening within my body.” Each item is rated using a 5-point ordinal scale, and the total scores range from 10 to 50.^{6,7}

The score is interpreted as a measure of the individual's somatic awareness.

The TMD Pain Screener is a 6-item questionnaire investigating the presence of jaw and facial pain in the last 30 days. The items are summed, and a cut-off of ≥ 3 has a sensitivity of 0.99 and a specificity of 0.97 for correct classification of the presence or absence of painful TMD.³³

Participants

A total of 255 students (161 women, 94 men; mean age \pm SD = 25.8 \pm 4.7 years) completed the web survey. The STAI-Y2 total scores were used to construct three study groups as follows: low trait anxiety (< 20th percentile of STAI-Y2 scores), intermediate trait anxiety (between 20th and 80th percentiles), and high trait anxiety (> 80th percentile). Based on the power analysis (see statistical analysis), at least 14 participants per group were attempted to be recruited. A phone call was scheduled with survey respondents in order to screen for exclusion criteria, which were: TMD pain screener score ≥ 3 ; current orthodontic treatment; active psychiatric disorders; use of medication acting on the central nervous system; habitual analgesic consumption, current pain or dental pain; any systemic disease that could affect pain perception, presence of fixed extended (three teeth) or complete/partial removable dentures; or not willing to participate in the study. Those who confirmed their interest in participation and who met the selection criteria were invited for a clinical assessment at the research lab, where the inclusion and exclusion criteria were verified further.

All participants received information about the study, signed an informed consent prior to participation, and were compensated with gift cards at the end of the experiment. The protocol was approved by the Research Ethics Board at the University of Toronto (#32797).

Experimental Design

At the research lab and following enrollment, each participant received a simple orthodontic procedure: the placement of two orthodontic separators (X-Ring Separators, American Orthodontics) at the mesial and distal interproximal contacts of a permanent first molar, as done previously,⁹ which results in orthodontic tooth movement when placed between teeth with tight interproximal contacts. To determine where to place the separators, the mesial and distal interproximal contacts of the first molars were examined in the following order: right side mandible, right side maxilla, left side maxilla, and left side mandible. The separators were placed on the first tooth examined with tight interproximal contacts. The separators were kept in place for 5 days. Thereafter, participants returned to the lab, and the separators were removed. All participants were

asked to again complete the STAI-Y2 to measure trait anxiety levels on the day before the actual experiment to confirm that they pertained to the same trait anxiety group (high, low, or intermediate).

Before placing the separators at baseline, and at day 5 before removing them, a single operator (J.C.) measured pressure pain thresholds (PPTs) at the anterior temporalis, superficial masseter, and thenar eminence on the same side where the separators were placed. All participants received standardized information during the different phases of the experiment. All procedures were conducted by a single operator (J.C.), who was blinded to the allocation of participants to the study groups during all phases of the study. The experimental procedures were completed between March and August 2017.

Longitudinal Measures

A custom-made pain diary was provided to all participants to report the intensity of tooth pain, occlusal discomfort, frequency of clenching, and perceived stress on four 100-mm visual analog scales (VAS), three times per day (10:00, 16:00, 22:00), over the course of the 5-day experiment. Each VAS was accompanied by a symptom question and had construct-relevant anchors.

For tooth pain, participants were asked: How severe is your tooth pain? (left anchor = no pain; right anchor = the worst pain ever). For occlusal discomfort, they were asked: How severely are you bothered by the separators? (left anchor = no bother at all; right anchor = extremely bothered; specifically, participants were told to rate how much they were bothered by the change to their bite due to the separators). For tooth clenching, participants were asked: How often did you clench or hold your teeth together in the last 6 hours? (left anchor = none of the time; right anchor = always). Participants received specific information about clenching as a motor behavior before the experiment. The specificity of oral behavior-related terms, such as “clench,” was validated in a previous study using surface electromyography.³⁴ Furthermore, another study showed that individuals understand well the meaning of oral behavior-related words.³⁵

Regarding perceived stress, the participants were asked: How severe is your perceived stress? (left anchor = no stress; right anchor = the worst stress ever). Participants were informed that their daily stress, not the stress related to the positioning of the separators, was the purpose of the measure.

Pressure Pain Thresholds

To determine whether the experimental procedure caused hyperalgesia of the masticatory muscles, a single operator (J.C.) measured PPTs at the anterior

temporalis and superficial masseter muscles before and after the 5-day experiment. PPTs were also measured at an extratrigeminal location, the thenar, to explore whether the intervention could have caused central effects.

PPTs were assessed using an electronic algometer (Medoc) equipped with a 1-cm² rubber tip. For the masseter, PPTs were measured halfway between the origin and insertion of the muscle and 1 cm posterior to its anterior boundary. For the temporalis, PPTs were measured on the line from the top edge of the eyebrow to the highest point of the pinna of the ear and 2 cm behind the anterior margin of the muscle. For the thenar, PPTs were measured on the thenar eminence located on the palmar side of the hand. The procedure was explained to the participants, and they were asked to press a button the moment the sensation changed from pressure to pain. For all measurements, the algometer was positioned perpendicular to the skin. The operator placed the algometer tip on the respective site and increased the pressure at a rate of 20 kPa/second using visual feedback from the instrument. Each measurement was serially repeated at each muscle site four times, with a 1-minute interval between each measurement.

Statistical Analysis

Continuous variables were reported as mean \pm SD, while categorical variables were reported as frequencies. Pearson correlation coefficients were computed for the relationships between tooth pain, occlusal discomfort, clenching, and stress recorded over the 5-day experiment. The values from each measurement scale, collected three times per day, were averaged for each day.

The effect of the intervention on tooth pain, occlusal discomfort, and clenching (dependent variables) was tested using mixed-effects models and by properly accounting for correlations between repeated measurements³⁶ using all available data collected over the 5 days. Study group, sex, stress, and time (day of recording) were included in the models as covariates. Interactions between covariates were preliminarily tested and retained in the final models only if statistically significant. Since the interaction of group*time was statistically significant, it was included as a covariate in each of the mixed models.

PPT data collected at baseline and day 5 were aggregated as follows: at each body location, the first trial was dropped, and the mean was computed for the subsequent three trials. To evaluate baseline associations between PPT and participants' trait anxiety, linear regression models were used. Baseline PPTs were considered as three separate dependent variables (ie, PPT for the masseter, temporalis, and thenar) for the respective models, and study group

Table 1 Baseline Characteristics of the Study Participants

	Low anxiety (n = 14)	Intermediate anxiety (n = 17)	High anxiety (n = 14)
Age, y	27.2 ± 2.7	26.9 ± 3.4	23.7 ± 2.9
STAI-Y2	28.4 ± 2.7	38.9 ± 4.7	57.3 ± 6.5
SSAS	14.2 ± 5.8	14.0 ± 7.4	16.5 ± 5.3

Data are reported as mean ± SD. STAI-Y2 = trait anxiety score; SSAS = Somatosensory Amplification Scale.

Table 2 Correlations Between Stress, Pain, Discomfort, and Clenching in the Study Sample

	Stress	Pain	Discomfort	Clenching
Stress	–	0.556 (0.314–0.730)	0.552 (0.308–0.727)	0.510 (0.255–0.699)
Pain	0.556 (0.314–0.730)	–	0.676 (0.477–0.809)	0.558 (0.316–0.731)
Discomfort	0.552 (0.308–0.727)	0.676 (0.477–0.809)	–	0.671 (0.470–0.806)
Clenching	0.510 (0.255–0.699)	0.558 (0.316–0.731)	0.671 (0.470–0.806)	–

Data are reported as Pearson correlation coefficients and 95% CI. Each construct was measured using a 100-mm visual analog scale.

and sex were used as independent variables. First-order interactions between study group and sex (group*sex) were retained in the final model when testing PPTs at the masseter and the temporalis because they were statistically significant. For each subject, relative changes in PPTs were computed at each muscle location ((PPT day 5 – PPT baseline)/PPT baseline × 100). Linear regression models were used to test the effects of sex and study group on PPT relative changes. Interactions between sex and study group were preliminarily tested, but they were not included in this model because they were not statistically significant.

Linear regression models were used to test between-group differences in SSAS scores. Post hoc comparisons were adjusted using Bonferroni method. Pearson correlation coefficient was calculated to test correlations between the SSAS and STAI-Y2 scores in each study group.

Similarly to a previous study,⁹ it was assumed that a difference of 20 in 0- to 100-mm pain ratings might be used for the sample size determination, and therefore, 14 participants per group were sufficient to obtain 80% power in this study. The statistical analysis was performed by a single operator who was masked to the allocation of participants to the study groups (I.C). The level of significance was set at $P < .05$. SPSS version 24 (IBM) was used for the analyses.

Results

A total of 47 individuals were excluded from the initial sample of 255 respondents to the web survey, as they

had a TMD pain screener score ≥ 3 . Seventy-five individuals were first contacted, of whom 14 refused to participate in the study and 16 were excluded based on selection criteria. Therefore, 45 healthy volunteers were recruited (31 women, 14 men; mean ± SD age = 26.0 ± 3.4 years). Based on the selected percentiles, the resulting trait anxiety groups were as follows: low (STAI-Y2 ≤ 32 ; n = 14, 8 women and 6 men), intermediate (33 < STAI-Y2 ≤ 50 ; n = 17; 14 women and 3 men), and high (STAI-Y2 > 50; n = 14; 9 women and 5 men). As this sample was deemed to be sufficient based on the sample size calculated, the remaining survey participants were not contacted or the experimental part of the study. Baseline age, STAI-Y2, and SSAS are reported in Table 1. No between-group differences in SSAS scores were found ($P = .500$). Correlations between tooth pain, occlusal discomfort, and stress recorded over the 5 days are reported in Table 2. STAI-Y2 was positively correlated with SSAS only in the high-anxiety group ($r = 0.443$, $P = .048$), but not in the low- or intermediate-anxiety groups (low anxiety: $r = 0.076$, $P = .398$; intermediate anxiety: $r = 0.040$, $P = .440$).

The trajectory of tooth pain for the three study groups is reported in Fig 1a. Pain was significantly affected by the interaction for group*time ($P = .007$) and was positively associated with stress ($P < .001$, Table 3). Sex did not affect the tooth pain trajectory ($P = .474$). Individuals with high anxiety reported their highest pain at baseline; ie, on the day the separators were placed (17.7 ± 2.9 mm), 24 hours earlier than those with low anxiety (15.9 ± 2.6 mm). A decrease of mean pain values was observed from baseline to day 5 in all three groups, although there were no

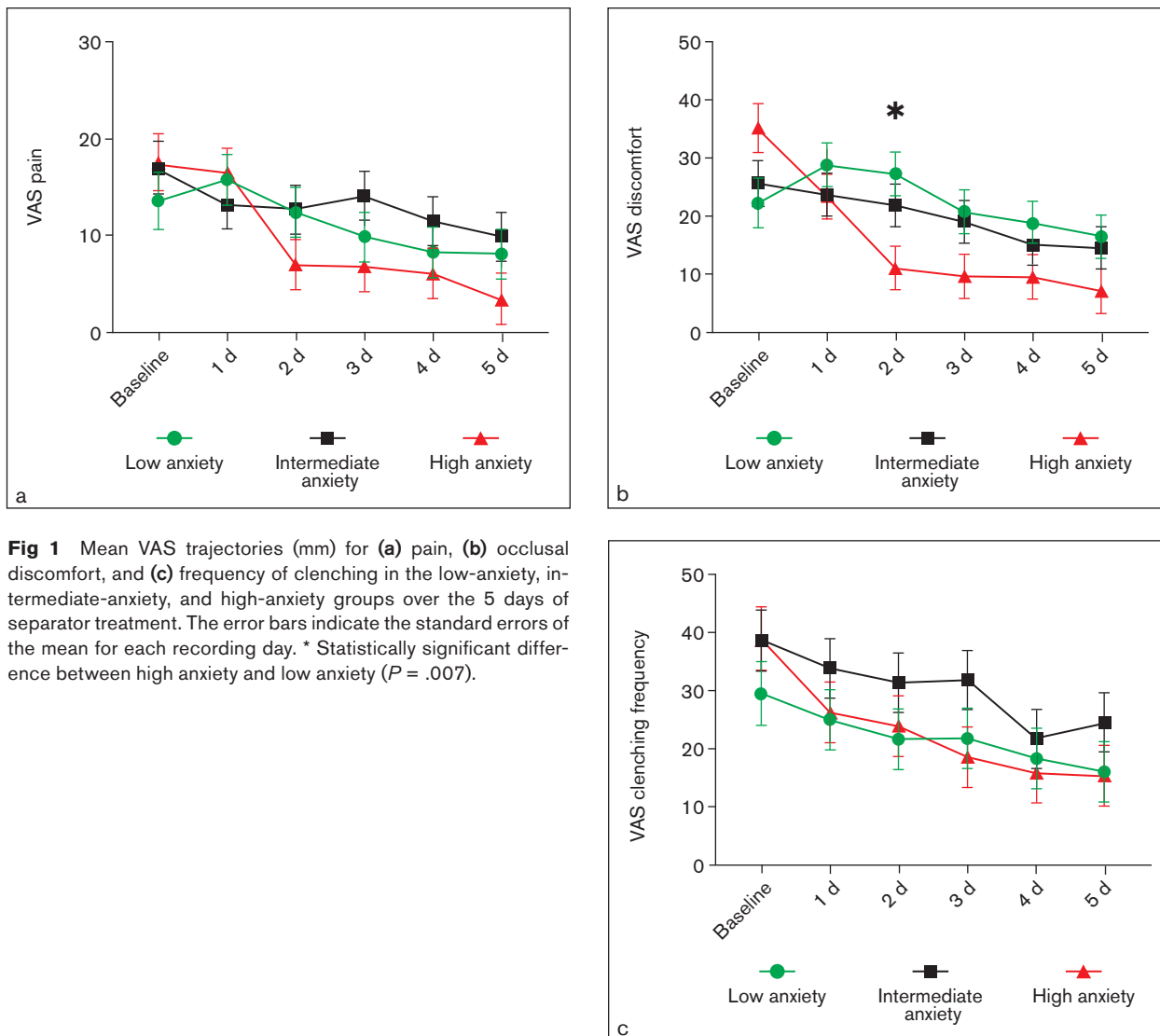


Fig 1 Mean VAS trajectories (mm) for (a) pain, (b) occlusal discomfort, and (c) frequency of clenching in the low-anxiety, intermediate-anxiety, and high-anxiety groups over the 5 days of separator treatment. The error bars indicate the standard errors of the mean for each recording day. * Statistically significant difference between high anxiety and low anxiety ($P = .007$).

Table 3 Results of the Mixed-Effects Models

	Pain	Discomfort	Frequency of clenching
Group	0.688 (.503)	0.947 (.388)	0.905 (.405)
Time	13.633 (< .001)*	24.002 (< .001)*	28.691 (< .001)*
Sex	0.513 (.471)	0.013 (0.911)	0.044 (.883)
Stress	18.333 (< .001)*	24.816 (< .001)*	4.055 (.044)*
Group*time	2.459 (.007)*	4.954 (< .001)*	1.815 (.055)

Data are reported as F value (P value). Each construct was measured using a 100-mm visual analog scale. *Statistically significant at $P < .05$.

significant between-group differences in tooth pain for any recording day (all $P > .05$). The decrease of mean pain was greater in the high-anxiety group than in the other groups: tooth pain dropped significantly from baseline to day 2 ($P < .001$), while there was no significant difference in tooth pain between baseline and day 2 for the low- and intermediate-anxiety groups ($P = .999$ and $P = .673$, respectively).

Occlusal discomfort (Fig 1b) was significantly affected by the interaction for group*time ($P < .001$) and positively associated with stress ($P < .001$, Table 3). Sex did not affect the occlusal discomfort trajectory ($P = .911$). Individuals with high anxiety reported their greatest occlusal discomfort at baseline (35.2 ± 4.1 mm), 24 hours earlier than individuals with low anxiety (28.8 ± 3.7 mm). A decrease of mean

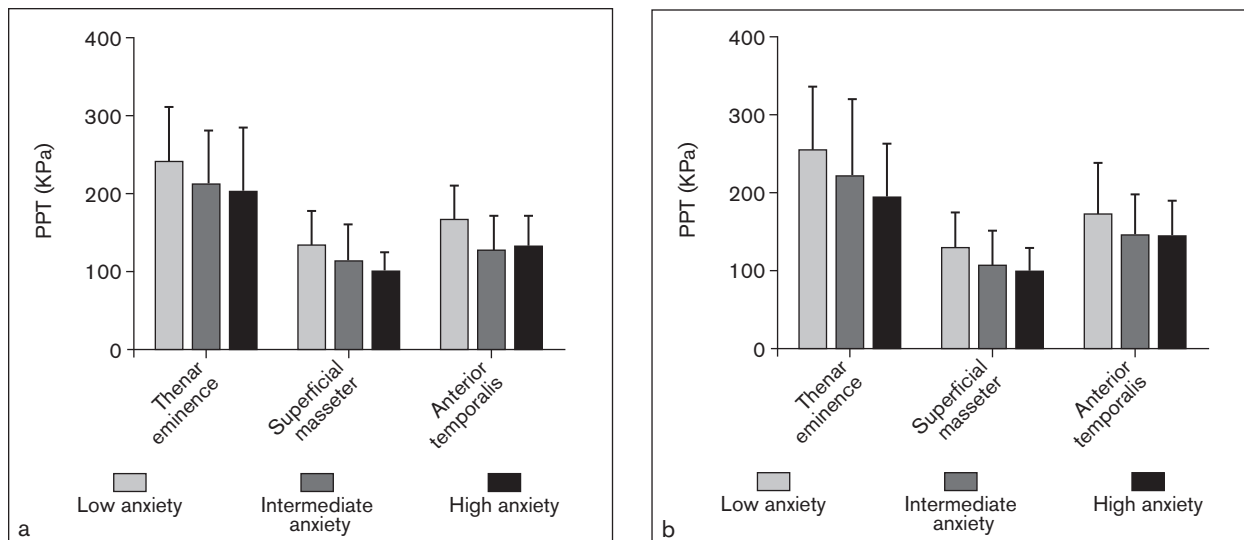


Fig 2 Mean pressure pain threshold (PPTs, KPa) (a) before separator placement and (b) after 5 days. The error bars indicate SDs.

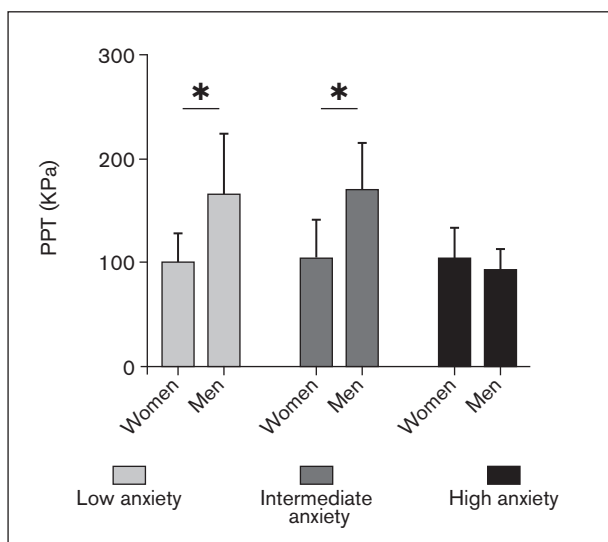


Fig 3 Sex differences in mean pressure pain thresholds (PPTs, KPa) recorded at the masseter before separator placement. The error bars indicate SDs. *Statistically significant difference at $P < .05$.

occlusal discomfort values was observed from baseline to day 5 in all three groups. Occlusal discomfort was significantly lower in the high-anxiety than the low-anxiety group during day 2 ($P = .007$). The decrease of mean occlusal discomfort was greater in the high-anxiety group than in the other groups: in the high-anxiety group, occlusal discomfort dropped significantly from baseline to day 2 ($P < .001$). In contrast, in both the low- and intermediate-anxiety groups, there was no significant difference in occlusal discomfort between baseline and day 2 ($P = .837$ and $P = .948$, respectively).

The motor response (ie, self-reported frequency of tooth clenching, Fig 1c) did not differ according to trait anxiety ($P = .405$) and was positively associated with perceived stress ($P = .044$, Table 3). Sex did not affect the motor response to the nociceptive stimulus ($P = .833$). Tooth clenching changed significantly across the 5 days: it decreased from baseline to day 5 in all groups ($P < .001$) and was weakly affected by the interaction for group*time ($P = .055$).

PPTs before separator placement, and at day 5 before separator removal, are reported in Fig 2. Relative changes in PPTs after the procedure at all muscle locations did not differ between groups or between male and female individuals (all $P > .05$, data not shown).

A significant effect of the interaction for group*sex on the baseline masseter PPTs was found ($P = .013$, Fig 3). In both the low- and intermediate-anxiety groups, women had lower PPTs than men (low anxiety: $P = .001$; intermediate anxiety: $P = .009$, Fig 3). No significant differences were found between men and women in the high-anxiety group ($P = .542$; Fig 3).

Men in the high-anxiety group had lower PPTs than men in the low- ($P = .001$) and intermediate-anxiety ($P = .016$) groups. Differently, the PPT scores of women were not affected by anxiety (all $P > .05$). Before separator placement, PPTs at the temporalis did not differ between the study groups ($P = .118$). No difference between men and women was found ($P = .178$). Similarly, PPTs measured at the thenar eminence before separator placement neither differed between the study groups ($P = .428$), nor between men and women ($P = .500$).

Discussion

This study aimed to determine how trait anxiety and stress regulate the sensory and jaw motor responses to an ecologically valid tonic orofacial nociceptive stimulus produced by orthodontic elastomeric separators. Orthodontic separators are routinely used to create interproximal space for the placement of orthodontic bands in preparation for orthodontic treatment and have been frequently used as an experimental model of orthodontic tooth movement to study orthodontic pain.^{9,37,38} This investigation focused only on specific hypothesized psychologic factors (ie, trait anxiety and stress) and cannot inform about several other biologic and psychosocial factors potentially influencing sensory and motor responses to the orthodontic separators.

The results of this study showed that trait anxiety strongly influenced pain and discomfort trajectories, but weakly influenced the jaw motor response to the nociceptive stimulus. Of importance, pain, discomfort, and tooth clenching were also significantly influenced by situational stress. Finally, masticatory muscle sensory changes after the experimental intervention were not affected by trait anxiety levels.

The pattern of pain related to orthodontic tooth movement has been extensively studied. Pain appears approximately 2 to 3 hours after orthodontic forces are applied to the teeth, with peak levels frequently occurring within the first 24 hours, followed by a steady decrease toward baseline levels within a few days.^{39–44} The present intervention produced mild tooth pain, within the ranges reported in previous studies,^{9,45,46} which was well tolerated by all participants. The significant effect of the group*time interaction on both tooth pain and occlusal discomfort indicates that their temporal trajectories were different between anxiety groups. Individuals with higher anxiety had the greatest tooth pain and occlusal discomfort just a few hours after the positioning of the separators. Indeed, on the day the separators were placed, tooth pain was maximum in the high-anxiety and intermediate-anxiety groups. Conversely, in the low-anxiety group, the greatest pain occurred the day after. A similar pattern was found for occlusal discomfort. The significant interaction for group*time, together with the lack of significant between-group differences in pain ratings during each day of the experiment, indicates that trait anxiety affected the temporal pattern of tooth pain rather than its magnitude. Of note, somatosensory amplification scores were positively correlated with trait anxiety only in the high-anxiety group. It is possible that high trait anxiety amplified arousal toward the separators. Therefore, individuals with high anxiety presented tooth pain and discomfort earlier than individuals with

low anxiety. Nonetheless, during day 2, discomfort became significantly lower in the high-anxiety than the low-anxiety group, which indicates that the former were less bothered by the separators and adapted better than those with low anxiety within 48 hours. An explanation for this finding may be, in part, related to minor between-group differences in the jaw motor response to the experimental nociceptive stimulus. In general, the frequency of tooth clenching after the experimental procedure decreased significantly in all study groups, which suggests an avoidance behavior. Of interest, results from the mixed-effects model showed a weak effect of the interaction for trait anxiety group*time ($P = .055$). As shown in Fig 1c, individuals with high trait anxiety reduced their clenching behaviors more compared to the other groups at day 1. The more pronounced avoidance behavior in the high-anxiety group may have led to a less frequent stimulation of the periodontal ligament in these subjects, which could have led to a greater reduction in occlusal discomfort and pain perception on the following days.

The lack of between-group differences in the magnitude of orthodontic pain contrasts with the authors' previous report⁹ showing that individuals with combined high levels of trait anxiety and somatosensory amplification had higher orthodontic pain than those with low scores of trait anxiety and somatosensory amplification. Discrepancies between the studies may be related to differences in recruitment of participants. In the previous study, participants were recruited using combined high scores of somatosensory amplification (SSA) and trait anxiety (STAI-Y2).⁹ The SSA cut-off score for inclusion in the high SSAS/STAI group was 23,⁹ which is higher than the average SSA of the high-anxiety group (mean SSA = 16.5) of the present study. Therefore, it is possible that the higher SSA contributed to a greater orthodontic pain in the previous investigation⁹ or that SSA and trait anxiety may have an additive effect on pain perception.

It is logical to assume that separators or orthodontic tooth movement produced by the separators interfered with intercuspation. First, separators are placed around the interproximal contact area between two adjacent teeth. The occlusal portion of the separators passes over the marginal ridges of the premolar and molar. Second, separators create a space of about 0.4 mm at each interproximal contact area,⁴⁷ which is due to minor orthodontic tooth movements. In studies testing the effects of experimental occlusal interferences on the habitual activity of the masseter,^{48,49} the frequency of tooth clenching and the electromyographic activity of the masseter significantly decreased when an active interference was placed on the occlusal surface of a molar. In an-

other study, individuals with high anxiety reduced the frequency of tooth contacts if subjected to occlusal interferences.²³ In summary, occlusal interferences induce an avoidance behavior in healthy individuals, with reduced activation of the masseter. Due to the relationship between anxiety and fear avoidance, it would have been possible that individuals with higher anxiety would have shown a greater reduction of clenching episodes than individuals with low anxiety. Although the frequency of clenching during orthodontic tooth movement was weakly affected by the participants' trait anxiety levels but strongly affected by the individuals' current stress, a greater reduction in the frequency of tooth clenching, although not statistically significant, was observed in the high-anxiety group. Although these data suggest that individuals with high anxiety adapted well to the intervention, which caused a minor occlusal discrepancy, it is not possible to exclude that this would not have been the case in the presence of a major occlusal discrepancy.²³

Tooth pain, clenching, and discomfort were highly intercorrelated. Therefore, it can be hypothesized that greater ratings of pain may be explained in part by trauma related to tooth clenching. Similarly, increased occlusal discomfort could be ascribed to an increased frequency of tooth clenching. Of importance, and in agreement with previous studies showing that stress heightens tooth pain perception and is related to more frequent jaw motor behaviors,^{9,18,24,50–52} tooth pain, discomfort, and frequency of tooth clenching were influenced by stress. This finding confirms that stress-related arousal contributes to shaping the sensory and jaw motor response to intraoral nociceptive inputs.

Baseline PPTs were within normal ranges^{9,53,54} and did not differ between study groups. In accordance with a previous study,⁵⁵ it was found that the PPTs measured at the masseter were lower in women than in men, although this difference was present in the low- and intermediate-anxiety groups but not in the high-anxiety group. In agreement with other investigations,^{9,23,49} orthodontic tooth movement did not affect PPTs at trigeminal and extratrigeminal muscle locations. Michelotti et al³¹ reported that orthodontic pain produced by separators determined a reduction in PPTs of the anterior temporalis and masseter muscles 24 hours after the intervention. Since PPTs were measured before separator placement and after 5 days in the present study, it could not be determined whether orthodontic tooth movement contributed to masticatory muscle hyperalgesia in the immediate short term.

There are a few limitations to this study related to the population of interest, the sampling method, and the experimental model. The study sample

was composed entirely of university students with a limited age range that may not be representative of the general population. Also, the intermediate-anxiety group presented a greater female to male ratio compared to the other groups. Although sex was accounted for in the models, this may still have affected the comparisons. Of note, this study may not have had sufficient power to test differences in tooth pain, occlusal discomfort, and tooth clenching between men and women. However, this was not an aim of the current investigation, and consequently sex was used only as a covariate, not for direct hypothesis testing. Moreover, cultural factors have been reported to influence pain perception.⁵³ Although the present study sample included university students from a multitude of different ethnicities, it was decided not to include this factor in the statistical analysis, as controlling for this may have significantly affected the power of the investigation.

The use of paper-based diaries with simultaneous sampling of pain, discomfort, and clenching could have increased the chances of recall bias, and it cannot be excluded that single-construct ratings may have affected other ratings. For instance, participants were asked to rate their occlusal discomfort as how much they were bothered by the change to their bite due to the separators. However, it cannot be excluded that this measure was not affected by the pain experience. Similarly, although participants were informed that their daily stress, not the stress related to the positioning of the separators, was the purpose of the measure, it cannot be excluded that the stress produced by the procedure could have affected participants' stress ratings. The use of mobile apps for collecting data⁵⁶ in real time together with electrophysiologic recordings and collection of stress biomarkers could have maximized the ecological validity of the present data.

Finally, a model of orthodontic tooth movement was used that elicited mild pain and a minor occlusal discrepancy. This stimulus did not determine peripheral sensitization of the muscles of mastication after 5 days. Yet, it is possible that the nociceptive input may have led to peripheral sensitization of the muscles of mastication in the immediate short term (eg, 24 to 48 hours), as reported in a previous study by Michelotti et al.³¹ The inclusion of an intermediate PPT assessment, such as when orthodontic pain peaks, could have provided more precise information about the effects of the experimental nociceptive stimulus on the muscles of mastication and is suggested for further research examining specific effects. Finally, as the nociceptive stimulus elicited by separators is mild, these findings cannot be generalized to other clinical interventions that produce moderate to severe pain.

Conclusions

This study demonstrated that an experimentally induced tonic orofacial nociceptive stimulus triggers an avoidance jaw motor behavior (eg, decrease in the frequency of spontaneous tooth clenching episodes). Both trait anxiety and situational stress heighten the sensory response to such a stimulus, but weakly affect the motor response to it.

Highlights

- Psychologic states and traits modulate the sensory and jaw motor responses to a tonic trigeminal nociceptive stimulus.
- The assessment of patient trait anxiety and stress chairside could be useful to prevent and better manage tooth pain and occlusal discomfort secondary to dental interventions.

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