PROSPECTIVE EVALUATION OF THE EFFECT OF THE PRESENCE OF MANDIBULAR THIRD MOLARS DURING SAGITTAL SPLIT OSTEOTOMIES OF THE MANDIBLE

by

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ABSTRACT

Problem:

Third molar removal in sagittal split osteotomies(SSOs) is recommended by some authors at least 6 months preoperatively to prevent unfavorable fractures. Others authors suggest concomitant removal. The purpose of this study was to investigate the effect of third molars during SSOs.

Methods:

A prospective study of 677 SSOs was conducted. GroupI consisted of 331 SSOs and third molar removal. GroupII consisted of 346 SSOs without third molar. Intraoperative and postoperative evaluations were recorded.

Results:

The overall rate of unfavorable fractures was 3.1%, with incidences of 2.4% in GroupI, compared to 3.8% in GroupII(P=0.3). The rate of IAN entrapment was lower in GroupI(37.2%) than in GroupII(46.5%;P=0.01). Third molars increased procedural time by 1.7 minutes. Neurosensory deficits were higher in GroupII.

Conclusion:

Removal of third molars during SSOs is not associated with increased incidence of unfavorable fractures. Their presence decreases IAN entrapment, improve neurosensory recovery, but slightly increases operating time.

LIST OF ABBREVIATIONS USED

2-PD	2-Point Discrimination
ANOVA	Analysis of Variance
BSSO	Bilateral Sagittal Split Osteotomy
CI	Confidence Interval
CT	Computed Tomography
gm	Gram
IAN	Inferior Alveolar Nerve / Neurovascular Bundle
i.e.	Id est
IVRO	Intraoral Vertical Ramus Osteotomy
LT	Static Light Touch Detection
min	Minutes
mm	Millimeters
MMF	Maxillomandibular Fixation
PIN	Pin Tactile Discrimination
PPV	Positive Predictive Value
S/B	Sharp/Blunt Discrimination
SD	Standard Deviation
SNAP	Sensory Nerve Action Potential
SSO	Sagittal Split Osteotomy
SSOs	Sagittal Split Osteotomies
TMD	Temporomandibular Joint Disorder
TMJ	Temporomandibular Joint
VAS	Visual Analog Scale

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CHAPTER 1 INTRODUCTION

The sagittal split osteotomy (SSO) is the most common procedure performed for the correction of mandibular deformities. This surgery can be performed with the presence or the absence of mandibular third molars. Two different philosophies exist regarding the timing of their removal in patients undergoing SSO. Some surgeons advocate the removal of mandibular third molars at least 6 months prior to the SSO, while others prefer to surgically remove them at the time of the procedure, making this a subject of controversy.

Some authors have reported that the presence of a third molar during SSO is associated with increased operating time, greater manipulation of the inferior alveolar neurovascular bundle (IAN), increased technical difficulty and increased incidence of unfavorable fractures. As a result they recommended their removal at least 6 months prior to the procedure. Reyneke et al. in 2002[1], showed an increased incidence of unfavorable splits when mandibular third molars were present during the SSO procedures. Unfavorable splits occurred in 6.25% when unerupted mandibular third molars were present during the SSO, compared to a rate of 0% when they were absent. These findings were supported by Schwartz in 2004[2].

Other studies suggest that removing the third molar concomitant with the SSO limits risks, is cost efficient, and is associated with a decreased incidence of unfavorable fractures. Precious et al. in 1998[3], in a retrospective study of 1256 SSOs, demonstrated that removal of impacted mandibular third molars at least 6 months before SSO would not reduce the incidence of unwanted mandibular fractures. In this study unfavorable split occurred in 0.94% when unerupted mandibular third molars were removed during the

SSO, compared to a rate of 2.62% when third molars were absent. Mehra and al. in 2001[4], and Kriwalsky et al. in 2008[5] also supported this conclusion.

For adequate patient care and treatment planning, it is imperative that the oral and maxillofacial surgeon understands and evaluates the main factors that will contribute to a successful SSO when preparing to perform orthognathic surgery. The following text will describe the surgeon's decision making process regarding the timing of removal of mandibular third molars.

CHAPTER 2 REVIEW OF LITERATURE

2.1 ORTHOGNATHIC SURGERY OF THE MANDIBLE

Orthognathic surgery refers to surgical procedures designed to correct dentofacial deformities, which were first described in the European literature over 80 years ago[6]. The term orthognathic originates from the Greek words *orthos*, meaning straight, and *gnathos*, meaning jaw. Orthognathic procedures can be divided into three categories: mandibular surgery, maxillary surgery, and bimaxillary procedures.

Mandibular orthognathic surgery was first described by Hullihen in 1849, by performing an anterior subapical osteotomy[7]. More than 50 years later, mandibular surgery resurged when Blair described the mandibular body osteotomy as an extraoral procedure in 1907[8]. The mandibular step osteotomy was popularised by Dingman in 1944, by using a combination of intraoral and extraoral access with preservation of the neurovascular bundle[9]. Subsequently, Caldwell and Letterman developed the intraoral vertical ramus osteotomy (IVRO) in 1954[10]. This was mainly a setback procedure and did not allow for anterior movement of the distal segment.

The sagittal split ramus osteotomy was first introduced by Schuchardt in 1942[11]. The current technique was refined and popularized by Trauner & Obwegeser in 1955[12]. The original technique has undergone numerous modifications (Fig. 1). DalPont first modified the technique in 1961, by advancing the oblique cut to the molar region and the vertical cut through the lateral cortex[13]. The horizontal cut along the medial cortex of the ramus was then shortened by Hunsuck in 1968, by taking it only as far as the mandibular foramen[14]. Bell, Schendel, Epker and colleagues modified this technique in the late 1970's, by extending the vertical cut through the inferior border of the mandible[15, 16].

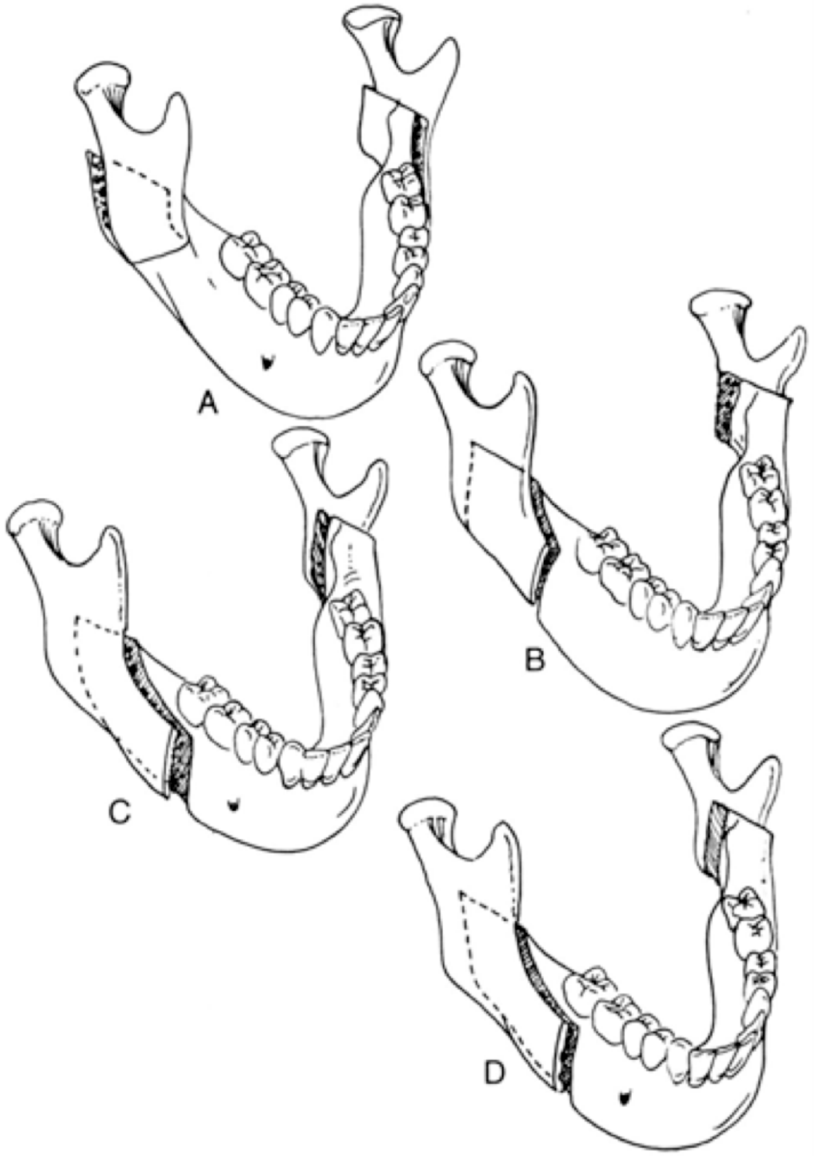

Figure 1. Evolution of the sagittal split ramus osteotomy of the mandible: **A**, Obwegeser and Trauner technique (1957); **B**, DalPont modification (1961); **C**, Hunsuck modification (1968); **D**. Bell, Schendel, Epker, and colleagues modification (1977-1978). In: Stearns JW, Fonseca RJ, Saker M. Revascularization and Healing of orthognathic surgical procedures. Fonseca RJ (ed), Oral and maxillofacial surgery, WB Saunders Co, Philadelphia, 2000: Vol 2; p. 162.

2.1.1 Sagittal Split Osteotomy of the Mandible

The bilateral sagittal split osteotomy (BSSO) became the predominant orthognathic surgery of the mandible. This procedure has been indicated for many different deformities including mandibular deficiency, excess and asymmetry.

The incision begins on the anterior border of the ramus, midway between the occlusal planes. It is then carried downward, following the external oblique ridge to the vestibular area just distal to the first molar (Fig. 2A). The periosteum is reflected laterally to expose the lateral cortex of the mandible down to the inferior border. The temporalis tendon is then retracted superiorly at the level of the anterior border of the ramus using a channel retractor (ramus stripper). Dissection proceeds then medially along the ramus to expose the lingula (Fig. 2B). This dissection is kept above the level of the lingula, with the periosteum carefully retracted medially to avoid injury to the IAN[17].

The osteotomy is started with a horizontal bone cut through the medial cortex of the vertical ramus, extending from a point just posterior and above the lingula to the anterior border of the ramus[18] (Fig. 2C). This cut is kept parallel to the occlusal plane. Between the first and the second molar, the vertical osteotomy is made through the inferior border of the mandible, perpendicular to the occlusal plane, up to the external oblique ridge (Fig. 2D). This cut is made through the lateral cortex only to avoid transecting the IAN. The horizontal and vertical cortical cuts are then connected in a sagittal direction, staying just inside of the external oblique ridge. If a mandibular third molar is present, the direction of the sagittal cut is not modified. The sagittal cut needs to be deepened at the level of the third molar to ensure it is through the crown of the tooth.

The split is then accomplished carefully using a series of spatulas, chisels and spreader instruments. The cortices should be gently separated, looking for the IAN. If the

IAN is entrapped within the proximal segment, the surgeon needs to carefully free it from its medullary encasement. If the IAN is encased in cortical bone, osteotomes or bone burs should be used to free it. It is also important to ensure that the inferior border is moving with the proximal segment before completing the split to avoid unfavorable fractures. Once the split is completed, the mandibular third molar is removed when present. The medial pterygoid muscle attachments should then be stripped off the proximal segment to facilitate movement of the segments into their new positions.

Once the osteotomy is completed, the distal segment is advanced into the predetermined position using an acrylic splint and maxillomandibular fixation (MMF). The proximal segment is then manipulated to ensure that the condyle is properly seated in the glenoid fossa, and that the inferior borders are well aligned. Bony excess or irregularities should be removed to allow proper adaptation of the proximal segment and to prevent injury to the IAN (Fig. 2E,F). The SSO is then fixated using monocortical screws and miniplates, or two to three bicortical bone screws[19]. The wound is then thoroughly irrigated and closed using resorbable sutures.

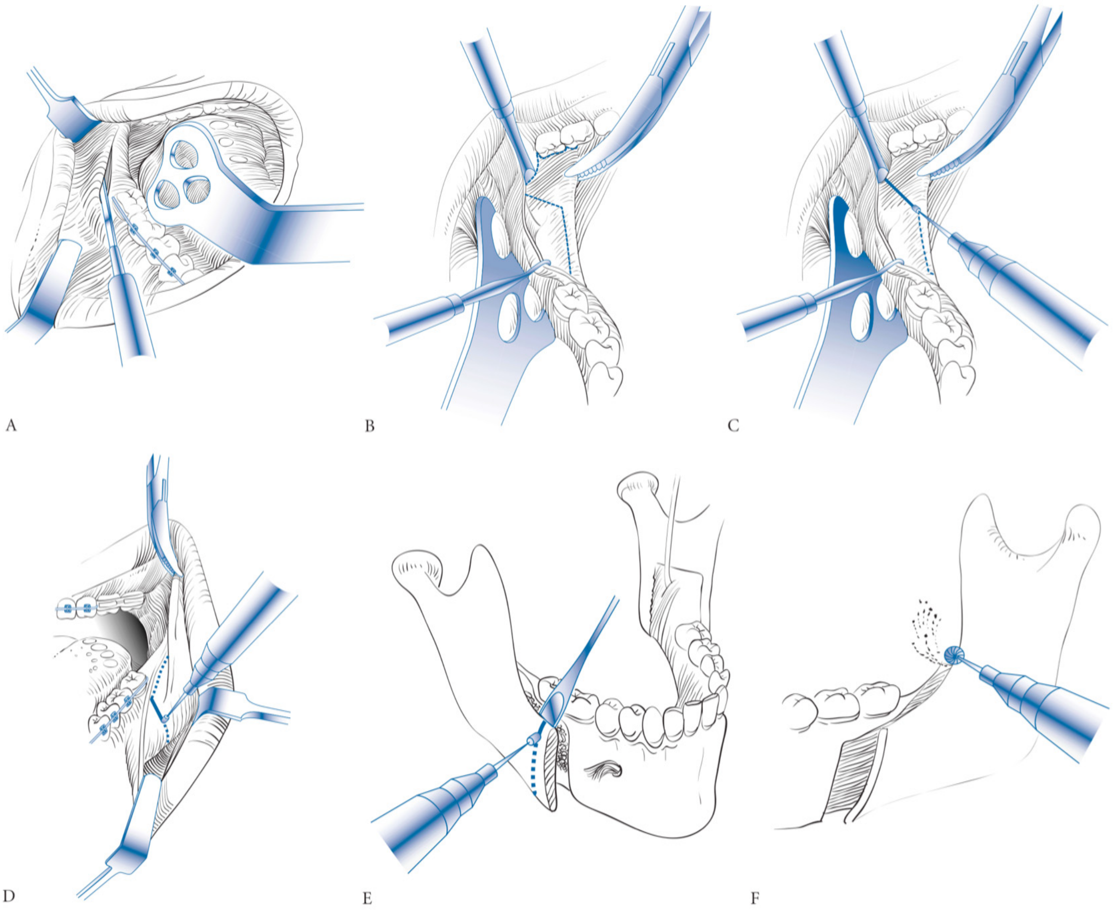

Figure 2. The bilateral sagittal split osteotomy. **A**, Incision. **B** and **C**, Medial exposure and horizontal cut. **D**, Vertical cut. **E**, Bone removal for setback. **F**, Bone removal for large adjustments. In: Bloomquist DS, Lee JJ. Principles of Mandibular Orthognathic Surgery. Miloro M (ed), Peterson's Principles of Oral and Maxillofacial Surgery. Vol 2; BC Decker Inc 2004: Chapter 56; p. 1152.

2.1.2 Other Mandibular Osteotomies

Vertical ramus osteotomies were initially done extraorally, but with the development of oscillating blades, the intraoral approach is now the preferred method. The IVRO divides the mandibular ramus posterior to the mandibular foramen, from the sigmoid notch down to the angle of the mandible[20, 21] (Fig. 3). The procedure is indicated for setback procedures of the mandible, especially when an associated temporomandibular joint disorder (TMD) is present.

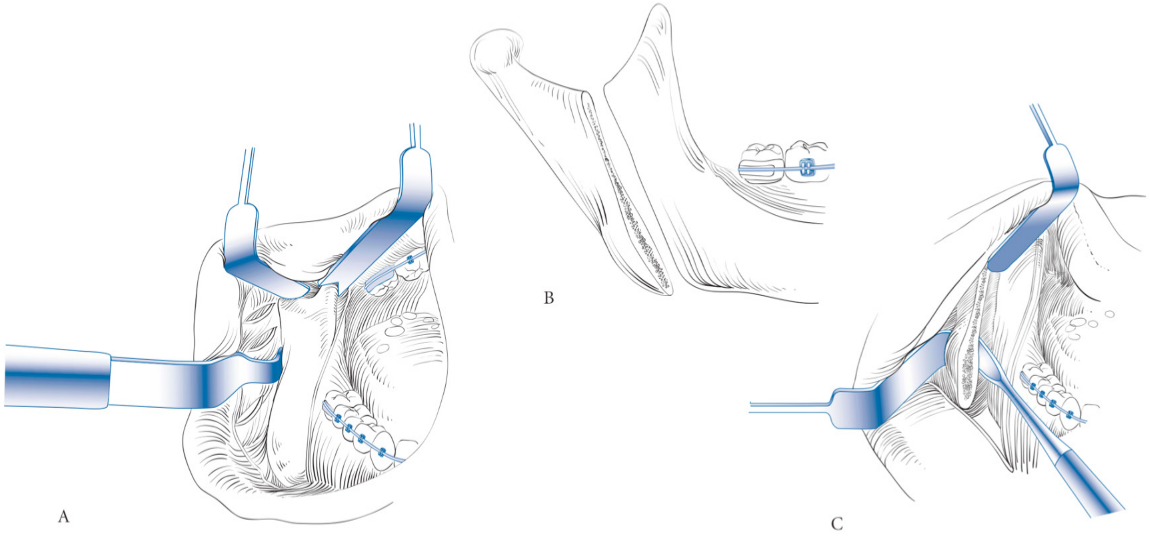

Figure 3. The intraoral vertical subcondylar osteotomy. **A**, Exposure. **B**, Vertical ramus osteotomy. **C**, Proximal fragment displaced laterally. In: Bloomquist DS, Lee JJ. Principles of Mandibular Orthognathic Surgery. Miloro M (ed), Peterson's Principles of Oral and Maxillofacial Surgery. Vol 2; BC Decker Inc 2004: Chapter 56; p. 1143.

Two modifications were then developed from the vertical ramus osteotomy: the inverted L osteotomy[22, 23] (Fig. 4A), and the C osteotomy[24] (Fig. 4B). These procedures are indicated to treat severe mandibular deformities, including large advancements and ramus lengthening.

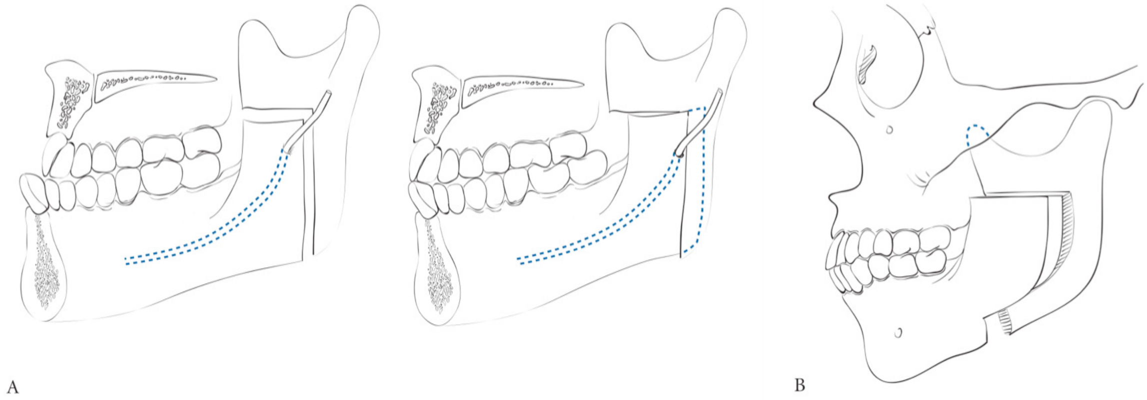

Figure 4. **A**, *L* osteotomy. **B**, *C* osteotomy. In: Bloomquist DS, Lee JJ. Principles of Mandibular Orthognathic Surgery. Miloro M (ed), Peterson's Principles of Oral and Maxillofacial Surgery. Vol 2; BC Decker Inc 2004: Chapter 56; p. 1137.

The mandibular body osteotomy, first described extraorally by Blair 1907[8], is now mainly an intraoral procedure. This approach is indicated in cases which may require mandibular setback, anterior open bite closure, curve of Spee reduction, progenia correction, or mandibular advancement (Fig. 5).

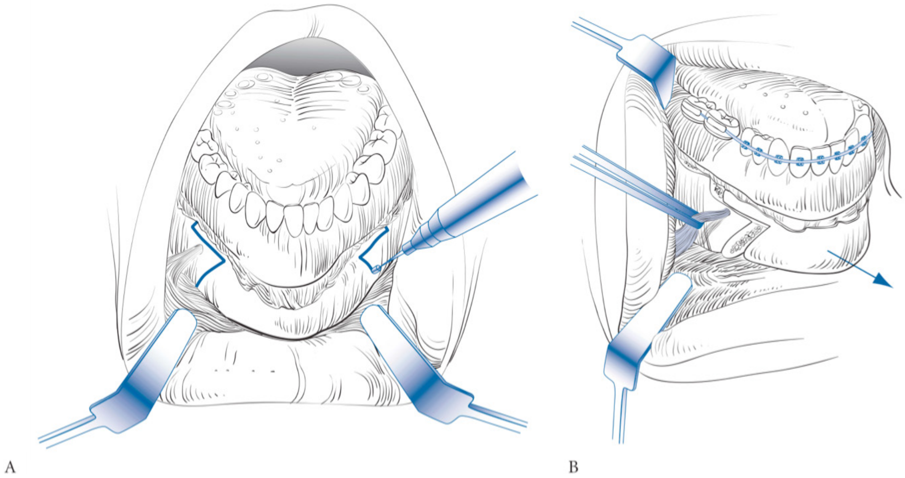

Figure 5. The step body osteotomy. In: Bloomquist DS, Lee JJ. Principles of Mandibular Orthognathic Surgery. Miloro M (ed), Peterson's Principles of Oral and Maxillofacial Surgery. Vol 2; BC Decker Inc 2004: Chapter 56; p. 1162.

The mandibular subapical osteotomies can be used to move portions of the mandibular dental alveolus. Indications include leveling of the occlusal plane, as well as changing the anteroposterior position or axial angulations of the teeth (Fig. 6).

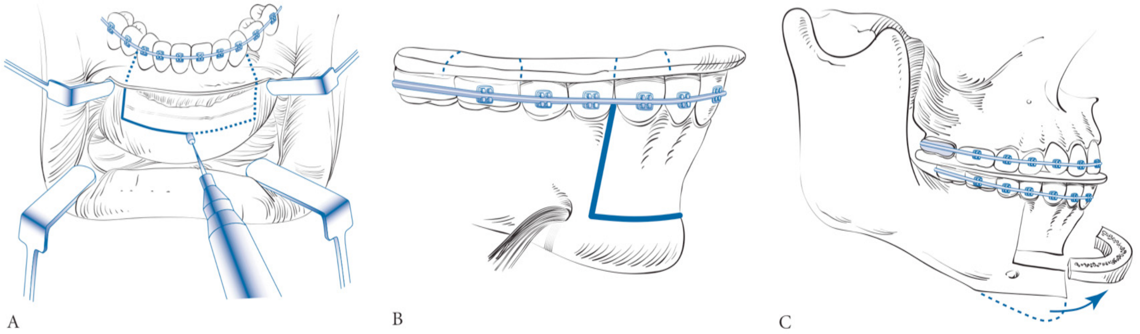

Figure 6. The anterior subapical osteotomy. **A**, Osteotomy. **B**, Occlusal splint. **C**, Bone graft from chin for correction of anterior open bite. In: Bloomquist DS, Lee JJ. Principles of Mandibular Orthognathic Surgery. Miloro M (ed), Peterson's Principles of Oral and Maxillofacial Surgery. Vol 2; BC Decker Inc 2004: Chapter 56; p. 1165.

The genioplasty was first introduced by Hofer in 1942, as an extraoral procedure[25]. Then in 1957, Trauner and Obwegeser described the procedure with an intraoral approach[26]. The cut is mainly a horizontal osteotomy across the symphysis, inferior to the mental foramina. This functional procedure has multiple indications, and can be used for correction of vertical and/or horizontal excess or deficiency, as well as for lip incompetence[27]. The genioplasty is often used in combination with other mandibular and maxillary osteotomies, to achieve normal facial balance[28].

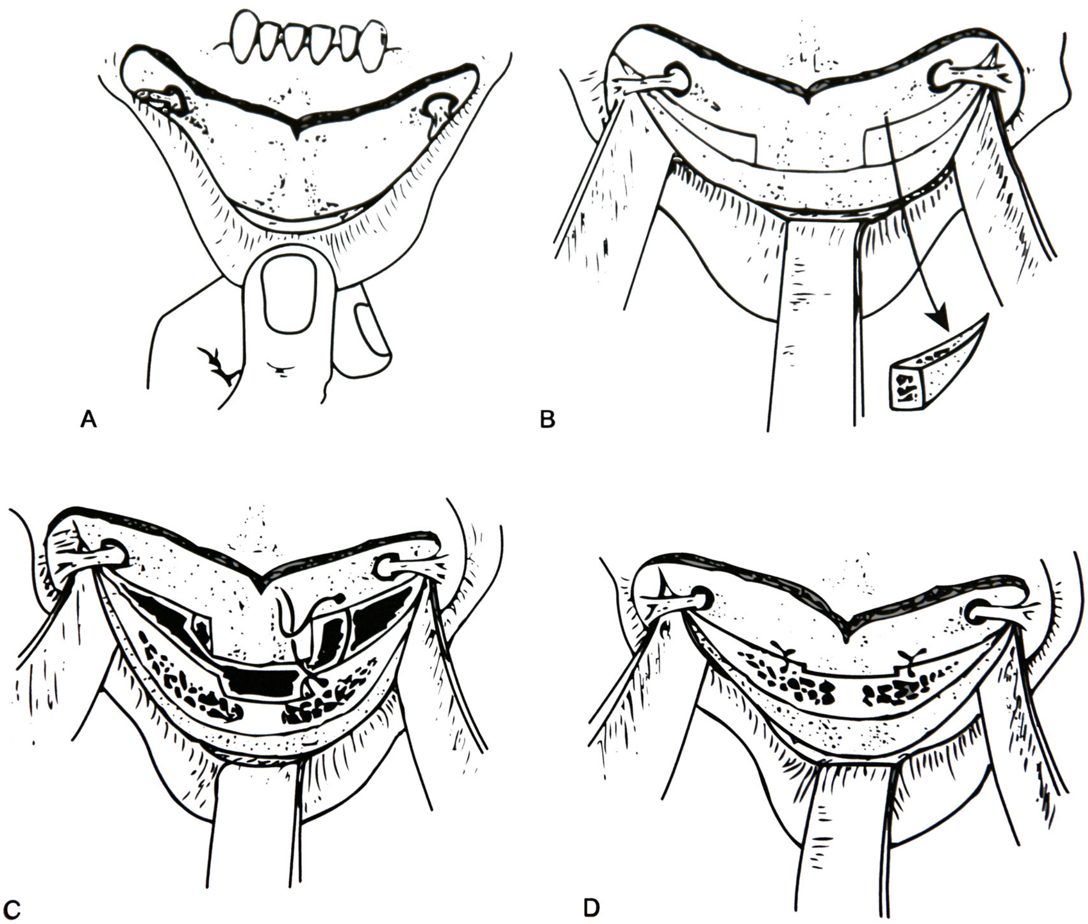

Figure 7. **A**, Subperiosteal exposure of the anterior surface of the chin and exposure of the mental nerves. **B**, Outline of osteotomy-ostectomy design. **C**, Lateral bony wedges removed and creation of mortise and tenon. **D**, Superiorly repositioned and advanced bony segment with attendant labiomental muscles. In: Precious DS. Genioplasty. Turvey TA (ed), Oral and Maxillofacial Surgery. Vol 3; Saunders Elsevier Inc 2009: Chapter 5; p. 141.

2.1.3 Complications after Sagittal Split Osteotomy.

Usual immediate postoperative sequellae of a SSO includes bruising, edema, limited range of motion, and neurosensory alterations.

Nerve injury following SSO of the mandible, can involve the inferior alveolar nerve, the lingual nerve, and, very rarely, the facial nerve. Long-term sensory alteration, 1 or 2 years after a BSSO, ranges from 0 to 85%. This is largely dependent on the testing method used[29], and whether concomitant genioplasty is performed[30]. Trauma to the IAN can be divided into open injury (observed by the surgeon at the time of injury), which is most often caused by direct mechanical damage, and closed injury (not observed by the surgeon at the time of surgery). Mechanical damage can be caused by stretching or compression of the IAN near the mandibular foramen during medial retraction[31]. The IAN can also be lacerated during the osteotomy cuts, or during administration of local anesthesia. Teltzrow et al. in 2005[32], in a retrospective review of 1264 consecutive patients who underwent a BSSO, reported that the IAN was inadvertently cut in 2.1% of patients. The presence of entrapment of the IAN within the proximal segment during the split requires manipulation and possible bone removal in order to mobilize the nerve and this dissect it free, leading to further mechanical damage. The IAN can be stretched as the distal bone fragment is mobilized and repositioned resulting in neuropraxia. Direct damage to the IAN can be the result of injury from the sharp bony fragments on the medial side of the proximal segment, or by the incorrect placement of screws. The nerve may be compressed between the proximal and distal segments with unwanted osteosynthesis techniques. Postoperatively, edema or hematoma in the mandibular canal may also lead to compression neuropathy[33]. Abnormal anatomic location of the IAN can further predispose a patient to inadvertent mechanical injury. It has also been proposed that the presence of a mandibular third molar could influence the neurosensory recovery, due to the increased manipulation of the IAN, and the close relationship of the roots with the mandibular canal[1].

The incidence of lingual nerve neurosensory disturbance has been reported to occur in up to 19.4% of patients following a BSSO[34]. Injury to the lingual nerve can result from direct trauma or stretching during the dissection of the medial aspect of the ramus. Damage to the lingual nerve can also occur during bicortical screw placement, and by compression neuropathy from a hematoma on the lingual side of the mandible.

Impairment of the facial nerve is rare, with an incidence of less than 1%[35]. It has only been reported following BSSO setback procedures.

Temporomandibular joint (TMJ) dysfunction can persist or develop following orthognathic surgery. The incidence of TMD in patients with dentofacial deformity is comparable to the general population, varying between 20% and 25%. Karabouta et al. in 1985, reported a preoperative incidence of TMJ dysfunction symptoms of 40.8% in patients with mandibular deformities planned for BSSO[36]. Of these patients, 11.1% had persistent TMD following orthognathic surgery. Of the asymptomatic patients, 3.7% had symptoms postoperatively. Panula et al. in 2000, also reported a low incidence of new TMD of 6.7%, after a 4 year follow-up period[37].

Condylar resorption has also been reported to occur following orthognathic surgery, with an incidence of 1% to 31%[38]. Predisposing risk factors include: female sex, high mandibular plane angle, preoperative TMJ dysfunction, large mandibular advancement, counterclockwise rotation of the mandible, and condylar malposition[38-42].

The reported incidence of unfavorable splits during a SSO ranges from 0.7% to 20%[43, 44]. Unfavorable splits can be divided into proximal segment (buccal plate) fractures, or distal segment (lingual plate) fractures. These can lead to difficulties with fixation, sequestration of the fragment, infection, delayed union or malunion of the osteotomy site, and malocclusion. Proposed risk factors include: difficult anatomy, incomplete osteotomies, poor osteotomy design, and presence of a mandibular third molar.

Relapse following BSSO is multifactorial, but the type of rigid internal fixation does not significantly affect skeletal stability. In a systematic review of mandibular advancement with BSSO, the short-term relapse at B point was between 1.5% and 32.7% for bicortical screws, between 1.5% and 18.0% for miniplates, and between 10.4% and 17.4% for bioresorbable bicortical screws[45]. The long-term relapse at B point was between 2.0% and 50.3% for bicortical screws, and between 1.5% and 8.9% for miniplates[45]. Involved risk factors included: the improper seating of the condyles, the magnitude of advancement, the tension on the soft tissue and muscles, the mandibular plane angle, and the remaining growth and remodeling. A high mandibular plane angle was associated with more horizontal relapse, whereas a low mandibular plane angle was associated with increased vertical relapse. Advancements greater than 6 mm predisposed to horizontal relapse[45]. In a systematic review of mandibular setback with BSSO, Joss et al. found that the horizontal short-term relapse was between 15.7% and 91.3% at pogonion, and between 9.9% and 62.1% at B point[46]. Long-term relapse was between 11.5% and 25.4% at pogonion, and between 14.9% and 28.0% at B point[46]. Etiologies identified included: proper seating of the condyles, the amount of setback, the soft tissue and muscle pull, as well as the remaining growth and remodeling[46].

Other possible complications include: hemorrhage (from the retromandibular vein, inferior alveolar vessels, and facial vessels), infection, dental damage, periodontal damage, non-union, and fixation failure.

2.2 PRESENCE OF MANDIBULAR THIRD MOLARS AS A FACTOR FOR UNFAVORABLE FRACTURES IN SAGITTAL SPLIT OSTEOTOMIES

An unfavorable fracture of the mandible is one of the most important intraoperative complications that can occur during a SSO. The unfavorable fractures can be subdivided into proximal segment fractures, also known as buccal plate fractures, and distal segment fractures, also known as lingual plate fractures (Fig. 8). These can be further subdivided into complete or incomplete (green stick) fractures.

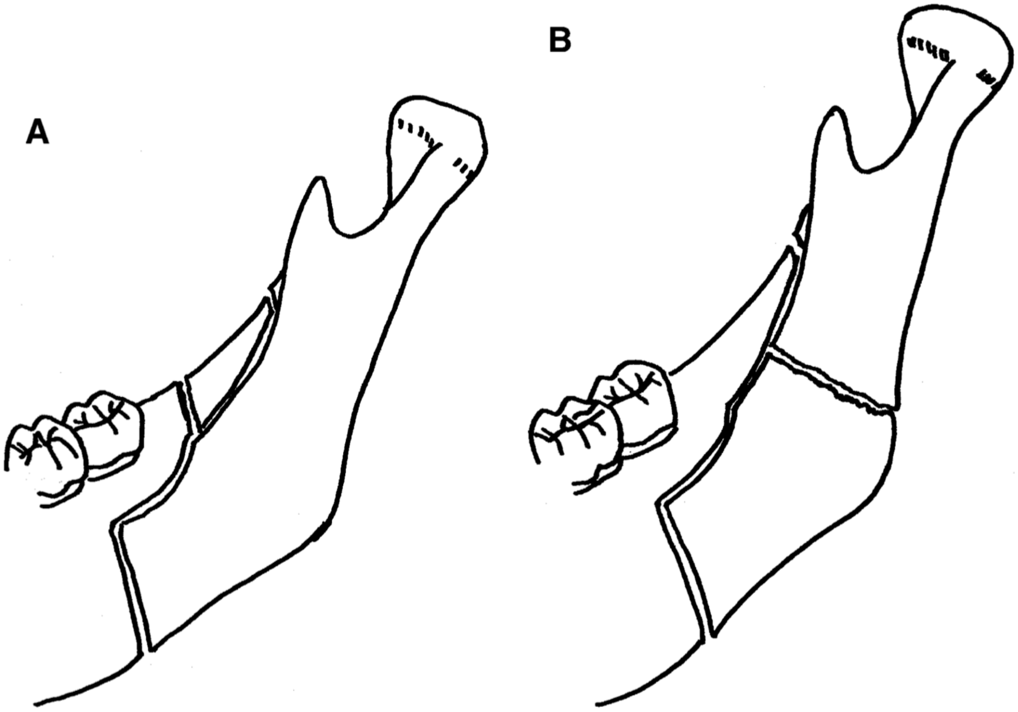

Figure 8. General location of unfavorable fractures. **A**, Type of fracture seen in the distal segment. **B**, Type of fracture seen in the proximal segment. In: Mehra P, Castro V, Freitas RZ, Wolford LM. Complications of the Mandibular Sagittal Split Ramus Osteotomy Associated With the Presence or Absence of Third Molars. J Oral Maxillofac Surg 2001;59:854-858.

The presence of mandibular third molars has been proposed as a risk factor increasing the occurrence of unfavorable fractures during a SSO. Due to this hypothesis, some authors have recommended their removal at least 6 months prior to the procedure.

However, other authors do not support this theory, favoring their removal at the time of the SSO. These two philosophies remains a subject of controversy.

2.2.1 Evidence Supporting Removal of Mandibular Third Molars at Least Six Months Prior to Sagittal Split Osteotomy

Reyneke et al. in 2002[1], prospectively evaluated the effect of the presence of mandibular third molars in 139 SSOs in 70 patients. Unerupted third molars were present in 45.7% (64 SSOs; 32 patients) of the cases. Unerupted third molars were absent in 54.3% (75 SSOs; 38 patients) of cases. Data related to gender, age, presence or absence of unerupted third molar teeth, split difficulty during SSO, unfavorable fractures, and neurovascular bundle involvement at surgery were recorded. Postoperative nerve recovery was evaluated on the day of surgery and at 1, 6, 13, 26, and 52 weeks. Neural recovery was evaluated both subjectively and objectively using light touch. The group with third molars present was younger, with a mean age ± standard deviation (SD) of 18.5 ± 6.8 years, versus 27.3 ± 9.6 years for the other group. Unfavorable fractures occurred in 6.25% (4 of 64) of patients in the group with third molars present, compared to 0% (0 of 75) in the group with third molars absent[1]. The overall incidence was 2.86%. Of these unfavorable splits, three fractures occurred within the distal segment, and one in the proximal segment. All fracture patients were aged 20 years and younger with their mandibular third molars being unerupted. The SSOs were considered significantly more difficult when a mandibular third molar was present ($P < 0.001$)[1]. SSOs were regarded as easy in 92% of the cases without unerupted third molars, compared to 40% when unerupted third molars were present. Risk ratios revealed that the chance of a difficult split was 7 to 8 times greater when unerupted third molar teeth were present ($P < 0.05$).

The difficulty of the SSO was also associated with a younger age ($P = 0.004$)[1]. There was slightly more manipulation of the IAN in the presence of unerupted third molars, with dissection or bony release from the proximal segment in 37.5% (24 of 64), compared to 24% (18 of 75) with mandibular third molars absent. This increase in IAN manipulation did not affect neurosensory recovery, with both groups showing similar recovery curves ($P = 0.38$)[1]. The authors concluded that fractures of the proximal and/or distal segments during SSO tend to occur more frequently in the younger age group (<20 years) when unerupted third molars are present. To reduce the risk of complications, they recommended the removal of unerupted third molars 6 to 9 months before orthognathic surgery in patients younger than 20 years, but that prior removal may not be necessary for those older than 20 years[1].

An opinion paper, published by Schwartz in 2004[2], supported these conclusions. He stated that the presence of unerupted third molars during SSO increases the operating time and the technical difficulty of the procedure. In his opinion, the presence of a mandibular third molar will also increase the incidence of unfavorable fractures, while decreasing available sites for rigid fixation. He added that if an unfavorable fracture takes place, operating time, technical difficulty, local infection, nonunion, malunion, prolonged neurologic symptoms, and relapse will all be further increased. His recommendation was that all candidates for SSO should have impacted third molars removed at the beginning of orthodontic treatment or at least 6 months before orthognathic surgery, to allow for ossification of the extraction sites[2].

Falter et al. in 2010[43], reported the lowest rate of unfavorable splits, with an incidence of 0.7% (14 of 2005 SSOs). This was a retrospective chart review of 1008 patients. All of the patients had mandibular third molars removed at least 6 months prior to the procedure. Of the 14 unfavorable fractures, 13 involved a buccal plate fracture, and 1 a lingual plate fracture. All unfavorable splits were resolved perioperatively by plate osteosynthesis without the need of additional MMF. All of these patients had a good and functional occlusion 6 months postoperatively, with no reported infections at the osteotomy sites. No unfavorable fracture occurred in patients younger than 20 years. The predicted probability of an unfavorable split increased rapidly in females older than 40 years of age. This influence of age was not found in males. There was no correlation between the type of dentofacial deformity, or Angle skeletal class. The surgeon's experience did not reduce the occurrence of unfavorable fractures. They concluded that their low incidence of unfavorable splits could possibly be explained by their standard preoperative extraction of unerupted third molars, also recommending their removal at least 6 months before the SSO[43].

2.2.2 Evidence Supporting Removal of Mandibular Third Molars at the Time of Sagittal Split Osteotomy

Precious et al. in 1998[3], retrospectively evaluated 1256 SSOs in two groups of patients: Group I (*n* = 532) had impacted third molars removed during the SSO; Group II (n = 724) had third molars removed at least 6 months prior to the SSO. The overall incidence of unfavorable splits was 1.9% (24 of 1256). The presence of impacted third molars during SSO showed a decreased frequency of unwanted fractures, with an incidence of 0.94% (5 of 532) for Group I, compared to an incidence of 2.62% (19 of 724) for Group II[3]. This difference was not statistically significant ($P = 0.052$). Of the 24 unfavorable fractures, 15 were proximal segment fractures (2 in Group I; 13 in Group II), and 9 were distal segment fractures (3 in Group I; 6 in Group II). The authors concluded that the removal of impacted mandibular third molars at least 6 months before SSO would not reduce the incidence of unfavorable mandibular fractures. They recommended that in most cases, mandibular third molar removal and SSO could be safely carried out in one operation[3].

Another retrospective review of 500 SSOs in 262 patients, was published by Mehra et al. in 2001[4]. Group I consisted of 250 SSOs and concomitant removal of impacted mandibular third molars, and Group II consisted of 250 SSOs with absence of third molars. The average age for Group I was 17.7 years, and 36.6 years for Group II. The overall frequency of unfavorable fractures was 2.2% (11 of 500). The incidence of unfavorable splits was 3.2% in Group I (8 of 250), and 1.2 % in Group II (3 of 250)[4]. The difference was not statistically significant ($P > 0.05$). In Group I, 7 of 8 fractures (87.5%) occurred vertically through the third molar socket in the distal segment. Three were incomplete (greenstick), and five were complete. Six fractures (75%) were associated with full bony impaction of the third molars, and 2 (25%) occurred with partially impacted third molars. All patients with unfavorable fractures were between 15 to 16 years of age (14% of these patients). In Group II, all 3 fractures were complete and involved the proximal segment. No significant difference was seen in the amount of relapse at B point in patients with unfavorable or favorable splits ($P > 0.05$, average follow up of 19.4 months). No trends for increased risk of an unfavorable fracture were observed relative to the type of mandibular movement (advancement or setback), occlusal plane angle, and posterior mandibular height. They concluded that the occurrence of unfavorable splits is infrequent, irrespective of the presence or absence of third molars.

When third molars are present during the SSOs, unfavorable fractures usually occur in young, teenage patients, but this had no adverse influence on the success or stability of the SSO[4].

The case for removal of third molars at the time of SSOs was again supported by Precious in 2004[47]. He pointed the lack of evidence supporting the contention that impacted third molars compromise the bony architecture of the mandible such that there is increased incidence of intraoperative mandibular fractures. Furthermore, this approach prevents an additional surgical procedure. This will reduce costs and risks of anesthesia, and will avoid the patient to be subject to 2 recovery periods of pain and swelling. He also stated that the presence of a third molar helps identify the position of the IAN during the SSO, and practically eliminates complaints related to alveolar osteitis. The author recommended that, with few exceptions, impacted mandibular third molars should be removed concomitantly with SSOs for patients undergoing mandibular orthognathic surgery[47].

Witherow et al. in 2006[48], reviewed 104 SSOs over a 1 year period. Variables recorded included: the surgical technique, sex, age, presence or absence of third molars, and the height of the mandible in the region of the osteotomy. All SSOs where fixated with three bicortical screws placed at the upper border of the mandible (retromolar bone) through a transbuccal approach. Twenty-eight of the 104 SSOs had impacted mandibular third molars present at the time of the osteotomy. No intraoperative unfavorable splits occurred. Postoperative fractures of the lingual plate occurred in 7 of the 104 SSOs (6.7%)[48]. There was no significant association between the presence of mandibular third molars at the time of operation and postoperative fractures of the lingual plate.

Significant risk factors were a vertical mandibular height of 2 cm or less posterior to the last molar ($P = 0.02$), and a depth of 0.6 cm or less between the apex of the last molar and the inferior border of the mandible ($P = 0.005$). They recommended using fixation with miniplates and monocortical screws for these cases of reduced mandibular height to prevent postoperative fractures of the lingual plate[48].

Risk factors for unfavorable fractures during SSO were retrospectively evaluated by Kriwalsky et al. in 2008[5]. Two hundred and twenty SSOs in 110 consecutive patients were reviewed and divided into three groups. Group I had missing third molars ($n = 168$); Group II had retained or impacted third molars that were removed during the SSOs ($n = 23$); and Group III had third molars left in place during the SSOs ($n = 29$). Unfavorable splits occurred in 5.5% of all cases (12 of 220)[5]. There was no significant difference of frequency among the 3 groups ($P = 0.8$). The incidence was 5.4% in Group I (9 of 168), 8.7% in Group II (2 of 23), and 3.4% in Group III (1 of 29). The surgeon's qualification also had no influence on the incidence ($P = 0.4$). Older age had a significant effect on the occurrence of unfavorable fractures ($P = 0.01$). They concluded that the timing of removal of third molars during SSOs should depend on the angulation, relative height, and root form of the third molar, and its morphological relation to the IAN. The authors recommended that third molars should generally be removed at the time of the SSOs to allow a better operative view, which facilitates the removal and reduces the risk of injury to the IAN, as well to avoid a second operation and the additional bone loss associated with the tooth removal[5].

2.3 ANATOMY RELEVANT TO THE SAGITTAL SPLIT OSTEOTOMY

2.3.1 Variation of Mandibular Ramus Morphology

Anatomical variations can make the SSO procedure more difficult, predisposing certain patients to a higher risk of unfavorable fractures. This is especially true when the medial horizontal osteotomy is performed at or above a point of fusion between the external and internal cortical plates of the mandibular ramus, or when the mandibular ramus is thinner mediolaterally. Anatomic studies have shown that the thickness of the mandibular buccal cortex decreases significantly from the second molar to the ramus region[18, 49, 50]. Prognathic patients have been shown to have a generally thinner mandibular ramus, and a mandibular canal located more buccally, when compared with patients with retrognathia, making them more likely to have unfavorable splits and perioperative impairment of the IAN[51-53].

Noleto et al. in 2010[54], evaluated the mandibular ramus morphology of 40 patients using high resolution computed tomography (CT) scanning. Twenty patients had prognathism and 20 had retrognathia. The mean thickness of the ramus in the prognathism group was significantly thinner (8.17 mm) compared to the group with retrognathia (8.88 mm; $P = 0.014$)[54]. The mean vertical distance of the point of fusion between the cortical plates above the lingula was 8.95 mm in prognathism, compared to 9.41 mm in retrognathia. This difference was not statistically significant ($P = 0.364$). The mean horizontal distance of the point of fusion between the cortical plates posterior to the lingula was 8.32 mm for patients with prognathism, and 9.74 mm for those with retrognathia. This was also not significant ($P = 0.066$). They concluded that the mandibular ramus of patients with prognathism is thinner when compared with those of patients with retrognathia, making the execution of SSOs more difficult[54].

2.3.2 Mandibular Canal Position

The position of the mandibular canal and IAN can influence the neurosensory recovery after a SSO. Kim et al. in 2009[55], evaluated the location of the mandibular canal and the topography of its neurovascular structures, using dissection and histologic sections of 62 mandible sides. The buccolingual location of the mandibular canal was classified into 3 types (Fig. 9). Type 1 was the most common (70%), with a mandibular canal following the lingual cortical plate in the region of the mandibular ramus and body. In type 2 (15%), the canal followed the middle of the ramus behind the second molar and the lingual plate at the level of the second and first molars. In type 3 (15%), the canal followed the middle or the lingual one third of the mandible from the ramus to the body. Three-dimensional reconstruction of the mandibular canal revealed that the inferior alveolar vessels traveled above the inferior alveolar nerve in 8 cases (80%), with the inferior alveolar artery being lingual to the inferior alveolar vein. In 2 cases (20%), the inferior alveolar vessels were buccal to the nerve.

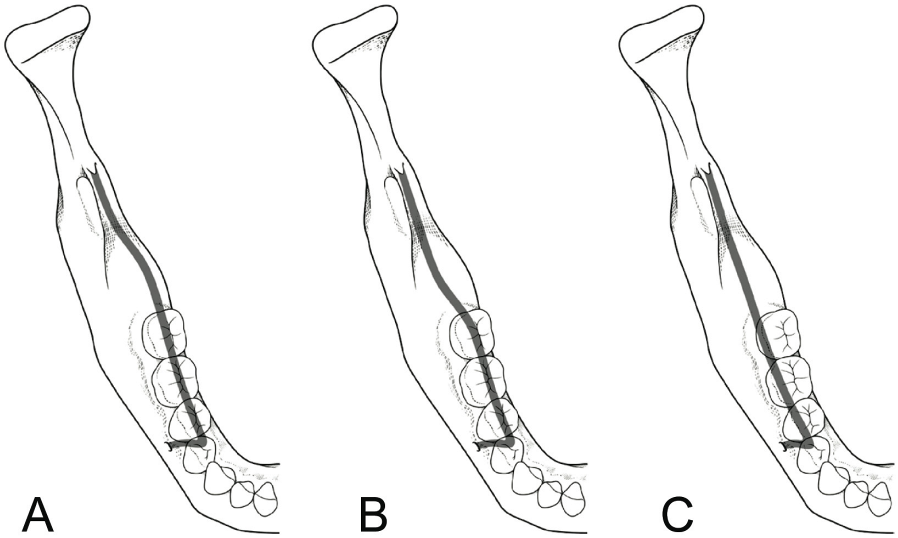

Figure 9. Three identified types of locations of the mandibular canal. **A**, Type 1. **B**, Type 2. **C**, Type 3. In: Kim ST, Hu KS, Song WC, Kang MK, Park HD, Kim HJ. Location of the Mandibular Canal and the Topography of Its Neurovascular Structures. J Craniofac Surg 2009;20:936-939.

Yamamoto et al. in 2002[56], evaluated the relationship of the mandibular canal to the lateral cortex of the mandibular ramus in 20 patients undergoing BSSO using CT. Objective neurosensory examinations were performed more than 1 year after surgery (4 tests: quantitative algesiometer, a thermocryesthesiometer, a 2-point threshold discriminator, and light-touch discrimination). The mandibular canal was contacting the external cortical bone in 25% of the cases. The mean vertical extent of contact ± SD was 10.6 ± 4.9 mm (range 2 to 18 mm). No contact was present in 75%. Neurosensory disturbance, which was present in 100% of the cases with contact, was significantly greater, compared to the 20% incidence in cases without contact between the canal and the external cortical bone ($P < 0.05$). When the width of the marrow space between the mandibular canal and the external cortical bone was 0.8 mm or less, neurosensory disturbance was significantly more likely to be present 1 year after surgery ($P < 0.002$)[56].

The position of the mandibular canal at the level of the second molar was further evaluated in patients with prognathism. Yoshioka et al. in 2010[57], used CT images of 28 patients with prognathism, and 30 patients without prognathism to compare the distance from the buccal aspect of the IAN canal to the outer buccal cortical margin of the mandible in the mandibular second molar region. All patients with prognathism underwent a BSSO setback, and had neurosensory testing at 3 months postoperatively (subjective testing with a visual analog scale (VAS), and objective testing with light touch, brush stroke direction, and 2-point discrimination). The mean distance ± SD between the mandibular canal and the buccal cortical margin was 6.04 mm ± 1.66 mm in patients with prognathism, compared to 6.50 ± 2.11 mm in patients without. This difference was not statistically significant ($P = 0.34$). No significant difference was also found in the linear distance between the superior aspect of the IAN canal and the alveolar crest ($P = 0.22$; 16.45 ± 3.24 mm with prognathism; 15.84 ± 2.96 mm without prognathism). Similarly, no significant difference was found in the incidence of contact between the IAN canal and the inner aspect of the buccal cortex ($P = 0.705$; 3.6% with prognathism; 5.0% without prognathism). Neurosensory testing of patients with prognathism revealed that the rate of disturbances of the IAN after SSOs was related to the anatomical position of the mandibular canal. The shorter the distance from the buccal aspect of the IAN canal to the outer buccal cortical margin, the more frequent the occurrence of neurosensory disturbances of the IAN ($P < 0.001$; 4.53 ± 1.03 mm with disturbance; 7.11 ± 1.10 mm without disturbance). Women also had a greater incidence of neurosensory disturbances ($P = 0.043$). However, neurosensory deficit was not related to the distance from the IAN to the alveolar crest, or to the presence of contact with the inner buccal cortical margin (*P* = 0.056 and 0.706 respectively)[57].

2.3.3 Position of the Mandibular Third Molar in Relation to the Mandibular Canal

The relationship of the mandibular third molar with the IAN canal has been evaluated numerous times. When combining the results of most papers published since 1990, a total of 1172 mandibular third molars have been studied with CT[58-65]. The course of the mandibular canal was buccal to the roots in 43.9%, lingual in 34.9%, inferior in 12.8%, and interradicular in 8.4%. These results confirmed that the majority of the IAN canals do not follow a vestibular course (56.1%).

2.4 INFERIOR ALVEOLAR NERVE FUNCTION AFTER SAGITTAL SPLIT OSTEOTOMY

Neurosensory disturbance of the IAN is one of the most common significant complications after BSSO. The IAN is at risk in all stages of surgery, including incision, dissection, retraction, osteotomies, mobilization and internal fixation. The reported incidence of neurosensory disturbance immediately after BSSO ranges from 80% to 100%, while long-term follow-up studies have shown incidences ranging from 0% to up to 85%, 1 to 2 years after surgery[17, 42, 66-84].

Colella et al. in 2007[85], published a systematic review of neurosensory disturbance of the IAN after BSSO. Results showed a frequency of nerve impairment on the seventh postoperative day of 63.3% when using objective tests, and 83% when using subjective evaluation. The frequency decreased to 49.2% with objective methods, and 73.6% with subjective methods at 2 weeks, and to 42.5% objectively, and 69.2% subjectively at 1 month. At 3 months post-surgery, neurosensory deficit was present in 49.3% with objective evaluation, and 50% with subjective tests. At 6 months postoperatively, the incidence decreased further to 33.0% with objective methods, and 36.7% with subjective methods. After 1 year of follow-up, the frequency of neurosensory disturbance was down to 12.8% with objective tests, and 23.8% with subjective tests[85].

Numerous factors have been suggested to influence the neurosensory recovery of the IAN. The general factors reported include the age and sex of the patient, the bone quality, the position of the mandibular canal, as well as the surgical skill of the operator. Intraoperative factors suggested include: the presence of concomitant genioplasty, the dissection technique, the manipulation of the IAN, the amount of mandibular advancement, the fixation technique, the presence of an unfavorable split, and the presence of a mandibular third molar.

2.4.1 Effect of Age

A direct relationship between increasing age and postoperative paresthesia after SSO has been reported. Ylikontiola et al. in 2000[86], prospectively evaluated the neurosensory recovery of 60 SSOs in 30 patients. Subjective evaluations of neurosensory status were done preoperatively and postoperatively at 4 days, 3 weeks, 3 months, 6 months, and 1 year. A statistically significant positive correlation was found between subjective neurosensory loss and the patient's age ($P = 0.039$), with patients younger than 30 years having fewer neurosensory problems[86].

Van Sickels et al. in 2002[87], supported these findings in their prospective evaluation of 127 subjects who underwent a BSSO. During the 2 years of follow-op, damage to the IAN was assessed objectively by testing both light touch detection threshold, and brush stroke direction discrimination threshold. Results showed that patients of age 35 and older had the tendency to have larger sensory deficits immediately after surgery and less complete recovery over time. This effect of age was only significant 1 week, and 6 months after surgery in the case of light touch detection threshold ($P < 0.05$)[87].

Other studies supported this effect of age[31, 84, 88-90], while others did not[75, 91-93]. Kim et al. in 2011[93], evaluated 47 patients undergoing BSSO with subjective evaluation. Visual analog scales (VAS) were used to evaluate altered sensation and pain at 1 month, 3 months, and 6 months after surgery. Age showed no statistically significant difference in the VAS scores for pain and altered sensation at all follow-up times[93].

2.4.2 Effect of Gender

Most recent reports demonstrate no gender-related difference in the neurosensory recovery of the IAN following BSSO[31, 86, 88, 90-93]. Other studies have suggested that female have a higher incidence of neurosensory disturbance[57, 89]. Al-Bishri et al. in 2004[89], supported this effect of gender with questionnaire evaluation of 86 SSOs. Results showed that 16.7% of the operated sides in the female patients had long lasting neurosensory disturbance, compared with 3% of the operated sides in the male patients[89].

2.4.3 Effect of Bone Quality

Only one study evaluated the correlation of mandibular bone quality with neurosensory disturbance after SSOs. Yoshioka et al. in 2010[94], assessed the density of bone around the IAN in 35 patients undergoing BSSO using CT. At 3 months postoperatively, these patients had neurosensory evaluation using a VAS, light touch, direction of brush stroke, two-point discrimination, and temperature. Results showed that mandibles with higher bone density, measured with Hounsfield units, had a significantly higher incidence of neurosensory disturbance ($P < 0.01$)[94].

2.4.4 Effect of the Position of the Mandibular Canal

Studies have shown that postoperative neurosensory impairment of the IAN after BSSO was associated with a shorter distance from the buccal aspect of the mandibular canal to the outer buccal cortical margin[56, 57]. This relation was especially true when the width was 0.8 mm or less ($P < 0.002$)[56].

2.4.5 Effect of the Skill of the Operator

Westermark et al. in 1998[88], subjectively evaluated the IAN function after 496 SSOs. Nerve dysfunction persisted in 40% of patients tested two years postoperatively. A higher rate of neurosensory disturbance was found in the SSOs performed by surgeons in training ($P = 0.05$)[88].

2.4.6 Effect of the Presence of Concomitant Genioplasty

The addition of a genioplasty at the time of the BSSO has been associated with increased neurosensory injury of the IAN[30, 87, 93]. Gianni et al. in 2002[30], evaluated neurosensory alterations of the IAN after genioplasty alone or associated with SSO. Fifty patients were tested at least 1 year after orthognathic surgery. Ten were controls, 12 patients had genioplasty alone or in association with maxillary osteotomy or vertical mandibular ramus osteotomy, 10 patients had BSSO alone, and 18 patients had BSSO with concomitant genioplasty. Neurosensory disturbance was evaluated objectively with tactile sensitivity, stimulus localization, sharp/blunt discrimination, thermal sensitivity, and two-point discrimination. Results showed that the combination of genioplasty and SSO was more detrimental for the lip sensibility than genioplasty or SSO alone (all P's < 0.05)[30].

Another prospective evaluation of 127 patients undergoing BSSO demonstrated that the addition of a genioplasty increased the risk of neurosensory injury[87], while other reports have not shown this relationship[84, 95]. Al-Bishri et al. in 2004[95], retrospectively evaluated 66 patients who underwent BSSO alone, and 27 patients who underwent both BSSO and genioplasty. The incidence of neurosensory disturbance was reported to be 37% for both groups[95].

2.4.7 Effect of the Dissection Technique

Dissection and distraction of the soft tissues on the medial aspect of the ramus during a BSSO can lead to neurosensory deficits of the IAN[31, 91]. Teerijoki-Oksa et al. in 2002[91], intraoperatively evaluated IAN injury during 40 SSOs. Orthodromic sensory nerve action potentials of the IAN were continuously recorded. Changes in latency, amplitude, and sensory nerve conduction velocity were analysed at baseline, and at different stages of the operation. The most prominent changes in IAN conduction occurred during medial dissection. There was also a clear tendency towards more disturbed IAN conduction with longer medial opening times ($P < 0.05$)[91].

This effect was also prospectively evaluated. Panula et al. in 2004[31], looked at the influence of soft tissue handling medial to the ascending ramus in 39 consecutive BSSO patients. For each patient, soft tissues of the ramus were retracted extremely gently and minimally on one SSO side, and more widely on the contralateral side. Neurosensory function was tested subjectively and objectively with 2-point discrimination (2-PD), and vitality scanner tests preoperatively and four times postoperatively up to 1 year. Both 2-PD and vitality scanner tests showed increased neurosensory deficit on the side with wider soft tissue retraction. This difference was statistically significant only with the vitality scanner test at 6 months ($P = 0.028$)[31].

2.4.8 Effect of Manipulation of the Inferior Alveolar Nerve

Neurosensory disturbance has also been associated with a higher degree of manipulation of the IAN during SSO[86, 88, 90]. Ylikontiola et al. in 2000[86], prospectively evaluated the subjective neurosensory recovery of 60 SSOs with a follow-up of 1 year. During surgery, nerve encounter was documented as: nerve not encountered; nerve visible, but embedded in the medial fragment; nerve between the fragments or dissected from the lateral fragment; and nerve transected. A high correlation was found between the degree of manipulation of the nerve and the degree of postoperative sensory loss ($P = 0.0007$).

Other studies do not support this relationship[75, 84, 91]. Fridrich et al. in 1995[75], evaluated 42 consecutive patients undergoing BSSO using subjective questionnaires and five neurosensory tests (static light touch, moving touch discrimination, 2-PD, nociception, and thermoreception), for a follow-up period of 2 years. Results showed that nerves visualized and manipulated, or traumatized had greater neurosensory deficit in the immediate postoperative period (1 week to 1 month). Over time (6 months to 1 year) these nerves recovered to comparable levels as nerves not visualized in the distal segment, or nerves visualized but not manipulated or traumatized. They concluded that as long as the IAN is intact, the long-term (6 months and greater) chance for neurosensory recovery is good despite manipulation[75]. Intraoperative evaluation also showed that exposure or manipulation of the IAN usually had no effect on nerve function, but that the IAN conduction tended to be more disturbed in cases with nerve laceration[91].

2.4.9 Effect of Mandibular Advancement

Most of the evidence does not support the relationship between the amount of mandibular advancement and the impairment of sensation of the IAN [75, 90, 92, 95]. Other studies have found that large mandibular advancements further increased the risk of IAN injury after BSSO[86, 87]. Ylikontiola et al. in 2000[86], found a statistically significant positive correlation between subjective neurosensory loss and a magnitude of mandibular movement greater than 7 mm ($P = 0.044$).

2.4.10 Effect of Fixation Technique

Monocortical miniplate fixation of SSO has been shown to be associated with less neurosensory disturbance of the IAN, when compared to bicortical screws[76, 90, 96, 97]. Fujioka et al. in 1998[76], prospectively evaluated 124 SSOs fixated with bicortical osteosynthesis, and 104 SSOs fixated with monocortical osteosynthesis using miniplates. Static light touch and subjective evaluation were used for neurosensory testing. Subjective testing resulted in a rate of neurosensory disturbance of 78% at 6 months, and 48% at 12 months for the bicortical fixation group, compared to 30% at 6 months, and 10% at 12 months for the monocortical group. Similarly, the rate of light touch disturbance was 68% at 6 months, and 29% at 12 months for the bicortical fixation group, compared to 18% at 6 months, and 9% at 12 months for the monocortical group. These differences were statistically significant ($P < 0.05$). Results failed to show a significant difference between the groups after 18 months with subjective evaluation, and beyond 12 months with static light touch[76].

2.4.11 Effect of the Presence of an Unfavorable Split

Only one study evaluated the effect of an unfavorable fracture on the neurosensory recovery of the IAN after a SSO[84]. August et al. in 1998[84], retrospectively evaluated 85 patients more than 2 years after BSSO with a questionnaire. Logistic regression identified that unfavorable splits were associated with functional sensory deficit ($P = 0.03$)[84].

2.4.12 Effect of the Presence of a Mandibular Third Molar

The presence of a mandibular third molar during SSO has not been show to affect the neurosensory recovery of the IAN[1, 84]. Regression analysis, by August et al. in 1998[84], showed that an increase in neurosensory deficit was not associated with simultaneous mandibular third molar removal ($P = 0.660$). Reyneke et al in 2002[1], evaluated the effect of the presence of mandibular third molars in 139 SSOs (64 SSOs with third molars; 75 without third molars). Neurosensory recovery, although slower during the first 6 months in the group with third molar teeth present, was the same for both groups by 12 months. This difference was not significant (similar recovery curves for both groups; $P = 0.3832$)[1].

2.5 TYPES OF NERVE INJURY

2.5.1 Inferior Alveolar Nerve Anatomy

The nerve trunk is composed of four connective tissue sheaths. The components of a nerve from outside to inside are the mesoneurium, epineurium, perineurium, and endoneurium (Fig. 9). The mesoneurium suspends the nerve trunk within the soft tissue, and is continuous with the outer epineurium that defines the nerve trunk. The epineurium is divided into outer and inner epineuria. The inner epineurium contains loose connective tissue that protects against mechanical stress. Fascicles are delineated by the perineurium, which is a continuation of the pia-arachnoid layer of the central nervous system. It provides structural support and acts as a diffusion barrier. Individual nerve fibers and their Schwann cells are surrounded by the endoneurium. The fascicular pattern can be monofascicular (one large fascicle), oligofascicular (2 to 10 fascicles), or polyfascicular (more than 10 fascicles). The inferior alveolar and lingual nerves are polyfascicular.

The nerve fiber is the functional unit responsible for transmitting stimuli. The nerve fiber is composed of an axon, a Schwann cell, and a myelin sheath in myelinated nerves. The A-alpha fibers are the largest myelinated fibers with the highest conduction velocity. They mediate position and fine touch through muscle spindle afferents and skeletal muscle efferents. The A-beta fibers are the next largest myelinated axons. They mediate proprioception. The A-delta fibers are the smallest of the myelinated fibers. They transmit stimuli encoded for temperature and pain (first or fast pain). The C-fibers are the smallest axons and are unmyelinated. They transmit stimuli encoded for slow or second pain, temperature, and efferent sympathetic fibers.

Two types of nerve injury classification are generally accepted. In 1943, Seddon described a three-stage classification of mechanical nerve injuries[98]. The classes of nerve injury are: neuropraxia, axonotmesis and neurotmesis. In 1951, Sunderland revised and further subclassified nerve injuries into five grades[99].

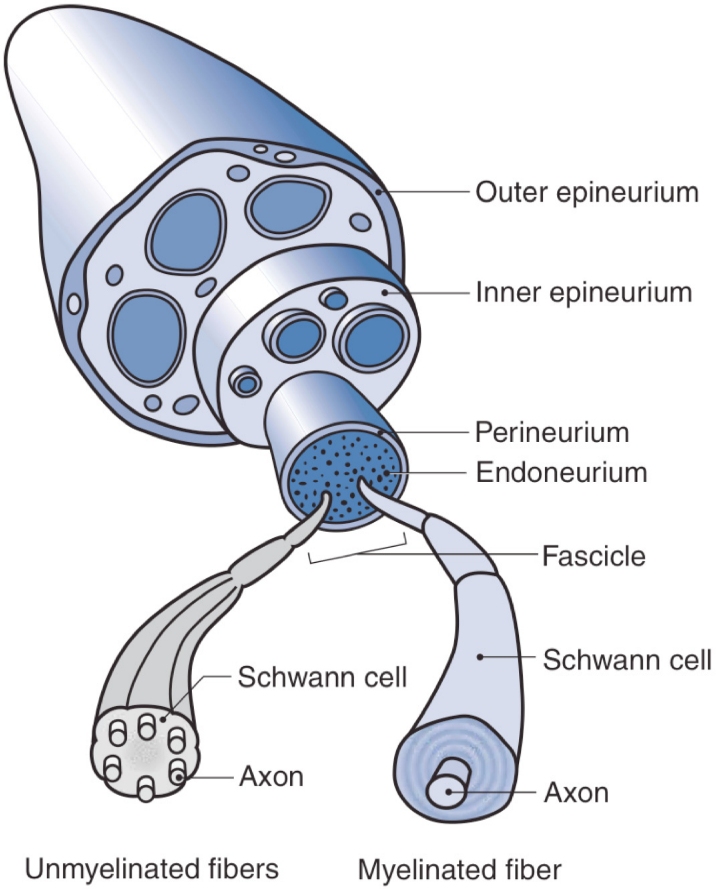

Figure 10. Trigeminal nerve anatomy. In: Miliro M. Microneurosurgery. Miloro M (ed), Peterson's Principles of Oral and Maxillofacial Surgery. Vol 2; BC Decker Inc 2004: Chapter 41; p. 822.

2.5.2 Neuropraxia

Neuropraxia is characterized by a conduction block from transient anoxia owing to acute epineurial and endoneurial vascular interruption. This type of injury is usually the result of nerve trunk manipulation, traction, or compression. Recovery is rapid and complete, with no axonal degeneration. Neuropraxia corresponds to a first degree Sunderland injury, which is further subdivided into types I, II, and III. Type I results from mild nerve manipulation. Recovery occurs in hours when neural blood flow is restored. Type II is due to moderate traction or compression with intrafascicular edema. Return of sensation occurs in days following edema resolution. Type III injuries result from significant nerve manipulation with segmental demyelination. Recovery occurs within days to weeks. The majority of IAN injuries following SSOs are neuropraxias.

2.5.3 Axonotmesis

Axonotmesis is characterized by axonal injury with subsequent degeneration due to severe ischemia, intrafascicular edema, or demyelination. Traction and compression are the usual causative mechanisms. Even though the axons are damaged, there is no disruption of the endoneurial sheath, perineurium, or epineurium. The neural response is an initial anesthesia followed by a paresthesia as recovery begins. Recovery occurs in 2 to 4 months, but improvement leading to complete recovery may take as long as 12 months. Axonotmesis corresponds to second, third, and fourth degree Sunderland injuries. Second-degree injuries extend through and include the endoneurium with no significant axonal disorganization. Recovery takes weeks to months, and may not be complete. Third-degree injuries are due to significant neural trauma with variable degrees of intrafascicular architectural disruption and damage extending to the perineurium.

Return of sensation occurs in months, and may be incomplete. Fourth-degree injuries extend through the perineurium to the epineurium, with the epineurium remaining intact. Axonal, endoneurial, and perineurial damage is present with disorganization of the fascicles. Full recovery is unlikely. Minimal improvement may occur in 6 to 12 months.

2.5.4 Neurotmesis

Neurotmesis, which corresponds to a fifth-degree Sunderland injury, is characterized by severe disruption and epineurial discontinuity. The etiology of nerve injury results from nearly complete or complete transection of the nerve. The immediate neural response is anesthesia. This may be followed by paresthesia, or possibly neuropathic responses such as allodynia, hyperpathia, hyperalgesia, or chronic pain. Associated neuroma formation is common. The prognosis for return of sensation is poor. Sensory and functional recovery is never complete.

2.6 NEUROSENSORY TESTING OF THE INFERIOR ALVEOLAR NERVE

Neurosensory evaluation of the IAN is performed to detect the presence and quantify neurosensory deficits, and to monitor sensory recovery. Numerous testing methods exist. These are generally divided into subjective and objective evaluations. Objective evaluations can be divided into clinical neurosensory testing and into purely objective tests.

2.6.1 Subjective Evaluation

Subjective evaluation is obtained directly from the patient's report, or with the use of a questionnaire. Subjective evaluation collected from the patient's history is difficult to standardize because of the difference in interpretation of the deficit between examiner and patient. Patients tend to report neurosensory disturbance in a higher proportion than clinical testing methods have been able to detect[100, 101].

Questionnaires can be in the form of a "yes" or "no" answers, multiple-choice questions, or VAS. The VAS is an uninterrupted horizontal line anchored by word descriptors at each end. The patients mark on the line the point that represents their perception of their current state. The score is determined by measuring the distance from the left-hand end of the line to the marked point. The VAS tool is accepted for standardizing symptoms and complaints.

2.6.2 Clinical Neurosensory Testing

Clinical neurosensory testing can be divided into mechanoceptive and nociceptive tests, based upon the specific receptors stimulated through cutaneous contact. Mechanoceptive tests include static light touch detection (LT), two-point discrimination

(2-PD), and brush stroke directional discrimination. Nociceptive tests include pinprick discrimination, sharp/blunt discrimination (S/B), and thermal discrimination.

2.6.2.1 Mechanoceptive Tests

Static light touch detection (LT)

Static light touch detection assesses the integrity of pressure sensation, which is a function of intact myelinated afferent A-beta axons. This test is performed with Semmes-Weinstein monofilaments or von Frey hairs. These devices are rods with nylon filaments of varying diameters. The stiffness of each filament determines the force necessary to bend the filament. The narrowest diameter filament that requires the least amount of force to be detected is recorded. The evaluator size 3.22 (Force = 0.166 gm; Pressure = 11.1 gm/mm^2) has been reported to be the upper normal limit for neurosensory testing of the mental nerve region[101, 102]. The LT test has been shown to be the most sensitive and clinically useful neurosensory test[101-103]. It also correlates best with electrophysiological testing[102].

Brush stroke directional discrimination

Brush stroke directional discrimination is a test of proprioception that assesses the integrity of the large A-alpha and A-beta myelinated axons. The test is performed with a cotton swab, soft brush, or Semmes-Weinstein monofilament. The brush is stroked gently across the area of involvement, and the patient is asked to indicate the direction of movement. The number of correct statements out of 10 is recorded. Standardization of this test has been shown to be difficult[103].

Two-point discrimination (2-PD).

Two-point discrimination assesses the quantity and density of functional sensory receptors and afferent fibers. The test is performed in a static fashion using a millimeter caliper with sharp or blunt tips. If sharp points are used, the small myelinated A-delta and unmyelinated C afferent fibers are assessed. If blunt points are used, the larger myelinated A-alpha afferent fibers are tested. The minimal distance a patient can consistently discriminate between 2 separate points is then recorded. Some investigators find the 2-PD test to be less sensitive than the LT test[80], mainly because of the variability in the 2-PD values[70, 71], whereas others find that the 2-PD test compares best with subjective complaints[104, 105].

2.6.2.2 Nociceptive Tests

Pinprick discrimination

Pin tactile discrimination (PIN) assesses the small A-delta and C fibers that innervate the free nerve endings responsible for nociception. This test uses a device applying different forces to a needle to produce a nociceptive stimulus. The pinprick sensory threshold is the magnitude of force necessary to elicit sharpness. A force of 15 g has been considered to be a reproducible test stimulus in normal subjects[104, 106].

Sharp/blunt discrimination (S/B)

Sharp/blunt discrimination is performed using a mechanical probe with two heads, one sharp and the other blunt. The sharp point is used to test nociception (A-delta and C fibers) and the blunt end to test for pressure detection (A-beta fibers). The patient’s task is to determine if the stimulus is sharp or blunt. The test is difficult to standardize due to the variability of the applied pressure[103].

Thermal discrimination

Thermal discrimination tests the differentiation between hot (50ºC) and cold (15ºC) nociceptive stimuli. Warmth sensation is attributed to A-delta fibers and cold to C fibers. Multiple instruments are available for thermal testing, including Minnesota thermal disks, thermodes, ethyl chloride sprays, acetone, ice, and water. This test has been shown to have a low sensitivity[101, 102].

2.6.3 Objective Sensory Tests

2.6.3.1 Nerve conduction studies

Orthodromic sensory nerve action potential (SNAP) recording can monitor the function of the IAN[17]. The recording electrode is inserted below the zygomatic arch in front of the temporomandibular joint, to lie near the foramen ovale. Electrical stimuli are administered at the mental foramen. SNAP onset latencies and amplitudes are recorded, and nerve conduction velocity of the IAN can be calculated.

2.6.3.2 Trigeminal somatosensory evoked potentials

Trigeminal somatosensory evoked potentials is an electrophysiologic method of evaluating the trigeminal pathway[107]. The IAN can be tested using stimulating electrodes placed in the cutaneous region of the mental nerve. Recording electrodes are applied to the scalp. An electroencephalograph recording system is used for analysis of the potentials to determine peak latencies and amplitudes.

2.6.3.3 Mental nerve blink reflex

Sensory conduction velocity of the IAN can be recorded using the mental nerve blink reflex[108]. This electrophysiological technique elicits blink reflexes by electrical stimulation with a small bipolar surface electrode at the mental nerve distribution. The responses are recorded with surface electrodes from the orbicularis oculi muscles, simultaneously, on both sides.

2.6.3.4 Other tests

Numerous other objective tests have been used for neurosensory testing of the IAN. These include the vitality scanner test[106], the current perception threshold[109], and the thermal quantitative sensory testing[110].

CHAPTER 3 PURPOSE OF THE STUDY

The aim of the present study is to investigate the effects of the presence or absence of a mandibular third molar on the ability to perform a sagittal split osteotomy of the mandible.

The primary outcome measure is:

> To determine if the presence of mandibular third molars influences the incidence of unfavorable fractures during SSOs.

The secondary outcome measures are:

1. To evaluate the effect of the presence or absence of a mandibular third molar during SSO on the degree of entrapment and manipulation of the IAN.
2. To compare the times to complete the SSO in the presence or absence of a mandibular third molar.
3. To observe the occurrence of neurosensory disturbance of the IAN when a mandibular third molar is either present or absent during a SSO.

CHAPTER 4 PATIENTS AND METHODS

4.1 PATIENTS

A prospective evaluation of 677 SSOs performed in 339 patients was conducted by the department of Oral and Maxillofacial Surgery, Queen Elizabeth II Health Sciences Center, Halifax, Nova Scotia, Canada. The evaluation period was over 4 years (November 2006 to October 2010). Ethical approval was obtained by the Capital Health Research Ethics Board of Nova Scotia, Canada.

Patients presenting for the SSO procedure, who also consented to be included in the study, were divided in 2 groups based on the presence or absence of mandibular third molars at the time of surgery:

a) Group I consisted of 331 SSOs with concomitant removal of mandibular third molars (48.9% of all SSOs).
b) Group II consisted of 346 SSOs in which the mandibular third molars were congenitally absent or removed at least 6 months prior to the procedure (51.1% of all SSOs).

Of these 339 patients, 30 had a mandibular third molar present on one side, but absent on the other side. Only 1 patient required a unilateral SSO to correct the dentofacial deformity.

Neurosensory evaluation of the mental nerve was offered to all the patients from the Halifax Regional Municipality area. Seventy-two patients agreed to participate in this part of the study. Twelve of the 72 patients (16.7%) missed at least one nerve-testing follow-up, and had to be excluded from the IAN evaluation part of the study. A total of 120 SSOs in 60 patients were analyzed and again similarly divided into 2 groups:

a) Group I consisted of 64 SSOs with concomitant removal of mandibular third molars (53.3% of all SSOs).

b) Group II consisted of 56 SSOs in which the mandibular third molars were congenitally absent or removed at least 6 months prior to the procedure (46.7% of all SSOs).

Of these 60 patients, 4 had a mandibular third molar present on one side, but absent on the other side. No patient required a unilateral SSO to correct the dentofacial deformity.

4.2 METHODS

4.2.1 Subject Selection

Subjects were selected based on pre-determined inclusion and exclusion criteria. Inclusion criteria were:

a) All patients presenting to the department of Oral and Maxillofacial Surgery, Queen Elizabeth II Health Sciences Center, Halifax, Nova Scotia, Canada, requiring SSO as part of the correction of their dentofacial deformity were recruited for the study.

b) Neurosensory evaluation of the mental nerve branch of the IAN was assessed only in patients from the Halifax Regional Municipality area, due to their proximity to the department.

Exclusion criteria were:

a) Patients with mandibular third molars removed less than 6 months prior to the planned SSO were excluded from the study. In these patients, incomplete healing of the extraction site could possibly increase the complications associated with the procedure.

b) Patients who had a previous SSO were excluded from the study, due to the possibility of increased complications.

c) Patients who had a prior mandibular fracture were excluded from the study, again due to the possibility of increased complications.

d) Patients with preoperative neurosensory disturbance of the IAN were also excluded from the study.

4.2.2 Surgery

The SSO operation was performed as previously described[111]. All of the operations were carried out by one of six oral and maxillofacial surgeons and their residents in both Groups I and II. During the operation, the medial surface of the mandible was exposed with a Henahan retractor. The horizontal cut was made just above the lingula on the medial surface of the ramus, and the vertical cut between the first and second molar on the buccal surface of the mandible with a Lindemann bur. A #701 bur was used to cut the cortical bone in a sagittal direction. When a mandibular third molar was present, cuts were performed through the greater sagittal length of the tooth during the sagittal osteotomy. The sagittal split was initiated with a flat blade spatula followed by the use of a ¼ inch chisel, Smith spreaders, and Tessier spreaders, respectively. The split completion was not achieved by malleting a chisel. Rigid internal fixation was achieved with one miniplate and monocortical screws.

4.2.3 Data Collected at Time of Surgery

Data related to age, gender, concomitant functional genioplasty, and presence or absence of mandibular third molars was recorded at the time of surgery (Appendix A).

When mandibular third molars were present, the degree of impaction and development was recorded. The degree of impaction was categorized into: 1) erupted; 2) partially erupted; and 3) soft tissue or bony impaction. The degree of development was also subdivided into: 1) incomplete crown formation; 2) complete crown formation; and 3) complete root formation.

The magnitude of advancement or setback of the mandible was recorded in millimeters. A negative number was recorded in cases of mandibular setback.

The presence of an unfavorable fracture during SSO was also recorded. Unfavorable splits were categorized into: 1) proximal segment (buccal plate) fracture; and 2) distal segment (lingual plate) fracture. The extent of the fracture was also subdivided into: 1) complete proximal segment fracture; 2) incomplete (green stick) proximal segment fracture; 3) complete distal segment fracture; and 4) incomplete (green stick) distal segment fracture.

The degree of entrapment and manipulation of the IAN was registered at the time of the splitting procedure. The absence of entrapment was divided into: 1) IAN in distal segment, not visualized; and 2) IAN in distal segment, visualized, not manipulated. The presence of entrapment was also categorized into: 3) IAN dissected from proximal segment; 4) IAN released from proximal segment after bony removal; 5) IAN released with visible injury or bleeding; and 6) IAN transected.

The time to achieve the split was recorded in minutes. Timing began at the start of the osteotomy and stopped at the completion of the split. The time required to free the IAN from the proximal segment was part of the time recorded. The total time also included the time required to extract the mandibular third molar when present.

Finally, the surgeon's experience was categorized into: 1) staff versus 2) resident.

4.2.4 Neurosensory Evaluation of the Inferior Alveolar Nerve

The IAN function was subjectively and objectively evaluated preoperatively, and postoperatively at 3 months, and 6 months (Appendix B, C, and D).

Objective testing was performed in 3 different areas of the mental nerve distribution: Area 1= vermillion; Area 2 = labial skin; and Area 3 = mental skin (Fig. 11).

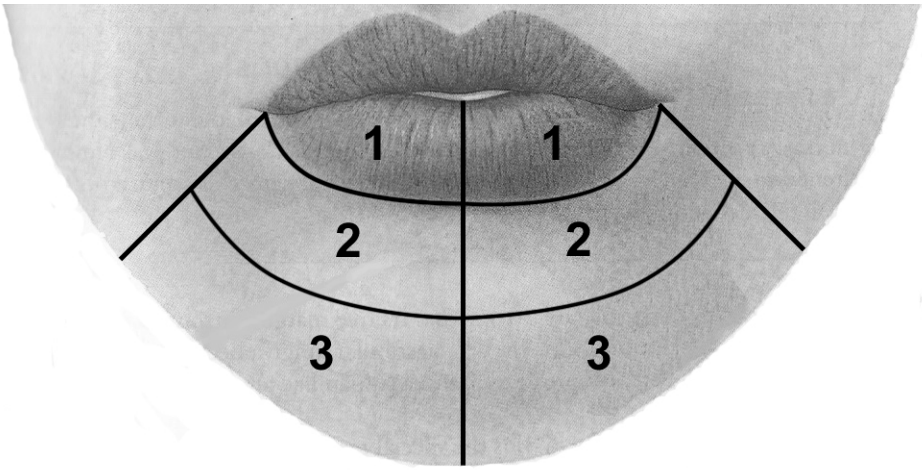

Figure 11. Tested areas of the mental nerve distribution. **1**, Vermillion. **2**, Labial skin. **3**, Mental skin.

Each region was assessed using three tests: 1) two-point discrimination (2-PD); 2) static light touch detection (LT); and 3) sharp/blunt discrimination (S/B). All of the assessments were done after asking the patients to close their eyes and separate their lips in a comfortable position. The examiner was blinded to previous neurosensory test results. The patient's response was recorded when ≥80% (4 of 5) of the answers were consistent.

The 2-PD test was done using a caliper graduated in millimeters. The ends of the caliper were blunt to stimulate the larger myelinated A-alpha afferent fibers. The test was conducted by beginning with the points closed and progressively opening them in 1 mm increments until the patient could consistently (≥80%) discriminate two points of contact. This distance was then recorded. Care was taken to ensure that the ends touched the cutaneous surface at the same time. The maximum millimeter limit was considered to be 20 mm.

The LT test was accomplished using Semmes-Weinstein Von Frey Aesthesiometer monofilaments from the Touch Test™ sensory evaluator. All patients were tested with the 3.22 evaluator size (Force = 0.166 gm; Pressure = 11.1 gm/mm^2). The myelinated afferent A-beta axons were stimulated in each of the 3 areas by applying the monofilament at a 90º angle with the skin or vermillion. A positive response was recorded if the patient could discern the stimulus four of five times (≥80%).

The S/B test was performed using the sharp and blunt heads of a mechanical probe. Each of the 3 areas of the mental skin was touched randomly with the sharp end (A-delta and C fibers) and dull end (A-beta fibers) of the probe. The patient had to decide whether the stimulus was sharp or blunt. A normal response was recorded when 80% of the answers were correct.

Subjective sensation was evaluated by asking the patient to select one of three choices between: 1) normal sensation; 2) numbness, tingling and/or pain, that is not disturbing; 3) numbness, tingling, and/or pain, that is disturbing.

4.2.5 Statistics

Statistical analysis of the data was performed using the SPSS Statistics 17.0 software (version 17.0.0). All variables were divided into continuous and categorical variables. Groups I and II were compared for each of these variables. For all statistical tests, a 95% confidence interval was used, and a *P* value less than 0.05 was considered statistically significant.

Continuous variables included: age (in years); movement of the mandible (in mm); time to achieve the SSO (in minutes); and 2-PD values (in mm). For statistical analysis, a negative movement (setback) of the mandible was considered to be nil. For the

2-PD, the 3 months and 6 months postoperative values were compared to the preoperative values, and the difference was recorded in millimeters. If the postoperative reading was lower than the preoperative reading (i.e., the patient was more "sensitive"), the difference was considered to be 0 mm.

Categorical variables were subdivided into dichotomous and polychotomous variables. Dichotomous categorical variables included: presence of mandibular third molar (yes / no); gender (male / female); concomitant functional genioplasty (yes / no); presence of unfavorable fracture (yes / no); presence of IAN entrapment (yes / no); type of operator (staff / resident); positive LT response (yes / no); and positive S/B response (yes/ no). Polychotomous categorical variables included: degree of impaction of mandibular third molar (erupted / partially erupted / soft tissue-bony impaction); degree of development of mandibular third molar (incomplete crown formation / complete crown formation / complete root formation); type of unfavorable fracture (complete proximal segment fracture / incomplete proximal segment fracture / complete distal segment fracture / incomplete distal segment fracture); degree of entrapment and manipulation of the IAN (in distal segment, not visualized / in distal segment, visualized, not manipulated / dissected from proximal segment / released from proximal segment after bony removal / visible injury or bleeding / nerve transected); and subjective evaluation response (normal sensation / numbness, tingling, or pain, not disturbing / numbness, tingling, or pain, disturbing).

The Pearson Chi-Square test was used to analyze 2 dichotomous categorical variables, or a polychotomous categorical variable with a dichotomous categorical variable. The T-test was employed to evaluate a dichotomous categorical variable with a continuous variable. An analysis of variance (ANOVA) was chosen to study polychotomous categorical variables with continuous variables. The Pearson correlation test was used to measure the strength of linear dependence between two continuous variables. Logistic regressions were used to investigate the effect of a categorical variable, while controlling for the influence of other variables. Finally, linear regressions were used to investigate the effect of a continuous variable, while adjusting for the influence of other variables.

CHAPTER 5 RESULTS

5.1 GROUP DISTRIBUTION

The group comparisons are shown in Table 1. Group I consisted of 331 SSOs and concomitant removal of mandibular third molars (48.9% of all SSOs). Group II consisted of 346 SSOs with mandibular third molars congenitally absent or removed at least 6 months prior to the procedure (51.1% of all SSOs). The mean age ± SD for Group I was 19.6 ± 7.4 years, which was significantly different than the mean age of Group II at 30.4 ± 12.1 years (t = -14.1; $P < 0.001$). Gender distribution for Group I showed a 63.1% proportion of females and 36.9% proportion of males, compared to 74.0% female and 26% male for Group II ($X^2 = 9.25$; $P = 0.002$). Most of the mandibular third molars present were impacted (71.0%), with complete crown formation (48.3%).

Table 1. *Group Comparison*

Variables	Group I (with third molar)		Group II (without third molar)		*P*-value
	n (%)	Mean ± SD	*n* (%)	Mean ± SD	
SSOs	331 (48.9%)		346 (51.1%)		
Age (years)		19.6 ± 7.4		30.4 ± 12.1	<0.001*
Gender					0.002*
Male	122 (36.9%)		90 (26.0%)		
Female	209 (63.1%)		256 (74.0%)		
Unfavorable Fracture	8 (2.42%)		13 (3.76%)		0.315
Proximal	1		4		
Distal	7		9		
IAN Entrapment	123 (37.2%)		161 (46.5%)		0.014*
Time to Complete SSO (min)		11.9 ± 5.5		10.2 ± 5.3	<0.001*

* Statistically Significant

5.2 EFFECT OF THE PRESENCE OF MANDIBULAR THIRD MOLARS DURING SAGITTAL SPLIT OSTEOTOMIES

In 677 mandibular SSOs, there were 21 (3.1% of all sites) unfavorable fractures. When mandibular third molars were removed during SSOs the incidence of unwanted fracture was 2.42% (8 of 331). This is in contrast with the 3.76% (13 of 346) incidence of unfavorable splits when the third molar was congenitally absent or removed at least 6 months before the SSO. This difference was not statistically significant (X^2 = 1.01; P = 0.315). Logistic regression analysis also showed that the presence of mandibular third molars during SSOs had no significant effect on the incidence of unfavorable fractures when adjusted for age, gender, experience of the operator, and presence of IAN entrapment (B = 0.05; 95% confidence interval (C.I.) = 0.38 to 2.92; P = 0.932).

The type and extent of unfavorable splits are shown in Table 2. Distal segment fractures were more common (76.2%; 16 of 21 fracture sites) than proximal segment fractures (23.8%; 5 of 21 fracture sites). Proximal segment fractures were more common in Group II (80.0%; 4 of 5 fractures). Distal segment were also more common in Group II (56.3%; 9 of 16 fractures). No significant differences in type or extent of unfavorable fractures were found between Group I and Group II (X^2 = 1.74; P = 0.628).

Table 2. *Type and Extent of Unfavorable Splits*

Variables	Group I (with third molar)		Group II (without third molar)		P-value
	n	%	*n*	%	
SSOs	331	48.9%	346	51.1%	
Unfavorable Fracture	8	2.42%	13	3.76%	0.315
Type and Extent					0.628
Proximal Segment	1	12.5%	4	30.8%	
Complete	1	12.5%	2	15.4%	
Incomplete	0	0%	2	15.4%	
Distal Segment	7	87.5%	9	69.2%	
Complete	3	37.5%	5	38.5%	
Incomplete	4	50.0%	4	30.8%	

The IAN was entrapped in the proximal segment more frequently when the mandibular third molar was absent or removed at least 6 months prior to the SSO. The incidence of entrapment was 37.2% for Group I, and 46.5% for Group II. This difference was statistically significant ($X^2 = 6.10$; $P = 0.014$). Table 3 also shows that the degree of entrapment was significantly more severe for Group II ($X^2 = 23.22$; $P < 0.001$).

Table 3. *Degree of Entrapment of the Inferior Alveolar Neurovascular Bundle During Sagittal Split Osteotomy*

Variables	Group I (with third molar)		Group II (without third molar)		*P*-value
	n	%	*n*	%	
SSOs	331	48.9%	346	51.1%	
IAN Entrapment	123	37.2%	161	46.5%	0.014*
<u>*Degree of Entrapment*</u>					<0.001*
In distal segment, not visualized	43	13.0%	12	3.5%	
In distal segment, visualized, not manipulated	167	50.5%	173	50.0%	
Dissected from proximal segment	60	18.1%	79	22.8%	
Released from proximal segment after bony removal	56	16.9%	76	22.0%	
Released with visible injury or bleeding	4	1.2%	4	1.2%	
IAN transected	1	0.3%	2	0.6%	

* Statistically Significant

The presence of a mandibular third molar increased the time to accomplish the SSO by 1.7 minutes. The mean ± SD time to perform the procedure was 11.9 ± 5.5 min for Group I, compared to 10.2 ± 5.3 min for Group II. The T-test showed that the difference was statistically significant ($t = 4.21$; $P < 0.001$). An ANOVA also revealed that the degree of entrapment significantly affected the time to achieve the split, as demonstrated in Table 4 ($F = 24.4$; $P < 0.001$).

Table 4. *Effect of the Degree of Entrapment of the Inferior Alveolar Neurovascular Bundle on Time to Accomplish the Sagittal Split Osteotomy*

Variables	Time to Complete SSO (min)		*P*-value
	Mean	± SD	
Degree of Entrapment			<0.001*
In distal segment, not visualized	10.6	± 4.6	
In distal segment, visualized, not manipulated	9.4	± 4.3	
Dissected from proximal segment	11.2	± 5.6	
Released from proximal segment after bony removal	14.5	± 6.1	
Released with visible injury or bleeding	16.8	± 5.1	
IAN transected	21.7	± 8.1	

* Statistically Significant

5.2.1 Effect of Degree of Impaction and Development of Mandibular Third Molars

The distribution of impaction and development of mandibular third molars in Group I is shown in Table 5. The degree of impaction or development had no significant effect on the frequency of unfavorable splits or presence of IAN entrapment (all $P > 0.05$). The time to achieve the SSO was significantly affected by the degree of development of the tooth ($F = 3.22$; $P = 0.041$), but not by the type of impaction ($F = 0.79$; $P = 0.454$). Faster splits were associated with incomplete crown formation of the third molar.

Table 5. *Effect of Degree of Impaction and Development of Mandibular Third Molars During Sagittal Split Osteotomy*

Variables	Group I (with third molar)		Unfavorable Fracture	IAN Entrapment	Time (min)
	N	%	*n* (%)	%	Mean ± SD
SSOs	331	48.9%	8 (2.42%)	37.2%	11.9 ± 5.5
<u>*Degree of Impaction*</u>					
Erupted	50	15.1%	2 (4.0%)	24.0%	12.1 ± 5.9
Partially Erupted	46	13.9%	1 (2.2%)	37.0%	12.8 ± 6.2
Soft tissue/Bony Impaction	235	71.0%	5 (2.1%)	40.0%	11.7 ± 5.3
		P-value	0.731	0.104	0.454
<u>*Degree of Development*</u>					
Incomplete Crown	15	4.5%	0 (0.0%)	20.0%	8.6 ± 2.6
Complete Crown	160	48.3%	4 (2.5%)	41.9%	11.8 ± 5.2
Complete Root	156	47.1%	4 (2.6%)	34.0%	12.3 ± 5.9
		P-value	0.823	0.129	0.041*

* Statistically Significant

5.2.2 Effect of Age

Table 6 demonstrates the different effects of age. Older age was significantly associated with an increased frequency of unfavorable splits, as well as increased entrapment and manipulation of the IAN (all $P < 0.05$). Age was not correlated with an increased time to achieve the SSO ($r = -0.055$; $P = 0.152$). The significance of the effect of age on the incidence of unwanted fractures was lost when controlling for gender, presence of mandibular third molars, experience of the operator, and presence of IAN entrapment ($B = 0.03$; 95% C.I. = 0.997 to 1.068; $P = 0.070$). Furthermore, patients younger than 20 years of age had an incidence of unfavorable fractures of 2.2%, compared to an incidence of 3.9% for patients of age 20 and older. This difference was again not significant ($X^2 = 1.62$; $P = 0.203$).

Table 6. *Effect of Age During Sagittal Split Osteotomy*

Variables	Age (years) Mean	± SD	*P*-value
Unfavorable Fracture			0.018*
Yes	31.0	± 13.7	
No	25.0	± 11.3	
IAN Entrapment			0.020*
Yes	26.4	± 12.1	
No	24.3	± 10.8	
Degree of Entrapment			<0.001*
In distal segment, not visualized	21.5	± 8.7	
In distal segment, visualized, not manipulated	24.7	± 11.1	
Dissected from proximal segment	24.6	± 10.6	
Released from proximal segment after bony removal	27.9	± 13.2	
Released with visible injury or bleeding	25.3	± 13.4	
IAN transected	46.7	± 5.5	
Time to Complete SSO			0.152

* Statistically Significant

5.2.3 Effect of the Presence of Mandibular Third Molars in Different Age Categories

Table 7 illustrates the effect of the presence of mandibular third molars in three different age categories: 1) age below 20 years; 2) age 20 to 30 years; and 3) age above 30 years. For the patients under 20 years of age, no significant difference was found between Group I and Group II in the rate of unfavorable splits, IAN entrapment, or time to achieve the SSO (all $P > 0.05$). The only significant effect in patients of 20 to 30 years of age was that the absence of a mandibular third molar during SSO was associated with an increased incidence of IAN entrapment ($X^2 = 5.55$; $P = 0.019$). In patients older than 30 years of age, increased procedural time was associated with the presence of a mandibular third molar during SSO ($t = 3.65$; $P < 0.001$).

Table 7. *Effect of the Presence of Mandibular Third Molars During Sagittal Split Osteotomy in Different Age Categories*

Variables	Group I (with third molar)		Group II (without third molar)		*P*-value
	n	%	*n*	%	
Age < 20 years	246	77.4%	72	22.6%	
Mean Age ± SD	16.7	± 1.6	17.2	± 1.3	0.028*
Gender					0.413
Male	88	35.8%	22	30.6%	
Female	158	64.2%	50	69.4%	
Unfavorable Fracture	5	2.0%	2	2.8%	0.705
IAN Entrapment	91	37.0%	32	44.4%	0.253
Time to Complete SSO (min)	11.9	± 5.5	10.6	± 5.6	0.097
Age 20-30 years	60	32.1%	127	67.9%	
Mean Age ± SD	22.2	± 2.9	24.2	± 3.2	< 0.001*
Gender					0.208
Male	23	38.3%	37	29.1%	
Female	37	61.7%	90	70.9%	
Unfavorable Fracture	1	1.7%	4	3.1%	0.557
IAN Entrapment	17	28.3%	59	46.5%	0.019*
Time to Complete SSO (min)	11.2	± 5.1	10.2	± 5.3	0.221
Age > 30 years	25	14.5%	147	85.5%	
Mean Age ± SD	41.7	± 10.2	42.3	± 8.6	0.746
Gender					0.014*
Male	11	44.0%	31	21.1%	
Female	14	56.0%	116	78.9%	
Unfavorable Fracture	2	8.0%	7	4.8%	0.501
IAN Entrapment	15	60.0%	70	47.6%	0.252
Time to Complete SSO (min)	14.1	± 6.2	9.9	± 5.2	<0.001*

* Statistically Significant

5.2.4 Effect of Gender

Table 8 shows that gender only influenced the time to achieve the SSO, with males having longer procedures than females ($t = 6.05$; $P < 0.001$). All other variables were not significant (all $P > 0.05$).

Table 8. *Effect of Gender During Sagittal Split Osteotomy*

Variables		Gender		*P*-value
		Male	Female	
SSOs	*n (%)*	212 (31.3%)	465 (68.7%)	
Age (years)	*Mean* ± *SD*	24.3 ± 11.7	25.6 ± 11.3	0.163
Unfavorable Fracture	*n (%)*	7 (3.3%)	14 (3.0%)	0.839
IAN Entrapment	*n (%)*	93 (43.9%)	191 (41.1%)	0.495
Time to Complete SSO (min)	*Mean* ± *SD*	13.0 ± 6.3	10.1 ± 4.8	<0.001*

* Statistically Significant

5.2.5 Effect of the Surgeon's Experience

The surgeon's experience significantly affected the time to achieve the SSO as well as the occurrence of unfavorable fractures. Table 9 shows that the residents took 3.5 min longer to complete the split, compared to staff surgeons ($t = -9.28$; $P < 0.001$). The incidence of unfavorable fractures was 1.3% for the staff surgeons, compared to 4.5% for the residents ($X^2 = 5.73$; $P = 0.017$). After controlling for age, gender, presence of mandibular third molars, and presence of IAN entrapment, the effect was still statistically significant ($B = -1.29$; 95% C.I. = 0.09 to 0.84; $P = 0.023$).

Table 9. *Effect of Surgeon's Experience During Sagittal Split Osteotomy*

Variables		Surgeon		*P*-value
		Staff	Resident	
SSOs	*n (%)*	302 (44.6%)	375 (55.4%)	
Unfavorable Fracture	*n (%)*	4 (1.3%)	17 (4.5%)	0.017*
IAN Entrapment	*n (%)*	129 (42.7%)	155 (41.3%)	0.717
Time to Complete SSO (min)	*Mean* ± *SD*	9.1 ± 3.6	12.6 ± 6.1	<0.001*

* Statistically Significant

5.2.6 Analysis of Patients Serving as Their Own Control

Thirty patients who underwent a BSSO had a mandibular third molar present on one side, but absent on the other side, and could be used as their own controls. Table 10 reveals that the presence of a mandibular third molar in these patients had no significant effect on the outcomes (all $P > 0.05$).

Table 10. *Group Comparison in Patients Serving as Their Own Control*

Variables	Group I (with third molar)		Group II (without third molar)		*P*-value
	n (%)	Mean ± SD	*n* (%)	Mean ± SD	
SSOs	30 (50.0%)		30 (50.0%)		
Age (years)		30.5 ± 15.7		30.5 ± 15.7	
Unfavorable Fracture	2 (6.7%)		1 (3.3%)		0.554
Proximal	0		0		
Distal	2		1		
IAN Entrapment	11 (36.7%)		9 (30.0%)		0.584
Time to Complete SSO (min)		11.9 ± 6.3		10.2 ± 5.1	0.259

5.3 EFFECT OF THE PRESENCE OF MANDIBULAR THIRD MOLARS ON THE NEUROSENSORY RECOVERY OF THE INFERIOR ALVEOLAR NERVE AFTER SAGITTAL SPLIT OSTEOTOMIES

Neurosensory recovery of the IAN was evaluated preoperatively, 3 months postoperatively, and 6 months postoperatively in 120 SSOs (60 patients). Group I consisted of 64 SSOs and concomitant removal of mandibular third molars (53.3% of all SSOs). Group II consisted of 56 SSOs with mandibular third molars congenitally absent or removed at least 6 months prior to the procedure (46.7% of all SSOs). Group II was significantly older than Group I (t = -3.34; P = 0.001). Table 11 illustrates that both groups had otherwise similar intraoperative outcomes. A concomitant genioplasty was performed in 21 of the 64 SSOs (32.8%) in Group I, and in 23 of the 56 SSOs (41.1%) in Group II. This difference was not significant ($X^2 = 0.88$; P = 0.349). The magnitude of advancement was also similar for both groups (t = -1.30; P = 0.196).

Table 11. *Group Comparison in Patient with Neurosensory Evaluation of the Inferior Alveolar Nerve*

Variables	Group I (with third molar)		Group II (without third molar)		*P*-value
	n (%)	Mean ± SD	*n* (%)	Mean ± SD	
SSOs	64 (53.3%)		56 (46.7%)		
Age (years)		19.3 ± 8.0		24.9 ± 10.0	0.001*
Gender					0.353
Male	27 (42.2%)		19 (33.9%)		
Female	37 (57.8%)		37 (66.1%)		
Genioplasty					0.349
Yes	21 (32.8%)		23 (41.1%)		
No	43 (67.2%)		33 (58.9%)		
Advancement (mm)		3.8 ± 2.8		4.5 ± 3.3	0.196
Unfavorable Fracture	2 (3.1%)		2 (3.6%)		0.892
Proximal	0		0		
Distal	2		2		
IAN Entrapment	25 (39.1%)		31 (55.4%)		0.074
Entrapment Degree					0.400
In distal segment, not visualized	3 (4.7%)		1 (1.8%)		
In distal segment, visualized, not manipulated	36 (56.3%)		24 (42.9%)		
Dissected from proximal segment	12 (18.8%)		11 (19.6%)		
Released from proximal segment after bony removal	12 (18.8%)		18 (32.1%)		
Released with visible injury or bleeding	1 (1.6%)		1 (1.8%)		
IAN transected	0 (0.0%)		1 (1.8%)		
Time to Complete SSO (min)		12.4 ± 5.1		11.6 ± 5.3	0.432

* Statistically Significant

5.3.1 Two-Point Discrimination

Sensory recovery of the IAN is improved if mandibular third molars are present at the time of the SSOs, when tested with 2-PD (Table 12, Figs. 12-14). This positive relationship was significant in the area of the vermillion, labial skin, and mental skin at 3 months and 6 months postoperatively, after controlling for the effect of age, genioplasty, mandibular advancement, unfavorable fracture, presence of entrapment, time to complete the SSO, and experience of the operator (all $P < 0.01$).

Age and time to complete the SSO had both a negative effect on the outcome. Older age and longer procedures were significantly associated with larger 2-PD values in all 3 tested areas at 3 months, and 6 months postoperatively, after adjusting for the effect of all other variables (all $P < 0.05$).

In the vermillion area only, larger mandibular advancements were associated with greater neurosensory deficit at 3 months ($B = 1.54$; 95% C.I. = 0.03 to 0.28; $P = 0.015$) and 6 months postoperatively ($B = 0.161$; 95% C.I. = 0.06 to 0.26; $P = 0.003$).

The presence of a concomitant genioplasty only had a borderline significant effect in the mental skin area at 6 months postoperatively ($B = 0.82$; 95% C.I. = 0.00 to 1.64; $P = 0.05$).

Table 12. *Two-Point Discrimination*

Difference in 2-PD responses ***(Postop minus Preop; in mm)***	Group I (with third molar)		Group II (without third molar)		*P*-value
	Mean	± SD	Mean	± SD	
Vermillion					
3 months Postop - Preop	0.91	± 1.16	2.11	± 2.63	0.002*
6 months Postop - Preop	0.22	± 0.60	1.27	± 2.39	0.002*
Labial Skin					
3 months Postop - Preop	1.38	± 1.71	2.75	± 2.65	0.001*
6 months Postop - Preop	0.50	± 0.93	1.64	± 2.35	0.001*
Mental Skin					
3 months Postop - Preop	1.72	± 1.84	3.05	± 2.62	0.001*
6 months Postop - Preop	0.73	± 1.21	2.23	± 2.85	<0.001*

* Statistically Significant

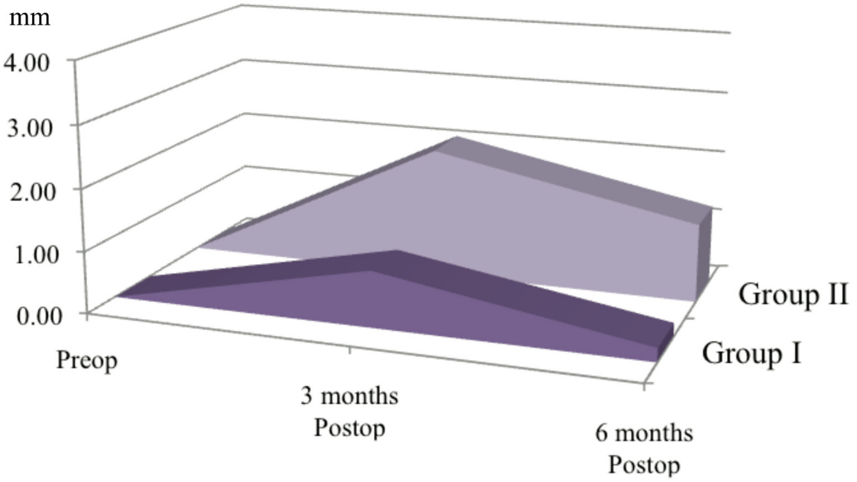

Figure 12. Difference in Two-Point Discrimination Responses in Vermillion Area.

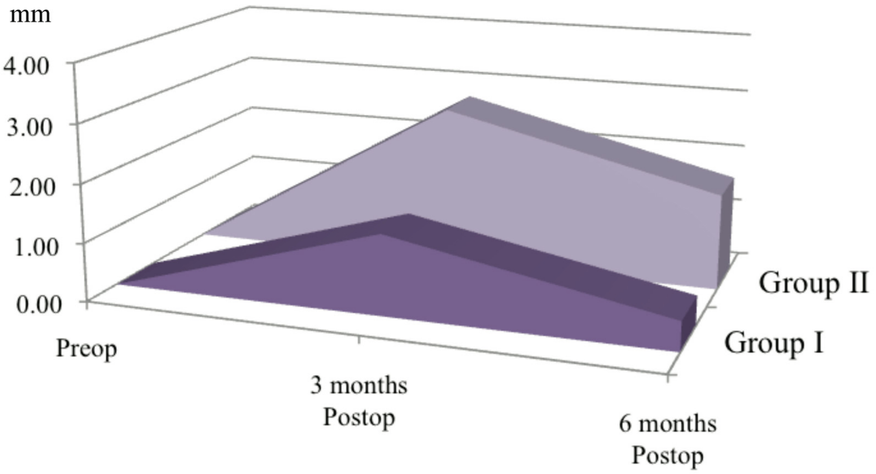

Figure 13. Difference in Two-Point Discrimination Responses in Labial Skin Area.

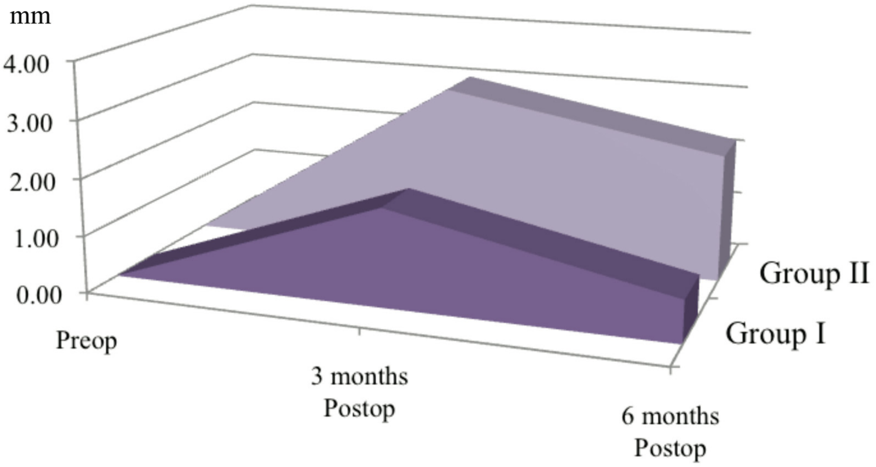

Figure 14. Difference in Two-Point Discrimination Responses in Mental Skin Area.

5.3.2 Static Light Touch Detection

The LT test showed that the presence of mandibular third molars during SSOs was associated with a superior neurosensory recovery (Table 13; Figs. 15-17).

In the mental skin area, the presence of third molars was significantly associated with a decrease incidence of neurosensory deficit at 3 months (*B* = 1.67; 95% C.I. = 1.82 to 15.36; *P* = 0.002), and 6 month postoperatively (*B* = 2.89; 95% C.I. = 1.63 to 199.00; *P* = 0.018), after adjusting for age, genioplasty, mandibular advancement, unfavorable fracture, presence of entrapment, time to complete the SSO, and experience of the operator. This logistic regression also indicated that greater age was associated with a decreased likelihood of normal LT at 3 months (*B* = -0.08; 95% C.I. = 0.88 to 0.97; *P* = 0.003), and 6 months postoperatively (*B* = -0.11; 95% C.I. = 0.82 to 0.98; *P* = 0.020). The magnitude of mandibular advancement also had a negative relationship with the neurosensory recovery of the IAN at 6 months (*B* = -0.36; 95% C.I. = 0.49 to 0.99; *P* = 0.043).

Positive LT responses in the labial skin area were significantly more frequent for Group I at 3 months postoperatively only (X^2 = 9.80; *P* = 0.002). This significance was lost after controlling for all other variables (*B* = 19.03; *P* = 0.997). None of the other variables had a significant effect at 3 or 6 months postoperatively.

No significant difference was found between Group I and Group II in the vermillion area of the lip at 3 months and 6 months postoperatively (all P > 0.05). Age also had no significant effect in this area.

Table 13. *Static Light Touch Detection*

Abnormal LT responses	Group I (with third molar)		Group II (without third molar)		*P*-value
	n	%	*n*	%	
Vermillion					
Preop	0	0.0%	0	0.0%	
3 months Postop	0	0.0%	1	1.8%	0.283
6 months Postop	1	1.6%	1	1.8%	0.924
Labial Skin					
Preop	0	0.0%	0	0.0%	
3 months Postop	0	0.0%	8	14.3%	0.002*
6 months Postop	0	0.0%	2	3.6%	0.127
Mental Skin					
Preop	0	0.0%	0	0.0%	
3 months Postop	8	12.5%	24	42.9%	<0.001*
6 months Postop	1	1.6%	10	17.9%	0.002*

* Statistically Significant

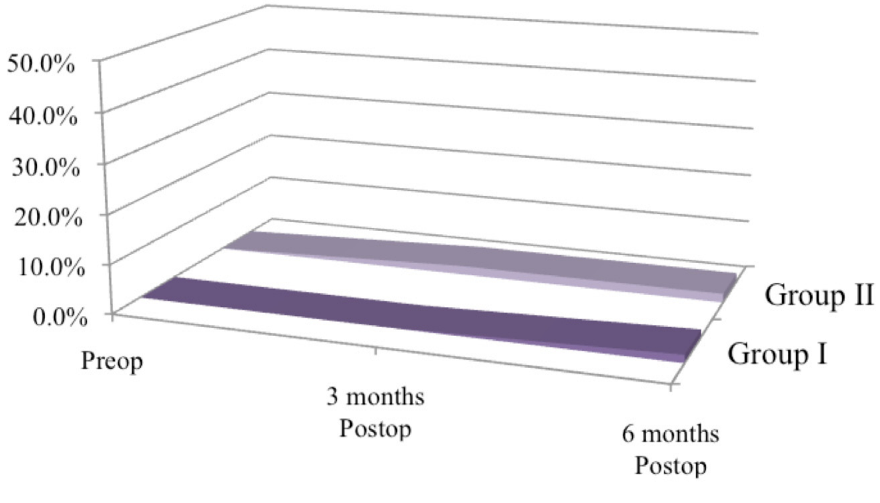

Figure 15. Abnormal Static Light Touch Detection in Vermillion Area.

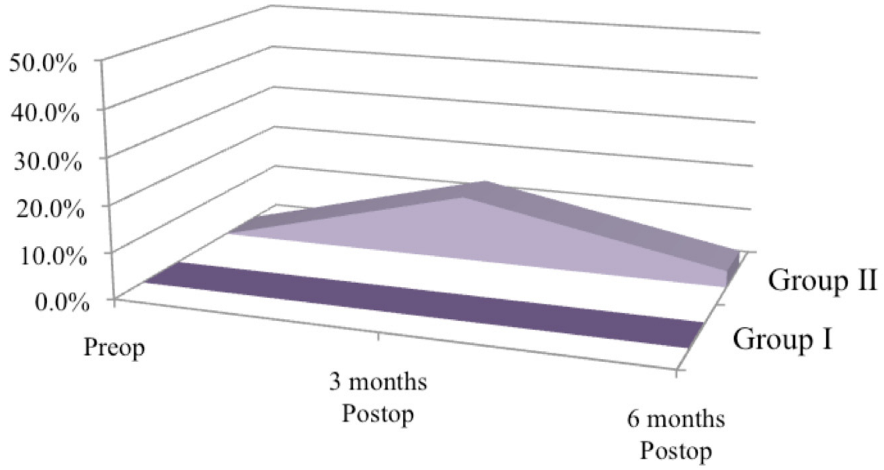

Figure 16. Abnormal Static Light Touch Detection in Labial Skin Area.

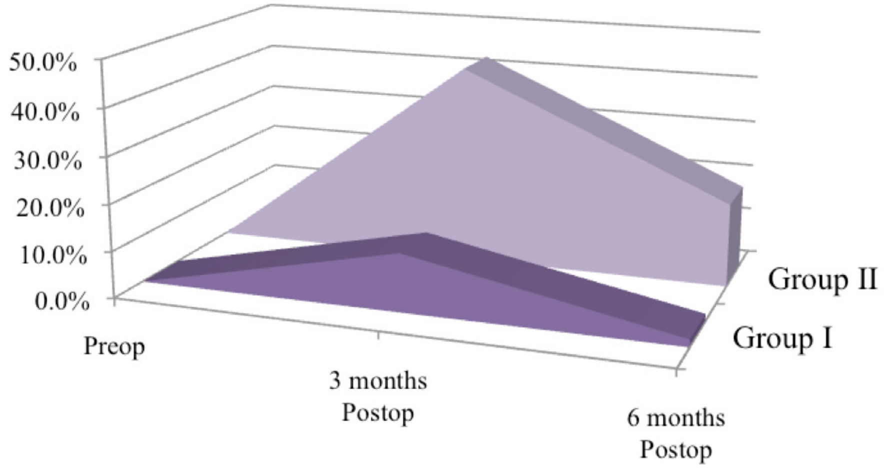

Figure 17. Abnormal Static Light Touch Detection in Mental Skin Area.

5.3.3 Sharp / Blunt Discrimination

Older age and the absence of mandibular third molars during SSOs were associated with increased neurosensory disturbance of the mental skin, when evaluated with the S/B test (Table 14; Figs. 18-20).

In the area of the vermillion and the labial skin, S/B showed no significant difference between the groups (all $P > 0.05$). The only significant effect was the influence of younger age on the increased likelihood of a normal S/B at 3 months postoperatively in the area of the vermillion ($B = -0.11$; 95% C.I. = 0.81 to 1.00; $P = 0.047$), and the labial skin ($B = -0.13$; 95% C.I. = 0.78 to 0.98; $P = 0.020$). Age had no significant effect at 6 months postoperatively for either of these areas (all $P > 0.05$).

The Pearson Chi-Square test demonstrated that the presence of mandibular third molars during SSOs was significantly associated with an improved neurosensory response to the S/B in the mental skin area at 3 months ($X^2 = 13.37$; $P < 0.001$), and 6 months postoperatively ($X^2 = 4.87$; $P = 0.027$). This positive effect was only significant at 3 months ($B = 2.63$; 95% C.I. = 2.84 to 67.08; $P = 0.001$), after adjusting for the effect of age, genioplasty, mandibular advancement, unfavorable fracture, presence of entrapment, time to complete the SSO, and experience of the operator. Age had a negative influence on the neurosensory recovery. This outcome was statistically significant at 3 months ($B = -0.12$; 95% C.I. = 0.83 to 0.95; $P = 0.001$), but not significant at 6 months postoperatively. The magnitude of mandibular advancement had a borderline significant negative effect at 3 and 6 months (both $P = 0.05$). It was also noted that a longer procedure time was associated with a prolonged neurosensory deficit at 3 months ($B = -0.33$; 95% C.I. = 0.58 to 0.89; $P = 0.002$).

Table 14. *Sharp / Blunt Discrimination*

Abnormal S/B responses	Group I (with third molar)		Group II (without third molar)		*P*-value
	n	%	*n*	%	
Vermillion					
Preop	0	0.0%	0	0.0%	
3 months Postop	2	3.1%	3	5.4%	0.542
6 months Postop	0	0.0%	0	0.0%	
Labial Skin					
Preop	0	0.0%	0	0.0%	
3 months Postop	2	3.1%	6	10.7%	0.096
6 months Postop	0	0.0%	1	1.8%	0.283
Mental Skin					
Preop	0	0.0%	0	0.0%	
3 months Postop	4	6.3%	18	32.1%	<0.001*
6 months Postop	2	3.1%	8	14.3%	0.027*

* Statistically Significant

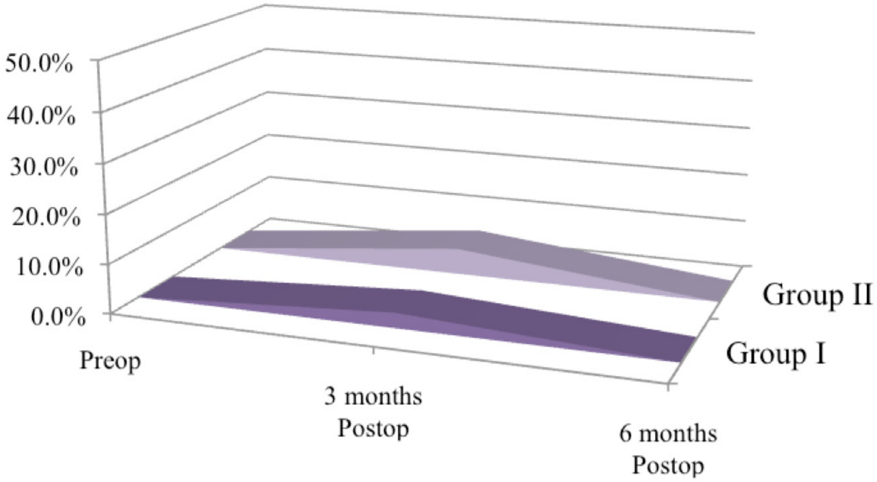

Figure 18. Abnormal Sharp / Blunt Discrimination in Vermillion Area.

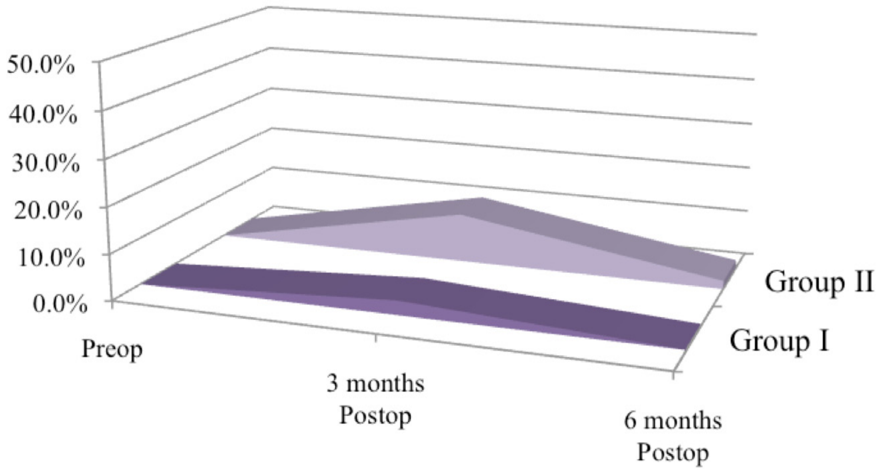

Figure 19. Abnormal Sharp / Blunt Discrimination in Labial Skin Area.

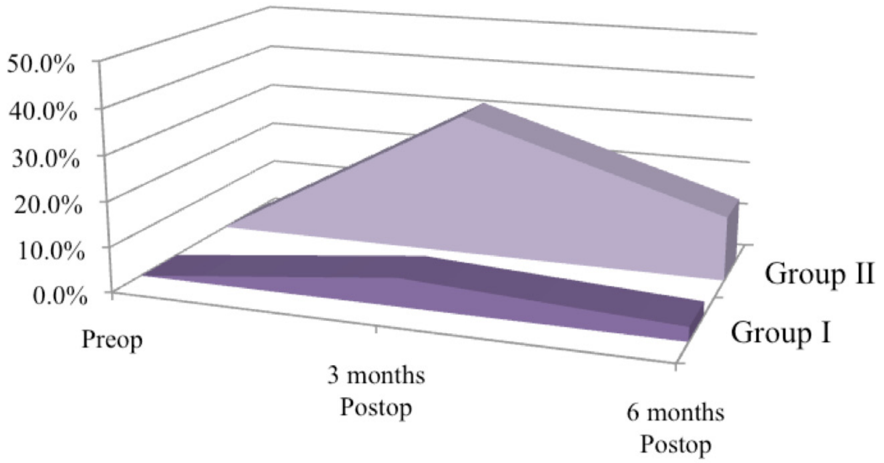

Figure 20. Abnormal Sharp / Blunt Discrimination in Mental Skin Area.

5.3.4 Subjective Evaluation

Patients with mandibular third molars present at the time of the SSOs had an improved subjective recovery, compared to patients with mandibular third molars congenitally absent or removed at least 6 months prior to the SSO (Table 15; Figs. 21-22).

At 3 months postoperatively, patients in Group I reported a "normal sensation" in 70.3%, "numbness, tingling and/or pain, that is not disturbing" in 25.0%, and "numbness, tingling, and/or pain, that is disturbing" in 4.7%. This was in contrast with rates of 48.2%, 37.5%, and 14.3% respectively for Group II ($X^2 = 6.95$; $P < 0.031$). This difference was borderline significant after controlling for the effect of age, genioplasty, mandibular advancement, unfavorable fracture, presence of entrapment, time to complete the SSO, and experience of the operator ($B = 0.84$; 95% C.I. = 0.99 to 5.39; $P = 0.05$).

At 6 months postoperatively, a "normal sensation" was reported in 90.5% of the patients in Group I, compared to 67.9% of the patients in Group II. "Numbness, tingling and/or pain, that is not disturbing" was present in 7.9% of Group I, and 25.0% of Group II. "Numbness, tingling, and/or pain, that is disturbing" was reported in 1.6% of Group I, and 7.1% of Group II. These differences were statistically significant ($X^2 = 9.48$; $P < 0.009$). When the influence of all other variables was taken into account, the presence of mandibular third molars during SSOs continued to be positively related with a normal subjective outcome ($B = 1.28$; 95% C.I. = 1.19 to 10.84; $P = 0.023$).

Older age was also associated with a decreased incidence of subjective "normal sensation" at 3 months (borderline significant: $B = -0.04$; 95% C.I. = 0.92 to 1.00; $P = 0.05$), and 6 months postoperatively ($B = -0.06$; 95% C.I. = 0.89 to 0.99; $P = 0.015$).

Table 15. *Subjective Evaluation*

Variables	Group I (with third molar)		Group II (without third molar)		*P*-value
	n	%	*n*	%	
Preoperative					
Normal sensation	64	100.0%	56	100.0%	
Numbness/tingling/pain, not disturbing	0	0.0%	0	0.0%	
Numbness/tingling/pain, disturbing	0	0.0%	0	0.0%	
3 months Postoperative					0.031*
Normal sensation	45	70.3%	27	48.2%	
Numbness/tingling/pain, not disturbing	16	25.0%	21	37.5%	
Numbness/tingling/pain, disturbing	3	4.7%	8	14.3%	
6 months Postoperative					0.009*
Normal sensation	57	90.5%	38	67.9%	
Numbness/tingling/pain, not disturbing	5	7.9%	14	25.0%	
Numbness/tingling/pain, disturbing	1	1.6%	4	7.1%	

* Statistically Significant

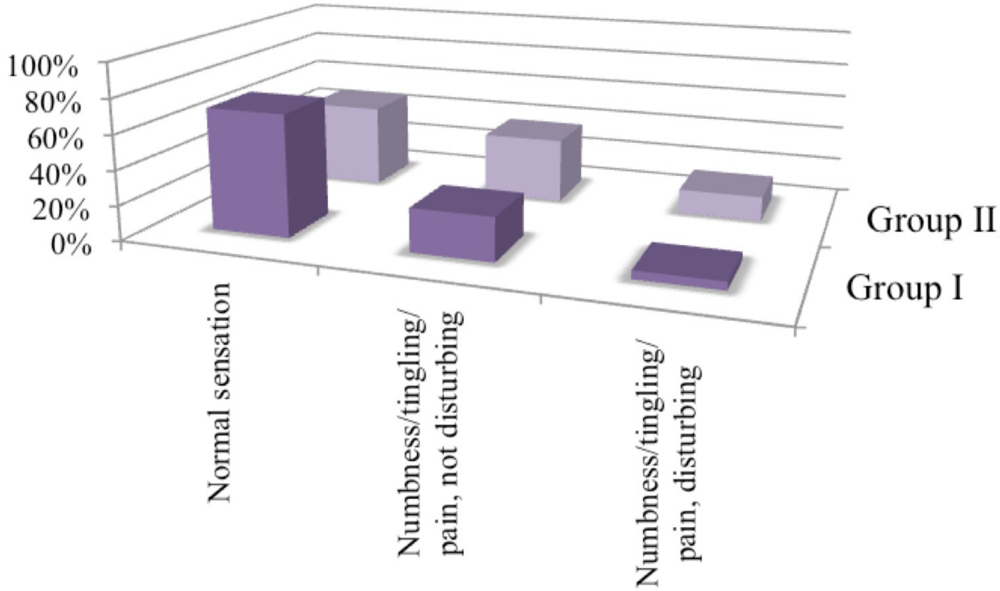

Figure 21. Subjective Evaluation at Three Months.

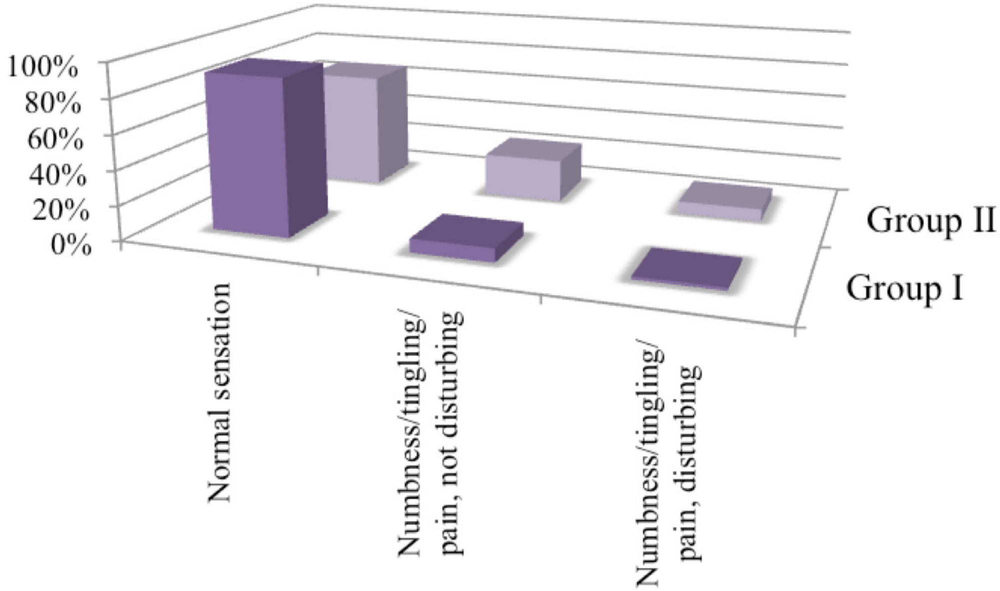

Figure 22. Subjective Evaluation at Six Months.

CHAPTER 6 DISCUSSION

The SSO is the most common mandibular osteotomy used in orthognathic surgery. It is a versatile and reliable technique for advancement, setback, and asymmetrical movements of the mandible. Despite being an overall safe procedure, one of the most important intraoperative complications is the occurrence of an unfavorable fracture. Incidences as low as 0.7%[43], or as high as 20% have been reported[44]. Postoperatively, IAN injury is one of the main long-term sequellae of the SSO operation, with rates ranging from 0% to 85%, 1 to 2 years after surgery[17, 42, 66-84].

Numerous risk factors influencing these complications have been identified. It has been suggested that the presence of mandibular third molars during SSOs will increase the incidence of unfavourable splits, as well as operating time, and technical difficulty of the procedure[1, 2]. It has also been advanced that removing mandibular third molars at the time of the SSOs will result in greater manipulation of the IAN, leading to greater postoperative neurosensory deficit[1, 2]. Other authors do not support these conclusions[3-5, 47], making this possible risk factor one of the main subjects of controversy.

6.1 METHODOLOGICAL ASPECTS

The design of this study, despite being prospective, was not randomized. A randomized clinical trial could have prevented the introduction of selection bias. This lack of randomization generated differences between the groups. The main difference was the older age of Group II, with a mean age ± SD of 30.4 ± 12.1 years, compared to 19.6 ± 7.4 years for Group I (t = -14.1; $P < 0.001$). The proportion of females was also greater for Group II ($X^2 = 9.25$; $P = 0.002$). The effects of these variables were controlled for during the analysis of the data.

The surgeon could obviously not be blinded to the operation, but the examiner was blinded to the previous results during the neurosensory evaluation of the mental nerve. This lack of blinding could have introduced some measurement bias.

Neurosensory testing of the IAN was based on three objective tests (2-PD, LT, and S/B), and one subjective evaluation. The objective evaluations were dependent on the subjective recording of an examiner, and therefore were not purely objective. The subjective evaluation was based on a multiple-choice question, and not on a standardized VAS. These issues could have introduced errors from an instrument bias.

The length of the follow-up was only 6 months, while neurosensory recovery of the IAN can continue for more than one year after surgery[85]. This short follow-up may have affected differences between the groups, which could present or disappear at the 1 year follow-up.

Patients with concomitant genioplasty were not excluded from the study, even though the addition of this procedure at the time of the BSSO has been associated with increased neurosensory injury of the IAN[30, 87, 93]. This could be viewed as a confounder, but the inclusion of these patients was important to evaluate the true relationship of this effect.

The choice of two mechanoceptive test (2-PD, and LT), one nociceptive test (S/B), and subjective evaluation, was based on prior research[85, 101-103, 106]. Ylikontiola et al. in 2000[106], evaluated 5 different objective tests: LT, 2-PD, PIN, thermal discrimination, and sensibility testing of the mandibular molars. Other than sensibility testing, the 3 tests with the best positive predictive values (PPV) for recovery from the neurosensory deficit at 1 year after SSO were: LT (68%), 2-PD (73%), and PIN (76%). The PPV improved after combining 2-PD + PIN (83%), or LT + PIN (78%). The PPV improved further when combining these tests with sensibility testing (83%). The authors concluded that combining the sensibility testing of the molars with a mechanoceptive and nociceptive test (LT + PIN or 2-P + PIN) would best predict recovery from the neurosensory deficit after BSSO[106]. Furthermore, Teerijoki-Oksa et al. in 2003 and 2004[101, 102], determined that LT was the diagnostically most sensitive clinical test, and that S/B had one of the best early PPV. Finally, Poort et al. in 2009[103], reviewed methods of sensory testing of the IAN used in prospective studies and recommended that the use of LT combined with subjective evaluation would provide the best monitoring, but that the use of 2-PD compares best with subjective complaints.

6.2 INTRAOPERATIVE EFFECTS OF THE PRESENCE OF MANDIBULAR THIRD MOLARS DURING SAGITTAL SPLIT OSTEOTOMIES

Our study confirmed that the presence of mandibular third molars during SSOs had no significant effect on the incidence of unfavorable fractures (B = 0.05; 95% confidence interval (C.I.) = 0.38 to 2.92; P = 0.932). The overall incidence was of 3.1% (21 of 677 SSOs), with a tendency for a higher rate of unfavorable splits when the third molar was congenitally absent or removed at least 6 months before the SSO (3.76%), compared to their concomitant removal (2.42%). These results are similar to a prior review of 1256 SSOs, which also found a higher rate of fracture of 2.62% with third molars absent, in contrast to 0.94% with third molars present[3]. Therefore, it can be postulated that excessive bone removal during the preoperative extraction of a mandibular third molar may predispose the mandible to an unfavorable fracture during the splitting procedure, particularly when the ramus is thin or other anatomical irregularities are noted. This finding contradicts other prior reports[1, 2, 112]. Reyneke et al. in 2002[1], in a prospective evaluation of 139 SSOs, showed opposite findings with an increased incidence of unfavorable splits when mandibular third molars were present during the SSO procedures (6.25% with third molars; 0% without). Most other studies have not found significant differences[4, 5, 47, 48, 113, 114]. Tucker in 1995[113], evaluated 400 SSOs with and without third molars and reported the incidence of unfavorable fractures to be 4% with third molars, and 3% without third molars. Similarly, a retrospective review of 500 SSOs by Mehra et al. in 2001[4], revealed a frequency of unfavorable fracture of 3.2% with mandibular third molars present, and of 1.2 % with mandibular third molars absent (P > 0.05). No significant differences (P = 0.8) were also found by Kriwalsky et al. in 2008[5], who reviewed 220 SSOs. The incidence of unwanted splits was

5% with missing third molars, 9% with retained or impacted third molars that were removed during the SSOs, and 3% with third molars left in place during SSOs[5].

Patients with mandibular third molars congenitally absent or removed at least 6 months before the SSOs tend to have more proximal segment fractures (80.0%; 4 of 5 fractures), compared to patients with third molars present at the time of the SSOs. When an unwanted fracture occurred in the presence of a third molar, these were most commonly incomplete (greenstick) distal segment fractures. Similar results were also shown by Precious et al. in 1998[3], with 87% (13 of 15) of their proximal segment fractures occurring in osteotomy sites where the impacted third molar tooth was removed before the surgery. Mehra et al. in 2001[4], also described that 75% (3 of 4) of the buccal plate fractures occurred with third molars absent, with 100% (7 of 7) of the lingual plate fractures occurring in the presence of a third molar. This tendency toward a greater incidence of proximal segment fractures in patients without mandibular third molars at the time of the SSO is clinically relevant. The completion of the split becomes much more difficult when a buccal plate fracture occurs, in contrast with a lingual plate fracture. Extra fixation will also be necessary to stabilize the fractured segment. Furthermore, the risk of fixation failure or malunion is increased, often requiring longer periods of MMF.

The presence of a mandibular third molar during SSO was also found to significantly decrease the rate of entrapment and manipulation of the IAN. The incidence of entrapment was of 37.2% with third molars present, in contrast to 46.5% with third molars absent ($X^2 = 6.10$; $P = 0.014$). The presence or absence of mandibular third molars significantly affected the severity of entrapment and manipulation of the IAN ($X^2 =$

23.22; $P < 0.001$), with 22.0% of the IAN requiring release from the proximal segment after bony removal with a burr or chisel in the group without third molars, compared to 16.9% in the group with third molars. When third molars were present, 63.5% of the IAN did not require any manipulation, which was significantly lower than the rate of 53.5% with third molars absent. One possible explanation of this finding could be that the roots of the mandibular third molar keep the IAN in the distal segment during the splitting procedure. Anatomical studies support this finding with most (70%) of the mandibular canals following the lingual cortical plate at the mandibular ramus and body[55], and with the majority (56.1%) of the IAN canals being lingual, inferior, or interradicular to the roots of the mandibular third molars[58-65]. These results are dissimilar to Reyneke et al. in 2002[1], who found slightly more manipulation of the IAN in the presence of an unerupted third molar, with dissection or bony release from the proximal segment in 37.5% (24 of 64), compared to 24% (18 of 75) with a mandibular third molar absent. These findings also point to the lack of evidence of Schwartz's[2] proposition, who stated that "when an impacted tooth is present during SSO, initial complete separation of the proximal and distal segments can fail to take place at the inferior aspect of the tooth socket. Additional manipulation of the segments is then necessary to complete the osteotomy. The inferior alveolar nerve in these cases is more frequently trapped in the proximal segment below the tooth socket. Careful bone removal is necessary to free the nerve. This can result in prolonged neurologic symptoms."

The presence of a mandibular third molar increased the time to accomplish the SSO by less than 2 minutes (11.9 ± 5.5 min with third molar; 10.2 ± 5.3 min without; $P < 0.001$). Timing included the removal of the mandibular third molar. The clinical significance of this statistical difference is not relevant, especially with respect to the entire length of the orthognathic procedure. This small difference also illustrates that the presence of a mandibular third molar does not significantly affect the difficulty of the procedure, which is not in concordance with other authors[1, 2, 112]. Colella and Schwartz indicated that the presence of unerupted third molars increases the operating time and the technical difficulty of the SSOs[2, 112]. Reyneke et al. in 2002[1], also reported that 92% of the SSO cases without third molar teeth were regarded as easy splits, compared with approximately 40% of those with third molars, with risk ratios suggesting that the chance of a difficult split was 7 to 8 times greater when a third molar tooth was present at the time of the SSO.

The degree of impaction or development of the mandibular third molars had no significant effects on the incidence of unfavorable splits or presence of IAN entrapment (all $P > 0.05$). Similar conclusions were found by Precious et al. in 1998[3], which is opposite to the results of Mehra et al. in 2001[4]. In their study, the degree of third molar impaction and development did affect the incidence of unwanted fractures, with complete tooth impaction seen in 75% of the fractures, and two thirds crown formation in 62.5% of the fractures.

Older age was associated with an increased frequency of unwanted splits, but this effect was not significant after controlling for gender, presence of mandibular third molars, experience of the operator, and presence of IAN entrapment ($B = 0.03$; 95% C.I. = 0.997 to 1.068; $P = 0.070$). Furthermore, patients younger than 20 years of age did not have a higher incidence of unfavorable fractures, compared to patients over the age of 20 (2.2% versus 3.9%; $X^2 = 1.62$; $P = 0.203$). These findings contrasted with the results of two prior studies, which both found that unfavorable splits tend to occur more frequently in the younger age group (<20 years). Mehra et al. in 2001[4], found that 14% of the patients in the 15 to 16 year age category had unfavorable fractures, whereas no patient in the other age category had an unfavorable fracture, when evaluating their group of 250 SSOs with third molars present. Similarly, Reyneke et al. in 2002[1], reported unwanted splits only in patients younger than 20 years who had third molar teeth present and removed at the time of surgery. Other studies showed an increase of incidence with age, and agreed with our results[5, 43]. Kriwalsky et al. in 2008[5], indicated that patients with unwanted fractures were significantly older than those who had uneventful operations ($P = 0.01$). This effect of age was also supported by a retrospective evaluation of 2005 SSOs, with a mean age of 33.1 years in patients experiencing the complication, compared with a mean age of 25.9 years for patients who did not[43].

Age was also associated with an increased rate of entrapment and manipulation of the IAN (all $P < 0.05$), but not with an increased time to achieve the SSO ($r = -0.055$; $P = 0.152$). Contrarily, another study suggested that these procedures in patients with unerupted third molar teeth were significantly easier in the older age group (mean 22.3 ± 9.6 years), and significantly more difficult in the younger age group (mean 15.9 ± 1.6 years; $P = 0.004$)[1].

Male gender only influenced the time to complete the SSO, with males having longer procedures than females ($t = 6.05$; $P < 0.001$). The rate of unfavorable fractures was not influenced by gender ($P = 0.839$), which concurred with the results of Precious et al. in 1998[3]. On the other hand, Falter et al. in 2010, showed a borderline significant effect of gender ($P = 0.05$), with a slight increase incidence in males.

As one would expect, greater surgeon experience was associated with a shorter procedure time, as well as with a lower incidence of unfavorable fractures. On average, staff surgeons were 3.5 min faster than residents (t = -9.28; $P < 0.001$). The occurrence of unwanted splits was of 4.5% for the residents, compared to 1.3% for the staff surgeons (B = -1.29; 95% C.I. = 0.09 to 0.84; P = 0.023). Such influence was not demonstrated in most prior studies[5, 43, 114]. Kriwalsky et al. in 2008[5], failed to establish significant differences between operations performed by residents under supervision, and operations performed by specialists (P = 0.4). In addition, Falter et al. in 2010[43], showed that evolution of the surgeon's experience over time (20-year period) was not associated with a decline in occurrence of unfavorable splits.

6.3 POSTOPERATIVE INFLUENCES OF THE PRESENCE OF MANDIBULAR THIRD MOLARS ON THE NEUROSENSORY RECOVERY OF THE INFERIOR ALVEOLAR NERVE AFTER SAGITTAL SPLIT OSTEOTOMIES

Our study illustrated that the presence of mandibular third molars during SSOs was associated with a decreased incidence of neurosensory disturbance of the IAN. Two-point discrimination testing demonstrated this positive relationship in all three tested areas of the mental nerve distribution at 3 months and 6 months postoperatively, after controlling for the effect of age, genioplasty, mandibular advancement, unfavorable fracture, presence of entrapment, time to complete the SSO, and experience of the operator (all $P < 0.01$). The other objective tests showed that this effect was only significant in the mental skin area at 3 and 6 months postoperatively with LT, and at only 3 months with S/B (all $P < 0.05$). Subjective reports of "normal sensation" at 3 and 6 months postoperatively in patients with mandibular third molars present at the time of the SSOs were found in 70.3% and 90.5% respectively, in contrast with rates of 48.2% and 67.9% in patients with mandibular third molars congenitally absent or removed at least 6 months before the SSOs (all $P \leq 0.05$). These results can possibly be explained by the fact that mandibular third molars usually keep the IAN in the distal segment, decreasing the incidence of its entrapment and manipulation. The older mean age of patients with third molars absent could have also contributed to this effect, although all analyses were adjusted for the influence of age. Only 2 other studies looked at this effect[1, 84]. August et al. in 1998[84], reported no association between neurosensory deficit and simultaneous mandibular third molar removal ($P = 0.660$). Opposite findings were published by Reyneke et al in 2002[1], indicating a slower neurosensory recovery during the first 6 months after SSOs when mandibular third molars were present at the time of the procedures. This difference was lost by 12 months, with recovery curves similar to patients without third molars ($P = 0.3832$)[1].

Similar to the results of prior studies[31, 84, 86-90], a direct relationship was found between increasing age and postoperative neurosensory deficit after SSO. After controlling for the effect of all other variables, this effect of age was significant in all 3 tested areas at 3 months and 6 months postoperatively with 2-PD, and at 3 months only with S/B (all $P < 0.05$). Static light touch detection was significant only in the mental skin area at 3 and 6 months postoperatively. Subjective evaluation also showed an association between younger age and reports of "normal sensation". This influence was borderline significant at 3 months ($B = -0.04$; 95% C.I. = 0.92 to 1.00; $P = 0.05$), but statistically significant at 6 months postoperatively ($B = -0.06$; 95% C.I. = 0.89 to 0.99; $P = 0.015$). Ylikontiola et al. in 2000[86], also found a positive correlation between subjective neurosensory deficit and age ($P = 0.039$), with patients younger than 30 years of age having fewer neurosensory problems. Similarly, Van Sickels et al. in 2002[87], reported that patients of age 35 and older had a tendency to have larger sensory deficits immediately after the SSO, and less complete recovery over time. Other studies did not support these findings[75, 91-93]. Kim et al. in 2011[93], showed no statistically significant associations between age and VAS scores for pain and altered sensation at 1 month, 3 months, and 6 months after surgery.

In concert with most recent reports[31, 86, 88, 90-93], our study showed no gender related differences in the neurosensory recovery of the IAN after SSO. Contrarily, Al-Bishri et al. in 2004[89], suggested a higher incidence with female gender, with 16.7% of female patients reporting long lasting neurosensory disturbance, compared with 3% in male patients.

The addition of a genioplasty at the time of the BSSO was not significantly associated with increased neurosensory deficit of the IAN; this result was similar to other prior studies[84, 95]. The only possible effect shown, with borderline significance, was with the 2-PD in the mental skin area at 6 months only ($P = 0.05$). All other testing did not support this relationship. Most other papers have demonstrated that the combination of genioplasty and SSO was more detrimental to the mental nerve than genioplasty or SSO alone [30, 87, 93].

No associations were found between postoperative neurosensory disturbance and the incidence of entrapment and manipulation of the IAN during SSO. The only possible correlation found was with 2-PD in the mental skin area at 3 months postoperatively ($P = 0.022$). This significance was lost after controlling for the effect of other variables. Other reports agreed with our findings[75, 84, 91]. Fridrich et al. in 1995[75], concluded that as long as the IAN is not lacerated or transected, the long-term likelihood for neurosensory recovery is good despite manipulation. Intraoperative monitoring also demonstrated that exposure or manipulation of the IAN usually had no effect on nerve function[91]. Other papers were able to reveal a negative effect[86, 88, 90]. Ylikontiola et al. in 2000[86], reported a high correlation between the degree of manipulation of the IAN and the degree of postoperative sensory deficit ($P = 0.0007$).

Longer procedure times were associated with prolonged neurosensory recovery of the IAN. The 2-PD revealed this significant negative relationship in all three tested areas of the mental nerve distribution at 3 months and 6 months postoperatively (all $P < 0.05$).

Testing with S/B was significant only in the mental skin area at 3 months (*B* = -0.33; 95% C.I. = 0.58 to 0.89; *P* = 0.002). Subjective evaluation and LT did not show any significant correlations. This effect of time could not be directly attributed to the greater manipulation of the IAN with longer procedures, given that no significant association was found between the degree of entrapment and the neurosensory recovery. The length of medial retraction could possibly explain this finding, since Teerijoki-Oksa et al. in 2002[91], showed a clear tendency towards more disturbed IAN conduction with longer medial opening times ($P < 0.05$). No other studies directly evaluated this effect of time.

Our study did not express the negative influence of unfavorable fractures on the neurosensory recovery after SSOs. This could possibly be explained by the fact that only 4 unwanted splits occurred in the group of 120 SSOs studied. Only one other study evaluated this effect, and showed that unfavorable splits were associated with functional sensory deficit ($P = 0.03$)[84].

Most prior research did not support the relation between the magnitude of mandibular advancement and the impairment of sensation of the IAN [75, 90, 92, 95]. Our study indicated that increased neurosensory disturbance had the tendency to be associated with larger mandibular movements. This link was significant only in the vermillion area at 3 and 6 months with the 2-PD, while the LT revealed statistical significance only in the mental skin area at 6 months postoperatively (all $P < 0.05$). Subjective reports were not significant, and S/B showed borderline significance at 3 and 6 months in the mental skin area only (both $P = 0.05$). Other studies have also established a similar connection[86, 87]. Ylikontiola et al. in 2000[86], found that mandibular movements greater than 7 mm were positively correlated with subjective neurosensory loss ($P = 0.044$).

The surgeon's experience had no effect on the sensory recovery of the IAN after a SSO. Another study recognized a higher rate of neurosensory disturbances in the SSOs performed by surgeons in training ($P = 0.05$)[88].

6.4 CLINICAL IMPLICATIONS AND RECOMMENDATIONS

Bilateral sagittal split osteotomy is a versatile technique for advancement, setback, and asymmetrical movements of the mandible. Despite being a predictable procedure, an important intraoperative complication is the occurrence of an unfavorable fracture with associated postoperative neurosensory disturbance of the IAN. This complication, although significant, has been shown on numerous occasions to be a rare event. Our data confirmed this finding with an overall incidence was of 3.1%.

Numerous authors have postulated that the presence of mandibular third molars would act as a predisposing factor for unwanted fractures during SSOs, recommending their removal at least 6 months prior to the procedure. Our study refutes this proposition, and establishes that unfavorable splits occurred less frequently in the presence of mandibular third molars.

Concomitant removal of mandibular third molars during SSOs offers numerous other advantages. This approach will avoid subjecting the patient to a second unnecessary surgical procedure, with its associated pain, edema, risks, and complications. This protocol is also more cost efficient for the patients, surgeons, assistants, nurses, anesthesia personnel, and health care system. Furthermore, removing mandibular third molars at the time of the procedure will minimize postoperative neurosensory disturbance of the IAN by decreasing its entrapment and manipulation.

Finally, patients should always come first. So until the presence of clear evidence showing the detrimental effects of mandibular third molar removal during SSO, a single staged procedure should be planned for the patient’s best interest.

CHAPTER 7 CONCLUSIONS

The following main conclusions can be drawn from the results obtained in the present study:

1. The presence of a mandibular third molar during sagittal split osteotomy is not associated with an increased incidence of unfavorable fractures of the mandible.
2. The presence of a mandibular third molar during sagittal split osteotomy decreases the rate and severity of neurovascular bundle entrapment, thus reducing manipulation of the inferior alveolar nerve.
3. The presence of a mandibular third molar during sagittal split osteotomy improves postoperative neurosensory recovery of the inferior alveolar nerve.
4. The presence of a mandibular third molar during sagittal split osteotomy increases the operating time by less than two minutes per side.

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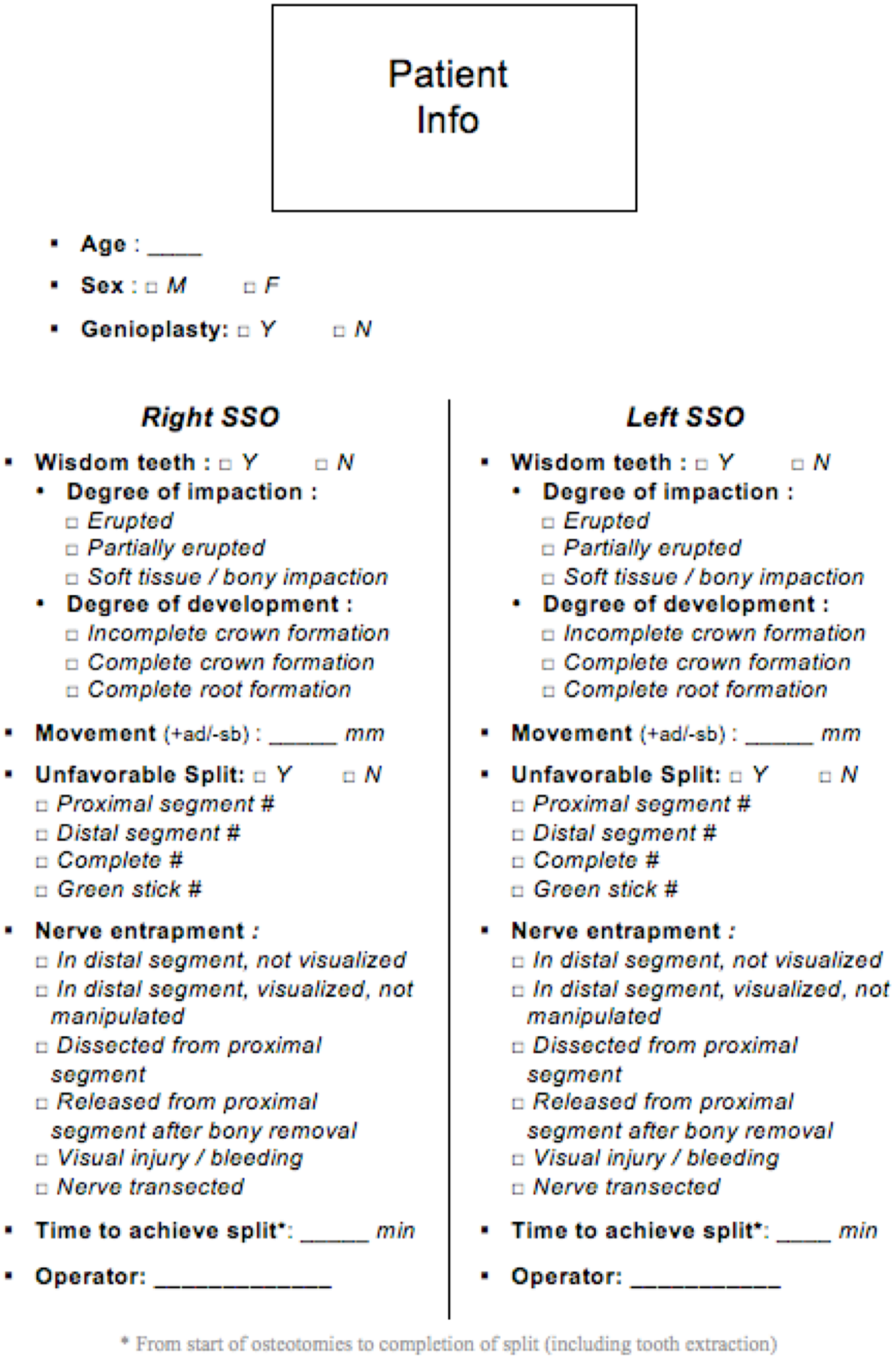
APPENDIX A INTRAOPERATIVE FORM



Patient Info

- **Age** : ____
- **Sex** : ☐ *M* ☐ *F*
- **Genioplasty:** ☐ *Y* ☐ *N*

Right SSO

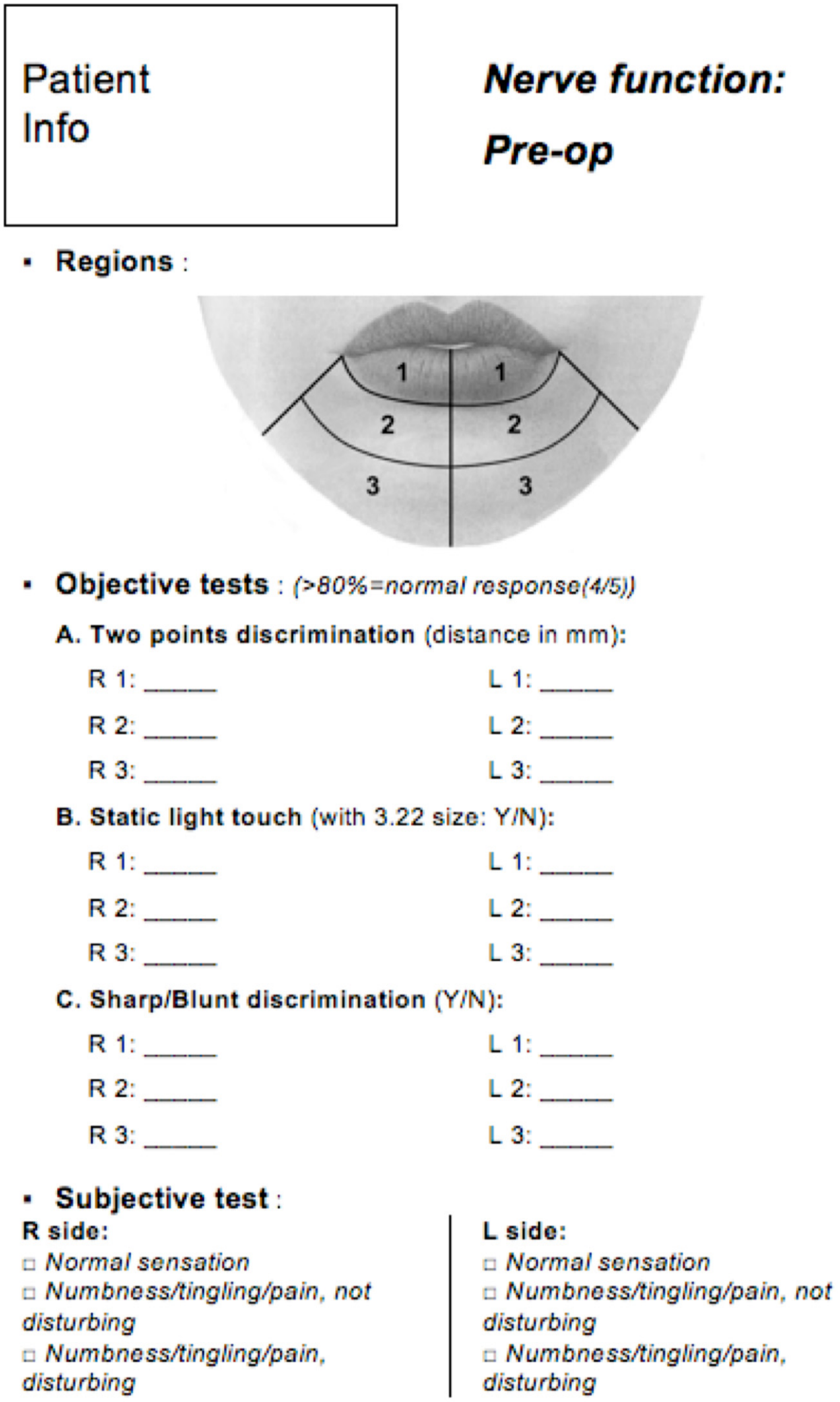
- **Wisdom teeth :** ☐ *Y* ☐ *N*
  - **Degree of impaction :**
    ☐ *Erupted*
    ☐ *Partially erupted*
    ☐ *Soft tissue / bony impaction*
  - **Degree of development :**
    ☐ *Incomplete crown formation*
    ☐ *Complete crown formation*
    ☐ *Complete root formation*
- **Movement** (+ad/-sb) : _____ *mm*
- **Unfavorable Split:** ☐ *Y* ☐ *N*
  ☐ *Proximal segment #*
  ☐ *Distal segment #*
  ☐ *Complete #*
  ☐ *Green stick #*
- **Nerve entrapment :**
  ☐ *In distal segment, not visualized*
  ☐ *In distal segment, visualized, not manipulated*
  ☐ *Dissected from proximal segment*
  ☐ *Released from proximal segment after bony removal*
  ☐ *Visual injury / bleeding*
  ☐ *Nerve transected*
- **Time to achieve split*:** _____ *min*
- **Operator:** ____________

Left SSO

- **Wisdom teeth :** ☐ *Y* ☐ *N*
  - **Degree of impaction :**
    ☐ *Erupted*
    ☐ *Partially erupted*
    ☐ *Soft tissue / bony impaction*
  - **Degree of development :**
    ☐ *Incomplete crown formation*
    ☐ *Complete crown formation*
    ☐ *Complete root formation*
- **Movement** (+ad/-sb) : _____ *mm*
- **Unfavorable Split:** ☐ *Y* ☐ *N*
  ☐ *Proximal segment #*
  ☐ *Distal segment #*
  ☐ *Complete #*
  ☐ *Green stick #*
- **Nerve entrapment :**
  ☐ *In distal segment, not visualized*
  ☐ *In distal segment, visualized, not manipulated*
  ☐ *Dissected from proximal segment*
  ☐ *Released from proximal segment after bony removal*
  ☐ *Visual injury / bleeding*
  ☐ *Nerve transected*
- **Time to achieve split*:** ____ *min*
- **Operator:** __________

* From start of osteotomies to completion of split (including tooth extraction)

APPENDIX B PREOPERATIVE NEUROSENSORY FORM



Patient
Info

Nerve function:

Pre-op

- **Regions** :

- **Objective tests** : *(>80%=normal response(4/5))*

A. Two points discrimination (distance in mm):

R 1: ______ L 1: ______

R 2: ______ L 2: ______

R 3: ______ L 3: ______

B. Static light touch (with 3.22 size: Y/N):

R 1: ______ L 1: ______

R 2: ______ L 2: ______

R 3: ______ L 3: ______

C. Sharp/Blunt discrimination (Y/N):

R 1: ______ L 1: ______

R 2: ______ L 2: ______

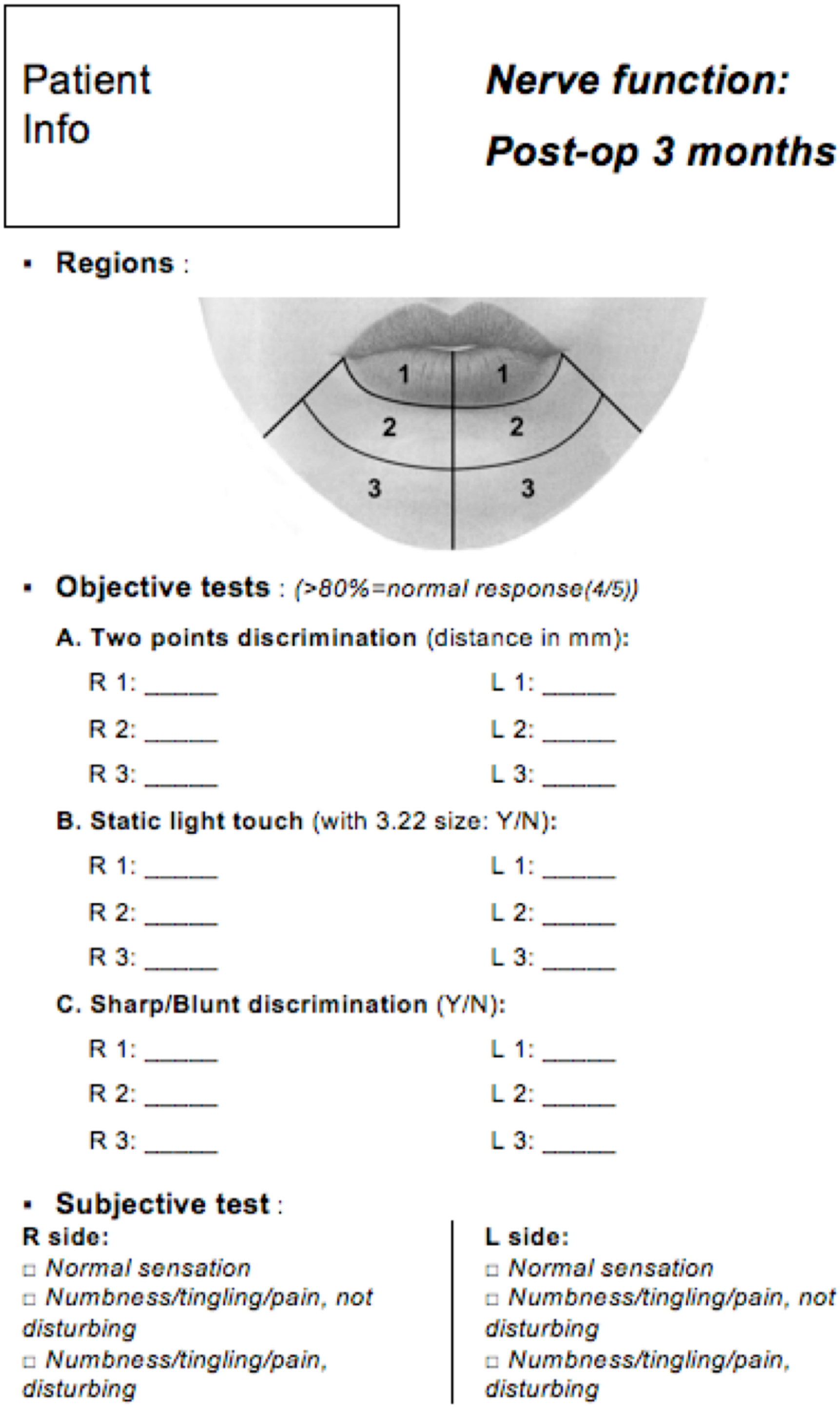
R 3: ______ L 3: ______

- **Subjective test** :

R side:
☐ *Normal sensation*
☐ *Numbness/tingling/pain, not disturbing*
☐ *Numbness/tingling/pain, disturbing*

L side:
☐ *Normal sensation*
☐ *Numbness/tingling/pain, not disturbing*
☐ *Numbness/tingling/pain, disturbing*

APPENDIX C THREE MONTHS POSTOPERATIVE NEUROSENSORY FORM



Patient Info

Nerve function:

Post-op 3 months

- **Regions** :

- **Objective tests** : *(>80%=normal response(4/5))*

A. Two points discrimination (distance in mm):

R 1: ______ L 1: ______

R 2: ______ L 2: ______

R 3: ______ L 3: ______

B. Static light touch (with 3.22 size: Y/N):

R 1: ______ L 1: ______

R 2: ______ L 2: ______

R 3: ______ L 3: ______

C. Sharp/Blunt discrimination (Y/N):

R 1: ______ L 1: ______

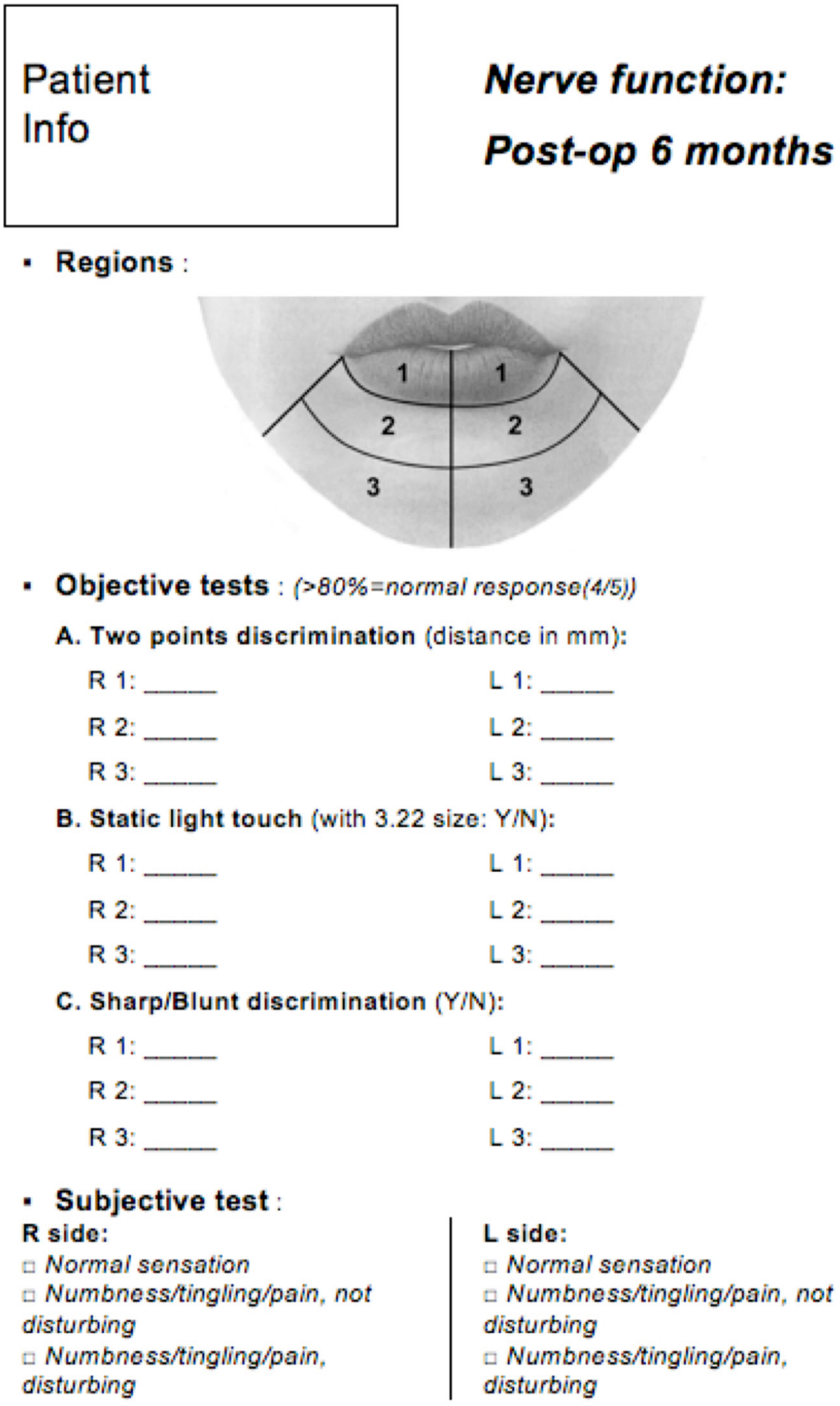
R 2: ______ L 2: ______

R 3: ______ L 3: ______

- **Subjective test** :

R side:	**L side:**
☐ *Normal sensation*	☐ *Normal sensation*
☐ *Numbness/tingling/pain, not disturbing*	☐ *Numbness/tingling/pain, not disturbing*
☐ *Numbness/tingling/pain, disturbing*	☐ *Numbness/tingling/pain, disturbing*

APPENDIX D SIX MONTHS POSTOPERATIVE NEUROSENSORY FORM



Patient
Info

Nerve function:

Post-op 6 months

- **Regions** :

- **Objective tests** : *(>80%=normal response(4/5))*

A. Two points discrimination (distance in mm):

R 1: ______	L 1: ______
R 2: ______	L 2: ______
R 3: ______	L 3: ______

B. Static light touch (with 3.22 size: Y/N):

R 1: ______	L 1: ______
R 2: ______	L 2: ______
R 3: ______	L 3: ______

C. Sharp/Blunt discrimination (Y/N):

R 1: ______	L 1: ______
R 2: ______	L 2: ______
R 3: ______	L 3: ______

- **Subjective test** :

R side:

☐ *Normal sensation*
☐ *Numbness/tingling/pain, not disturbing*
☐ *Numbness/tingling/pain, disturbing*

L side:

☐ *Normal sensation*
☐ *Numbness/tingling/pain, not disturbing*
☐ *Numbness/tingling/pain, disturbing*