The relationship between neurosensory disturbance of the inferior alveolar nerve and the lingual split pattern after sagittal split osteotomy

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Objective. The aim of this study was to evaluate the relationship between neurosensory disturbance (NSD) and the different types of bilateral sagittal split osteotomy (BSSO) lingual fracture created.
Study Design. The study group consisted of 45 patients with mandibular deformities (90 sides; 14 males and 31 females). Computed tomography (CT) scans were obtained preoperatively and 1 week postoperatively. All patients were divided into lingual fracture line groups on the basis of their postoperative scans. NSD was tested preoperatively and 1, 3, and 12 months postoperatively by using a sensory touch Semmes-Weinstein (SW) test and the 2-point discrimination (TPD) test.
Results. Patients were divided into 2 groups on the basis of their lingual fracture lines after mandibular BSSO; among the 45 patients, 39 sides (43.3%) had short-splits, and 51 sides (56.7%) had long-splits. The short-split group was less affected at all tested times, and the difference between the 2 groups was significant 1 month postoperatively on TPD test but not at other times on the both tests.
Conclusions. The split type did not affect the NSD incidence at 3 and 12 months postoperatively. (Oral Surg Oral Med Oral Pathol Oral Radiol 2020;130:373−378)

Bilateral sagittal split osteotomy (BSSO) is widely used to correct jaw deformities. Its benefits include correction of the skeletal class, affording better masticatory function, reduced temporomandibular joint pain, improved facial aesthetics, and alleviation of obstructive sleep apnea.[1-3] BSSO is performed close to the inferior alveolar nerve (IAN), which often is damaged by the procedure.[4] Maxillofacial surgical procedures pose significant risks of injury to sensory branches of the trigeminal nerve, and the IAN damage explains most BSSO postoperative complications.[5,6] Sensation and sensory function are often impaired but not completely lost, and only a small proportion of patients develop posttraumatic neuropathic pain.[7,8] Factors causing IAN neurosensory disturbance (NSD) include neurovascular bundle compression by bone fragments, direct mechanical stimulation of the nerve or indirect damage caused by surgical instruments, and movement of distal bone fragments.[9,10] IAN damage can include complete or partial transection, extension, compression, crushing, or ischemia.[11]

A few studies have investigated fracture patterns by using 3-dimensional (3-D) cone beam computed tomography (CBCT) data reconstructions.[12-16] In most studies, BSSO was performed according to the popular Hunsuck modification: The medial cortical osteotomy is extended just posterior to, or above, the mandibular foramen, creating a fracture through or behind the foramen and reducing the splitting area.[17] Plooij et al. were the first to use a 3-D method to describe and classify lingual fracture patterns after mandibular BSSO.[14] These patterns are usually divided into 4 or 5 categories, and although the evaluation and classification methods differ, it is agreed that such reconstructions control the postoperative fracture line.

NSD is difficult to assess in a standardized manner because it highly subjective (relying on patient-provided information), and correct testing and interpretation are dependent on the skill of the evaluators. Because there is no clear consensus on how patients should be evaluated after surgery, clinicians commonly use a few simple, rapid sensory tests: The 2-point discrimination (TPD) test and the light touch test. Weber et al. first introduced the former in 1853 to determine "the distance between

Statement of Clinical Relevance

The lingual split pattern at bilateral sagittal split osteotomy did not affect the neurosensory disturbance incidence by testing with the Semmes-Weinstein and 2-point discrimination at 3 and 12 months postoperatively.

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compass points necessary to feel two contacts."[18] Sensory testing methods are not widely used, and many clinicians prefer to question patients in terms of altered facial sensations, especially in the lower lip and the chin.

To the best of our knowledge, no study has yet addressed the relationship between mandibular split patterns after BSSO and the NSD rate. The aim of this study was to evaluate the relationship between NSD and the different types of BSSO lingual fracture created.

MATERIALS AND METHODS

The Institutional Ethics Committee of Tohoku University approved the present retrospective study (No. 2017-03-015), which was conducted in accordance with the principles of the Helsinki Declaration. G*Power software (version 3.1.9.4) was used for sample size calculation with a power of significance of 80%. At a minimum, 39 patients were required for the study.

Sixty-two patients underwent BSSO in the Division of Oral and Maxillofacial Surgery of Tohoku University Hospital (Sendai, Japan) from April 2014 to September 2015. Those who underwent inverted L-shaped osteotomies or genioplasty, and those who developed abnormal fractures after BSSO, were excluded. We included 45 patients with mandibular deformities (90 sides; 14 males and 31 females). Of the 45 patients, 4 had skeletal class I deformity, 5 had class II deformity, and 36 had class III deformity. Mean ages were 26 years for males (range 19−50 years) and 26.4 years for females (range 18−46 years). Preoperative radiographic evaluation, clinical examination, and planning were identical for all patients. Informed written consent was obtained from each patient after he or she received an explanation regarding treatment. All surgeries were performed by 2 surgeons with 31 and 17 years of experience, respectively; one surgeon operated on 23 patients and the other on 22 patients. Both surgeons had been working together for 14 years, and there were no significance differences between their results.

Surgery

The mandibular third molars were removed at least 4 months before surgery in all cases. The operations were performed with patients under general anesthesia after additional induction of local anesthesia with lidocaine plus adrenaline in the surgical area. The surgical technique was that of Dal Pont. Using a fissure bar, we positioned the horizontal medial cut as close to the lingual side as possible. A burr was used to continue the cut anteriorly, medial to the external oblique ridge. At the second molar teeth, the osteotomy proceeded vertically to the inferior border of the mandible. A thin osteotome was part-malleted to this section (from the anterior area). When confirming the mandibular split, we ensured that the neurovascular bundle was not in the proximal segment. Finally, a bone spreader was used to complete and separate the split. Semi-rigid fixation was achieved using 4- or 6-hole miniplates and monocortical screws (Stryker, Freiburg, Germany). Intermaxillary fixation was employed for about 4 days postoperatively, and elastic guidance was used to stabilize the occlusion. After surgery, patients were given vitamin C daily for 1 week.

CT scans were obtained 1 week after surgery by using a Toshiba Aquilion platform (Toshiba, Otawara, Japan), with a slice thickness of 0.5 mm and scan time of 0.35 seconds. Transverse scans of the head were collected parallel to the mandibular occlusal plane, from the level of the temporomandibular joint to the inframandibular margin. All scans were later evaluated with the aid of WeVIEW Z V1.0 (Hitachi Medical Corporation, Tokyo, Japan) viewer software.

CT scan evaluation

All patients were divided into lingual fracture line groups on the basis of their postoperative scans. The sagittal split pattern was subdivided into 3 types: in type I, the fracture line ran through the mandibular canal to the inferior border of the mandible; in type II, the fracture was created by using the Hunsuck technique; thus, a vertical fracture line was created from the lingula to the inferior border of the mandible; and in type III, a horizontal fracture line running to the posterior border of the ramus was created (Figures 1A, 1B, and 1C). Types I and II were considered short splits, and type III was considered a long split. All CT scans were examined by a single experienced clinician, who has been working in our department for over 9 years (Figure 2).

Tactile sensory tests

Bilateral NSD was tested preoperatively and 1, 3, and 12 months postoperatively by using a sensory touch test (the Semmes-Weinstein [SW] monofilament kit) and the TPD test (Sakaimed, Japan). SW monofilaments are calibrated, single-fiber nylon threads that are identified by values ranging from 1.65 to 6.65 and that generate reproducible buckling stresses, ranging from 0.008 to 300 *g*. Higher monofilament values indicate

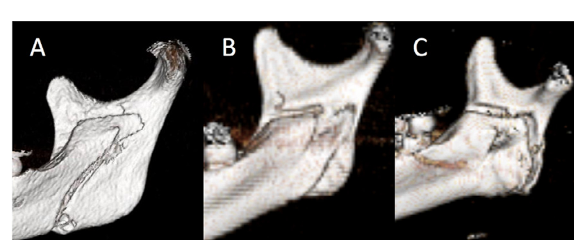

Fig. 1. **A,** Split pattern type I: Fracture runs through the mandibular canal. **B,** Split pattern II: Fracture runs from the lingual to the inferior border. **C,** Split pattern III: Horizontal pattern of fracture, extends to the posterior border.

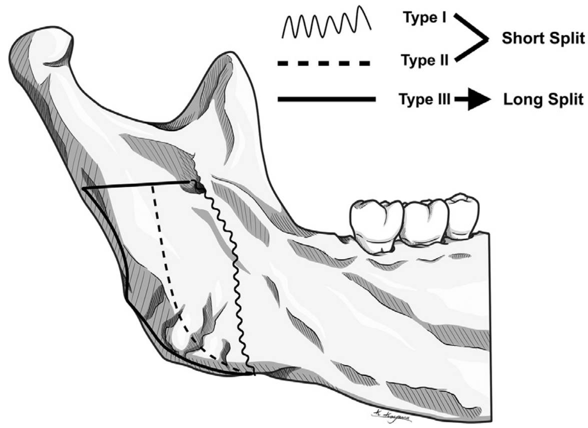

Fig. 2. Split pattern types divided into short and long split groups. Split pattern types I and II belong to the short group, and split pattern type III belongs to the long group.

greater monofilament stiffness. The TPD test evaluates the ability to discriminate between 2 points on a Dellon disk that are simultaneously applied to the skin under light pressure with the patient's eyes closed. The 2 points are gradually separated until the patient feels 2 separate points. The separation ranges from 1 to 20 mm. Bilateral sensory testing was performed by 2 experienced clinicians, who used an identical protocol; the test sites included the median region of the chin (1 cm from the mandibular symphysis), the paramedial region (2 cm), and the mental foramen (3 cm).

The SW test

Bilateral testing was performed with the patient sitting with eyes closed; the test areas were selected in random order. Each test was performed 4 times in each area of interest; monofilaments were applied in ascending order of stiffness. When the stimulus was felt 3 times, the test was considered positive. Patients who responded postoperatively to only those filaments that were stiffer than those to which they responded preoperatively were considered to have NSD.

TPD test

Bilateral testing was performed with the patient sitting with eyes closed; the test areas were selected in random order. Both points were simultaneously positioned in the area of interest and gradually separated until the patient perceived 2 points; ascending and descending stimuli were then applied to verify the result. The test was considered positive when the patient initially correctly differentiated 2 points on three occasions. Patients who postoperatively perceived 2 points only at distances that were at least 3 mm longer than those they perceived before surgery were considered to have NSD.

Statistical analysis

The χ^2 test was used to compare the differences in sensory test results between the long- and short-split-pattern groups at 1, 3, and 12 months after surgery.

RESULTS

Patients were divided into 3 groups on the basis of their lingual fracture lines after mandibular BSSO; among the 45 patients, 5 sides (5.5%) had type I splits, 34 sides (37.8%) had type II splits, and 51 sides (56.7%) had type III splits (Table I). Seventy-two sides were of skeletal class III (5 sides of type I, 22 of type II, and 45 of type III); 10 sides were of skeletal class II (9 sides of type II, 1 of type III); and 8 sides were of skeletal class I (3 sides of type II and 5 of type III).

In the long-split group, the TPD test revealed that 16 sides experienced NSD at 1 month, 6 sides at 3 months, and 7 sides at 1 year postoperatively. The SW test revealed that 14 sides experienced NSD at 1 month, 2 sides at 3 months, and 2 sides at 1 year postoperatively. In the short-split group, the TPD test revealed that 7 sides experienced NSD at 1 month, 1 side at 3 months, and 3 sides at 1 year postoperatively. The SW test revealed NSD in 7 sides at 1 month, 2 sides at 3 months, and 2 sides at 1 year postoperatively (Table II). In total, the TPD revealed NSD in 23 sides at 1 month, 7 sides at 3 months, and 10 sides at 1 year after surgery.

According to the SW test, NSD affected 21 sides at 1 month, 4 sides at 3 months, and 4 sides at 1 year postoperatively (Table III). The short-split group was less affected at all tested times, and the difference between the 2 groups was significant 1 month postoperatively but not at other times.

DISCUSSION

Few studies have evaluated the fracture patterns after BSSO, but we believe that this is important in terms of postoperative NSD. Plooij et al. found that 51% of fracture lines ran through the mandible when the Hunsuck modification was employed (33% through the mandibular canal), and 13% extended to the posterior border.[14] Song and Kim et al. found that such fractures accounted for approximately 60% of all procedures.[16] Muto et al. reported that only 33% of split patterns ran behind the mandibular foramen through the lingual cortex.[13] Dreiseidler et al. used the Obwegeser-Dal

Table I. Number of sides in each type of split pattern.

	Right side	*Left side*	*Total*
Type I	2	3	5 (5.5%)
Type II	16	18	34 (37.8%)
Type III	27	24	51 (56.7%)

Table II. NSD results between long and short splits, and between the sensory tests: comparison of preoperatively and 1 month, 3 months, and 1 year postoperatively*

	TPD test			*SW test*		
	Short (type I, II)	*Long (type III)*	*P value*	*Short (type I, II)*	*Long (type III)*	*P value*
Preoperative/1 month	7 (17.9%)	16 (31.3%)	.04	7 (17.9%)	14 (27.4%)	.103
Preoperative/3 months	1 (2.5%)	6 (11.7%)	.122	2 (5.12%)	2 (3.9%)	.613
Preoperative/1 year	3 (7.6%)	7 (13.7%)	.328	2 (5.12%)	2 (3.9%)	.613

NSD, neurosensory disturbance; *SW test,* Semmes-Weinstein test; *TPD test,* 2-point discrimination test.
*Percentage according to total number of sides in short and long groups.

Table III. Total NSD results, long and short split groups together*

	TPD test	*SW test*
Preoperative/1 month	23 (25.5%)	21 (23.3%)
Preoperative/3 months	7 (7.7%)	4 (4.4%)
Preoperative/1 year	10 (11.1%)	4 (4.4%)

NSD, neurosensory disturbance; *SW test,* Semmes-Weinstein test; *TPD test,* 2-point discrimination test.
*Percentage according to total number of sides.

Pont modification and reported a Hunsuck fracture pattern of 40%.[15] All studies except the latter used the Hunsuck modification. We employed the Dal Pont surgical technique; 2 experienced surgeons used the same technique and materials, extending the medial bone cut toward the posterior border before aligning the cut to the inferior border of the ramus to increase the splitting surface by completely mobilizing each segment. Our data differ from those of Plooij et al. and of Song and Kim et al.: 37.5% of our fracture lines were of type II (the Hunsuck type), as also found by Muto et al. and Dreiseidler et al. However, some of our data differed; 5.5% of our fractures were of type I (the fracture line ran through the mandibular canal), and 56.7% were of type III (the fracture line extended to the posterior border of the ramus). Plooij et al. were the first to classify lingual fractures; 4 split patterns were proposed; Muto et al. identified 5 patterns, and Dreiseidler et al. identified 27.[13-15] Based on Plooij et al.'s classification, we decided to simplify our results into 3 patterns and divide them into "long" or "short" group to better fit our purposes in this study.

The development of NSD after BSSO is a well-known complication of orthognathic surgery. Westermark et al. found that the incidence was 0% to 85%, reflecting different follow-up times, the lack of reliable standardized tests, and various definitions of nerve damage.[19] Our NSD incidence was 23.3% to 25.5% 1 month postoperatively, depending on the sensory test used. As the IAN is located within the osteotomy area, the risk of nerve damage exists at several stages of BSSO. Dissection of soft tissues medial to the mandibular ramus may compress or stretch the IAN; mandibular sawing and splitting may lacerate or cut the nerve; mandibular advancement may stretch it; and osteotomy fragment fixation may compress it. Additionally, individual mandibular features may increase the risk of nerve damage. Postoperative NSD is, thus, very common; the recovery period varies individually, but most patients do recover.[20] Van Sickels reported significant NSD findings in patients 35 years and older compared with younger patients immediately after surgery and over time, at 1 week and 6 months, respectively.[21] Recovery is most marked during the first 3 months after surgery,[22] which is consistent with our findings. On TPD testing, postoperative NSD fell from 25.5% to 7.7% 3 months; on SW testing, NSD decreased from 23.3% to 4.4% over the same period, and it was eliminated by 1 year.

Nerve degradation is triggered by trauma and is categorized as neurapraxia, axonotmesis, or neurotmesis.[23] The most common trauma after orthognathic surgery is neurapraxia causing paresthesia; compression during BSSO triggers demyelinating lesions that patients usually recover from during the first 4 postoperative months. Deumens et al. found that nerves generally regenerated at a rate of 1 to 3 mm/day.[24] Gianni et al. reported improvements in NSD for up to 1 year after BSSO[25]; at least 2 of our patients reported improvements 1 year after surgery (compared with 3 months). Recovery is a complex process involving cellular and molecular signaling. After recovery, sensorial changes may be evident, attributable to anatomic or functional alterations in the nerve or in the central nervous system.

The long-split group experienced more NSD compared with the short-split group on both tests 1 month postoperatively, and they also did so at 3 months and 1 year after surgery on the TPD test but not on the SW test. However, except for the TPD test data at 1 month postoperatively, the differences were not significant. It seems that the type of split does not affect the NSD risk in the long term.

No standardized method for estimating IAN NSD is available, and we used 2 of the most common subjective tests. The TPD test assesses the quantity and density of functional sensory receptors and afferent fibers; the small myelinated A-delta and unmyelinated C-afferent fibers are assessed if sharp points are used, and the larger myelinated A-alpha afferent fibers are assessed if blunt points are used. The SW test assesses the status of myelinated afferent A-beta axons (pressure receptors) susceptible to compression injury. Other sensory tests include subjective nociceptive tests using pins and hot probes. Objective sensory tests afford more reliable and sensitive results but are not used clinically because they are expensive and time-consuming. One common objective test involves electrophysiologic evocation of trigeminal somatosensory potentials; peripheral nerves are electrically stimulated with small (safe) pulses at several points.[26,27]

We found that the TPD test was very subjective, thus poorly reproducible and unreliable; moreover, the results varied extensively and were often inconsistent. The SW test was more reliable and consistent[28]; we agree with other authors that this should be the gold standard of sensory tactile tests. Problems with the TPD test have been discussed in many studies. For example, Rosen et al. suggested that the 2 points have to be applied at absolutely the same time; if not, the 2 points may be distinguished on the basis of temporal, rather than spatial, considerations, reflecting the confusion of the patient, who then provides erroneous information.[29] TPD data can be influenced by gender, age, the applied force, and the tip bluntness or sharpness.[30-32] Won et al. reported that females were more sensitive than males, perhaps because of a higher mechanoreceptor density in the orofacial region.[33]

We observed a higher incidence of TPD-indicated NSD at 1 year (11.1%) than at 3 months (7.7%) postoperatively; we believe that this reflects the unreliability of the test. The TPD test remains very controversial, particularly given the lack of a standardized protocol, but it remains commonly used because it is simple. The TPD test should not be the sole method used; the SW test, or pin tactile discrimination test, is also required. Additionally, inexperienced clinicians require training before using the TPD test.

We found that the split type did not affect the NSD incidence; in future studies, we will explore whether the depth and area of the mandibular foramen are relevant in this context. Further studies are necessary to help us better understand the most common complication of BSSO.

CONCLUSIONS

The split pattern did not affect the NSD rate except at 1 month postoperatively (TPD test).

REFERENCES

1. Frey DR, Hatch JP, Van Sickels JE, Dolce C, Rugh JD. Effects of surgical mandibular advancement and rotation on signs and symptoms of temporomandibular disorder: a 2-year follow-up study. *Am J Orthod Dentofacial Orthop*. 2008;133:490-498.
2. Ding Y, Xu TM, Lohrmann B, Gellrich NC, Schwestka-Polly R. Stability following combined orthodontic−surgical treatment for skeletal anterior open bite—a cephalometric 15-year follow-up study. *J Orofac Orthop*. 2007;68:245-256.
3. Agbaje J, Luyten J, Politis C. Pain complaints in patients undergoing orthognathic surgery. *Pain Res Manag*. 2018;2018:4235025.
4. Baas EM, Horsthuis RB, de Lange J. Subjective alveolar nerve function after bilateral sagittal split osteotomy or distraction osteogenesis of mandible. *J Oral Maxillofac Surg*. 2012;70:910-918.
5. Al-Bishri A, Rosenquist J, Sunzel B. On neurosensory disturbance after sagittal split osteotomy. *J Oral Maxillofac Surg*. 2004;62:1472-1476.
6. D'Agostino A, Trevisiol L, Gugole F, Bondi V, Nocini PF. Complications of orthognathic surgery: the inferior alveolar nerve. *J Craniofac Surg*. 2010;21:1189-1195.
7. Essick GK. Psychophysical assessment of patients with posttraumatic neuropathic trigeminal pain. *J Orofac Pain*. 2004;18:345-354.
8. Jääskeläinen SK, Teerijoki-Oksa T, Virtanen A, Tenovuo O, Forssell H. Sensory regeneration following intraoperatively verified trigeminal nerve injury. *Neurology*. 2004;62:1951-1957.
9. Wijbenga JG, Verlinden CR, Jansma J, Becking AG, Stegenga B. Long-lasting neurosensory disturbance following advancement of the retrognathic mandible: distraction osteogenesis versus bilateral sagittal split osteotomy. *Int J Oral Maxillofac Surg*. 2009;38:719-725.
10. Yamauchi K, Takahashi T, Kaneuji T, et al. Risk factors for neurosensory disturbance after bilateral sagittal split osteotomy based on position of mandibular canal and morphology of mandibular angle. *J Oral Maxillofac Surg*. 2012;70:401-406.
11. Agbaje JO, Salem AS, Lambrichts I, Jacobs R, Politis C. Systematic review of the incidence of inferior alveolar nerve injury in bilateral sagittal split osteotomy and the assessment of neurosensory disturbances. *Int J Oral Maxillofac Surg*. 2015;44:447-451.
12. Möhlhenrich SC, Kniha K, Peters F, et al. Fracture patterns after bilateral sagittal split osteotomy of the mandibular ramus according to the Obwegeser/Dal Pont and Hunsuck/Epker modifications. *J Craniomaxillofac Surg*. 2017;45:762-767.
13. Muto T, Takahashi M, Akizuki K. Evaluation of the mandibular ramus fracture line after sagittal split ramus osteotomy using 3-dimensional computed tomography. *J Oral Maxillofac Surg*. 2012;70:e648-e652.
14. Plooij JM, Naphausen MT, Maal TJ, et al. 3 D evaluation of the lingual fracture line after a bilateral sagittal split osteotomy of the mandible. *Int J Oral Maxillofac Surg*. 2009;38:1244-1249.
15. Dreiseidler T, Bergmann J, Zirk M, Rothamel D, Zöller JE, Kreppel M. Three-dimensional fracture pattern analysis of the Obwegeser and Dal Pont bilateral sagittal split osteotomy. *Int J Oral Maxillofac Surg*. 2016;45:1452-1458.
16. Song JM, Kim YD. Three-dimensional evaluation of lingual split line after bilateral sagittal split osteotomy in asymmetric prognathism. *J Korean Assoc Oral Maxillofac Surg*. 2014;40:11-16.
17. Hunsuck EE. A modified intraoral sagittal splitting technic for correction of mandibular prognathism. *J Oral Surg*. 1968;26:250-253.
18. Weber EH. Uber den tastsinn. *Arch Anatom Physiol Wissenschaftliche Med*. 1835:152-160. [in German].
19. Westermark A, Englesson L, Bongenhielm U. Neurosensory function after sagittal split osteotomy of the mandible: a comparison between subjective evaluation and objective assessment. *Int J Adult Orthod Orthognath Surg*. 1999;14:268-275.
20. Kim YK, Kim SG, Kim JH. Altered sensation after orthognathic surgery. *J Oral Maxillofac Surg*. 2011;69:893-898.

21. Van Sickels JE, Hatch JP, Dolce C, Bays RA, Rugh JD. Effects of age, amount of advancement, and genioplasty on neurosensory disturbance after a bilateral sagittal split osteotomy. *J Oral Maxillofac Surg*. 2002;60:1012-1017.
22. Brusati R, Fiamminghi L, Sesenna E, Gazzotti A. Functional disturbances of the inferior alveolar nerve after sagittal osteotomy of the mandibular ramus: operating technique for prevention. *J Maxillofac Surg*. 1981;9:123-125.
23. Sunderland S. A classification of peripheral nerve injuries producing loss of function. *Brain*. 1951;74:491-516.
24. Deumens R, Bozkurt A, Meek MF, et al. Repairing injured peripheral nerves: bridging the gap. *Prog Neurobiol*. 2010;92:245-276.
25. Giannì AB, D'Orto O, Biglioli F, Bozzetti A, Brusati R. Neurosensory alterations of the inferior alveolar and mental nerve after genioplasty alone or associated with sagittal osteotomy of the mandibular ramus. *J Cranio-Maxillofac Surg*. 2002;30:295-303.
26. Ylikokontiola L, Kinnunen J, Oikarinen K. Comparison of different tests assessing neurosensory disturbance after bilateral sagittal split osteotomy. *Int J Oral Maxillofac Surg*. 1998;27:417-421.
27. Teerijoki-Oksa T, Jääskeläinen S, Forssell K, Virtanen A, Forssell H. An evaluation of clinical and electrophysiologic tests in nerve injury diagnosis after mandibular sagittal split osteotomy. *Int J Oral Maxillofac Surg*. 2003;32:15-23.
28. Vaira LA, Massarelli O, Gobbi R, Biglio A, De Riu G. Tactile recovery assessment with shortened Semmes-Weinstein monofilaments in patients with buccinator myomucosal flap oral cavity reconstructions. *Oral Maxillofac Surg*. 2018;22:151-156.
29. Lundborg G, Rosén B. The two-point discrimination test−time for a re-appraisal. *J Hand Surg Br*. 2004;29:418-422.
30. Chen CC, Essick GK, Kelly DG, Young MG, Nestor JM, Masse B. Gender-, side- and site-dependent variations in human perioral spatial resolution. *Arch Oral Biol*. 1995;40:539-548.
31. Kaneko A, Asai N, Kanda T. The influence of age on pressure perception of static and moving two-point discrimination in normal subjects. *J Hand Ther*. 2005;18:421-424.
32. Vriens JP, van der Glas HW. The relationship of facial two-point discrimination to applied force under clinical test conditions. *Plast Reconstr Surg*. 2002;109:943-952.
33. Won S-Y, Kim H-K, Kim M-E, Kim K-S. Two-point discrimination values vary depending on test site, sex and test modality in the orofacial region: a preliminary study. *J Appl Oral Sci*. 2017;25:427-435.

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