Quantitative sensory testing of mandibular somatosensory function following orthognathic surgery - A pilot study in Chinese with Class III malocclusion

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Quantitative sensory testing of mandibular somatosensory function following orthognathic surgery – A pilot study in Chinese with Class III malocclusion

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Data availability statement:

All data included in this study are available upon request by contact with the corresponding author.

The study was designed by Jiayi He, Hua Yuan, Kelun Wang, Peter Svensson, Hongbing Jiang. The data was collected and analyzed by Jiayi He and Xin Chen. The paper was written by Jiayi He and Xin Chen and revised mainly by Kelun Wang, Peter Svensson. Ping Zhang is mainly responsible for the two revisions of the study, including data collection, analysis and modification of the text. All authors have approved the submission.

Abstract

Background: Somatosensory changes after sagittal split ramus osteotomy (SSRO) have not been fully studied in Chinese patients by the latest technologies.

Objective: To provide a comprehensive analysis of somatosensory function at the lower lip and chin at different time points following SSRO in a Chinese population.

Methods: A total of 22 patients (18-27 years; 9 men) with skeletal III malocclusion and scheduled for SSRO were recruited. Quantitative sensory testing (QST) was performed at pre-operation (baseline), 1 week (1W), 1, 3 and 6 months (1M, 3M, 6M) postoperatively. Cold detection threshold (CDT), warm detection threshold (WDT), cold pain threshold (CPT), heat pain threshold (HPT), mechanical detection threshold (MDT), mechanical pain threshold (MPT), pressure pain threshold (PPT) and two-point discrimination threshold (2PD) were tested at the lower lip and chin.

Results: Except for PPT at both test sides at 1W and 1M, all QST values indicated a significantly reduced sensitivity ($P<0.05$). All values had returned to baseline values at 3M with exception of HPT at the right chin which, however, had recovered at 6M ($P>0.05$).

Conclusions: Somatosensory function at the lower lip and chin appears to be fully recovered in the majority of young Chinese adults 6 months after SSRO for skeletal class III malocclusion.

Keywords: sagittal split ramus osteotomy, quantitative sensory testing, altered somatosensory function, inferior alveolar nerve, sensory recovery

Introduction

With development of orthognathic surgery and inter-disciplinary cooperative treatment, more and more people with skeletal malocclusion may obtain a better physical appearance. [1] However, not only their quality of life, but also their self-confidence may be improved. [2] Unfortunately, there are several potential complications of orthognathic surgery that can not be neglected in the information to patients considering treatment, for example, numbness, unexpected fractures, bleeding, osteonecrosis, infections and even partial relapse. [3] Injury to the inferior alveolar nerve (IAN) has the highest occurrence of such complications. [3] Injury to the IAN is typically characterized by numbness of the lower lip and mental skin, and has received the most attention both from surgeons and from patients. [4-7] Although a lower prevalence of post-operative neurosensory disturbances has been observed following intraoral vertical ramus osteotomy, then sagittal split ramus osteotomy (SSRO) has a relatively better vertical skeletal stability, which reduces the occurrence of more severe types of complications[8]. Being one of the most popular mandibular orthognathic types of operation, SSRO has, indeed, been extensively applied in orthognathic surgery. [8]

Due to the differences in surgical skills, patterns of somatosensory recovery and sample size, the incidence of IAN injury after SSRO has been reported ranging from 70%-91%, [6, 9] which no doubt has a negative influence on quality of life. [10] In addition to altered sensitivity in the inferior labial and mental regions, other common symptoms reported include drooling, lower lip biting by mistake, difficulty of eating, and disability to detect food debris. [9] In the worst situation, few patients (1-2%) may experience persistent chronic pain and post-traumatic trigeminal neuropathic pain associated with more discomfort especially when chewing, drinking and speaking.[6] Fortunately, by improving surgical skills to reduce IAN exposure and direct injury during the operation, the incidence of neurosensory disturbance one year post operation could be as low as 3.5%-18.4%. [11, 12] However, it is still not possible to predict the exact time course for recovery of somatosensory function.

As a reliable and stable psychophysical tool for evaluation of the conscious perception of different somatosensory stimuli,[13, 14] quantitative sensory testing (QST) is a valuable tool to quantify the functional status of somatosensory nerve fibers in the clinic. [15] Comparing both the thermal and mechanical thresholds between baseline (before surgery) and after surgery, QST can help to distinguish the type of impaired somatosensory nerve fibers.

The somatosensory changes in SSRO patients without per-operative complications to IAN are characterized by reversible somatosensory loss. However, the recovery period is still unclear. Thus, the present study aimed to quantitatively evaluate altered somatosensory function at the lower lip and mental nerve region following SSRO for up to 6 months in a Chinese population.

Materials and Methods

Participants

The participants were randomly selected from 2016 to 2020, who visited the department of oral and maxillofacial surgery, Affiliated Hospital of Stomatology, Nanjing Medical University. The inclusion criteria for all participants were as follows: 1. Accepted SSRO (combined with Le Fort I osteotomy and genioplasty). 2. Age range from 18 to 30 years. 3. Preoperative diagnosis of skeletal malocclusion according to the angular measurement (Eastman standard means for ANB angle) and linear measurement (Wits appraisal analysis and gnathion displacement in relation to the mid-sagittal plane). [16, 17] 4. No reports of pre-surgical paresthesia in the oral and maxillofacial region. 5. No severe systemic disease or nerve rupture occurred during surgery. The participants who had accepted or were scheduled for another oral or maxillofacial operation were excluded.

All orthognathic surgeries were conducted by one experienced (>10 years of experience) oral and maxillofacial surgeon of our hospital. The study was approved by the local ethics committee (No: PJ2016-037-001) in accordance with the Helsinki Declaration II. Written informed consent was obtained from all participants before they were included in the study.

Surgical technique

The SSRO was conducted according to Obwegeser et al [18]. All osteotomies were performed with a fissure bur and a reciprocating saw. The splitting procedures were completed using a hammer and fine chisels first, then medium chisels. A total of one 1.2 mm titanium plates and four moncortical screws were used to fix Proximal and distal segments. Third-generation cephalosporin-type antibiotics were infused until discharge time. Detailed data about pre-operative diagnosis, surgery name, mandibular movement, IAN exposure and nerve injury were recorded for each patient.

Quantitative sensory testing

Before each test, the responsible orthodontist performed a detailed oral examination. No medication was taken the day before each investigation. QST based on our previous studies [10, 19, 20] and 2-point discrimination were performed at the following sites for all participants: left and right lower lip, central area of the left and right mental region (Fig.1). Each participant was sitting naturally in a dental chair, relaxed, throughout the procedure. The experiment was performed in a quiet room with an ambient temperature between 21 °C and 25 °C by the same examiner who had been trained extensively in the use of QST. Before tests, the examiner carefully explained and demonstrated the tests in details to facilitate the understanding of the participants. The assessments were performed pre-operation (baseline), 1 week (1W), 1, 3 and 6 months (1M, 3M, 6M) after SSRO. All included tests were performed in the same order as suggested by the standardized protocol.[13]

Thermal thresholds

The thermal tests were performed using a computerized thermal stimulator (MEDOC TSA-2001 apparatus, Medoc Ltd, Ramat-Yishai, Israel). An extra-oral thermode with 30 × 30 mm contact area was used for the assessments without contacting other adjacent sites. This was achieved by asking the participants to open their mouth slightly, which allowed a fairly uniform contact between the thermode and the extra-oral test regions.

Cold and warm detection thresholds (CDT, WDT) were measured first, followed by cold and heat pain thresholds (CPT, HPT). The mean thresholds of three consecutive measurements were calculated. The temperature of the thermode started from a baseline of 32 °C for the extra-oral site and heated-up or cooled-down at a rate of 1 °C/s to the lower limits of 0 °C or upper limits of 50 °C. [20] The participants were instructed to press a button on the computer mouse as soon as they perceived the respective thermal sensation of cold, warm, cold pain, or heat pain following the instructions developed by the German Research Network on Neuropathic Pain (DFNS). [13] The participants were instructed not to look at the computer screen at any time during the testing procedures. [20]

Mechanical thresholds

Mechanical detection thresholds (MDT) were measured using standardized Semmes-Weinstein monofilaments with 20 different diameters (North Coast Medical, Canada). The number of each filament (1.65 to 6.65) corresponds to the logarithmic function of the equivalent forces of .008 to 300 g. The filament was applied vertically to the test sites, and pressure was applied slowly until the filament bowed with a total contact time of approximately 1 second. [21]

To assess the mechanical pain threshold (MPT), weighted pinprick stimuli delivered with a custom-made set of seven pinprick stimulators (Aalborg University, Denmark) were used. [22] Each stimulator had a flat contact surface of 0.2 mm that exerted forces of 8–512 mN. MDT and MPT were measured using the "method of limits" technique described by Baumgartner et al. [23] Five threshold measurements were made, applying a series of ascending and descending stimulus intensities. One threshold value was determined by calculating the geometric mean of these five series.

A hand-held pressure algometry (MEDOC AlgoMed, Medoc Ltd, Ramat-Yishai, Israel) was used to measure pressure pain threshold (PPT) in the present study. In the study, the diameter of the probe was 1 cm. The pressure was increased with a constant application rate of 30 kPa/s. The participants were instructed to concentrate on the test stimulus and to press the switch button as soon as they felt that the pressure changed to the slightest level of pain. [19] The amount of pressure at this point was defined as the PPT value. Three measurements per site were made at 1-min intervals to obtain a mean value.

Static two-point discrimination threshold

Static two-point discrimination threshold based on Ylikontiola et al. [24] was measured using the points of calipers, placed on the tested region starting with a distance of 25 mm and then using decrements of 2 mm until the patient only felt a single point. The lowest value at which the patient identified 2 points was recorded as the value for the task.

In addition, a subjective evaluation was performed at 6M after operation. Each participant was asked to choose “complete recovery of sensation” or “numbness” or “definitive pain” for somatosensory changes at the bilateral test sites (Fig.1).

Statistics

The sample size was calculated with the risk of type I and type II errors of 5% and 20% respectively and an estimate of the inter-individual variation of 20% and a minimal relevant difference to detect as 20%. However, taking into account an anticipated 20% dropout rate, a total of 20 participants should be recruited. This study recruited 22 patients, providing enough subjects for analysis.

Descriptive statistics were used to summarize the data. Thermal and mechanical thresholds were expressed as the means ± SD (standard deviation). The necessary logarithmic transformation was applied when the data was not normally distributed.[13, 25] A one-way analysis of variance (ANOVA) test was performed to analyze the different outcomes of QST and 2PD at each follow-up period. Post-hoc tests were performed using Tukey’s Honest Significant Difference test with corrections for multiple comparisons. All values at different stages were compared between the left and right side with the use of paired t tests. Each side was analyzed respectively so that one patient could not bias the results. The participants were also divided into the mandibular deviation group and the non-deviation group [17] and the side difference between both groups were analyzed. The significance level was set at $P < 0.05$.

Z-scores were adopted to indicate the degree of differences between QST and 2PD values from test sites and follow-up periods for the prospective group. The data before surgery were used as the reference values. The data of WDT, HPT, MDT, MPT, PPT, 2PD at each follow-up period were transformed using the following formula: Z-score = (Value $_{control}$ – Value $_{surgery}$) / SD $_{control}$, and Z-score = (Value $_{surgery}$ – Value $_{control}$) / SD $_{control}$ for CDT and CPT. [25] A Z-score between -1.96 and + 1.96 corresponds to the 95% confidence interval and can be considered normal, whereas a Z-score below -1.96 indicates a loss of somatosensory function. All statistical calculations were performed using the Statistical Package for Social Sciences, version 19 (SPSS, IBM).

Results

Twenty-six patients were recruited. Four of them, 1 experienced IAN rupture and 3 received operations without SSRO, were excluded. A total of 22 subjects (9 men, 13 women) with a mean age of 20 years were recruited in accordance with the inclusion criteria. All participants experienced skeletal class III malocclusion, 11 of them were also diagnosed as mandibular deviation. All patients included experienced small mandible setback with a mean distance of 4.1 cm. Among these patients, 7 had bilateral IANs exposed, 5 had unilateral IAN visualized and 10 had no IAN exposure. Besides compression of the nerve, no other IAN and mental nerve injuries were observed during the operation. All included participants completed the tests. The QST and 2PD values are presented as means ± SD (standard deviation) in Table 1.

The self-reports regarding somatosensory alterations are shown in Table 2. We performed Pearson correlation analysis to detect the relationship between the mandibular setback distance and the QST changes at 1W, 1M, 3M and 6M (Supplement Table 1-4). Only PPT changes at the left chin at 1W ($r=0.453$, $p=0.034$) and PPT changes at the right lower lip at 3M ($r=0.427$, $p=0.048$) showed moderate correlation with mandibular setback distance.

Thermal thresholds

In the study, the patients who underwent SSRO experienced altered sensitivity in thermal function. All thermal thresholds for both test sites at 1W, 1M and HPT for the right side of the chin at 3M were significantly different compared to the baseline ($P<0.006$) (Table 1). No significant difference of any thermal threshold was observed at 6M ($P>0.075$).

Mechanical thresholds

MDT for the right side at 1W and left side at 1M were significant higher (less sensitive) at the lower lip compared to the baseline ($P<0.039$). The chin at both sides also showed significantly higher MDT values at 1W ($P<0.011$). At the bilateral lower lips and chin, MPT values were significantly higher (less sensitive) at 1W and 1M compared to baseline ($P<0.032$). No significant difference was observed for the MDT and MPT at 3M, 6M ($P>0.989$). Meanwhile, there were no significantly lower PPT values at each postoperative period compared to baseline ($P>0.122$).

2PD

2PD was significantly higher at both test sites at 1W and 1M compared to baseline ($P<0.038$), except at the bilateral chin at 1M ($P>0.069$). No other significant differences at any of the test sites were observed at 3M and 6M ($P>0.478$).

Side-to-side differences

All values for the left and right sides of the lower lip and the chin were compared (Table 1). At the chin, CDT, MDT and 2PD at 1W showed a significant difference between the left and right side ($P<0.012$). Both CDT and CPT of the right side at the lower lip showed significantly reduced sensitivity at 1W ($P<0.033$). No other significant side differences were observed ($P>0.052$).

At 1W, the mandibular deviation group showed significantly larger side difference of CDT, WDT, CPT, HPT and 2PD at both test sites than the non-deviation group ($P<0.043$) (Fig. 2, Fig. 3). The side-to-side difference of MDT at the chin was also significant in the mandibular deviation group ($P=0.004$). No significant differences were observed between groups at baseline and at 6M ($P>0.085$).

Z-score profiles

Fig. 4 and 5 show the Z-scores for all the QST variables and 2PD. Significant loss of all included somatosensory modalities (Z-scores < -1.96) can be identified on both test sides at 1W and 1M, except for PPT. Moreover, the Z-score profiles show loss of thermal function for the chin at 3M. Also note recovery of somatosensory functions in the majority of patients at 6M.

Discussion

The present study showed significant differences in the majority of somatosensory measures at early stages after SSRO, however recovery was observed at 6M without significant differences compared to baseline values. Despite the rapid development of advancement in mandibular orthodontic techniques, little attention has been given to the recovery of IAN injury, characterized by numbness of lower lip and mental skin. This study quantitatively analyzed the altered somatosensory function at both sites at different time points after SSRO to have a better understanding on the recovery process. In general, the prospective patients experienced altered sensitivity at the lower lip and chin area, as described in a previous study. [10]Nonetheless, patient-reported symptoms tended to decrease with time and changes in somatosensory function of the IAN returned to baseline values half a year after surgery.

Recovery of thermal sensation

The thermal sensation at both test sides was less sensitive at 1W and 1M compared to baseline. Abnormal HPT at the right chin could also be observed at 3M. However, mechanical thresholds (PPT, MDT) showed no significant difference at 1M compared to baseline. It is suggested that the recovery of thermal sensation appears to be relatively slower than for mechanical sensation.

According to physiological studies, somatosensory nerve fibers consist of Aβ, Aδ and C fibers. [26] External vibratory stimuli are conducted by large myelinated Aβ fibers, cold thermal stimuli by small myelinated Aδ fibers, warm thermal stimuli by unmyelinated C fibers and painful thermal stimuli by small myelinated Aδ fibers and unmyelinated C fibers. [26] In terms of the membrane properties, Stephanova concluded that the myelin sheath aqueous layers play an important role in the accommodative and adaptive processes in patients with incomplete myelin sheath. [27]When conducting SSRO, the movement of the mandible may to some extent influence the IAN by stretching or compressing the nerve fibers, but the exact extent may not easily be predicted. Aβ fibers mediate tactile and pressure sensations and it could be speculated that the myelinization of the Aβ fibers may have a supportive and adaptive effect during the faster recovery. Another reason may be related to relatively large nerve diameter of the Aβ fibers compared to Aδ and C fibers. Compared with our previous studies,[20, 25]the 2PD was also included as a supplementary index to indicate the recovery of Aβ fibers.

From a pain perspective, sharp pin-prick-like pain thresholds also achieved better outcomes at 6M compared to thermal pain sensitivity, which are both transmitted by Aδ and C fibers. C fibers lack the protection offered by the myelinization. Thus, it could be that C fibers are key mediators in the recovery of thermal nociceptive function following orthognathic surgery.

Recovery of mechanical sensation

Based on the available mechanical data, PPT recovered first on the lower lip, followed by MDT, 2PD and MPT (Table 1, Fig. 4). While on the chin, PPT and 2PD recovered faster than the MDT (Table 1, Fig. 5). One obvious trend is that tactile and pressure pain are faster to recover followed by the sharp pin-prick-like pain sensation, which corresponds with the finding of somatosensory recovery on the tongue with skin flap transplantation.[28] That study implied that somatosensory recovery is presented in an order despite of different operations and test sides.[28] Further research may be required to have a general idea about the consistency and mechanism of postoperative somatosensory recovery.

A previous study performed QST in 40 healthy volunteers at the lower lip and mental nerve regions. [20] No significant difference was observed in normal MDT between test sides, which indicate that both sides have similar somatosensory function. However, in our study, the lower lip recovered faster than the chin in terms of MDT. One reason to be considered is that the chin experienced more damage during SSRO combined with genioplasty, and the QST results may be influenced by the surgical bone trauma. Another matter of concern is that there are titanium plates and screws in the mental foramen area.

The present study also proposed the use of Z-score profiles to assess the time-dependent results in individual patients. In accordance with the above analyses, the Z-score profiles indicated a better recovery for mechanical thresholds than thermal ones. Obviously, almost all somatosensory parameters were within the normal range on bilateral lower lips and chins at 6M.

A previous study based on the evaluation of IAN evoked potentials during SSRO showed that a series of peaks following bone cuts, splitting or rigid fixation could be identified and both the amplitude and latency of the response were significantly affected. However, the waveforms would return to baseline with 20 minutes[29]. This finding provides direct evidence that a transient neurapraxia appears following SSRO but does not account for postsurgical loss of sensation completely. Postoperative pain is an expected consequence of most surgeries and always accompanies swelling and edema. Many cytokines including interleukin-1β, nerve growth factor, tumor necrosis factor or even complement component could be produced at the wound site and play a vital role in the control of pain and swelling[30]. The obvious swelling at the lower lip and the chin following SSRO could affect the sensory threshold. We suggest that swelling might inhibit the thermal sensation but benefit mechanical sensation. This study could not eliminate the influence of postoperative swelling.

Side-to-side differences

Previous research showed no significant right-to-left side difference of CPT and MDT of healthy participants. [13, 20] However, this study presented new findings in terms of side-to-side differences in patients shortly after SSRO (Table 2). Plooij et al. [31] analyzed 3-dimensional computed tomography scans after SSRO and found that 33% of the osteotomy lines ran through the mandibular canal. Another report showed a significant correlation between the somatosensory recovery and the extent of the exposed nerve during SSRO. [32] We suggest that the left-to-right side difference might be attributed to the different osteotomy lines during surgery. The pre-operative orthodontic treatment might cause separate forces on the unilateral mandible, which could also exacerbate the early-postoperative side difference of MDT at the chin. Though there were minor side-to-side differences in QST values at 1W after surgery, the left-to-right recovery trends were consistent. Our study indicated that individuals with mandibular deviation showed more evident somatosensory side-to-side difference following orthognathic surgery, especially in terms of thermal sensation. This can be understood as bilateral IAN would experience different force when performing surgical rotation of the jaw or aligning the mandibular symphysis to the facial midline. However, the side difference had disappeared at 3M.

Our perception of somatosensory stimuli in the trigeminal region is based on inputs from both sides which normally have equal or almost equal sensitivity, however, subtle differences may occur to the IAN during SSRO and lead to detectable side-to-side differences in QST parameters. The present study indicated that such side-to-side differences were common at the early stages after SSRO but tended to resolve during the observation period. It can be recommended to assess both QST and self-reported findings to obtain the most comprehensive assessment of somatosensory function and to follow such changes over time.

QST versus self-reported findings

Our clinical examinations showed patient-reported pain on both test sites immediately after SSRO, which lasted for one or two weeks. After that, the majority of patients complained of local numbness especially when drinking or chewing. The range of such abnormal somatosensory function would most likely decrease with time, eventually disappear or concentrate in a small local area. The patient-based reports showed the somatosensory recovery in the majority of included patients at 6M (Table 2), which coincided with the individual Z-score findings.

However, in accordance with a previous report, [31] there was still some descriptive difference between the objective and patient-based evaluations. For example, only one patient, who experienced mandibular setback for 6.5 mm and right rotation of the jaw, complained of pain at the right lower lip and numbness at the left lower lip at 6M. Based on our surgical records, this patient had visible exposure of left IAN but no exposure of the right IAN. Six months after surgery, only WDT and CDT were slightly abnormal, and the other measures of somatosensory function were within the normal range in this patient. We suggest that pain could be related to subclinical levels of injury, large movement of the mandible (6.5 mm), significant post-operative swelling or rotation of the jaw. However, the patient reported recovery at the bilateral lower lips after one year. This observation calls for caution in clinical evaluation of per-operative clinical findings.

In an animal research study, the uninjured infraorbital nerve region showed hypersensitivity to mechanical stimulation following IAN transaction for a long time, which was confirmed related with changes in K^+ current and hyperpolarization-activated current in trigeminal ganglion neurons. [33] It is suggested that the injury of branches of trigeminal nerve might even trigger hypersensitivity at the control and uninjured areas. [33] Such a prolonged neuropathic hypersensitivity was not rare in previous studies of post-SSRO patients[34] and needs further exploration.

Limitations of the study

First, the sample size of the study was relatively small. Second, we excluded those patients suffering IAN rupture during surgery who are not expected to recover in terms of somatosensory deficits. [35]Only young individuals were recruited in the study and the possible impact of age was not tested in the presented study but could be important to include in future research projects. Similarly, gender differences could be included in a more comprehensive analysis of somatosensory changes over time.

Conclusions

Somatosensory changes in selected SSRO patients without per-operative complications to the IAN were characterized by reversible somatosensory loss for both thermal and mechanical stimuli. The mechanical sensitivity recovered faster compared to the thermal sensitivity. Somatosensory function at the lower lip and chin following SSRO appears to be fully recovered in the majority of young Chinese adults 6 months after atraumatic surgery for skeletal class III malocclusion.

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Conflicts of Interest

None of the authors have any relevant financial relationship (s) related to this study.

Data availability statement

All data included in this study are available upon request by contact with the corresponding author.

Author contributions

The study was designed by Jiayi He, Hua Yuan, Kelun Wang, Peter Svensson, Hongbing Jiang. The data was collected and analyzed by Jiayi He and Xin Chen. The paper was written by Jiayi He and Xin Chen and revised mainly by Kelun Wang, Peter Svensson. Ping Zhang is mainly responsible for the two revisions of the study, including data collection, analysis and modification of the text. All authors have approved the submission.

Ethical approval

The study was approved by the local ethics committee (No: PJ2016-037-001) in accordance with the Helsinki Declaration II. Written informed consent was obtained from all participants before they were included in the study.

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Tables:

Table 1. QST and 2PD values in the study.

Test	Position		Baseline	1W	1M	3M	6M
CDT（℃）	Lower Lip	Left	30.4 ± 0.9	21.0 ± 10.3*†	22.6 ± 10.3*	27.9 ± 4.1	29.5 ± 1.6
		Right	30.4 ± 0.9	17.5 ± 11.1*	20.1 ± 10.6*	29.2 ± 1.7	29.7 ± 1.4
	Chin	Left	30.5 ± 1.0	23.0 ± 9.3*†	23.8 ± 9.1*	28.1 ± 5.4	29.7 ± 1.4
		Right	30.4 ± 1.1	18.0 ± 10.5*	20.0 ± 10.8*	28.9 ± 2.1	30.0 ± 1.0
WDT（℃）	Lower Lip	Left	34.0 ± 1.3	41.2 ± 6.9*	40.2 ± 6.9*	36.8 ± 5.2	35.1 ± 2.6
		Right	34.1 ± 1.2	42.5 ± 6.9*	41.8 ± 7.1*	36.1 ± 3.2	34.6 ± 1.6
	Chin	Left	34.3 ± 1.4	41.5 ± 6.4*	41.3 ± 6.7*	37.6 ± 4.6	36.5 ± 3.9
		Right	34.4 ± 1.5	42.5 ± 6.6*	42.3 ± 7.0*	37.9 ± 4.2	35.8 ± 2.0
CPT（℃）	Lower Lip	Left	27.6 ± 1.7	18.0 ± 9.0*†	19.6 ± 9.7*	24.4 ± 7.0	27.1 ± 2.7
		Right	28.0 ± 1.8	13.8 ± 9.9*	16.9 ± 9.8*	26.6 ± 2.9	27.6 ± 1.9

HPT（℃）	**Chin**	**Left**	28.6 ± 1.4	17.5 ± 9.5*	19.8 ± 9.1*	25.5 ± 5.7	27.5 ± 2.8
		Right	29.0 ± 1.0	14.4 ± 9.8*	16.5 ± 10.8*	26.3 ± 3.4	27.7 ± 2.1
	Lower Lip	**Left**	36.9 ± 2.2	44.5 ± 5.6*	43.7 ± 5.8*	40.5 ± 4.7	38.9 ± 3.3
		Right	37.2 ± 2.5	45.8 ± 5.9*	45.5 ± 5.7*	40.7 ± 3.9	38.8 ± 3.2
	Chin	**Left**	36.8 ± 2.1	45.0 ± 5.1*	44.2 ± 5.9*	40.4 ± 4.4	39.1 ± 3.5
		Right	36.4 ± 1.7	46.0 ± 5.2*	45.3 ± 5.7*	42.2 ± 4.6*	39.8 ± 3.3
MDT (mN）	**Lower Lip**	**Left**	2.3 ± 0.4	4.0 ± 3.1	4.1 ± 3.3*	2.5 ± 0.8	2.4 ± 0.5
		Right	2.3 ± 0.3	4.3 ± 3.1*	3.5 ± 2.4	2.4 ± 0.5	2.3 ± 0.3
	Chin	**Left**	2.0 ± 0.3	4.1 ± 3.2*†	3.7 ± 3.3	2.3 ± 0.8	2.0 ± 0.4
		Right	1.9 ± 0.2	4.6 ± 3.1*	3.1 ± 2.5	2.0 ± 0.4	1.9 ± 0.3
MPT (mN）	**Lower Lip**	**Left**	5.7 ± 4.9	37.8 ± 44.2*	27.9 ± 36.6*	6.5 ± 4.8	5.6 ± 2.5
		Right	5.7 ± 4.7	48.7 ± 44.6*	32.1 ± 39.1*	5.6 ± 3.9	5.0 ± 1.9
	Chin	**Left**	1.2 ± 1.0	37.0 ± 45.0*	20.7 ± 34.4*	3.3 ± 5.5	0.9 ± 0.1

		Right	1.1 ± 0.7	44.5 ± 40.8*	26.5 ± 37.5*	1.1 ± 0.9	0.8 ± 0.1
PPT (kPa)	**Lower Lip**	**Left**	48.4 ± 23.3	69.9 ± 68.5	47.2 ± 23.3	39.9 ± 19.1	43.5 ± 18.8
		Right	46.7 ± 20.9	68.5 ± 68.9	51.5 ± 32.6	31.9 ± 12.5	42.3 ± 18.8
	Chin	**Left**	74.1 ± 36.9	65.0 ± 29.0	57.8 ± 26.0	57.1 ± 23.5	61.0 ± 25.3
		Right	71.4 ± 37.6	62.4 ± 23.7	62.0 ± 18.5	53.0 ± 19.7	59.3 ± 22.6
2PD (mm)	**Lower Lip**	**Left**	2.0 ± 1.0	12.1 ± 12.7*	9.9 ± 11.7*	6.4 ±8.8	3.5 ± 3.8
		Right	2.0 ± 0.8	16.3 ± 13.3*	9.2 ± 10.5*	4.5 ±6.8	2.5 ± 3.0
	Chin	**Left**	4.6 ± 5.9	13.8 ± 12.6*†	10.6 ± 12.3	7.1±9.6	4.3 ± 6.3
		Right	3.1 ± 1.9	20.2 ± 12.3*	9.5 ± 9.2	4.5 ± 6.1	3.5 ± 6.1

Table 2. Patient-based evaluations on each side at 6 months after operation.

	Lower lip		Chin	
Complete recovery	29	65.9%	28	63.6%
Numbness	14	31.8%	16	36.4%
Definitive pain	1	2.3%	0	0%
Total	44	100%	44	100%

Figure and table legends

Fig 1.

Quantitative sensory testing sites. Left lower lip (LLL), Right lower lip (RLL), Left chin (LC), Right chin (RC).

Fig 2.

The effect of mandibular deviation on side difference of QST parameters and 2PD for the lower lip. Cold detection threshold (CDT); Warm detection threshold (WDT); Cold pain threshold (CPT); Heat pain threshold (HPT); Mechanical detection threshold MDT; Mechanical pain threshold (MPT); Pressure pain threshold (PPT); Two-point discrimination (2PD). * $P<0.05$; ** $P<0.01$; *** $P<0.001$.

Fig 3.

The effect of mandibular deviation on side difference of QST parameters and 2PD for the chin. Cold detection threshold (CDT); Warm detection threshold (WDT); Cold pain threshold (CPT); Heat pain threshold (HPT); Mechanical detection threshold MDT; Mechanical pain threshold (MPT); Pressure pain threshold (PPT); Two-point discrimination (2PD). * $P<0.05$; ** $P<0.01$; *** $P<0.001$.

Fig 4.

The Z-score profile of all QST parameters and 2PD for the lower lip. The grey zone indicates a Z-score between -1.96 and + 1.96, representing the normal range as determined from the preoperative baseline, and the Z-score below -1.96 indicates a loss of somatosensory function. Cold detection threshold (CDT); Warm detection threshold (WDT); Cold pain threshold (CPT); Heat pain threshold (HPT); Mechanical detection threshold MDT; Mechanical pain threshold (MPT); Pressure pain threshold (PPT); Two-point discrimination (2PD).

Fig 5.

The Z-score profile of all QST parameters and 2PD for the chin. The grey zone indicates a Z-score between -1.96 and + 1.96, representing the normal range as determined from the preoperative baseline, and the Z-score below -1.96 indicates a loss of somatosensory function. Cold detection threshold (CDT); Warm detection threshold (WDT); Cold pain threshold (CPT); Heat pain threshold (HPT); Mechanical detection threshold MDT; Mechanical pain threshold (MPT); Pressure pain threshold (PPT); Two-point discrimination (2PD).

Table 1. QST and 2PD values in the study.

Cold detection threshold (CDT); Warm detection threshold (WDT); Cold pain threshold (CPT); Heat pain threshold (HPT); Mechanical detection threshold MDT; Mechanical pain threshold (MPT); Pressure pain threshold (PPT); Two-point discrimination (2PD); Baseline: pre-operation; Data are shown by Mean ± SD.* Significant difference (P<0.05) compared to baseline; † Significant difference (P<0.05) between the left and right side.

Table 2. Patient-based evaluations on each side at 6 months after operation.

Supplement table 1. Pearson correlation analysis between mandibular setback distance and QST changes at 1 week after operation.

Cold detection threshold (CDT); Warm detection threshold (WDT); Cold pain threshold (CPT); Heat pain threshold (HPT); Mechanical detection threshold MDT; Mechanical pain threshold (MPT); Pressure pain threshold (PPT); Two-point discrimination (2PD); * Significant difference ($P<0.05$).

Supplement table 2. Pearson correlation analysis between mandibular setback distance and QST changes at 1 month after operation.

Cold detection threshold (CDT); Warm detection threshold (WDT); Cold pain threshold (CPT); Heat pain threshold (HPT); Mechanical detection threshold MDT; Mechanical pain threshold (MPT); Pressure pain threshold (PPT); Two-point discrimination (2PD);

Supplement table 3. Pearson correlation analysis between mandibular setback distance and QST changes at 3 months after operation.

Cold detection threshold (CDT); Warm detection threshold (WDT); Cold pain threshold (CPT); Heat pain threshold (HPT); Mechanical detection threshold MDT; Mechanical pain threshold (MPT); Pressure pain threshold (PPT); Two-point discrimination (2PD); * Significant difference ($P<0.05$)

Supplement table 4. Pearson correlation analysis between mandibular setback distance and QST changes at 6 months after operation.

Cold detection threshold (CDT); Warm detection threshold (WDT); Cold pain threshold (CPT); Heat pain threshold (HPT); Mechanical detection threshold MDT; Mechanical pain threshold (MPT); Pressure pain threshold (PPT); Two-point discrimination (2PD);

Fig 1. Quantitative sensory test sites.

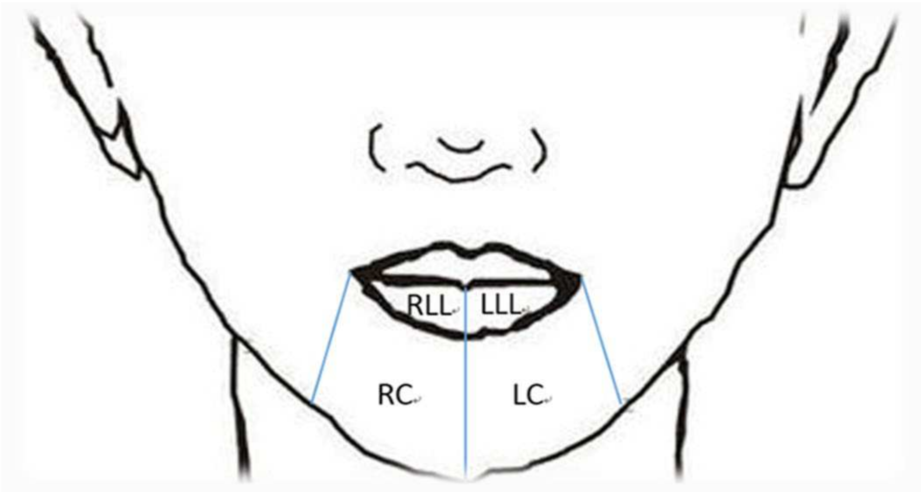

Fig 2. The effect of mandibular deviation on side difference of QST parameters and 2PD for the lower lip.

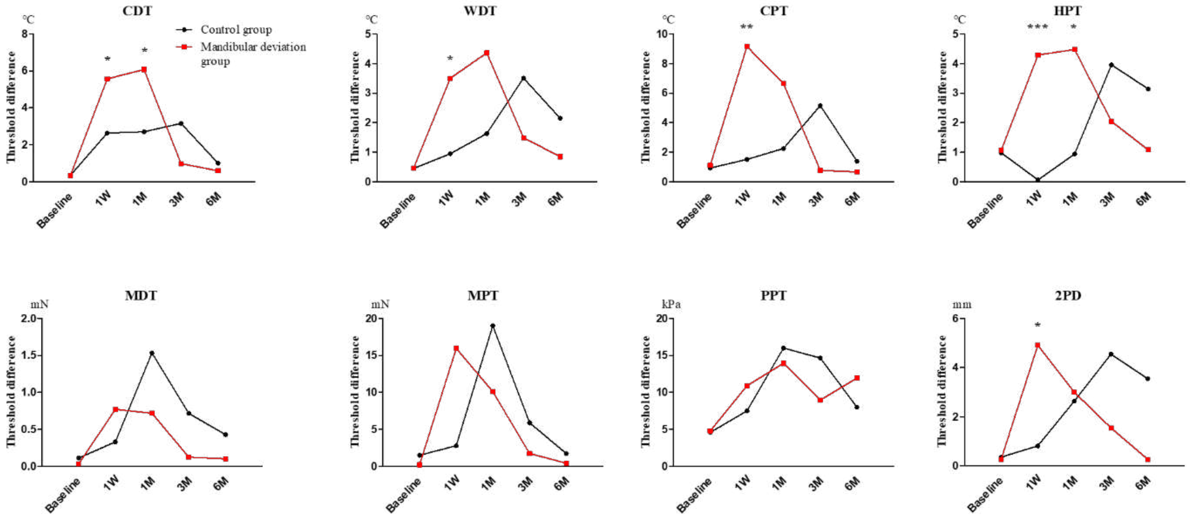

Fig 3. The effect of mandibular deviation on side difference of QST parameters and 2PD for the chin.

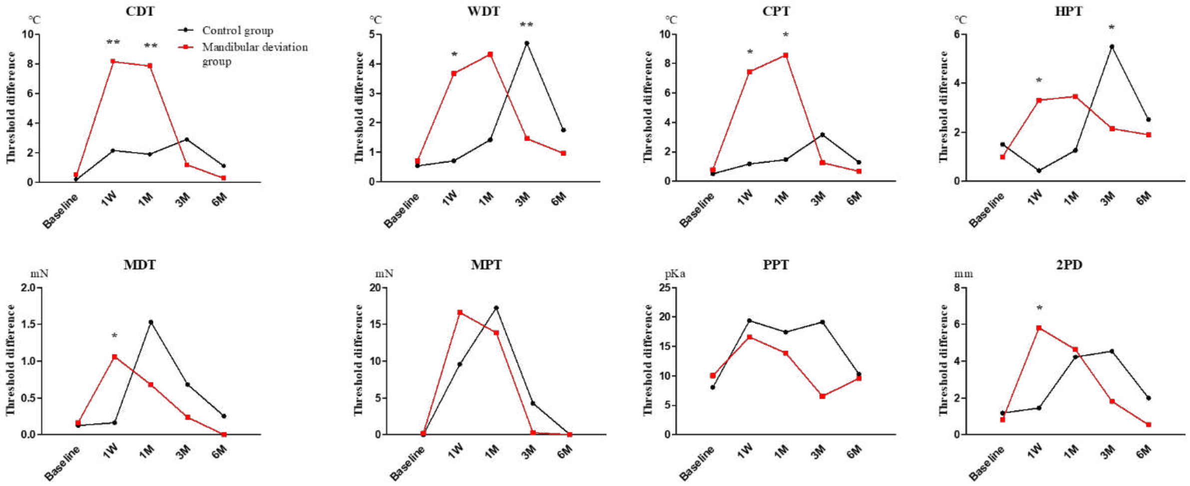

Fig 4. Z-score profiles for all QST parameters and 2PD for the lower lip.

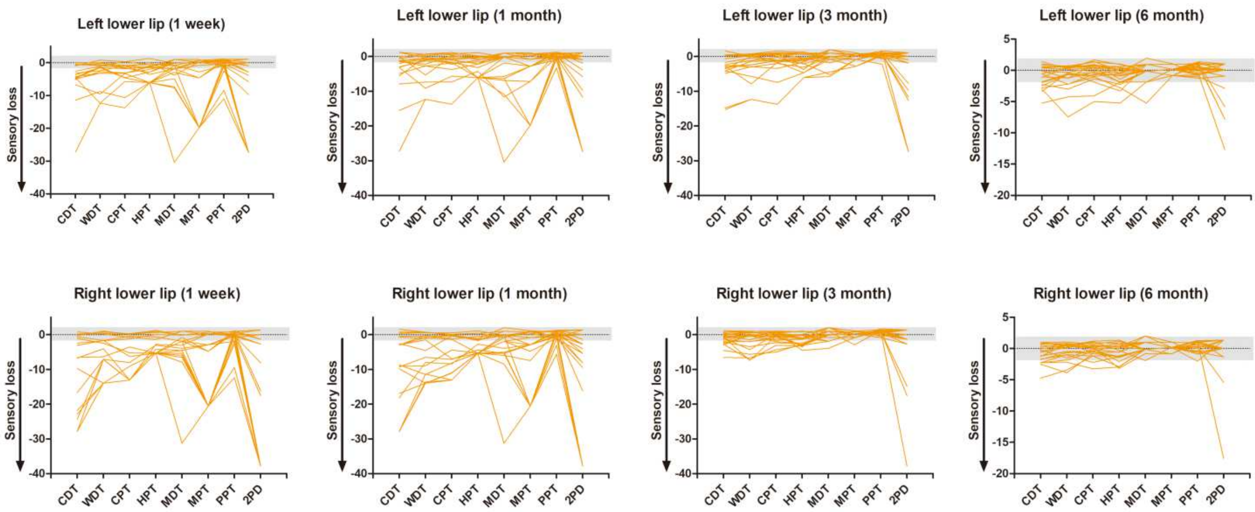

Fig 5. Z-score profiles for all QST parameters and 2PD for the chin.