Intraoperative Computed Tomography in Bilateral Sagittal Split Osteotomy

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Received: 18 February 2015 / Accepted: 11 November 2015 / Published online: 11 December 2015
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Abstract

Objectives The objective of the study was to show the importance of intraoperative computed tomography as an aid for ensuring inferior alveolar nerve safety during bilateral sagittal split osteotomy.

Materials and Methods This study included ten patients who underwent bilateral sagittal split osteotomy procedure. All patients were treated for orthognathic reasons. The unerupted lower third molars, if present, were removed at least 6 months prior to Sagittal Split Osteotomy. The Sagittal Split Osteotomy surgical technique was previously described in detail. Each patient underwent computed tomography with an Artis Zeego multi-axis system (Siemens AG, Healthcare Sector, Henkestrasse 127 D-91052 Erlangen, Germany) at the beginning of the operation and immediately after placement of the osteosynthesis plates and screws. The neurosensory tests consisted of a light touch test using the 5.07/10-g Semmes Weinstein monofilament (Stoelting Co, Wood Dale, IL), and patient self-reporting.

Results Eight (80 %) patients presented with hypoaesthesia of lower lip at 6 weeks follow up. At 6 month follow up only two patients (20 %) presented with diminished sensation in the lower lip. Labial sensibility was normal in all patients at the last follow-up visit.

Conclusion Intraoperative computed tomography enables immediate assessment of treatment and the option to modify the treatment if necessary. Our results indicate that intra-operative computed tomography would be a helpful procedure during orthognathic surgery to improve the postoperative health of the inferior alveolar nerve.

Keywords Inferior alveolar nerve · Orthognathic surgery · Osteotomy · Sagittal split ramus · Computed tomography

Introduction

Inferior alveolar nerve (IAN) damage is a major complication of sagittal split osteotomy (SSO) [1–3]. IAN injury results from manipulation of the nerve or structures surrounding the nerve, or from direct injury to the nerve during the operation [4–6]. The IAN can be damaged at the lingula during placement of the retractor posterior to or above the lingual, at the ascending ramus during horizontal osteotomy, at the bone cut at the lower border of the mandible, at the connecting bone cut between the lower border and the buccal osteotomy of the mandibular body, in the course of chiseling during the sagittal split (Fig. 1), due to impingement of the nerve between bone fragments after the bony movement, due to compression of the IAN during the placement of osteosynthesis material, and due to piercing of the nerve with the osteosynthesis screw (Fig. 2).

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Fig. 1 A lateral view of the mandible shows the locations of possible nerve damage during SSO

Fig. 2 IAN nerve damage by osteosynthesis screw during SSO

Cone beam computed tomography (CBCT) enables surgeons to locate the neurovascular bundle in three dimensions and to assess the position of the IAN in relation to the buccal plate and the lower border of the mandible. Surgeons can also make individual modifications to the approach of the lower border cut depending on the distance of the neurovascular bundle from the lower border and the buccal plate (Fig. 3).

Several methods have been devised to reduce the incidence of nerve damage following BSSO. One such method involves the identification and annotation of IAN position on patient's panoramic images [7]; this information is used to guide the surgeon during the operation (Fig. 4). A second CBCT-based method permits calculation of the linear distance from the buccal cortical margin of the IAN canal to the inner buccal cortical margin of the mandible (nerve to inner buccal plate), as well as determination of the linear distance from the inferior aspect of the IAN canal to the inner inferior border of the mandible (nerve to inner lower border) (Fig. 3) [7]. These measured linear distances indicate the approximate position of the IAN in this region, which is important information that helps the surgeons

Fig. 3 CBCT visualizes the IAN (left) as well as the distance from the neurovascular bundle to the lower border and the buccal plate (right)

know how close the nerve is to the lower border and the buccal plate during a lower border cut.

A third method involves nerve protection during the horizontal bone cut technique. In the classical BSSO technique, the IAN is prone to injury at the point of entry into the mandibular foramen during the horizontal bone cut. Before lingual osteotomy, the lingula, which lies above the opening of the mandibular canal, is located and canal entry is ascertained by using a hook-like object during placement of the Dumbach retractor. To ensure that the nerve hook is properly placed, visual control of the operating site must be established. Direct visualization is achieved by using a thick, round drill to remove the bony curvature on the medial side of the ascending ramus that obstructs a direct view of the mandibular foramen [8]. During the horizontal bone cut, the Hall burr is aimed at the mandibular foramen, endangering the exposed nerve. To better protect the IAN at this point, the nerve hook is carefully placed in the anterior part of the mandibular canal with the IAN lying posterior to the instrument, which

Fig. 4 Annotation of IAN position on patient's panoramic images (*top*) and images from CBCT (*bottom*)

protects it from possible damage from the rotating burr or chisel during the horizontal cut (Fig. 5).

Previous studies indicated that IAN attachment to the proximal segment of the mandible occurs in $\sim 39\%$ of BSSO sites [7, 9]. In the majority of these sites, a bone-cutting instrument is required to free the nerve, which increases the operating time and the possibility of nerve damage. To reduce nerve attachment to the proximal segment of the mandible during BSSO, a modified technique to control the lower border cut was developed by Politis et al. [10]. This technique reduces nerve attachment to the proximal segment of the mandible during BSSO from ~ 38 to 16% , with a consequent reduction in self-reported changed sensibility from 15.1% in the classical technique to 9.4% in the new technique [10]. In this modified technique [10], the lower border is divided into a lingual fragment that

Fig. 5 Proper placement of a nerve hook into the anterior aspect of the mandibular canal. This placement prevents nerve damage due to drilling during an osteotomy cut

Fig. 6 Buccal osteotomy technique: **a** illustration of old and new technique **b** a piezoelectric ultrasonic device is used to make the lower border cut that divides the lower border into a lingual and a buccal fragment

remains incorporated in the tooth-bearing fragment and a buccal fragment that comes with the proximal fragment (buccal plate). To achieve this division, the lower border cut vertically passes through the partial thickness of the border (Fig. 6). In the initial study, a bevel was constructed with a round burr on the distal end of the lower border cut to make room for a piezoelectric ultrasonic device (Mectron s.p.a., Bois d'Amont, France), which was used to divide the lower border into

lingual and buccal fragments (Fig. 6). However, the problems of nerve impingement between bone fragments after the bony movement, compression of the nerve during placement of the osteosynthesis material, and piercing of the IAN with osteosynthesis screws are yet to be solved.

The objective of the study was to show the importance of intraoperative computed tomography (CT) as an aid for ensuring IAN safety during BSSO surgery.

Materials and Methods

This study included ten patients who underwent BSSO procedure. These patients were treated for orthognathic reasons. The unerupted lower third molars, if present, were removed at least 6 months prior to SSO. This study complied with the principles laid down in the Declaration of Helsinki. All subjects agreed and signed informed consent forms before being included in the study. The study was approved by the ethical committee of UZ Leuven S55873.

During the preoperative examination, all patients underwent CBCT. Images were acquired using the Galileos CBCT scanner (Sirona Dental Systems, Bensheim, Germany). Each patient was positioned with the median sagittal plane perpendicular to the horizontal plane, as recommended by the scanner patient positioning protocol reference manual. The vertical laser-positioning guide was used to guide the proper orientation and positioning of each patient's head. Scans were made at 42 mAs and 85 kV, with a scan time of 14 s. Upon completion, panoramic views were automatically generated and presented using Galaxis software. These panoramic images were annotated with the position of the IAN and used during the operation to guide the surgeon (Fig. 4).

All procedures were conducted by the same surgeon using the same approach. The surgeon's experience included more than 1000 BSSO procedures. The SSO surgical technique was previously described in detail [11]. First, a horizontal bone cut was made with a Hall burr, aiming at the mandibular foramen. Protection of the soft tissues at the ascending ramus was ensured by use of a Dumbach retractor. Then, the osteotomy line was extended with the same Hall burr from the body of the mandible vestibular to the first molar. There, the vertical bone cut was made with the Hall burr.

Drilling of the lower border occurred in a closed mouth position, using an Obwegeser retractor and a fine suction device with a bright light at the tip, thus ensuring an excellent view during drilling. The lower border was divided into a lingual fragment and a buccal fragment (Fig. 6). Next, the vertical cut of the mandibular body osteotomy was made, connecting the lower border cut to the buccal osteotomy of the mandibular body. The second stage of the split was carried out using blunt-wedge osteotomes.

Each patients underwent CT with an Artis Zeego multi-axis system (Siemens AG, Healthcare Sector, Henkestrasse 127 D-91052 Erlangen, Germany) at the beginning of the operation and immediately after placement of the osteosynthesis plates and screws. Patients scans were done with C-arm at dose of 0.3 mSv with scanning time of 5 s,

in 2 × 2 Binning Mode that is used for 3D C-arm imaging for the head and neck.

Assessment of Postoperative Changes in Lower-Lip Sensation

Data from follow-up appointments of 10 consecutive patients treated with BSSO osteotomy were collected from patients. These patients were followed up at specific intervals of 1, 6 weeks, 3, 6 months and 1 year and the progress of the alter sensation were monitored over these periods. The assessment of the inferior alveolar nerve was done clinically preoperatively and postoperatively at follow up intervals. The neurosensory tests consisted of a light touch test using the 5.07/10-g Semmes Weinstein monofilament (Stoelting Co, Wood Dale, IL), and patient self-reporting.

The primary outcome measure was the presence of sensibility disturbance in the lower lip at the last follow-up visit. This sensation in the lower lip was categorized by the assessor as normal, hypoesthesia, hyperesthesia, or slightly diminished sensation in the central area of the chin [12]. The diagnosis was based on history and findings on physical examination as well as sensory testing [13]. The hypoesthesia group included data only on the presence or absence of neurosensory disturbance, not its severity.

Statistical Analysis

Descriptive statistics were used to describe patient and operation characteristics.

Results

The analysis included 20 operation sites (OPS) (from mandible) from 10 subjects (6 females, 4 males).

Immediate image generation from intraoperative CT enabled visualization of the state of the mandibular bone and the depth of the screws in the region of the osteosynthesis in all patients (Fig. 7).

Postoperative Changes in Lower-Lip Sensation in BSSO Patients

Eight (80 %) patients presented with lip sensibility at 6 weeks follow up (hypoesthesia of lower lip).

By 6 month follow up only two patients (20 %) presented with diminished sensation in the lower lip. Labial sensibility was normal in all patients at the last follow-up visit.

Fig. 7 Diagram of Intraoperative CT set up: **a** Artis Zeego CT machine **b** immediate CT image generated in the region of the osteosynthesis

Discussion

Neurosensory disturbances resulting from IAN injury are common complications of BSSO surgery, since injury can cause mild numbness, the loss of pain sensation, or even complete loss of the perception of stimulation. Previously, 9–85 % of patients reported varying degrees of numbness in the lower lip and chin [14]. Unpleasant sensations such as allodynia, dysesthesia, paresthesia, and continuous aching in the lower face (hyperalgesia, neuralgia) have far-reaching effects on the everyday lives of affected patients and result in negative social effect [3, 15, 16].

Proper localization of the IAN before the procedure is an essential preventive step. Although conventional radiography is most commonly used for this localization, CBCT

enables nerve assessment in three dimensions (Fig. 4). New surgical techniques such as safe surgical access to the IAN at the infratemporal fossa [8], as well as modifications of existing surgical techniques, for example to control the lower border cut, are important for reducing the occurrence of postoperative complications of SSO.

Since severe nerve injuries are often the result of drilling too deep (past the bone and into the nerve) or placing the osteosynthesis screw itself upon a nerve (Fig. 2), the accurate measurement of available bone can assist the surgeon in choosing the correct osteosynthesis screw length, thereby preventing over-penetration. The use of intraoperative CT during BSSO surgery allows intraoperative evaluation of osteosynthesis screw penetration and depth, making it possible to modify the treatment if necessary.

The use of intraoperative navigation systems in which the pre-operative CT data of the patient is used in conjunction with an easily portable navigation system to assist the surgeons during operation has proved useful in bimaxillary and Le fort I surgery [15, 16].

Both intraoperative CT/CBCT and intraoperative navigation are useful technical systems each with their specific uses. While the intraoperative CT/CBCT can detect the amount and the area of compression of the buccal and lingual plates after SSO surgery; it can also detect oversizing screws in the area of the lingual nerve after osteosynthesis of the SSO with positioning or lag screws and the malpositioning of the condyle after SSO surgery. In contrast however, the preoperative navigation system can easily detect deviations of the upper jaw midline compared to the planned midline position and check the sagittal and vertical positioning of the maxilla according to the treatment plan. It is important to note that both techniques fail to detect the damage caused to the intra-articular disc or damage inflicted on the inferior alveolar nerve proper.

Disadvantages of the intraoperative CT/CBCT is its high cost. In addition to the expensive head rest which is also less rigid than the usual metal frame headrest, its design as a bulky equipment often leads to infrastructural space constraints, which limits its use to specially designed operating rooms. The disadvantages of the navigation systems is that their use is very limited in mandibular orthognathic surgery due to the mobility of the lower jaw. Furthermore, the use of a navigation system requires the mounting of a navigation star during surgery and the tracking console needs an unobstructed access to the navigation star, which interferes with instrumentation during surgery. Lastly, navigation systems are not capable of detecting the compression of bony parts, and screws that over penetrate the lingual bone or any condylar position change.

Based on the aforementioned shortcomings of both intraoperative CT and navigation systems in orthognathic surgery, the use of intraoperative CT/CBCT is beneficial and thus recommended. More common use could be expected with technological improvements leading to an affordable, less bulky, and easier to handle intraoperative CT/CBCT equipment.

Conclusion

Intraoperative computed tomography enables immediate assessment of treatment and the option to modify the treatment if necessary. Our results indicate that intraoperative computed tomography would be a helpful procedure

during orthognathic surgery to improve the postoperative health of the inferior alveolar nerve.

Acknowledgments Agbaje Jimoh Olubanwo is a postdoctoral researcher of the Fund for Scientific Research (FWO-Vlaanderen).

Compliance with Ethical Standards

Conflict of interest The authors report no conflicts of interest related to this study.

References

1. Al-Bishri A, Rosenquist J, Sunzel B (2004) On neurosensory disturbance after sagittal split osteotomy. *J Oral Maxillofac Surg* 62:1472–1476
2. Boutault F, Diallo R, Marecaux C, Modiga O, Paoli JR, Lauwers F (2007) Neurosensory disorders and functional impairment after bilateral sagittal split osteotomy: role of the anatomical situation of the alveolar pedicle in 76 patients. *Rev Stomatol Chir Maxillofac* 108:175–182
3. D'Agostino A, Trevisiol L, Gugole F, Bondi V, Nocini PF (2010) Complications of orthognathic surgery: the inferior alveolar nerve. *J Craniofac Surg* 21:1189–1195
4. Wijbenga JG, Verlinden CR, Jansma J, Becking AG, Stegenga B (2009) Long-lasting neurosensory disturbance following advancement of the retrognathic mandible: distraction osteogenesis versus bilateral sagittal split osteotomy. *Int J Oral Maxillofac Surg* 38:719–725
5. Yoshioka I, Tanaka T, Khanal A, Habu M, Kito S, Kodama M, Oda M, Wakasugi-Sato N, Matsumoto-Takeda S, Fukai Y, Tokitsu T, Tomikawa M, Seta Y, Tominaga K, Morimoto Y (2010) 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* 68:3022–3027
6. Yamauchi K, Takahashi T, Kaneuji T, Nogami S, Yamamoto N, Miyamoto I, Yamashita Y (2011) 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* 70:401–406
7. Agbaje JO, Sun Y, De MS, Schepers S, Vrielinck L, Lambrichts I, Politis C (2012) CBCT-based predictability of attachment of the neurovascular bundle to the proximal segment of the mandible during sagittal split osteotomy. *Int J Oral Maxillofac Surg* 42:308–315
8. Agbaje JO, Sun Y, Lambrichts I, Vrielinck L, S S, Politis C (2014) Safe surgical access to the mandibular nerve at the infratemporal fossae. *J Craniofac Surg* 25(4):1454–1457
9. Borstlap WA, Stoelinga PJ, Hoppenreijns TJ, van't Hof MA (2004) Stabilisation of sagittal split advancement osteotomies with miniplates: a prospective, multicentre study with two-year follow-up. Part I. Clinical parameters. *Int J Oral Maxillofac Surg* 33:433–441
10. Politis C, Lambrichts I, Sun Y, Vrielinck L, Schepers S, Agbaje JO (2014) Attachment rate of the inferior alveolar nerve to buccal plate during bilateral sagittal split osteotomy influences self-reported sensory impairment. *J Craniofac Surg* 25:2121–2126
11. Falter B, Schepers S, Vrielinck L, Lambrichts I, Thijs H, Politis C (2010) Occurrence of bad splits during sagittal split osteotomy. *Oral Surg Oral Med Oral Pathol Oral Radiol Endodontology* 110:430–435

12. Politis C, Sun Y, Lambrichts I, Agbaje JO (2013) Self-reported hypoesthesia of the lower lip after sagittal split osteotomy. *Int J Oral Maxillofac Surg* 42:823–829
13. Gilron I, Watson CP, Cahill CM, Moulin DE (2006) Neuropathic pain: a practical guide for the clinician. *CMAJ* 175:265–275
14. Lee DH, Yu HS (2012) Masseter muscle changes following orthognathic surgery. *Angle Orthod* 82:792–798
15. Colella G, Cannavale R, Vicidomini A, Lanza A (2007) Neurosensory disturbance of the inferior alveolar nerve after bilateral sagittal split osteotomy: a systematic review. *J Oral Maxillofac Surg* 65:1707–1715
16. Lee EG, Ryan FS, Shute J, Cunningham SJ (2011) The impact of altered sensation affecting the lower lip after orthognathic treatment. *J Oral Maxillofac Surg* 69:e431–e445