Quantitative Sensory Testing in Patients With or Without Ongoing Pain One Year After Orthognathic Surgery

Yi Luo, DDS
PhD Student
Center for Sensory-Motor Interaction
Aalborg University
Aalborg, Denmark

Peter Svensson, DDS, PhD, Dr Odont
Professor
Department of Clinical Oral Physiology
School of Dentistry
Aarhus University
Center of Functionally Integrative Neuroscience
MindLab, Aarhus University Hospital
Aarhus, Denmark

Janek Dalsgaard Jensen, DDS
Specialist in Maxillofacial Surgery

Thomas Jensen, DDS
Specialist in Maxillofacial Surgery

Bjarne Neuman, DDS
Specialist in Maxillofacial Surgery
Department of Oral and Maxillofacial Surgery
Aalborg Hospital
Aalborg, Denmark

Lars Arendt-Nielsen, PhD, Dr Med Sci
Professor
Center for Sensory-Motor Interaction
Aalborg University
Aalborg, Denmark

Kelun Wang, DDS, PhD
Associate Professor
Center for Sensory-Motor Interaction
Aalborg University
Department of Oral and Maxillofacial Surgery
Aalborg Hospital
Aalborg, Denmark

Correspondence to:
Dr Kelun Wang
Center for Sensory-Motor Interaction
Aalborg University
Fredrik Bajers Vej 7 D3
9220 Aalborg, Denmark
Fax: + 45 9815 4008
Email: kelun@hst.aau.dk

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Aims: To *(1)* quantitatively investigate the possible long-term surgical impact of orthognathic surgery on the patients' trigeminal somatosensory functions and *(2)* investigate the influence of ongoing pain on the trigeminal somatosensory functions of the patients. **Methods:** A group of patients before orthognathic surgery (Pre-op), a group of patients 1 year after orthognathic surgery (Post-op), and a group of control participants (Control) were recruited (n = 28 in each group). A standardized quantitative sensory testing protocol was followed to record a battery of 13 parameters, which reflect both sensory loss and gain. The data were analyzed using three-way repeated measure analysis of variance with group and pain as between-subject factors and testing site as within-subject factor. **Results:** In the Post-op group, of the 21.4% patients who reported ongoing pain after surgery, 7.1% were diagnosed with neuropathic pain and 14.3% had musculoskeletal pain. Facial cold detection threshold (CDT) of the Post-op group was significantly lower (less sensitive) than that of the Pre-op group ($P < .039$). Facial pressure pain threshold (PPT) of the Post-op group was significantly lower (more sensitive) than that of the Pre-op and Control groups ($P < .006$). Masseter PPT of the Post-op group was significantly lower than that of the Control group ($P = .02$). The facial vibration detection threshold (VDT) of the Post-op group was significantly higher (less sensitive) than that of the Pre-op and Control groups ($P < .014$). Pain patients in the Post-op group showed significantly elevated VDT compared to patients without pain ($P < .001$). **Conclusion:** The pattern of sensory alteration in orthognathic surgical patients with or without pain was characterized by sensory loss in thermal parameters and non-nociceptive mechanosensory parameters and sensory gain in nociceptive mechanosensory parameters. The elevated VDT might be a potential indicator of the impact of postoperative pain on trigeminal somatosensory functions. *J Oral Facial Pain Headache 2014;28:306–316. doi: 10.11607/ofph.1275*

Key words: *musculoskeletal pain, neuropathic pain, orofacial pain, orthognathic surgery, quantitative sensory testing, somatosensory function*

Orthognathic surgery is performed to correct skeletal disharmonies of the jaws and malalignment of the dental arches. Alterations in somatosensory functions due to injuries to the trigeminal nerves have been reported as the leading complication following orthognathic surgery.[1–5] Almost all patients develop some altered sensation immediately after orthognathic surgery.[6–8] However, most of the injuries are temporary, and the majority of patients gradually regain normal somatosensory functions within a period from 1 month to 1 year after orthognathic surgery, depending on the location and severity of the injury.[6,7,9–14] It has been reported that about 10% to 30% of patients experience permanent impairment in somatosensory functions,[1,3,5,8,9,15] 15% to 20% of patients report ongoing pain 6 months to 1 year after orthognathic surgery,[14,16] and 5% of patients develop neuropathic pain.[17] The incidence and extent of alterations in somatosensory functions have great variations in studies that have followed patients at several time points up to 1 year after surgery.[4,6,8,10,18–21] Since there is no generally accepted, standardized method of estimating somatosensory disturbances in patients after orthognathic surgery,[22–24] it is often difficult to interpret and compare the results directly among such studies.

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Assessment by questionnaires is the simplest and most widely adopted method to evaluate subjective sensory alterations. However, the results of questionnaires have not always been consistent with the results of quantitative and objective measurements.[9,10,12,25] Objective sensory function evaluations, such as trigeminal somatosensory evoked potentials, blink reflexes, and nerve conduction recording,[9,18,26–29] can provide objective and accurate information of nerve injury, but they are complicated and not suitable for most clinical settings. Quantitative sensory testing (QST) methods are psychophysical techniques that are easy to perform and are able to acquire more mechanistic information than can questionnaires. Batteries of QST have recently been recommended for measurements of sensory functions since they have been shown to have good sensitivity and reproducibility.[23,24,26,30–32]

Since the German Research Network on Neuropathic Pain (DFNS) developed the standardized protocol of QST and found that it has good reliability on the face,[33,34] the protocol has been further applied intraorally[35] and extraorally[36] at different orofacial testing sites in healthy subjects to provide trigeminal reference data, and an acceptable reproducibility has been achieved. The protocol has also been applied to evaluate the somatosensory functions of patients with myofascial temporomandibular disorders (TMD), fibromyalgia syndrome,[37] and trigeminal neuralgia,[38] and it has provided more informative somatosensory profiles of these patients. However, no full set of QST data has yet been published for patients after orthognathic surgery in relation to potential ongoing orofacial pain and altered somatosensory functions. Therefore, the aims of the present study were to *(1)* quantitatively investigate the possible long-term surgical impact of orthognathic surgery on the patients' trigeminal somatosensory functions and *(2)* investigate the influence of ongoing pain on the trigeminal somatosensory functions of the patients.

Materials and Methods

Participants

Twenty-eight patients were recruited before orthognathic surgery as the Pre-op group (14 women and 14 men, mean age 24.5 years). Another group of 28 age- and gender-matched patients were recruited consecutively 1 year after orthognathic surgery as the Post-op group. Further, 28 age- and gender-matched participants with normal dentofacial structures who did not need orthognathic surgery served as the Control group. The study was approved by the local ethics committee (Project number: N-2008-0057) in accordance with the Helsinki Declaration II. Written informed consent was obtained from all participants before they were included in the study. All participants were identified only by numbers.

All patients were diagnosed with developmental dentofacial deformity (without a congenital anomaly or acute trauma) and were recruited from the Department of Oral and Maxillofacial Surgery, Aalborg Hospital, Denmark. In the Post-op group, 17 patients had been treated with Le Fort I maxillary osteotomy (Le Fort I) in combination with bilateral sagittal split ramus osteotomy (BSSRO) and 11 patients had only received single jaw surgery (6 had undergone Le Fort I and 5 had undergone BSSRO). All Post-op patients had finished their orthodontic treatment and were not wearing orthodontic appliances. All Pre-op patients were at the stage before or just at the beginning of their orthodontic treatment, free of fixed appliances. All participants in the Control group were recruited among students at Aalborg University. They had normal dentofacial structures with normal occlusion or minor malocclusion. None of the participants had any medical condition associated with systemic neuropathy.

Clinical Examinations and Questionnaires

All participants were assessed using clinical examinations and the questionnaires of the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD).[39] They were further diagnosed with a corresponding subtype of TMD when applicable. The examinations were all performed by one investigator (KW). The number of participants who reported spontaneous jaw pain in the past month was noted, as was the number who experienced headache during the last 6 months. The intensity of jaw pain of the last 6 months and at the time of the experiment was rated on a scale from 0 to 10, where 0 represented no pain and 10 represented most pain imaginable. Participants with ongoing pain were requested to fill out a McGill Pain Questionnaire (MPQ)[40] to describe the location and quality of the pain.

QST Protocol

The experiment was performed in a quiet room with a steady temperature (20°C to 23°C). Each participant was sitting naturally in a dental chair, relaxed, throughout the procedure. The standardized QST protocol used in the trigeminal region has been described in detail elsewhere[36] and was strictly followed. Thirteen selected QST parameters,[33,34] which included cold detection threshold (CDT), warm detection threshold (WDT), thermal sensory limen (TSL), cold pain threshold (CPT), heat pain threshold (HPT), paradoxical heat sensation (PHS), mechanical detection threshold (MDT), mechanical pain threshold (MPT), mechanical pain sensitivity (MPS), dynamic mechanical allodynia (ALL), windup ratio (WUR), vibration

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Table 1 Frequency and Intensity of Jaw Pain

Group	No. of patients			Pain intensity			RDC/TMD diagnosis of pain patients (Frequency*)
				Last 6 months (Mean ± SD)		On day of experiment (Mean ± SD)	
	Total	Pain		Max	Average	Average	
Pre-op	28	11		6.3 ± 1.5	3.8 ± 1.3	3.1 ± 1.7	Ia (8), Ib (2), IIa (1), IIIa (2)
Post-op	28	6		6.0 ± 1.1	3.3 ± 1.2	2.0 ± 1.1	Ia (3), Ib (1), IIa (2)
Control	28	0		NA	NA	NA	NA
	χ^2	$P = .29$	*t* test	$P = .73$	$P = .45$	$P = .17$	

*When IIa or IIIa was diagnosed on both left and right side in the same subject, the frequency was counted as 2.
Pre-op = patients before orthognathic surgery; Post-op = patients1 year after orthognathic surgery; Control = participants with normal dentofacial skeletal structures who did not need surgery. Ia = myofascial pain; Ib = myofascial pain with limited opening; IIa = disc displacement with reduction; IIIa = arthralgia; NA = not available.

detection threshold (VDT), and pressure pain threshold (PPT), were measured bilaterally on the facial skin overlying the infraorbital foramen (V2) and mental foramen (V3) in random order for all participants. All QST measurements were performed several times at each site by one of the authors (YL), according to the standardized QST protocol.[33,34]

Measurements of PPT on masseter and extratrigeminal sites

The PPT was also measured bilaterally on the masseter muscles and unilaterally (right side) on the neck, elbow, finger, and leg. Three measurements were averaged for each site.

Statistical Analyses

The incidence of pain was analyzed using the chi-square test, and pain scores were analyzed by independent *t* test.

The distribution for data of QST parameters, masseter PPT, and extratrigeminal PPTs was checked, and any necessary logarithmic transformation was performed.[33,34] These data were then analyzed using a three-way repeated-measure analysis of variance, with group and pain as between-subject factors and testing site as within-subject factor. A Bonferroni test was employed for post-hoc comparisons. All statistical calculations were performed using the Statistical Package for Social Sciences version 20 (SPSS, IBM). The significance level was set as .05.

To compare the QST profiles independently of the different units of the parameters, z-scores were calculated for patients in the Post-op and Pre-op groups. The QST data of the Control group were used as reference data. A detailed method of z-score calculation has been described elsewhere.[33,34] A z-score beyond ±1.96 (outside of the 95% confidence interval) is deemed as an abnormal value. A positive z-score indicates a sensory gain, and a negative z-score indicates a sensory loss. Signs of z-scores of the QST parameters were adjusted according to this definition.

Results

Incidence, Quality, and Intensity of Pain

Six patients in the Post-op group (21.4%) and 11 patients in the Pre-op group (39.3%) reported ongoing jaw pain for the past month, while no participants in the Control group reported any jaw pain in the same period (Table 1). Although the incidence of pain in the Pre-op group was higher than that in the Post-op group, this was not statistically significant and there was no correlation between the treatment status (before or after surgery) and the presence of jaw pain in the two patient groups (Table 1). Also, there was no significant difference in the ratings of jaw pain between the Post-op and Pre-op groups (Table 1). No subject in the Control group reported headache in the past 6 months. However, for the Post-op group, 2 out of 6 jaw pain patients and 11 out of 22 jaw pain–free patients reported headache. For the Pre-op group, 7 out of 11 jaw pain patients and 6 out of 17 jaw pain–free patients reported headache. There was no correlation between jaw pain and headache in the two patient groups ($P = .47$ and .14, respectively).

The drawings of pain location made by the participants in the Pre-op and Post-op groups are shown in Fig 1. The pain of the Post-op patients was limited to the craniofacial region, while the pain of the Pre-op patients was widespread both within and outside of the craniofacial region. Within the craniofacial region, the pain locations in both groups were concentrated around the temporomandibular joint (TMJ) and masseter muscles. However, the pain locations of the Pre-op group were never in regions around the upper lip, lower lip, or chin, while two patients in the Post-op group reported pain in these regions. Although the size of the pain area of the Pre-op group was larger, no significant difference was detected between the Post-op and Pre-op groups ($P = .072$). The top five most frequently chosen words from the MPQ to describe the pain were "quivering," "tingling," "tender," "taut," and "annoying" for the Post-op group and "tiring," "pressing," "taut," "shooting," and "annoying" for the Pre-op group.

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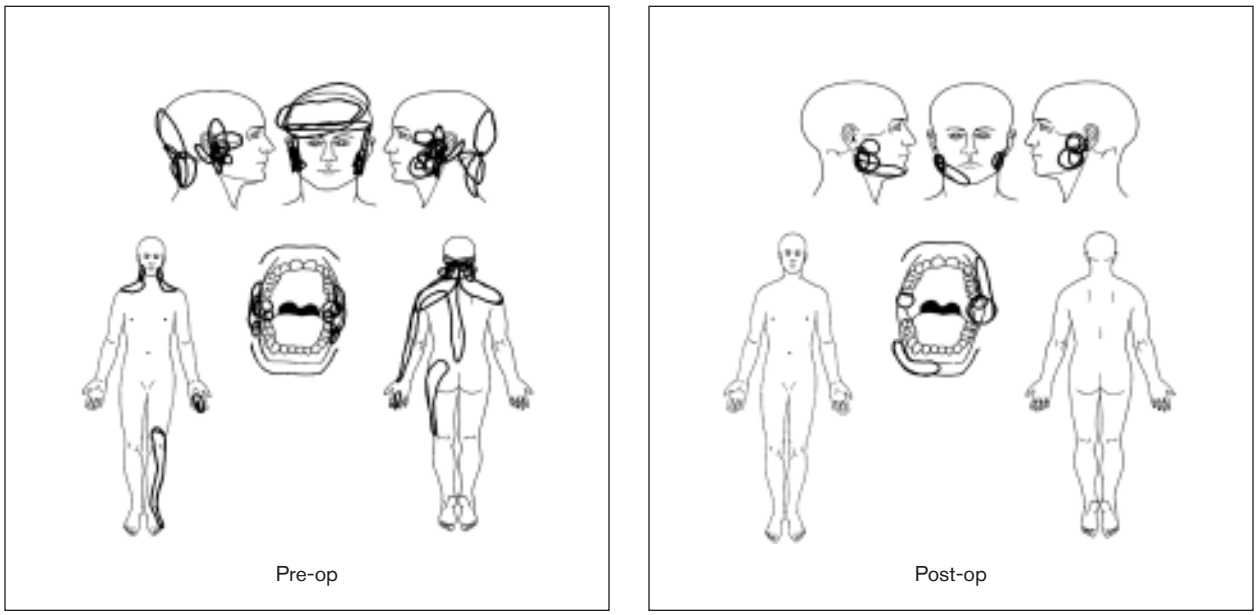

Fig 1 Locations of pain. Pre-op = patients before orthognathic surgery (n = 11); Post-op = patients 1 year after orthognathic surgery (n = 6). Since no one in the Control group reported any pain, no pain drawing data are available for this group. The pain of Post-op patients was limited within the trigeminal region, while the pain of Pre-op patients was widespread both within and outside of the craniofacial region. No significant difference was detected in the size of the pain area between the Post-op and Pre-op groups ($P = .072$).

Based on the pain characteristics, localization, quality, and self-reported sensory disturbances in specific areas, the two patients who indicated pain in the lips and chin in the Post-op group were categorized as neuropathic pain patients (7.1% of the Post-op group). For the other pain patients in the Post-op and Pre-op groups, the pain was deemed to be of musculoskeletal nature, in other words, jaw muscle/TMJ pain.

The pain patients were then further categorized as to the subtype of TMD, according to the RDC/TMD. Four out of 6 pain patients in the Post-op group and 10 out of 11 pain patients in the Pre-op group were diagnosed with myofascial pain, which was the dominant subtype in both groups (Table 1).

QST Parameters

PHS did not occur in any of the participants, and ALL was found only in one patient who was diagnosed with neuropathic pain in the Post-op group. Data of other QST parameters are presented in Fig 2. Data of the pain patients in the Post-op group showed larger variations due to a smaller sample size.

Group Differences

Significant group differences were found in CDT ($P = .017$), VDT ($P = .039$), and PPT ($P = .01$) (Fig 2). Post-hoc tests showed that the CDT of the Pre-op group was higher than that of the Post-op and Control groups ($P < .039$), but no significant difference was detected between the Post-op and Control groups. PPT of the Post-op group was significantly lower than that of both the Control and the Pre-op groups ($P < .006$), but no significant difference was detected between the Control and Pre-op groups (Fig 2). VDT of the Post-op group was significantly higher than that of Control and Pre-op groups ($P < .014$), but no significant difference was detected between the Control and Pre-op groups (Fig 2).

Influence of Pain

Generally, QST parameters were not significantly affected by pain. VDT was the only parameter that showed a significant difference between patients with or without pain in the Post-op group ($P < .001$), with higher VDT (lower vibration sensitivity) in pain patients (Fig 2).

PPT of Masseter and Extratrigeminal Sites

The masseter PPT was significantly different between groups ($P = .03$). Post-hoc tests showed that the masseter PPT of the Post-op group was significantly lower than that of the Control group ($P = .02$). However, no significant difference was found between the Pre-op and Post-op groups. No group difference was found in PPTs of extratrigeminal sites (neck, elbow, finger, and leg). In addition, there was no significant difference in masseter PPT or extratrigeminal PPTs between patients with and without ongoing pain.

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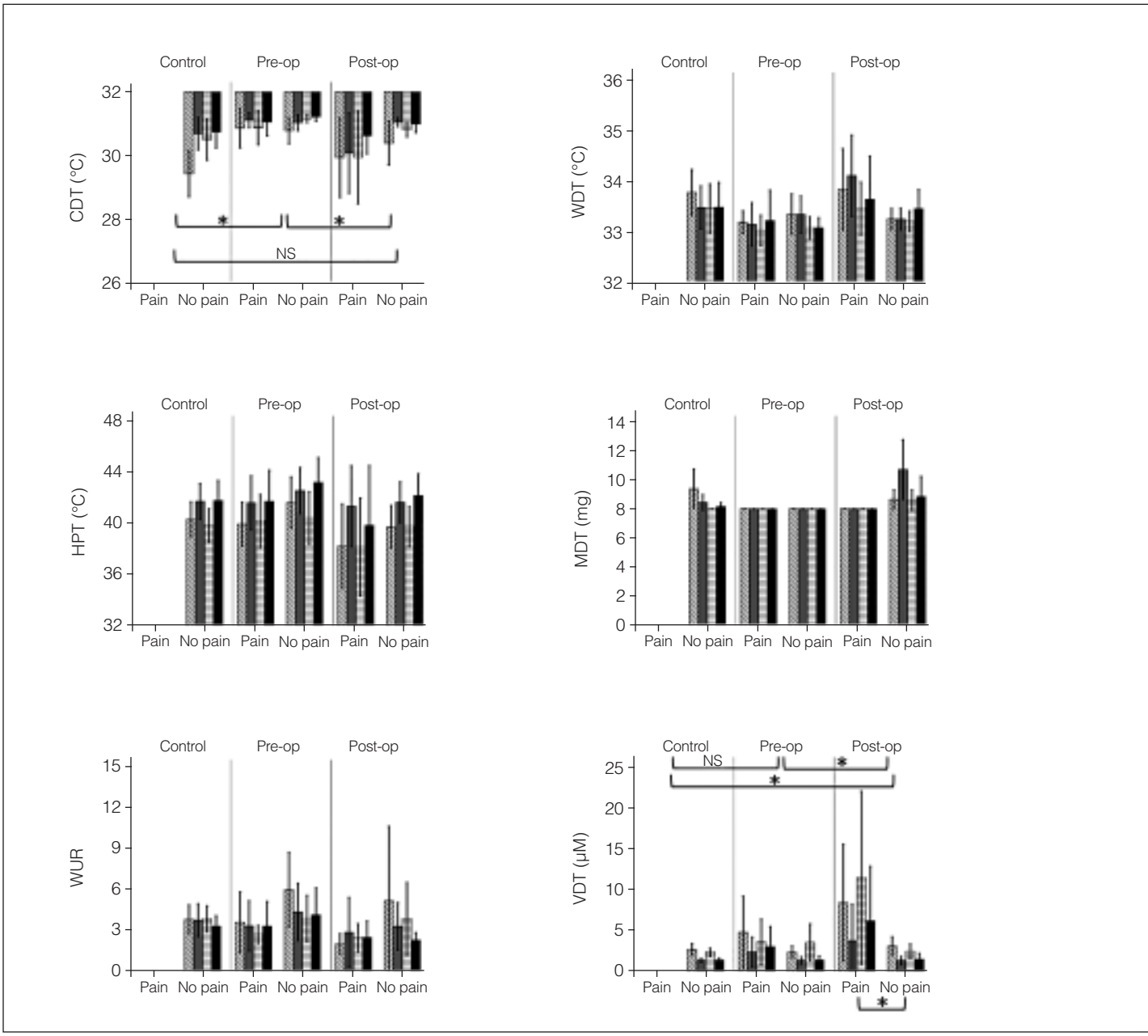

Fig 2 QST parameters (mean ± SE) of three groups: Control = participants with normal dentofacial skeletal structures who did not need surgery; Pre-op = patients before orthognathic surgery; Post-op = patients 1 year after orthognathic surgery. The four bar patterns each represent the four testing sites (left/right V2/V3). *Significant difference detected. NS = not significant.

QST Profiles

Individual QST profiles represented by z-scores of the pain patients from the Post-op and Pre-op groups (n = 6 in each group) are shown in Fig 3. Negative z-scores lower than –1.96 were found in both the Pre-op and Post-op groups in the thermal parameters (CDT, WDT, TSL, and CPT). However, abnormally negative z-scores of VDT were only found in the Post-op group (especially in the two neuropathic pain patients), indicating significant vibration sensory loss (Fig 3). Positive z-scores higher than 1.96 were found in PPT and WUR in the Post-op patients.

Percentages of abnormal z-scores for QST parameters were calculated in the Post-op group to reveal the somatosensory alteration pattern of the surgical patients.[38] In the Post-op group, 71.4% of the patients (20 out of 28) exhibited abnormal z-scores for at least one site. A total of 46 V2 sites and 44 V3 sites were directly affected by the surgery. The number of sites with an abnormal z-score was counted, and

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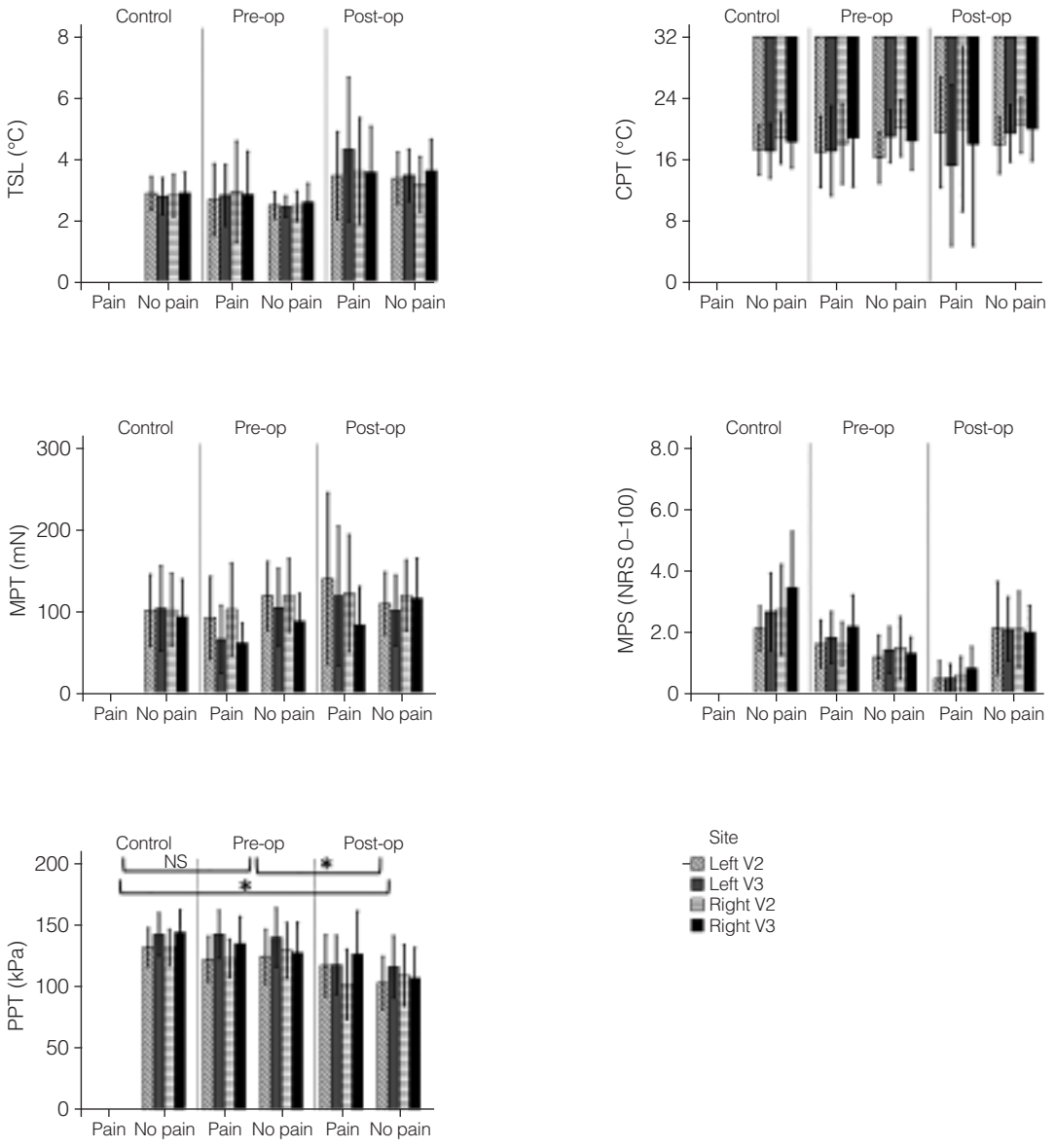

the percentages of sites with abnormality for each parameter were calculated[38] (Fig 4). Patients with or without pain showed similar patterns of sensory alteration presenting as sensory loss to the thermal stimuli, regardless of whether they were non-nociceptive (CDT, WDT, TSL) or nociceptive (CPT, HPT), but showed sensory loss in non-nociceptive mechanosensory parameters (MDT, VDT) and sensory gain in nociceptive mechanosensory parameters (MPS, WUR, PPT). The highest percentages of abnormality were found in PPT and VDT.

Discussion

The standardized QST protocol developed by DFNS[33,34,41] was applied for the first time to a group of patients 1 year after orthognathic surgery. The present findings show that 21.4% of the Post-op patients reported ongoing pain. Among these, 7.1% of the patients were diagnosed with neuropathic pain and 14.3% had musculoskeletal pain. Compared with the Control and Pre-op groups, the Post-op group showed significantly lower PPT and higher VDT.

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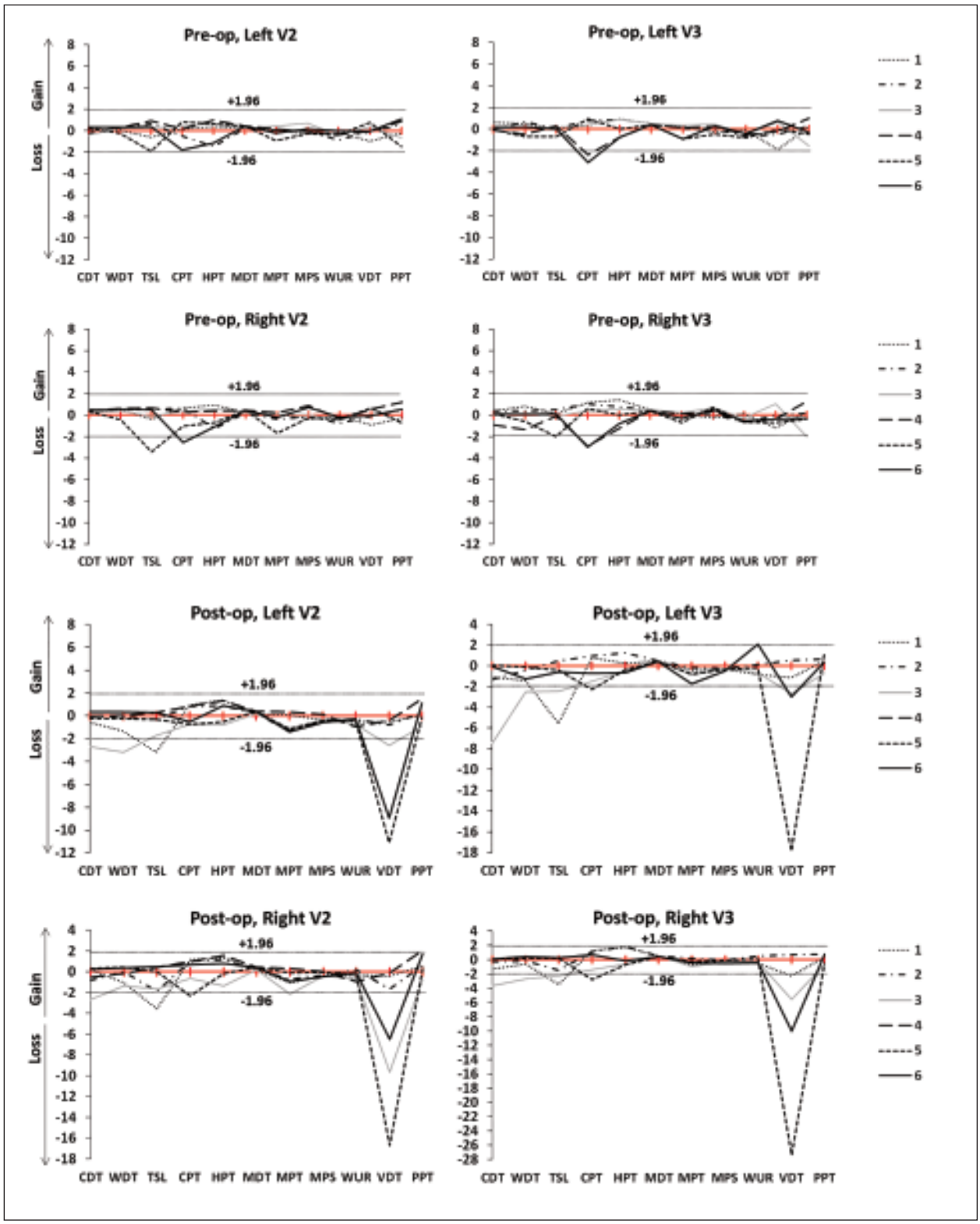

Fig 3 Individual QST profiles of the pain patients at the four testing sites, represented by z-scores. Pre-op = patients before orthognathic surgery; Post-op = patients 1 year after orthognathic surgery (n = 6 in each group). V2 site = skin overlying the infraorbital foramen; V3 site = skin overlying the mental foramen. Patient 4 in the Post-op group only underwent Le Fort I surgery in the maxilla; therefore, data from the site V3 are not available. Patients 5 and 6 in the Post-op group were the two patients with neuropathic pain. A z-score beyond ±1.96 (outside the 95% confidence interval) is deemed as an abnormal value. A negative z-score indicates sensory loss, and positive z-score indicates sensory gain. CDT = cold detection threshold; WDT = warm detection threshold; TSL = thermal sensory limen; CPT = cold pain threshold; HPT = heat pain threshold; MDT = mechanical detection threshold; MPT = mechanical pain threshold; MPS = mechanical pain sensitivity; WUR = windup ratio; VDT = vibration detection threshold; PPT = pressure pain threshold.

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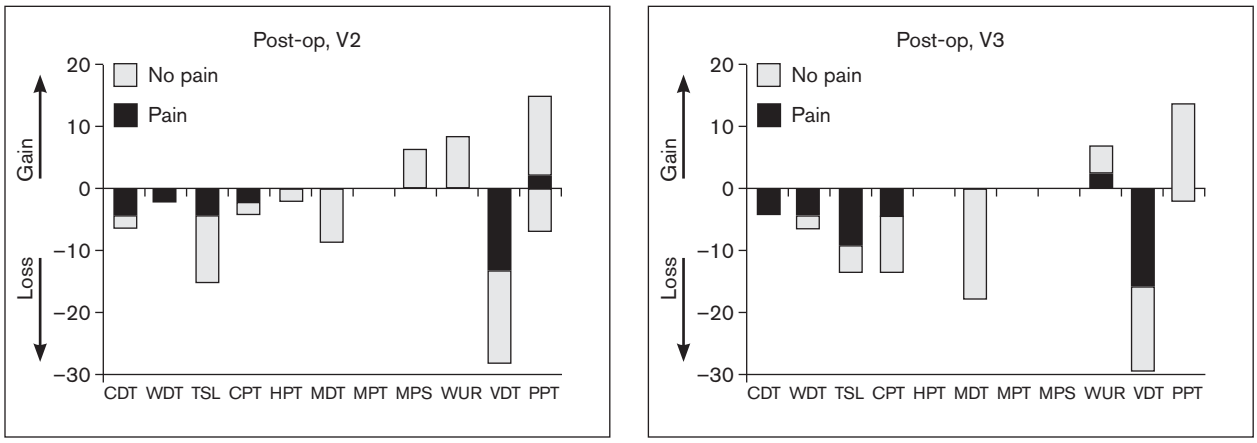

Fig 4 Percentages of abnormal of z-scores for QST parameters of all patients in the Post-op group (patients 1 year after orthognathic surgery). A positive axis reflects sensory gain, a negative axis sensory loss. V2 site = skin overlying the infraorbital foramen (n = 46); V3 site = skin overlying the mental foramen (n = 44). CDT = cold detection threshold; WDT = warm detection threshold; TSL = thermal sensory limen; CPT = cold pain threshold; HPT = heat pain threshold; MDT = mechanical detection threshold; MPT = mechanical pain threshold; MPS = mechanical pain sensitivity; WUR = windup ratio; VDT = vibration detection threshold; PPT = pressure pain threshold.

Post-op group patients with or without pain were both characterized by similar sensory alteration patterns, demonstrating sensory loss in thermal parameters and non-nociceptive mechanosensory parameters, and sensory gain in nociceptive mechanosensory parameters. Pain patients (especially neuropathic pain patients) in the Post-op group were characterized by significantly elevated VDT compared to non-pain patients in this group.

Long-Term Impact of Orthognathic Surgery

The infraorbital nerve of the second branch (V2) of the trigeminal nerve is prone to be injured in Le Fort I osteotomy,[42] whereas the inferior alveolar nerve (IAN), the main trunk of the third branch (V3) of the trigeminal nerve, is prone to be injured in BSSRO.[19,42] Thus, BSSRO and Le Fort I procedures may vary in their propensity to cause disturbances in somatosensory functions of the V2 and V3 regions. BSSRO has been reported to have a greater propensity to produce sensory impairment in the V3 area, especially in the lower lip and chin.[12] In addition, site differences of QST between V2 and V3 have been observed in healthy subjects.[36] Furthermore, damage to the left or the right trigeminal nerve by orthognathic surgery is unpredictable. Therefore, in the present study, QST was performed on each site of the left V2, left V3, right V2, and right V3, and site was considered as the between-subject factor for the statistical analysis. Since gender differences have also been reported in QST in the trigeminal region,[36] gender was matched between the different groups in this study.

The incidence of pain reported in the present study is consistent with previous findings that 15% to 20% of patients report ongoing pain 6 months to 1 year after orthognathic surgery[14,16] and that 5% of patients develop neuropathic pain.[17] The significant abnormal PPT, VDT, and masseter PPT values detected in the Post-op patients are consistent with previous findings that large fibers recover more slowly than small fibers when damaged, since large fibers (A-beta fibers) are involved in vibration and pressure sensations, whereas small fibers (A-delta and C-fibers) subserve tactile, temperature, and pain sensations.[13]

The present study revealed a difference in PPTs in the trigeminal region but not in the extratrigeminal regions. This indicates that the sensory changes were limited to local areas affected by the orthognathic surgery and suggests that although central sensitization may have contributed to the sensory changes in the trigeminal region, it was unlikely sufficient to provide changes in regions innervated by spinal sensory nerves.

Traditional data analysis can only reveal whether there is a difference between group average values of QST parameters. However, by using methods for calculating z-score and percentage of abnormality,[38] it was possible to analyze the individual QST profile, and by using the same data, more detailed information such as the pattern of somatosensory alterations of a group of patients could be revealed.

Influence of Pain

Interestingly, the incidence of pain in patients before surgery (39.3%) was much higher than that of the patients after surgery (21.4%), although it was not statistically significant. The pain locations in the Pre-op group were more widely spread and the pain

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area was larger compared with the Post-op group, although this was also not statistically significant (see Fig 1). It has been reported that for the vast majority of patients with dentofacial deformities, functional and pain-related problems, respectively, were the first and second reasons for seeking orthognathic surgery treatment, while cosmetic desire was the third reason.[1] The association between dentofacial deformities and TMD and the relationship between orthognathic surgery and TMD have been studied frequently. However, due to the heterogeneity of the study design and the different diagnostic criteria of TMD, these topics are quite controversial.[43,44] According to the results of three high-quality longitudinal, randomized, and controlled studies, signs and symptoms of TMD might[45,46] or might not[47] be improved after orthognathic surgery. However, none of the three studies adopted the RDC/TMD in the method, making comparison of results difficult. A recent longitudinal study applying the RDC/TMD reported that patients with dentofacial deformities had significantly higher frequencies of myofascial pain, disc displacement with reduction, and arthralgia than the control group (regular patients not requiring orthodontic or orthognathic treatment).[48] After orthognathic surgery, the frequencies of these diagnoses in patients were significantly reduced, except for an increased frequency of osteoarthrosis.[49]

In the present study, 21.4% of the patients reported ongoing pain after surgery, which is relatively lower than the incidence of pain after limb amputation, breast surgery, and gallbladder surgery, in which approximately 50% of the patients reported ongoing pain 1 year after surgery.[50] This could be attributed to differences in functional recovery between the trigeminal and spinal nerves.

The pain patients in the Post-op group, particularly the two neuropathic pain patients, showed a significant sensory loss in VDT and sensory gain in PPT and WUR, which is consistent with the findings of a previous study of a large patient sample demonstrating mixed sensory alterations that included both sensory loss and gain in most neuropathic pain patients.[38,51] However, for some neuropathic pain syndromes, a large portion of patients may only demonstrate sensory loss.[38] A recent study showed that the recovery pattern of sensory functions after othognathic surgery highly depends on the type of nerve injury. If it falls into the severe type of injury (axonal injury), not only will the time for recovery be longer, but also the sensory gain tends to increase over time while sensory loss might decrease over time.[6] Thus, long-term follow-up is essential to monitor dynamic changes in the QST profile.

In the present study, VDT seemed to be the most sensitive of all the QST parameters in revealing sensory abnormalities in patients after orthognathic surgery. However, the results might have benefited from the fact that in this study VDT was measured using a Vibrameter (100 Hz/0 to 400 μm, Somedic)[36] and not a tuning fork as adopted in the original QST protocol.[33] The obvious advantage of the Vibrameter is that the vibration stimulation changes gradually in a continuous way, allowing the subject to respond to a finer scale of the stimulation. Therefore, VDT was recorded as continuous data, which include more detailed information.

Another strength of this study was that the influence of orthodontic treatment could be ruled out. Orthodontic appliances on teeth can cause pain and discomfort, which might affect QST results.[52] This confounding factor has seldom been mentioned in previous studies when assessing the sensory functions in patients after orthognathic surgery.[22]

The results of this study should be interpreted with caution, as the study design was cross-sectional. Therefore, it is not clear whether surgical patients with musculoskeletal pain already had such pain before surgery. However, it can be concluded that the elevated VDT might be a potential indicator of the impact of postoperative pain on trigeminal somatosensory functions.

Conclusions

This study reported systematic QST profiles of a group of patients 1 year after orthognathic surgery. The pattern of sensory alteration in orthognathic surgical patients with or without pain was characterized by sensory loss in thermal parameters and non-nociceptive mechanosensory parameters and by sensory gain in nociceptive mechanosensory parameters. The elevated VDT might be a potential indicator of the impact of postoperative pain on trigeminal somatosensory functions.

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