

Research Article

Transversal Width of Mandibular Bone and Neurosensory Disturbance after Bilateral Sagittal Splitting Ramus Osteotomy

Yuichiro Takaku^a Masayuki Takano^a Shuichiro Yamashita^b
Kenichi Fukuda^c

Departments of ^aOral and Maxillofacial Surgery, and ^bRemovable Partial Prosthodontics, and ^cDivision of Special Needs Dentistry and Orofacial Pain, Department of Oral Health and Clinical Science, Tokyo Dental College, Tokyo, Japan

What Is It about?

Long-term residual neurosensory disturbances (NSD) can be problematic after bilateral sagittal splitting ramus osteotomy (BSSRO) of the mandible. To predict a general prognosis, we evaluated preoperative computed tomography images of 58 lateral mandibles (29 BSSRO patients) to determine whether the condition of mandibular cancellous and cortical bone influences postoperative development of NSD in the mental nerve region. Transversal width of the entire mandible was significantly different in region II between patients with and without NSD at 6 months after surgery ($p < 0.05$) and may be an important factor in predicting NSD incidence.

Keywords

Bilateral sagittal splitting ramus osteotomy · Neurosensory disturbance · Mandibular · Computed tomography

Abstract

Objective: This study evaluated the condition of mandibular cancellous and cortical bone on computed tomography (CT) images in order to investigate its relationship with the incidence of neurosensory disturbances (NSD) in the mental nerve region after bilateral sagittal splitting ramus osteotomy (BSSRO). **Methods:** BSSRO was performed on 58 lateral mandibles in 29 patients. From preoperative CT images, the width endpoints of the transversal bone were measured in region I immediately inferior to the mandibular foramen, region II in the mandibular angle region, and region III distal to the lower second molar. The incidence of NSD immediately after surgery and the residual NSD rate at 1, 3, and 6 months after surgery were inves-

This paper was originally a doctoral thesis submitted to the Graduate School of Tokyo Dental College in March 2012 (No. 1931) but has not been published previously.

Yuichiro Takaku
Department of Dentistry and Oral Surgery
National Hospital Organization Tokyo Medical Center
2-5-1 Higashigaoka, Meguro-ku, Tokyo 152-8902 (Japan)
E-Mail ytakaku@ntmc-hosp.jp

tigated. The correlation between incidence of NSD in the mental nerve region and each transversal bone width endpoint immediately after and at 6 months after surgery was also comparatively evaluated. **Results:** The overall incidence of NSD immediately after surgery was 67.2% (39/58 sides) and the overall residual NSD rate at 1, 3, and 6 months after surgery was 53.4% (31/58 sides), 31.0% (18/58 sides), and 17.2% (10/58 sides), respectively. No significant differences were observed for any width endpoints of the transversal bone measured at regions I or III, but the transversal width of the entire mandible was significantly different in region II between patients with and without NSD at 6 months after surgery ($p < 0.05$). **Conclusion:** These findings demonstrate that the transversal width of the entire mandible may be an important factor in predicting NSD incidence.

© 2017 The Author(s)
Published by S. Karger AG, Basel

Introduction

Bilateral sagittal splitting ramus osteotomy (BSSRO) of the mandible is an established procedure in oral and maxillofacial surgery [1, 2]. Although BSSRO has numerous advantages – it can be performed as an intraoral procedure, it results in a wide bone contact area, and it allows greater movement of the separated bone fragments – it also may promote the development of postoperative neurosensory disturbances (NSD) in the mental nerve region [3–5]. Preoperative computed tomography (CT) is now performed routinely, allowing BSSRO to be planned based on a detailed understanding of the characteristics of the cancellous bone and position of the mandibular canal; however, there remains an urgent need for new imaging techniques and evaluation methodologies that would allow the risk of NSD to be more accurately assessed.

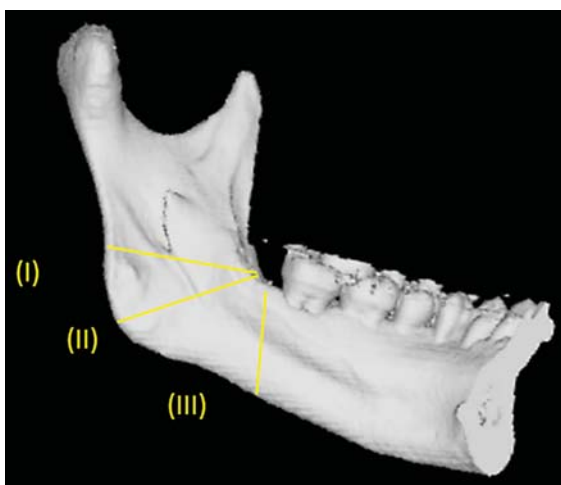
NSD, whose incidence has been attributed to various factors, occurs relatively infrequently after intraoral vertical ramus osteotomy [6], which also involves cutting the mandibular ramus. Therefore, its occurrence following BSSRO is believed to be associated with the close postoperative proximity of cancellous bone from the split portion to the mandibular canal. Previous studies have investigated the development of NSD based on measurement of the distance between the mandibular canal and external cortical bone or the course of the mandibular canal through the mandible [7–11] but did not assess preoperative CT images.

The present study therefore used CT images to evaluate the relationship between the condition of mandibular cancellous and cortical bone and the development of NSD in the mental nerve region. Recovery from NSD over time was also considered, given that long-term residual NSD can be problematic, particularly in the mental nerve region. An association was hypothesized between the transversal width of the cancellous and cortical bone of the mandible and NSD after BSSRO.

Materials and Methods

BSSRO was performed on 58 sides in 29 mandibles (11 males and 18 females; mean age \pm standard deviation, 28.5 ± 10.0 years; age range, 17–49 years) at the Department of Oral and Maxillofacial Surgery, Tokyo Dental College Suidobashi Hospital, from December 2008 through March 2011. The operating surgeon was the lead author of this paper and is a specialist in oral and maxillofacial surgery. Inclusion criteria were indication for surgery of mandibular prognathism ($n = 24$) or retrognathia ($n = 5$). Exclusion criteria were any psycho-

Fig. 1. Measurement sites on the mandible: plane parallel to the occlusal plane, 1 mm from the mandibular foramen (I); plane from the gonion to the anterior margin of the osteotomy line according to the 1957 Obwegeser method (II); plane perpendicular to the occlusal plane connecting the distal proximal surface of the mandibular second molar (III).

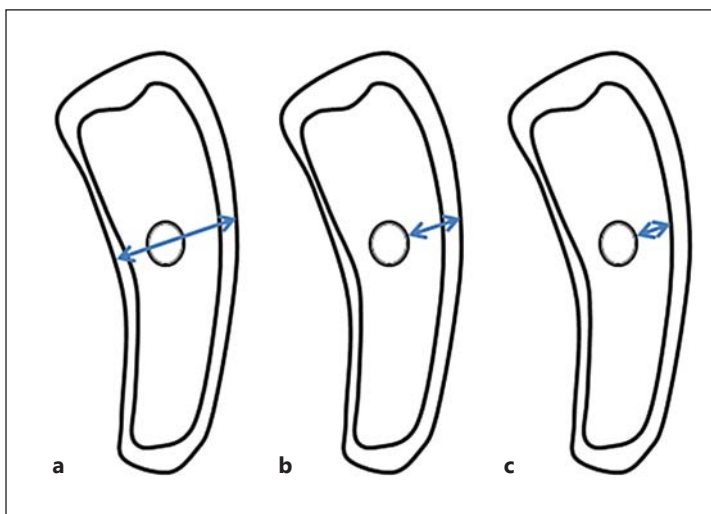


logical or physical disorder that might affect recovery of peripheral nerve disturbance. The surgical treatment plan was explained to the patients and their families and informed consent obtained. In addition, the study was carried out with the approval of the Ethics Committee of Tokyo Dental College (No. 304).

This study sought to obtain data for the purpose of predicting a general prognosis. Therefore, the results were examined collectively, without consideration of distance or direction of movement. As a rule, the lateral osteotomy line was determined according to the 1957 Obwegeser method [12] for mandibular prognathism and the Obwegeser-Dal Pont method [13] for retrognathism. The osteotomy procedure was as follows: (1) the lingual cortex of the ramus was cut with a Lindemann bur along a line 5 mm above the mandibular foramen and parallel to the occlusal plane of the mandible; (2) the buccal cortical bone of the mandible was cut with a Lindemann bur along a line from the distal region of the lower second molar to the mandibular angle; (3) the sagittal split line was cut using a drill, Fisher bur, and reciprocating bone saw, and carefully split with bone chisels and a bone separator. After maxillary-mandibular fixation, the bone segments were fixed using a titanium locking miniplate and monocortical screws on each side. The distance of movement of the mandibular body was <11 mm in mandibular setback surgery and <9 mm in advancement surgery. No severe intraoperative complications such as abnormal bleeding, fracture, or soft tissue damage were observed in any patient. Patients who complained of NSD following surgery were treated orally with a B₁₂ preparation containing a nerve stimulant until the impairment resolved.

The Somatom Emotion Duo CT scanner (Siemens, Germany) was used for CT under the following scanning conditions: tube voltage, 130 kV; tube current, 65 mA; field of view, 150 mm; voxel size, 0.29 mm; slice thickness, 1.25 mm; and slice interval, 1 mm. Based on preoperative CT images, measurements were made along the following 3 planes: (I) a plane parallel to the occlusal plane, 1 mm from the mandibular foramen; (II) a plane from the gonion to the anterior margin of the osteotomy line defined according to the 1957 Obwegeser method [12]; and (III) a plane perpendicular to the occlusal plane, connecting the distal proximal surface of the mandibular second molar (Fig. 1). These measurements were then used to determine the following 3 variables: (a) the transverse width of the entire mandible; (b) the combined transverse width of the buccal cortical bone and cancellous bone up to the outer wall of the mandibular canal; and (c) the transverse width of the cancellous bone from the inner edge of the buccal cortical bone to the outer wall of the mandibular canal. Each line and extension

Fig. 2. Three variables used as the transversal width of bone endpoints: transverse width of the entire mandible (a); combined transverse width of the buccal cortical and cancellous bone up to the outer wall of the mandibular canal (b); transverse width of the cancellous bone from the inner edge of the buccal cortical bone to the outer wall of the mandibular canal (c).



passed through the midpoint of the mandibular canal at the shortest distance, and these 3 variables were used as the transversal width of bone endpoints (Fig. 2).

To examine the development of NSD, we examined each patient preoperatively to verify the absence of sensory disturbance in the area innervated by the mental nerve. Then, after SSRO, we diagnosed NSD if any subjective symptom of anesthesia, hypoesthesia, dysesthesia, and paresthesia was present in the clinical interviews or during sensory testing with monofilaments. NSD incidence immediately after surgery and recovery and residual NSD rates at 1, 3, and 6 months after surgery were examined. Examinations were performed by the operators via interview and with a monofilament sensory tester. Comparative evaluation of the correlation between NSD incidence in the mental nerve region and each bone endpoint was also performed immediately after and at 6 months after surgery.

The Mann-Whitney U test was used to determine statistical significance. All analysis was performed using the SPSS for Windows Version 11.0 software, with the level of significance set at $p < 0.05$.

Results

Incidence of NSD Immediately after BSSRO

The overall incidence of NSD immediately after surgery was 67.2% (39/58 sides). No severe NSD such as anesthesia was observed.

NSD Recovery and Residual Rates

Among those patients who developed NSD immediately after BSSRO, the recovery rate at 1, 3, and 6 months after surgery was 20.5% (8/39 sides), 53.8% (21/39 sides), and 74.3% (29/39 sides), respectively, while the overall residual NSD rate at the same time points was 53.4% (31/58 sides), 31.0% (18/58 sides), and 17.2% (10/58 sides), respectively (Fig. 3).

Relationship between Postoperative NSD and the Transversal Width of Mandibular Bone

The 3 transversal widths of bone endpoints (a, b, and c) at the 3 measurement regions (I, II, and III) were compared based on presence or absence of NSD immediately after and at 6 months after surgery. No significant difference was observed for any of the transversal widths

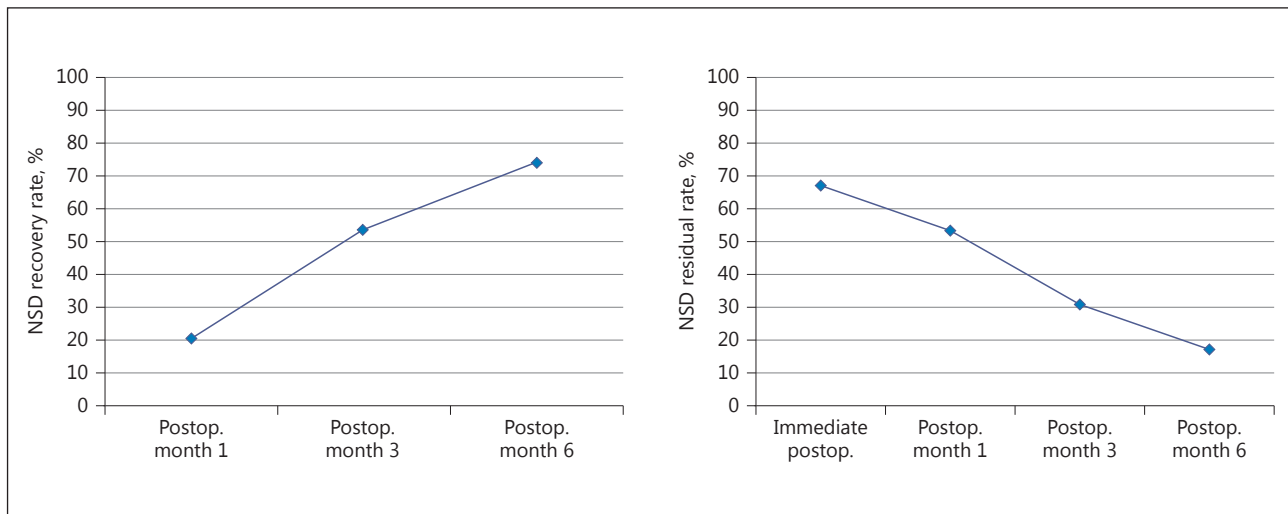


Fig. 3. NSD recovery rate and residual rate.

Table 1. Relationship between postoperative NSD and transversal width of the mandibular bone

	Transversal width, mm	NSD immediately after surgery			NSD at 6 months after surgery		
		yes	no	<i>p</i>	yes	no	<i>p</i>
Mandibular foramen	a	9.13±1.57	9.55±1.53	ns	8.86±1.61	9.35±1.55	ns
	b	4.98±1.61	4.95±1.15	ns	5.13±1.52	4.94±1.47	ns
	c	2.98±1.70	2.71±1.41	ns	3.28±1.66	2.81±1.60	ns
Mandibular angle	a	9.52±1.79	9.76±1.40	ns	9.09±1.85	9.71±1.62	*
	b	4.48±1.36	4.53±1.25	ns	3.97±1.58	4.61±1.24	ns
	c	2.05±1.55	2.16±1.20	ns	1.51±1.64	2.21±1.37	ns
Distal region of second molar	a	10.95±1.64	10.95±1.41	ns	10.39±1.85	11.07±1.49	ns
	b	5.28±2.08	5.54±1.61	ns	4.44±2.70	5.56±1.70	ns
	c	2.94±1.79	3.03±1.66	ns	2.14±2.26	3.15±1.58	ns

NSD, neurosensory disturbances; ns, not significant. a, transversal width of the entire mandible; b, combined transversal width of the buccal cortical bone and cancellous bone to the outer wall of the mandibular canal; c, transversal width of the cancellous bone from the inner edge of the buccal cortical bone to the outer wall of the mandibular canal. * $p < 0.05$ (Mann-Whitney U test).

of the bone endpoints at regions I or III, but there was a significant difference between patients with and without NSD at 6 months after surgery for endpoint a at region II ($p < 0.05$; Table 1). Namely, the width of the entire mandible in patients without NSD was significantly greater than that of patients with NSD. There were, however, no significant differences for the other bone endpoints at region II.

Discussion

Since it was first proposed in 1957 [12], BSSRO has come to be widely practiced in the field of oral and maxillofacial surgery because of its wide adaptability and the postoperative stability it affords.

Typically, surgical treatment of jaw deformities had been preceded by a diagnosis based on 2-dimensional cephalometric analysis using conventional cephalometric radiography alone. However, this approach allows only an approximate estimation of the mandibular osteotomy line and direction of the split, and cannot be used to develop an osteotomy model that takes into consideration the structure of the mandibular ramus and path of the mandibular canal. The introduction of X-ray CT has enabled a more detailed examination of mandibular morphology and structure, allowing surgeons to accurately determine the shape and internal structure of the mandible before operating. New developments in such technology have also allowed treatment plans to benefit from software-assisted 3-dimensional imaging [14], leading to improvements in both quality and safety of medical care. In particular, identifying the internal structure of mandibular cancellous bone is crucial in establishing the safety of BSSRO because this procedure requires the ramus to be split while avoiding injury to the inferior alveolar nerve or inferior alveolar vein running through the mandibular canal [15].

As BSSRO involves performing an osteotomy close to the mandibular canal, postoperative NSD may occur in the mental nerve region. Therefore, detailed and accurate preoperative information is essential to be able to explain the medium-to-long-term prognosis to the patient in detail and obtain informed consent. A number of reports have investigated NSD in patients who have undergone BSSRO [3–5, 16, 17], and some have investigated its onset using CT [7, 8, 11, 18–20]. However, to our knowledge, no studies have reported long-term NSD in BSSRO based on initial evaluation of the width of the cancellous bone, including at sites inside the mandibular canal, using preoperative CT. The present study, therefore, selected the transversal width of the mandibular cancellous and cortical bone as the factor to be evaluated in CT images and investigated its relationship with NSD in the mental nerve region while also assessing recovery from NSD over time. In daily clinical practice, we used the Semmes-Weinstein monofilament sensory test and a two-point discriminator pre- and postoperatively.

The study findings revealed a relatively high incidence of NSD immediately after surgery: 39 of 58 sides (67.2%). However, 74.3% of the affected sides recovered by 6 months after surgery, with NSD persisting in only 17.2% of the study population overall. NSD typically resolve in around 3–6 months, but when they persist beyond this point they often become refractory and ultimately problematic, and this has prompted a number of studies on long-term NSD [21–23]. The NSD recovery period may be prolonged depending on the extent of nerve damage caused by the surgery or postoperative inflammation. The longer it persists, the more likely it is to become refractory, implying that prolonged recovery has greater clinical significance than does the presence or absence of NSD immediately after surgery. Moreover, refractory NSD occurs as a result of direct injury to the mandibular canal or inferior alveolar neurovascular bundle. Therefore, protecting the mandibular canal and neurovascular bundle from damage, which is in fact the aim of BSSRO, is a crucial element of this procedure.

BSSRO involves osteotomy of the medial cortical bone superior to the mandibular foramen on the inner surface of the mandibular ramus, and the lateral cortical bone of the mandibular ramus in the vicinity of the mandibular angle, followed by splitting of the cancellous bone lateral to the mandibular canal from the anterior to posterior borders of the mandibular ramus using a bone saw and chisel/mallet. The mass of cancellous bone in this area has been associated with the occurrence of postoperative NSD. Yoshioka et al. [17] reported that the incidence of NSD of the inferior alveolar nerve at 1 year after BSSRO significantly increased when the distance from the buccal aspect of the inferior alveolar nerve canal to the outer buccal cortical margin was <6 mm. Yamamoto et al. [9] surveyed the width of the medullary cavity at 2-mm intervals, starting directly inferior to the mandibular foramen and moving downwards for 22 mm, and reported a significant difference in the incidence of NSD at 1 year after BSSRO when only ≤0.8 mm of this cavity remained. Meanwhile, after measuring

coronal CT slices at 3 locations on the mandibular ramus, Wittwer et al. [8] found that NSD could occur when the distance between the mandibular canal and the inner surface of the cortical bone was <1 mm or when the mandibular canal came into contact with the external cortical bone. In such cases, the authors recommended computer-assisted modified classical osteotomy or complete individualized osteotomy. In our study, the width of cancellous bone on the buccal side did not differ significantly, but as Table 1 shows, the transversal width of the mandible was smaller at all measurement points, except for b and c in region I, at 6 months in patients with postoperative NSD. Our findings partly support the importance of the buccal cortical bone width as reported in previous studies as well as newly highlight that the entire width of the mandible is also an important factor to consider.

As the position of the mandibular canal within the mandibular ramus varies and cancellous bone may be present between them, there may be cases where the canal and cortical bone are in close proximity or fused together [8, 24]. However, the width of the medullary cavity starting directly inferior to the mandibular foramen is not constant from the mandibular angle to the site where it dissects the lateral cortical bone, and we have encountered patients in clinical practice who do not manifest NSD despite having minimal medullary cavity width on the buccal mandibular canal, as well as patients whose NSD persists despite adequate cavity width. Therefore, in addition to the distance of the buccal mandibular canal to the medullary cavity measured in previous studies, the present study also measured the combined width of the buccal cortical and cancellous bone to the outer wall of the mandibular canal as well as the width of the entire mandible. These measurements were taken at a total of 9 positions immediately inferior to the mandibular foramen, at the mandibular angle region, and at the distal region of the lower second molar; and the presence or absence of NSD was investigated immediately after and at 6 months after BSSRO. No significant difference was observed between patients with and without NSD at either time point at any of the measurement regions for the combined width of buccal cortical and cancellous bone to the outer wall of the mandibular canal, or for the width of cancellous bone from the inner edge of the buccal cortical bone to the outer wall of the mandibular canal. These findings invalidate the assumption, made in previous reports, that cancellous bone mass sandwiched between the lateral cortical bone and buccal wall of the mandibular canal always affects the onset of postoperative NSD and delays medium- to long-term recovery.

Conversely, a significant difference was observed between patients with and without NSD at 6 months after surgery in the width of the entire mandible at the mandibular angle region. This suggests that total mandible thickness in the vicinity of the mandibular angle region influences the long-term prognosis for NSD recovery. While previous studies have reported that buccal bone thickness and the width of split cancellous bone affect the onset and long-term persistence of NSD, the present findings demonstrate that these variables have little impact on NSD, and instead that the transversal width of the total mandible might be an influential factor.

In BSSRO, the mandible is repositioned and the occlusion reconstructed after the mandibular ramus has been split into lateral and medial bone fragments, which may result in physical stimulation and injury to the inferior alveolar neurovascular bundle, causing NSD. However, the above findings suggest that the transversal width between the lateral cortical bone and mandibular canal is only one factor in the development of NSD. Moreover, the application of preoperative CT in clinical practice has enabled surgeons to identify the position and path of the mandibular canal, helping to reduce the probability of damage to the inferior alveolar neurovascular bundle. Preoperative CT was also used in the present study to confirm the path and positional relationship of the mandibular canal. Therefore, we believe that any direct damage to the neurovascular bundle would have been minimal. Meanwhile, the finding of a significant difference at the mandibular angle region may have been due not only to

mechanical stimulation from surgical instruments, but also to postoperative reactions and inflammation, such as hematoma and edema from postoperative intramedullary bleeding or stimulation by bone fragment migration.

Accurately predicting the onset of postoperative NSD in the mental nerve region – and, when it does occur, forecasting its prognosis as accurately as possible – would be very beneficial to the patient.

Conclusions

Although previous studies have suggested that buccal bone thickness and the width of split cancellous bone affect the incidence and long-term persistence of NSD after BSSRO, differences in the transversal width of cancellous bone showed no marked effect on NSD in the present study involving CT-assisted surgery. However, the results do suggest that the transversal width of the entire mandible is an important factor in predicting the incidence of medium- and long-term NSD.

Statement of Ethics

The surgical treatment plan was explained to the patients and their families, and informed consent was obtained. In addition, the present study was carried out with the approval of the Ethics Committee of Tokyo Dental College (No. 304).

Disclosure Statement

The authors declare no conflicts of interest.

Sources of Funding

None.

References

- 1 Booth WP, Schendel AS: Orthognathic surgery; in Ward Booth P, Schendel SA, Hausamen J-E (eds): Maxillofacial Surgery, ed 2. Hong Kong, Churchill Livingstone, 1999, pp 1205–1320.
- 2 Naumann H: Mandibular osteotomies; in Naumann HH (ed): Head and Neck Surgery: Face and Facial Skull, ed 2. Stuttgart, Thieme, 1980, pp 190–217.
- 3 Takasaki Y, Noma H, Masaki H, Fujikawa M, Alberdas JL, Tamura H, Ueda E, Takaki T, Yamane G: A clinical analysis of the recovery from sensory disturbance after sagittal splitting ramus osteotomy using a Semmes-Weinstein pressure aesthesiometer. Bull Tokyo Dent Coll 1998;39:189–197.
- 4 Westermark A, Bystedt H, von Konow L: Inferior alveolar nerve function after mandibular osteotomies. Br J Oral Maxillofac Surg 1998;36:425–428.
- 5 Westermark A, Bystedt H, von Konow L: Inferior alveolar nerve function after sagittal split osteotomy of the mandible: correlation with degree of intraoperative nerve encounter and other variables in 496 operations. Br J Oral Maxillofac Surg 1998;36:429–433.
- 6 Takazakura D, Ueki K, Nakagawa K, Marukawa K, Shimada M, Shamiul A, Yamamoto E: A comparison of postoperative hypoesthesia between two types of sagittal split ramus osteotomy and intraoral vertical ramus osteotomy, using the trigeminal somatosensory-evoked potential method. Int J Oral Maxillofac Surg 2007;36: 11–14.

- 7 Ma J, Lu L: Computed tomography morphology of the mandibular ramus at the lingual plane in patients with mandibular hyperplasia. *Int J Oral Maxillofac Surg* 2009;38:823–826.
- 8 Wittwer G, Adeyemo WL, Beinemann J, Juergens P: Evaluation of risk of injury to the inferior alveolar nerve with classical sagittal split osteotomy technique and proposed alternative surgical techniques using computer-assisted surgery. *Int J Oral Maxillofac Surg* 2012;41:79–86.
- 9 Yamamoto R, Nakamura A, Ohno K, Michi K: Relationship of the mandibular canal to the lateral cortex of mandibular ramus as a factor in the development of neurosensory disturbance after bilateral sagittal split osteotomy. *J Oral Maxillofac Surg* 2002;60:490–495.
- 10 Yamauchi K, Takahashi T, Kaneuji T, Nogami S, Yamamoto N, Miyamoto I, Yamahsita Y: 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 Yoshioka I, Tanaka T, Khanal A, Habu M, Kito S, Komada M, Oda M, Wakasugi-Sato N, Matsumoto-Takeda S, Fukai Y, Tokitsu T, Tomikawa M, Seta Y, Tominaga K, Morimoto Y: Relationship between inferior alveolar nerve canal position at mandibular second molar in patients with prognathism and possible occurrence of neurosensory disturbance after sagittal split ramus osteotomy. *J Oral Maxillofac Surg* 2010;68:3022–3027.
- 12 Trauner R, Obwegeser H: The surgical correction of mandibular prognathism and retrognathia with consideration for genioplasty. I. Surgical procedures to correct mandibular prognathism and reshaping of the chin. *Oral Surg Oral Med Oral Pathol* 1957;10:677–689.
- 13 Dol Pont G: Retromolar osteotomy for the correction of prognathism. *J Oral Surg Anesth Hosp Dent Serv* 1961;19:42–47.
- 14 Mori Y, Shimizu H, Minami K, Kwon TG, Mano T: Development of a simulation system in mandibular orthognathic surgery based on integrated three-dimensional data. *Oral Maxillofac Surg* 2011;15:131–138.
- 15 Yu IH, Wong YK: Evaluation of mandibular anatomy related to sagittal split ramus osteotomy using 3-dimensional computed tomography scan images. *Int J Oral Maxillofac Surg* 2008;37:521–528.
- 16 Fujioka M, Hirano A, Fujii T: Comparative study of inferior alveolar disturbance restoration after sagittal split osteotomy by means of bicortical versus monocortical osteosynthesis. *Plast Reconstr Surg* 1998;102:37–41.
- 17 Yoshioka I, Tanaka T, Habu M, Oda M, Komada M, Kito S, Seta Y, Tominaga K, Sakoda S, Morimoto Y: Effect of bone quality and position of the inferior alveolar nerve canal in continuous, long-term, neurosensory disturbance after sagittal split ramus osteotomy. *J Craniomaxillofac Surg* 2012;40:178–183.
- 18 Colella G, Cannavale R, Vicidomini A, Lanza A: Neurosensory disturbance of the inferior alveolar nerve after bilateral sagittal split osteotomy: a systematic review. *J Oral Maxillofac Surg* 2007;65:1707–1715.
- 19 Tsuji Y, Muto T, Kawakami J, Takeda S: Computed tomographic analysis of the position and course of the mandibular canal: relevance to the sagittal split ramus osteotomy. *Int J Oral Maxillofac Surg* 2005;34:243–246.
- 20 Yoshioka I, Tanaka T, Khanal A, Habu M, Kito S, Kodama M, Oda M, Wakasugi-Sato N, Matsumoto-Takeda S, Seta Y, Tominaga K, Sakoda S, Morimoto Y: Correlation of mandibular bone quality with neurosensory disturbance after sagittal split ramus osteotomy. *Br J Oral Maxillofac Surg* 2011;49:552–556.
- 21 August M, Marchena J, Donady J, Kahan L: Neurosensory deficit and functional impairment after sagittal ramus osteotomy: a long-term follow-up study. *J Oral Maxillofac Surg* 1988;56:1231–1235.
- 22 Martis CS: Complications after mandibular sagittal split osteotomy. *J Oral Maxillofac Surg* 1984;42:101–107.
- 23 Muto T, Shigeo K, Yamamoto K, Kawakami J: Computed tomography morphology of the mandibular ramus in prognathism: effect on the medial osteotomy of the sagittal split ramus osteotomy. *J Oral Maxillofac Surg* 2003;61:89–93.
- 24 Tamas F: Position of mandibular canal. *J Oral Maxillofac Surg* 1978;16:65–69.