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Aims: To measure brain activity in patients with bruxism and temporomandibular disorder (TMD)–related pain in comparison to controls using functional magnetic resonance imaging (fMRI) and to investigate whether modulations in jaw clenching led to different pain reports and/or changes in neural activity in motor and pain processing areas within and between both groups. **Methods:** A total of 40 participants (21 patients with bruxism and TMD-related pain and 19 healthy controls) performed a tooth-clenching task while lying inside a 3T MRI scanner. Participants were instructed to mildly or strongly clench their teeth for brief periods of 12 seconds and to subsequently rate their clenching intensity and pain experience after each clenching period. **Results:** Patients reported significantly more pain during strong clenching compared to mild clenching. Further results showed significant differences between patients and controls in activity in areas of brain networks commonly associated with pain processing, which were also correlated with reported pain intensity. There was no evidence for differences in activity in motor-related areas between groups, which contrasts with findings of previous research. **Conclusions:** Brain activity in patients with bruxism and TMD-related pain is correlated more with pain processing than with motoric differences. *J Oral Facial Pain Headache 2023;37:139–148. doi: 10.11607/ofph.3091*

Bruxism is the most frequently occurring oral movement condition[1,2] and is characterized by repetitive jaw muscle activity, such as clenching or grinding the teeth and/or bracing or thrusting of the mandible. Such activities can occur during sleep (sleep bruxism) or wakefulness (awake bruxism).[3] A recent proposition as put forward by the RDC/TMD Consortium Network Bruxism Consensus Meeting posits that sleep and awake bruxism should not be considered as disorders but rather as behaviors that can be aware or unconscious, involve involuntary 24-hour masticatory muscle activity,[4] have overlap and common etiology,[5,6] can be learned in childhood,[7] and can be a risk and/or protective factor for certain clinical consequences.[4] From this perspective, bruxism treatment may depend on whether it is considered to be harmless, a protective factor, or a risk factor with negative health outcomes[4] and only needs management when it has negative consequences for physical or mental health (eg, tissue damage and/or pain).[6,8] More particularly, temporomandibular disorder (TMD)–related pain, which is the most common cause of orofacial pain after odontogenic pain, may result from an overloading of different structures in the masticatory system during bruxism.[8–16] However, the degree of bruxism in relation to TMD-related pain is still debated. Some studies have suggested a correlation between pain and bruxism severity,[17,18] although one study suggested that this relationship may be mediated by mental health factors such as depression.[19]

One way to investigate pain in bruxism is to study the neural correlates of bruxism and TMD-related pain using functional magnetic resonance imaging (fMRI). Several studies have investigated the neural correlates of bruxism,[20–25] but in previous fMRI studies, experienced pain was not taken into consideration. Strong TMD-related pain could affect the performance of tooth-related tasks, such as withholding from tooth contact when experiencing severe pain or engaging in compensatory

movements during task execution to alleviate the pain experience. There is extensive evidence from human neuroimaging studies that the experience of physical pain is related to increased activity in a collection of brain areas that has been termed the *pain matrix*.[26–30] Further, it has been shown that experience or anticipation of pain may also lead to decreased brain activity[31] compared to resting baseline in areas that strongly overlap with the default mode network (DMN),[32–34] with the brain systems underlying increased or decreased activity contributing differentially to pain. These areas were not previously reported in bruxism fMRI studies.

The aim of this study was to explore whether there is a neural correlate for bruxism and/or pain, and, if so, what the relationship is between the two. To further investigate this issue, patients clinically diagnosed with bruxism and varying degrees of TMD-related pain and healthy controls with no bruxism or pain have been engaged in multiple trials of a parametric tooth contact task while undergoing fMRI scanning. Assuming that clenching is one of the main forms of bruxism, it was hypothesized that more intense clenching would result in higher pain ratings in patients with bruxism but not in healthy controls. Further, it was hypothesized that brain areas of the pain matrix would show larger changes in activity when patients with bruxism increased tooth clenching compared to healthy controls, whereas regions involved in motor control would show reduced activity. Finally, it was hypothesized that participants' self-reported pain ratings would be correlated with activity in brain areas that have been associated with the processing of pain.

Materials and Methods

Study Design

This study was conducted at the Maastricht University Medical Center (MUMC+) and at Maastricht University (the Faculty of Psychology and Neuroscience and the Faculty of Health, Medicine, and Life Sciences) from April 2017 to February 2018. Approval of the Medical Ethical Committee (METC) of the MUMC+ was obtained prior to participant recruitment (METC no. 162013). Potential clinical volunteers were alerted to the existence of the study during their regular visit to the department of Cranio-Maxillofacial Surgery of the MUMC+. All volunteers were invited to participate in the study and were informed orally and in writing by the investigator about the study details. After deciding to participate, an appointment was arranged for an initial screening examination, during which further information was given and any questions were answered. Written informed consent was obtained from all participants prior to the experimental session.

Group selection and differentiation was performed using the Oral Behaviors Checklist (OBC),[35,36] the Graded Chronic Pain Scale (GCPS),[37] clinical examination according to the Diagnostic Criteria for Temporomandibular Disorders (DC/TMD),[38] and a diagnostic grading system.[39] After completion of the questionnaires, a TMD-related pain and headache examination was undertaken to diagnose myalgia and/or arthralgia with or without associated headache according to the DC/TMD.[38] Subsequently, an oral exam that included clinical criteria according to Paesani et al[40] was completed. Based on the TMD-related pain diagnoses plus the interview (subjects self-reported by means of questionnaires and history-taking) and inspection parts of the clinical oral examination, the participants were divided into two groups: *(1)* a group of patients, which included all individuals with a mixture of at least two or more TMD-related pain types (arthralgia, [local] myalgia, myofascial pain with and without referral, headache attributed to TMD) and with a diagnosis of probable awake and/or sleep bruxism according to the diagnostic grading system,[39] and *(2)* a group of healthy controls, in which no bruxism was diagnosed and no TMD-related pain of any kind was found in any of the individual participants. Additional inclusion criteria were 18 years or older, mentally competent, and in good physical and mental health. Excluded were patients with TMD-related pain but no bruxism and patients with bruxism but no TMD-related pain. Further exclusion criteria were a complete denture in the maxilla or mandible, pain elsewhere in the body, and/or failure to meet the MRI safety screening.

Participants

A total of 41 participants complied with the clinical inclusion criteria. One participant was subsequently rejected due to a contraindication for MRI scanning, leaving a total sample size of 40 participants included in the study (21 patients: 13 women, mean ± SD age = 43.48 ± 18.19 years; 19 healthy controls: 11 women, mean ± SD age = 45.10 ± 18.30 years). After scanning, the data from 2 patients were discarded because their MRI images were of insufficient quality due to excessive head movement, leaving a total sample size of 38 participants for analysis (19 patients and 19 healthy controls).

Procedures for Measuring Brain Function During Tooth-Clenching Task

The tooth contact task comprised a series of tooth-clenching trials in which clenching instructions alternated between mild and strong clenching. During scanning, participants completed 14 tooth contact trials, which were interspersed by periods of resting baseline measurements. Each trial started with a cue (2 seconds) that indicated the intensity of clenching, followed by 12 seconds of clenching (7 times mild and 7 times strong in a random sequence) and then

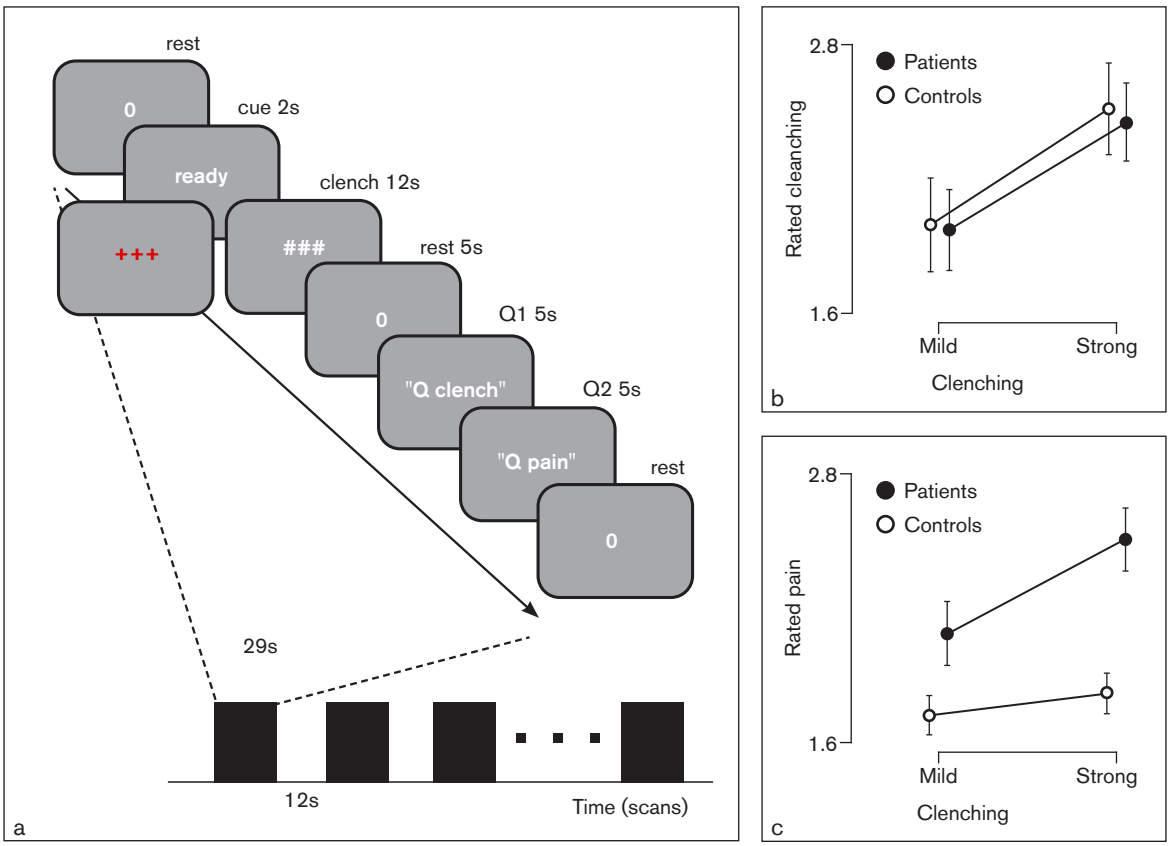

Fig 1 Experimental task paradigm and behavioral results. *(a)* Each measurement started with a cue of 2 seconds, followed by a randomly assigned clench block (mild [+++] or strong [###]) of 12 seconds and then ending with a rest/question block (Q1/Q2) of 14 seconds, for a total of 28 seconds for each trial, separated by12 seconds of rest. Mean ratings for *(b)* intensity of clenching and *(c)* experienced pain are plotted for patients (*black circles*) and healthy controls (*open circles*). Error bars are 95% CI.

4 seconds of resting after clenching. Participants then answered a question about the intensity of tooth contact ("Was there tooth contact?" with 5 seconds of response time; answer options = 0 [no contact], 1 [little contact], or 2 [much contact]) and a question about experienced pain intensity ("How much pain did you experience?" with 5 seconds of response time; answer options = 0 [no pain], 1 [only sensation], 2 [mild pain], or 3 [strong pain]). Participants responded to these questions with their dominant hand using an MRI-compatible response box. The preceding and following resting periods lasted 12 seconds before the next trial started. Task instructions were delivered by visual symbols using a coil-mounted display mirror inside the scanner bore, with "O" (white) indicating rest, "Ready" (white) for cue, "+++" (orange) for mild clenching, and "# # #" (purple) for strong clenching (Fig 1a). Prior to scanning, participants were trained in the clinic by an author (T.K.) on the meaning of and appropriate action following each symbol, in particular for mild and strong clenching, and the task trainer also verified that the behavior was consistent with the instructions. Experiment timing, visual presentation, and response collection were programmed in PsychoPy version 1.90.2.[41]

Image Acquisition, Preprocessing, and Statistical Analysis

Functional and anatomical brain images were acquired using a 3.0 Tesla Siemens Magnetom Prismafit MRI scanner using a transmit/receive 64-channel Head/Neck Coil at the Scannexus facility of Maastricht University. For each participant, functional images were acquired using an echo-planar imaging (EPI) sequence to measure blood oxygenation level–dependent (BOLD) signal (pixel resolution 3 × 3 mm^2; slice thickness 3 mm; no slice gap; 35 slices; field of view 216 mm; acquisition matrix 72 × 72; repetition time [TR] 2,000 ms; time to echo [TE] 30 ms; flip angle 77 degrees; and GRAPPA acceleration factor iPAT2 [in-plane acceleration]). For coregistration and spatial normalization, a high-resolution 3D T1-weighted anatomical image (MPRAGE; voxel size 1.0 × 1.0 × 1.0 mm) was acquired. The measurements were part of a larger study that included measurement of resting-state fMRI and diffusion-weighted imaging (DWI), which are not reported in

Table 1 Mean ± SD Ratings of Intensity of Clenching (0–2) and Pain (0–3) in Patients and Healthy Controls

	Clenching		Pain	
Clenching	Patients	Healthy controls	Patients	Healthy controls
Mild	1.969 ± 0.383	1.994 ± 0.358	1.556 ± 0.718	1.128 ± 0.277
Strong	2.457 ± 0.560	2.517 ± 0.595	2.053 ± 0.884	1.241 ± 0.444

this manuscript. Total scanning time encompassed approximately 60 minutes per participant.

The functional and anatomical MRI images were preprocessed and analyzed using BrainVoyager version 2.14.[42] Anatomical image quality was improved by using an automatic intensity inhomogeneity correction and by subsequently removing skull and other nonbrain matter from the images. Functional images were preprocessed using slice scan time correction, 3D motion correction, spatial smoothing using a full-width-at-half-maximum (FWHM) kernel of 4 mm, and temporal signal correction using linear trend removal and high-pass filtering (low-frequency cutoff at 2 cycles per time series). The preprocessed anatomical and functional images were then coregistered and normalized to Montreal Neurologic Institute (MNI) space, in which functional data were resampled to an iso-voxel resolution of $3 \times 3 \times 3$ mm^3.

Preprocessed and normalized functional time series were then analyzed using a two-level mixed-effects general linear model (GLM). At the first level, the signal amplitude was estimated for the various task conditions, which included cue, mild clenching, and strong clenching, and for answering the questions for tooth contact (QTooth) and pain (QPain) for each participant using a least-squares approach. Each task condition was convolved using a hemodynamic response function (HRF) to accommodate for the delay in the BOLD signal.[43,44] At the second level, the amplitude estimates from all participants were analyzed using a 2×2 factorial design using the within-subject factor clenching (mild vs strong) and between-subject factor group (patients vs healthy controls). This analysis was conducted using the BrainVoyager ANCOVA module.[45] This study was mostly interested in the mixed clenching × group interaction effect. Multiple-comparison correction was performed using a minimum cluster size procedure in which a statistical map at an uncorrected threshold of $P = .005$ was corrected at the cluster level using a Monte Carlo simulation procedure that utilizes the spatial smoothness of the statistical summary map.[42,46]

Further, to assess the relation between brain activity and pain experience during tooth clenching, the self-reported pain ratings were correlated with the amplitude difference of mild vs strong clenching in areas that survived the thresholding of the mixed interaction effect (regions of interest [ROIs]).

As a post hoc analysis, an ROI analysis was also conducted for (sub)cortical motor areas, in keeping with previous studies.[20,21] For this analysis, the effect of group on fMRI signal amplitudes was analyzed only for the mild clenching condition. The motivation for this analysis was that an a priori effect of bruxism is best represented in the condition in which clenching is least affected by the difference in experience between groups; ie, the mild clenching condition should lead to an equal amount of clenching effects in both groups without leading to the secondary effects of clenching in bruxism (such as anxiety for, or experience of, pain or possible hesitance in clenching strongly). ROIs from the motor system included the left and right sensorimotor cortex (l SMC, r SMC), supplementary motor area (SMA), and thalamus. Group differences in mean ratings for tooth contact and experienced pain were analyzed using JASP version 0.10.2. Group differences were considered statistically significant at $P = .05$.

Results

Behavior Analysis

Postclenching ratings for intensity of clenching (mild vs strong) and for group (patients vs healthy controls) were performed in order to assess task execution. A significant effect of clenching ($F_{1,36} = 30.90$, $P < .001$, $\eta_p^2 = 0.46$) was found, but no significant effect of group ($F_{1,36} = 0.11$, $P = 0.75$) or clenching × group interaction ($F_{1,36} = 0.04$, $P = 0.85$; Fig 1b). These findings indicate that participants generally complied with task instructions and that performance was similar for both groups. Analysis of the self-reported pain ratings showed a significant effect of intensity ($F_{1,36} = 21.39$, $P < .001$, $\eta_p^2 = 0.325$), a significant effect of group ($F_{1,36} = 10.41$, $P = .003$, $\eta_p^2 = 0.22$), and a significant clenching × group interaction effect ($F_{1,36} = 8.50$, $P = .006$, $\eta_p^2 = 0.13$; Fig 1c). Patients showed a significant difference in pain when strong clenching was compared to mild clenching ($t_{18} = -4.40$, $P < .001$, Cohen $d = -1.01$), while healthy controls showed no

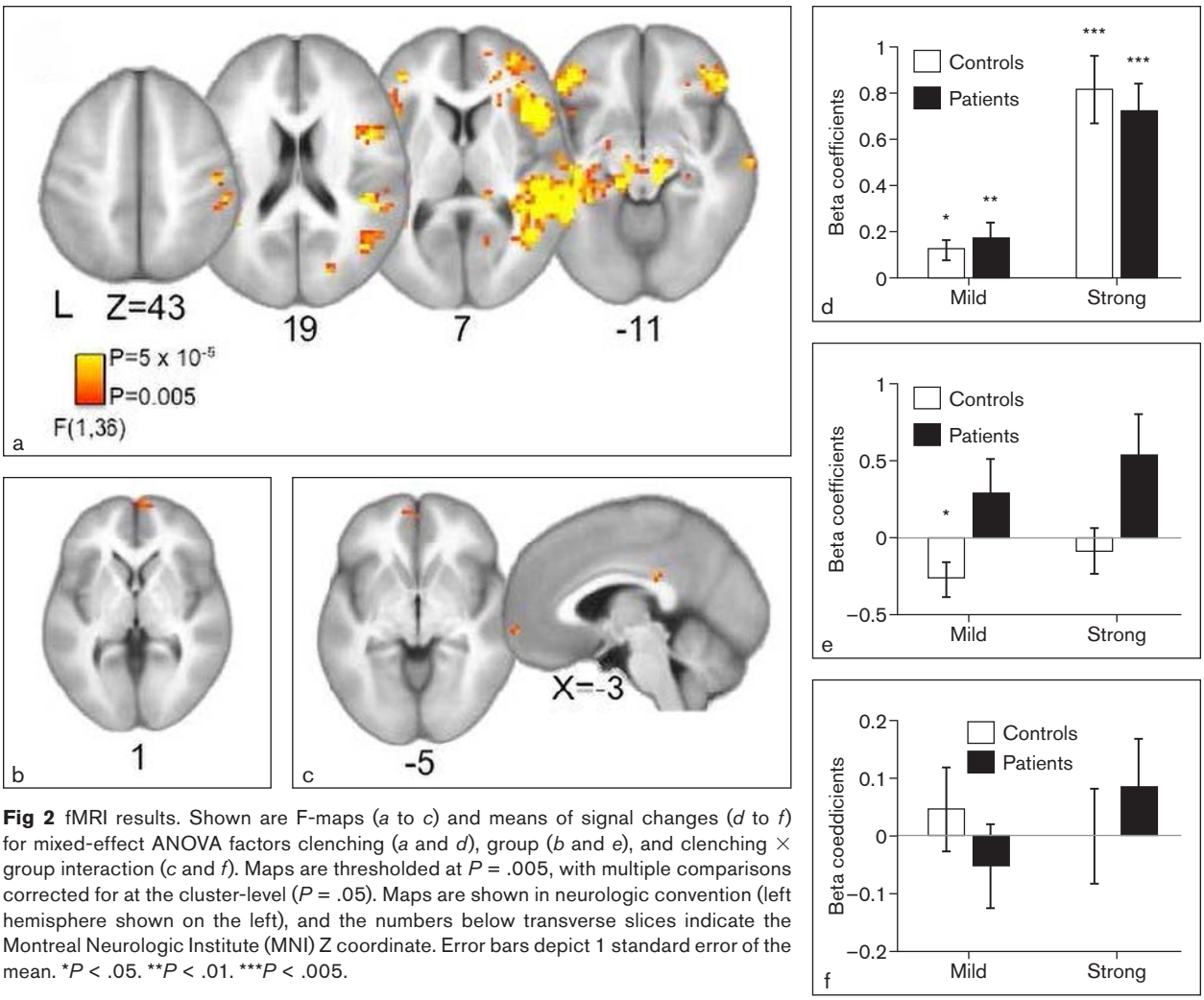

Fig 2 fMRI results. Shown are F-maps (*a* to *c*) and means of signal changes (*d* to *f*) for mixed-effect ANOVA factors clenching (*a* and *d*), group (*b* and *e*), and clenching × group interaction (*c* and *f*). Maps are thresholded at $P = .005$, with multiple comparisons corrected for at the cluster-level ($P = .05$). Maps are shown in neurologic convention (left hemisphere shown on the left), and the numbers below transverse slices indicate the Montreal Neurologic Institute (MNI) Z coordinate. Error bars depict 1 standard error of the mean. *$P < .05$. **$P < .01$. ***$P < .005$.

significant difference in pain ($t_{18} = -1.66$, $P = .11$). These findings suggest that patients experienced disproportionally heightened pain when tooth clenching intensified compared to healthy controls (Table 1).

Analysis of fMRI

Mild vs strong clenching.

F test for the within-subjects factor clenching (mild vs strong) showed a strong effect in the prefrontal cortex (PFC; Brodmann areas 46 and 9), premotor area (PMA), and SMC. These areas have been found to be activated during chewing tasks and executive control of behavior,[47,48] as well as other orofacial motor-related activities and functions, including clenching[20,23] (Figs 2a and 2d, Table 2).

Patients vs healthy controls.

F test for the between-subject factor group (patients vs healthy controls) showed a significant effect only in the medial PFC (Figs 2b and 2e, Table 2). No significant effects in premotor, motor, or somatosensory areas were found.

Interaction effect of clenching × group.

F test for the interaction between clenching (mild vs strong) and group (patients vs healthy controls) revealed a significant effect in the posterior cingulate cortex (PCC) and medial PFC (Figs 2c and 2f, Table 2). These areas largely coincide with areas of networks specifically involved in pain processing.[29–31,49]

Correlation of clenching with experienced pain.

To assess the relation between brain activity and experienced pain during tooth clenching, the difference in voxel-by-voxel brain activity with mild vs strong clenching was correlated with the difference in pain ratings. Significant negative correlations were found in the ventromedial PFC, left and right precuneus, and left somatosensory cortex (Figs 3a and 3b, Table 2). In these areas, larger deactivations were associated with higher subjective pain intensity. Many of these areas showed considerable overlap with areas of the pain matrix as well as core medial frontal and parietal areas of the DMN.[30–34] Positive correlations

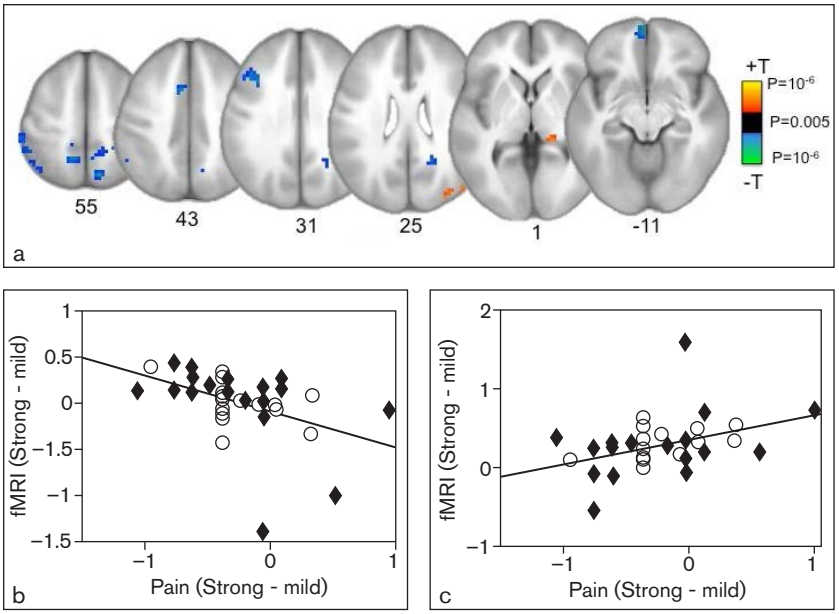

Fig 3 fMRI pain correlations. *(a)* Maps show positive and negative associations (ANCOVA) of changes in fMRI signal (strong and mild) with changes in self-reported pain (strong and mild; left hemisphere shown on the left). (b and c) Scatterplots show linear relation for *(b)* negative and *(c)* positive regions (data points corrected for group). Black diamonds = patients, open circles = healthy controls.

Table 2 MNI Coordinates of Significant Areas (see Figs 2 and 3)

ROI	MNI			Volume
Clenching	x	y	z	(mm^3)
PFC/PMA-r	47	30	–3	6,614
PFC/PMA-l	–46	28	–3	7,655
SMC-r	63	–35	–3	6,105
SMC-l	–63	–33	2	3,231
Group				
Medial PFC-r	7	64	0	378
Interaction				
Medial PFC	–2	57	–8	219
PCC	–4	–31	24	225
Pain				
Negative				
Medial PFC	–5	57	–11	324
Precuneus-l	–12	–47	44	918
Precuneus-r	13	–45	48	351
Precuneus-r cortex	11	–64	48	783
SSC-l	–49	–44	48	459
SSC-l caudalis	–50	–56	13	324
Positive	15	–28	7	567
Thalamus-r				
Superior occipital gyrus	48	–79	22	432

Significant clusters of the effect of mild vs strong clenching, the effect in patients vs healthy controls, the interaction effect of clenching × group, and the correlation between experienced pain and during clenching are listed.

in the posterior thalamus and superior occipital cortex were also found (Figs 3a and 3c, Table 2).

ROI Analysis

No evidence that activity in sensorimotor processing brain areas was different for patients compared to healthy controls was observed. One reason for this null finding could have been that such effects did exist but were overshadowed by the effect of increased pain in patients compared to healthy controls. To investigate whether an effect of bruxism could be found independent of experienced pain, a subsample of patients and healthy controls that showed similar pain ratings at the group level during the mild clenching condition was selected. This resulted in a subsample of 11 patients and 15 healthy controls for whom average subjective pain ratings for the mild condition were below 1.14. Pain ratings between these patients and healthy controls were not significantly different (t_{24} = –1.96, P = .06). A whole-brain t test between patients and healthy controls revealed no significant effects. To obtain higher statistical power, the ROI approach was used. To maximize the chances of finding a group effect in sensorimotor areas, a one-sample t test of mild clenching against resting baseline was calculated, which resulted in six ROIs that included the l and r SMC, right motor cortex (MC), right SMA, right caudate nucleus/putamen, and left nucleus accumbens (Fig 4 and Table 3). In these ROIs, t test for group and results were again calculated and then Bonferroni corrected for multiple comparisons. None of the ROIs revealed a significant difference between groups (corrected P > .09). Thus, no evidence was found of a difference in sensorimotor processing between patients and healthy controls when the reported pain levels did not differ between the groups.

Discussion

In this study, a neural correlate for pain but not for orofacial movement conditions was demonstrated in patients diagnosed with bruxism and TMD-related pain, and that pain was related to the intensity of

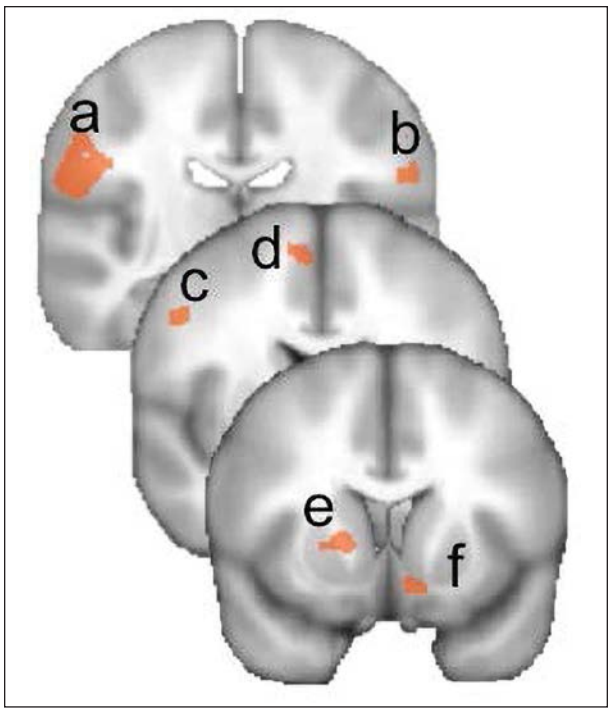

Fig 4 Motor ROIs for post hoc analysis. Orange areas indicate ROIs associated with motor activity in the mild clenching condition pooled across a subsample of participants with pain ratings below 1.14.

Table 3 MNI Coordinates of the ROIs (see Fig 4)

	MNI		
ROI	x	y	z
SMC-l *(a)*	–52	–24	28
SMC-r *(b)*	51	–18	22
Right motor cortex *(c)*	48	2	28
Supplementary motor area *(d)*	7	–4	52
Right basal ganglia *(e)*	17	9	2
Nucleus accumbens left *(f)*	–8	12	–12

clenching as a form of bruxism. The finding that a parametric increase in intensity of tooth clenching resulted in a disproportionally higher increase in reported pain in patients with bruxism compared to healthy controls supports an association between bruxism and TMD-related pain, which is in accordance with previous studies that reported orofacial pain and dysfunction in bruxism.[8–16] More specifically, this finding suggests a possible dose-response relationship, but not a causal relationship, between the degree of TMD-related pain and temporomandibular taxation (ie, intensity of clenching) in bruxism, which is in line with previous findings.[17–19]

The present fMRI results are also in line with reported pain ratings, with patients showing increased activity compared to healthy controls in medial frontal and parietal areas. These areas are part of the pain matrix and the DMN, which has been amply associated with self-reflective processing[50] but also with nonnociceptive–specific cognitive processes that support the experience or anticipation of pain rather than the sensation of pain.[26,31,51] From this, it can be suggested that the pain experience may play an important role in pain behavior of patients compared to healthy controls; ie, the way patients deal with their pain (see Loeser and Treede[52]). Furthermore, the finding that increased pain reported in patients was correlated with decreased activity in medial prefrontal and parietal areas supports this notion and fits with the suggested role of the DMN in monitoring external (environmental) influences without demanding attention or supporting internally directed (nonenvironmental) cognitive activity.[31] In addition, it was found that increased pain reporting was correlated with increased activity in visual cortical and subcortical areas. These areas are not commonly reported as being part of the pain processing neural networks; however, a recent study showed increased resting state connectivity between the visual cortex and cortical areas of the somatosensory and motor networks in chronic low back pain compared to healthy controls,[53] which may point to enhanced perceptual processing during the experience or anticipation of pain.[54] In all, these findings support the suggestion that patients anticipate experiencing pain when engaging in jaw clenching compared to healthy controls.

Further, no difference between patients and healthy controls was found in brain activity in motor-related cortical or subcortical areas, which appears partially in line with other studies that also showed little to no difference in brain activity in motor-related areas.[20,21] Notably, these studies observed group differences in SMA activity, whereas the present study did not show such findings in the whole-brain or SMA ROI analysis. It is unlikely that this null finding resulted from the present task design. It was found that brain activity increased in motor-related cortical or subcortical areas when clenching intensified for both patients and healthy controls, which corresponds with previous fMRI studies of jaw movements and tooth contact.[22–25] Of note, these previous studies contrasted task

performance against baseline on a variety of tasks. These findings are extended by showing a parametric relationship between brain activity and tooth clenching intensity in sensorimotor areas, thereby showing that brain activity in these areas scales with the intensity of task execution.

In sum, the present findings suggest that TMD-related pain is associated with bruxism (ie, clenching) and that the intensity of clenching affects pain experience and/or anticipation. TMD-related pain may be an important component of bruxism and play an important factor in general mental health[12,15] and for people seeking clinical help.[55–59] Resolving the debate about pain in bruxism is important, as diagnosing TMD-related pain may affect the decision-making process for intervention mapping of bruxism. In following, the authors suggest that alleviation of pain perception or anticipation (fear) of pain should be considered as the main therapeutic target in treating or coping with bruxism symptoms. Many patients who register in the clinic are patients with bruxism and orofacial pain, more particularly TMD-related pain and dysfunction.[19,55–59] The clinical consequences of these findings implicate that, if bruxism is associated with TMD-related pain, treatment is indicated.[6,8,60,61] And if (increasing) pain is affected by the intensity of clenching (ie, overloading of the masticatory system), diminishing the degree of clenching through behavioral interventions (eg, awareness training) may be warranted.[10,15] In the background of the new insights concerning therapeutic options in the treatment of bruxism,[4] the outcomes of this study may contribute to the decision-making process during the therapeutic management of bruxism.

Some notes on this study are warranted. The self-report nature of the screening tools used for participant selection, such as the OBC and the GCPS, pose a limit in objective diagnostic assessment. Also, the classification "probable" awake and/or sleep bruxism used in this study, which was based on interview and clinical examination, was according to a diagnostic grading system but is admittedly not the highest level of diagnostic grading system.[39] For this task, immobile tooth contact with two different forces of clenching intensity were chosen. Compared to other studies (eg,[20,21] in which participants with and without self-reported bruxism behavior performed clenching and grinding tasks), the present task required less mandibular movement throughout a trial compared to grinding tasks. While general tooth clenching could have resulted in other movements such as tongue pressing, the parametric variation in clenching intensity controls for such effects. Further, it was verified through self-report and statistical post-task analysis that patients and controls on average performed the task in a similar manner, which indicated that it is not likely that participants performed differently. More objective measures, such as scanner-compatible pressure-sensitive dental plates, could be used to further substantiate these findings, possibly in combination with an MRI acquisition design that allows for jaw movements in between moments of image acquisition.[62,63]

Conclusions

The results of the present task experiment show that tooth clenching in patients with bruxism and TMD-related pain correlates with decreased activity in the medial frontal and parietal DMN areas rather than with differences in activity in motor areas. These findings contribute to a better understanding of bruxism as a possible maladaptive behavior that results in pain experience and, as such, have important clinical and therapeutic ramifications.

Highlights

- Self-reported pain increased with increasing clenching intensity in patients but not in healthy controls.
- Patients, but not healthy controls, showed task-related brain activity changes in medial frontal and parietal areas that have been previously associated with pain anticipation, but not in motor-related areas. Brain activity in these areas was correlated with reported pain intensity.

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Author contributions: T.K.: study conceptualization and design, data collection, drafting Introduction and Materials and Methods, data acquisition, collection, and analysis, drafting Results and Discussion, critical revision of manuscript for important intellectual content; P.K.: critical revision of the manuscript after final conceptualization; B.J.: critical comments and revision of Materials and Methods, Results, and Discussion; A.K.: critical comments and revision of the results and their interpretation; V.v.d.V.: supervision, statistical analysis, drafting and critical revision of the Introduction, Materials and Methods, Results, and Discussion, critical review of the manuscript for submission.

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