Bilateral sagittal split osteotomy : risk factors for complications and predictability of the splitter-separator technique

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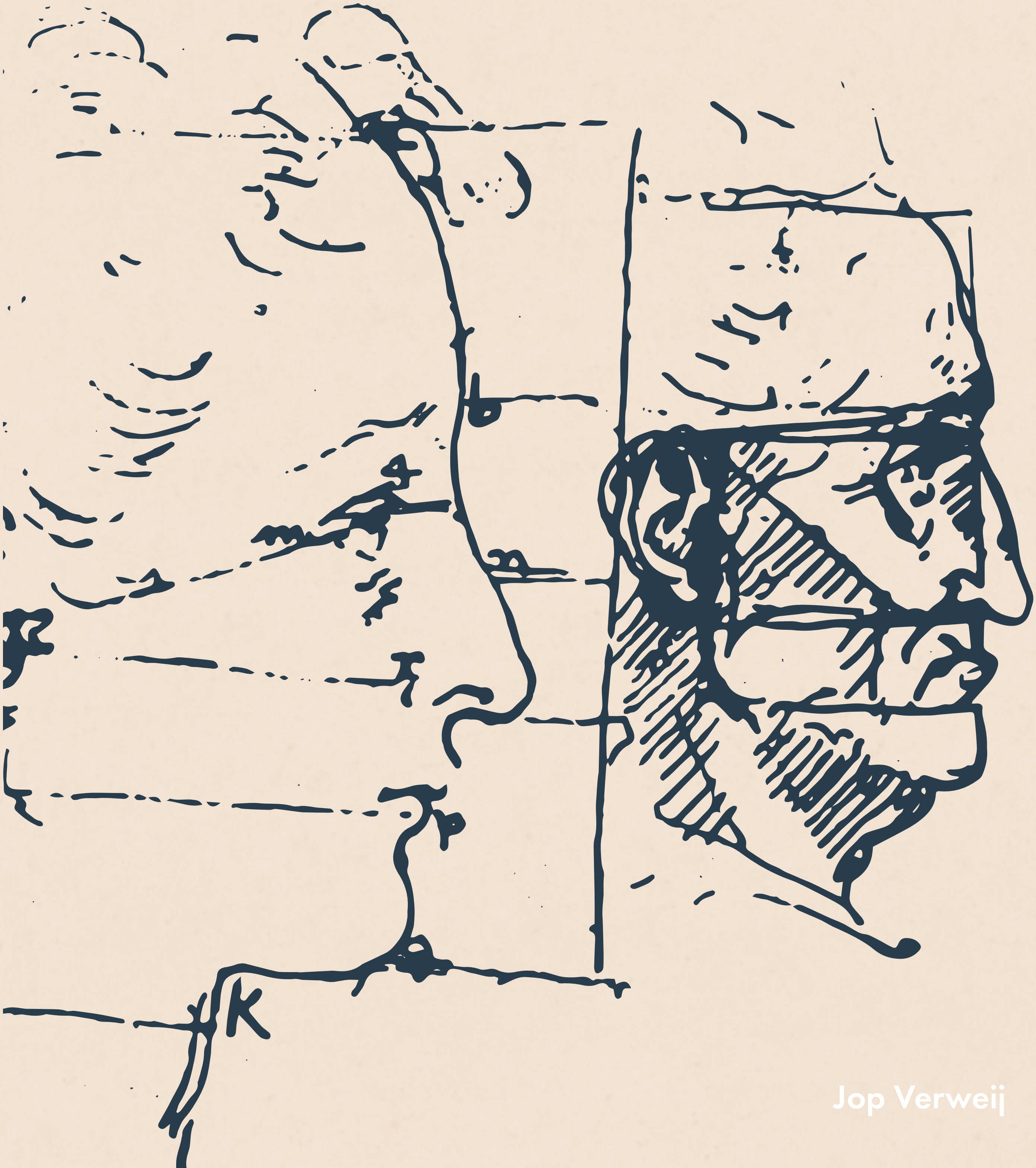
BILATERAL SAGITTAL SPLIT OSTEOTOMY

Risk factors for complications and predictability of the splitter-separator technique



Jop Verweij

STELLINGEN

behorende bij het proefschrift

BILATERAL SAGITTAL SPLIT OSTEOTOMY

Risk factors for complications and predictability of the splitter-separator technique

1. Het risico op permanente hypesthesie na een bilaterale sagittale splijtingsosteotomie neemt toe met de leeftijd van de patiënt (dit proefschrift).

2. De bilaterale sagittale splijtingsosteotomie met splijttang en splijthevels resulteert in patiënten van jonger dan 30 jaar in minder dan 8% permanente hypesthesie (dit proefschrift).

3. De sagittale splijtingstechniek met splijttang en splijthevels gaat niet gepaard met een hoger risico op bad splits dan klassieke technieken met beitels (dit proefschrift).

4. Verwijdering van schroeffixatie is aanzienlijk minder vaak geïndiceerd dan verwijdering van plaatfixatie na bilaterale sagittale splijtingsosteotomie (dit proefschrift).

5. Een botdefect van de onderrand van de mandibula na bilaterale sagittale splijtingsosteotomie komt vaker voor bij grote voorwaartse verplaatsingen, clockwise rotatie van het distale segment of een suboptimale positionering van het proximale segment (dit proefschrift).

6. De aanwezigheid van verstandskiezen tijdens de bilaterale sagittale splijtingsosteotomie geeft een kleine verhoging van het risico op bad split, maar heeft geen invloed op andere complicaties (dit proefschrift).

7. Het osteotomie-design en de geplande positie van de boorsneden tijdens een bilaterale sagittale splijtingsosteotomie zouden niet alleen chirurg-afhankelijk moeten zijn, maar ook patiënt-afhankelijk.

8. Een goede arts leert niet alleen de medische theorie en praktijk, maar ontwikkelt zich ook op het gebied van de menselijke, sociale en zakelijke kanten van de zorg.

9. Artsen denken met hun hoofd en tandartsen denken met hun handen, daarom kunnen beiden veel van elkaar leren.

10. Het onbekende is de grootste vijand en beste vriend van iedere ambitieuze onderzoeker.

11. Voor financiering van onderzoek geldt hetzelfde als Johan Cruijff (1947-2016) zei over voetbal: *"Ik heb nog nooit een zak geld een doelpunt zien maken."*

Bilateral sagittal split osteotomy

Risk factors for complications and predictability of the splitter-separator technique

Proefschrift

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Aan mijn ouders,

van wie ik zó veel heb geleerd.

Gelukkig is geluk voor ons

zo goed als gewoon,

zelfs als je promoveert.

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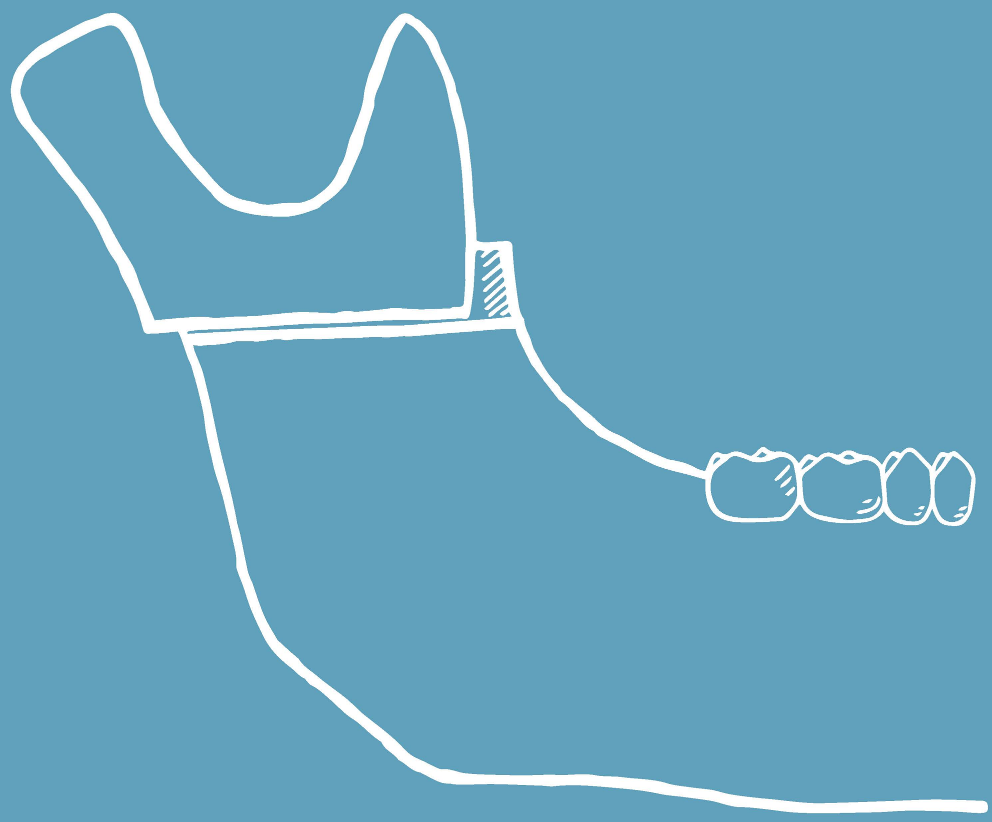

CHAPTER 1

Introduction and aim of the thesis

INTRODUCTION AND AIM OF THE THESIS

General introduction

Bilateral sagittal split osteotomy (BSSO) is a widely used orthognathic surgical technique. Since its development, it has become the cornerstone of modern maxillofacial surgery and an important part of the everyday practice of many maxillofacial surgeons.[1] Although alternative techniques are available to treat mandibular hyperplasia or hypoplasia, such as intra-oral vertical ramus osteotomy or distraction osteogenesis, BSSO is generally considered the golden standard to treat mandibular deformity.

The elective nature of orthognathic surgery makes it very important to minimize the risk of complications and adverse effects associated with BSSO. Increasing the predictability and safety of the surgical procedure is therefore an important topic and should be of major interest to the surgeon.

Development of the technique

The first surgical correction of malocclusion was performed in 1849 by Hullihen, an American general surgeon with dental training.[2] He performed an osteotomy of the mandibular body for correction of mandibular prognathism.[2]

The initiation of early orthognathic surgery, however, came to light in the beginning of the twentieth century in St. Louis, USA.[3] Plastic surgeon Vilray Blair and orthodontist Edward Angle were the first to describe an osteotomy of the horizontal ramus for the correction of mandibular prognathism.[4] They were furthermore the first to emphasize the importance of cooperation between orthodontists and surgeons. However, focus shifted towards the development of maxillofacial traumatology because of the First World War, and it would take a long time before orthognathic surgery would be rediscovered in the USA again.[3]

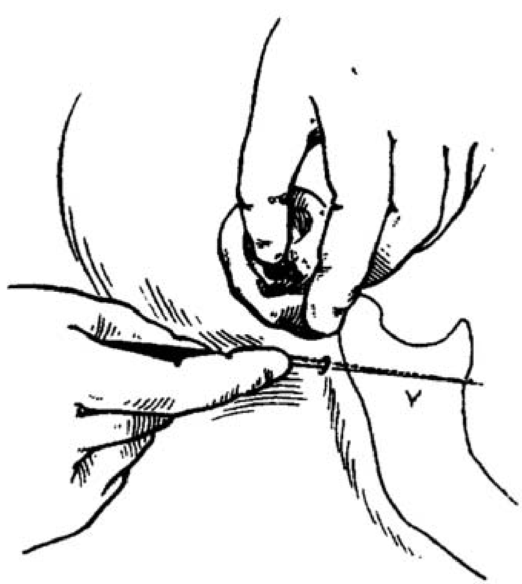

Figure 1: Osteotomy of the horizontal ramus as described by Blair.[4]

Later, in 1942, Schuchardt[5] was the first to describe a sagittal osteotomy of the mandibular ramus. This technique was carried out via an intra-oral approach and introduced the popularization of the BSSO. Trauner and Obwegeser[6] subsequently further developed and popularized this technique and are currently viewed as the founding fathers of the sagittal split osteotomy.

Initially, the BSSO technique consisted of two horizontal bone cuts, approximately 25mm apart in the lingual and buccal cortex of the mandibular ramus. These cuts were connected along the medial aspect of the lateral oblique ridge, separating a proximal and distal mandibular segment.

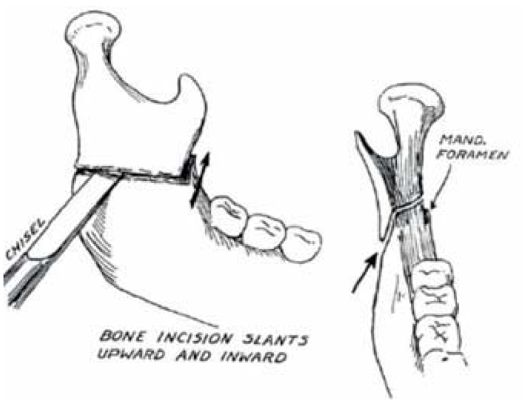

Figure 2: *Sagittal horizontal split osteotomy, as described by Schuchardt.*[5]

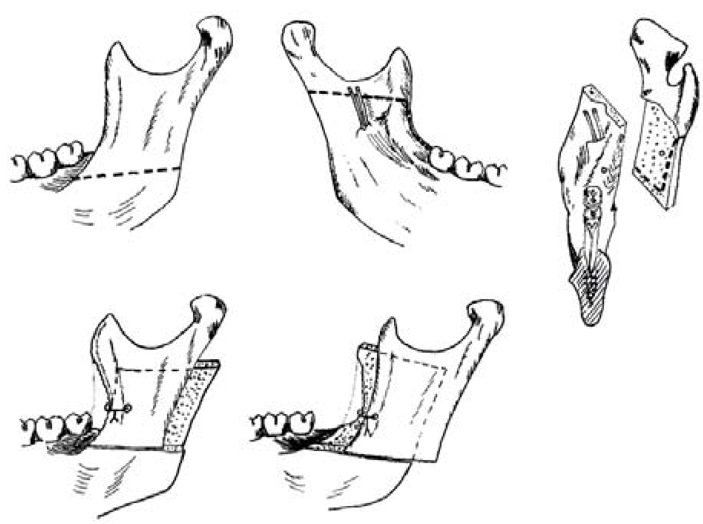

Figure 3: *Sagittal split osteotomy, as described by Obwegeser.*[6]

Soon after the introduction of the technique important modifications were suggested. In 1961, Dal Pont[7] advanced the lateral bone cut anteriorly towards the distal border of the second molar. Hunsuck[8] later shortened the medial bone cut, ending it just posterior of the lingula instead of carrying it through until the posterior border of the ramus. Hunsuck[8] furthermore suggested progressing the lateral bone cut through the inferior mandibular cortex, to establish an inferior border cut reaching into the lingual cortex. With these modifications, Hunsuck[8] was the first to complete the sagittal split with a fracture in the lingual cortex.

1

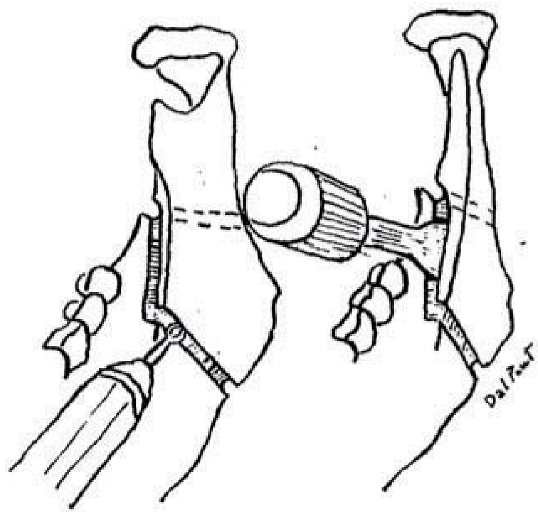

Figure 4: *Sagittal split osteotomy, as described by Dal Pont.*[7]

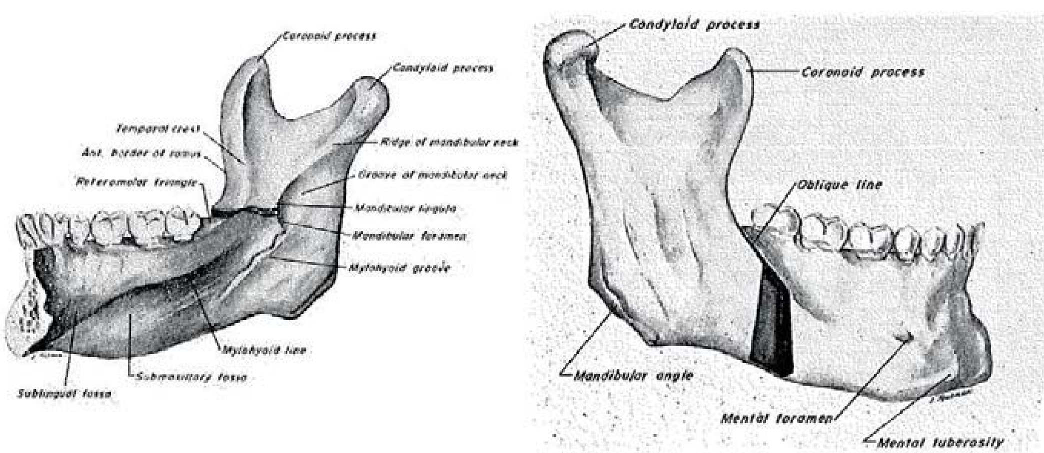

Figure 5: *Sagittal split osteotomy with lingual fracture, as described by Hunsuck.*[8]

Bell and Schendel[9] reported on the biological basis of BSSO in 1977. Epker[10] elaborated on these principles and suggested more biological modifications, such as limited mucoperiosteal stripping. He furthermore emphasized the importance of a complete osteotomy through the inferior mandibular cortex.

With these modifications, the major components of the contemporary BSSO technique were accomplished.[1] Many surgeons nowadays still perform BSSO according to these principles. Nevertheless, the surgical instruments with which the sagittal split is achieved vary.

The splitter-separator technique

Classic techniques used mallet and chisels to perform the split.[6] With this technique, the surgeon chiselled along the inner side of the buccal cortex until the chisel reached the inferior cortex of the mandible, effectively splitting the mandibular ramus in a proximal/buccal and distal/lingual segment.

More recently, the use of a sagittal splitter and separators has been suggested to split the mandibular segments using a prying and spreading technique. This splitter-separator technique prevents the use of sharp instruments near the inferior alveolar nerve.[11] BSSO with splitter and separators instead of chisels has shown to result in a low incidence of permanent neurosensory disturbances of the lower lip.[12] The use of a splitter and separators furthermore enables application of gradual force when performing the split and facilitates easy splitting of the mandible.

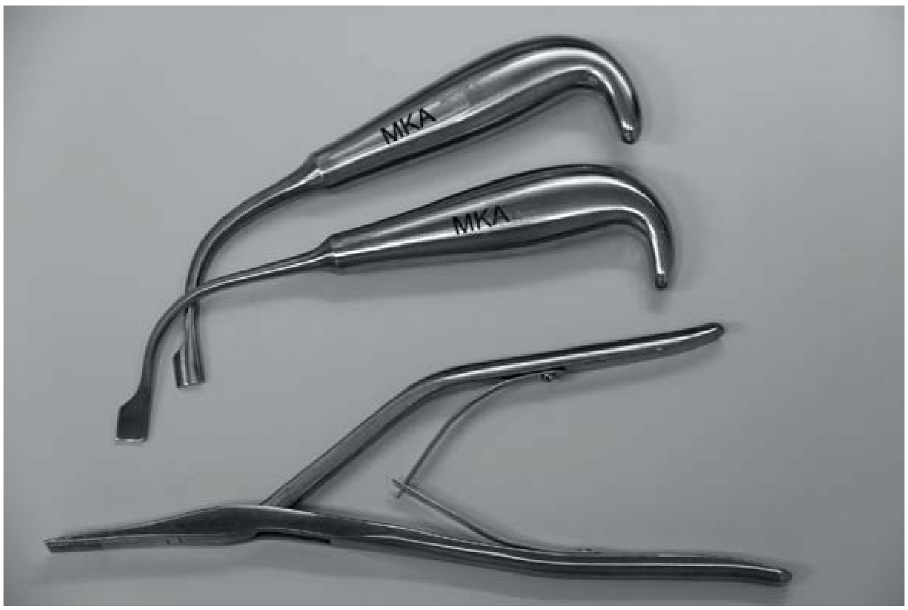

Figure 6: *Sagittal splitter and separators (Walter Lorenz Surgical, Jacksonville, FL, USA).*

Clinical complications associated with BSSO

Neurosensory disturbances

The inferior alveolar nerve (IAN) runs through the mandible and innervates the sensitivity of the lower lip and chin. It is regularly encountered during the sagittal splitting procedure.[13] Neurosensory disturbances (NSD) of the lower lip are frequent after BSSO and usually display as either increased sensation (hyperaesthesia), a tingling sensation (paraesthesia) or absence of sensitivity of the lower lip (hypoaesthesia).

Different aspects of the procedure present a risk of damaging the IAN. First of all, manipulation of the nerve should be minimized. Mucoperiosteal retraction to visualize the mandibular ramus can cause traction on the nerve near the mandibular foramen.[10] The risk of damaging the nerve is furthermore increased when the nerve is positioned near the buccal cortex or the nerve needs to be freed from the buccal segment after the split.[14] Splitting with chisels instead of splitters and separators could also increase the risk of NSD.[15, 16] After a successful split, damage to the nerve can be caused by stretching of the nerve in large advancements.[17] When fixating the mandibular segments, sharp bony interferences in between the mandibular segments should be removed and pressure on the nerve should be avoided to prevent crushing or puncturing the IAN.[18]

If altered sensation of the IAN is present for more than one year after BSSO, it is considered permanent.[12] Permanent neurosensory disturbances are one of the most important complications associated with BSSO. They have a significant influence on oral health related quality of life and patient satisfaction after the procedure.[19] Sensory retraining exercises could help patients when the altered sensation causes burden in daily life.[20] Although most patients eventually learn to adjust to the altered sensation, it is very important to reduce and possibly even eliminate this complication after BSSO.

Bad split

The development of an unfavourable fracture pattern during the splitting of the mandible is called a bad split. This is a well-known intra-operative complication of BSSO. Different types of bad split can occur.

- A fracture in the lingual cortex resulting in a loose lingual plate. This is called a lingual plate fracture.
- A fracture in the buccal cortex usually starting in the vertical osteotomy of BSSO that can run until the semilunar incisure. This is called a buccal plate fracture.
- Relatively rare miscellaneous bad splits, such as a fracture of the coronoid process or condylar neck.

Some authors state that a bad split is particularly challenging to the surgeon, but not that damaging to the patient.[21] Patients eventually recover with good functional and aesthetic results.[22] Nevertheless, this complication leads to prolonged surgical time and the use of additional osteosynthesis material which sometimes has to be applied through a transbuccal approach. In some cases, postoperative intermaxillary fixation is even necessary to allow proper healing of the bone fragments.[23] In our opinion, it is therefore valuable for both the surgeon and the patient, to increase the predictability of the procedure by controlling the lingual fracture during BSSO.

Postoperative infection

Postoperative infection is a complication that can occur after any form of surgery. Infection of the surgical wound after BSSO is fairly common, due to the presence of oral flora in the mouth.[24] Different regiments of perioperative prophylactic antibiotics have been proposed, but the effect of prophylactic antibiotics on postoperative infection remains under debate. If postoperative infection does occur, it can usually be easily treated with additional antibiotics in the form of amoxicillin-clavulanate.[24]

Removal of the osteosynthesis material

The introduction of rigid fixation after BSSO has been a big leap forward in the development of the technique. Rigid fixation with either bicortical screws or monocortical miniplates eliminates the need for postoperative intermaxillary fixation.[25-27] This not only produces a more reliable end result, but also facilitates a more patient-friendly procedure.

If the patient does not experience any complaints related to the hardware, no removal is needed. In some cases, however, removal of the osteosynthesis material because of symptoms is necessary.[28, 29] This can be due to infection or other complaints, such as palpability of the hardware, subjective discomfort (for example related to cold weather), or breakage of the material.

When removal of osteosynthesis material after BSSO is necessary, it can usually be performed under local anaesthesia. After this additional postoperative procedure, the patient completely recovers without any remaining symptoms.

Inferior border defects

A mandibular inferior border defect is a postoperative complication that consists of an unaesthetic osseous defect of the inferior border of the mandible. This complication can occur due to insufficient bone healing at the caudal part of the vertical bone cut after BSSO, for example because of large mandibular advancements, clockwise rotation of the distal segment, or inclusion of the full thickness of the lower border in the split.[30] Persisting inferior border defects can also be associated with the surgical technique.[31] Unaesthetic inferior border defects can in rare cases even necessitate secondary procedures after BSSO and are a relevant complication of this type of surgery.[30, 32] In order to maximise the result of BSSO and minimise the risk of secondary procedures, the occurrence of inferior border defects should thus be minimised. Patients should furthermore be informed about the risk of this complication to ensure proper patient counselling and maximise patient satisfaction after BSSO.

Aim of this thesis

This thesis aims to investigate the risk of complications associated with bilateral sagittal split osteotomy (BSSO), performed with a splitter and separators. Specific risk factors for intra- and postoperative complications that occurred within the first year after surgery are investigated. Factors influencing the predictability of the technique are furthermore analysed in order to increase predictability of the split and therefore minimise sequelae.

This could facilitate individual counselling of patients before BSSO and help maxillofacial surgeons attempt to minimise the risk of complications associated with this procedure.

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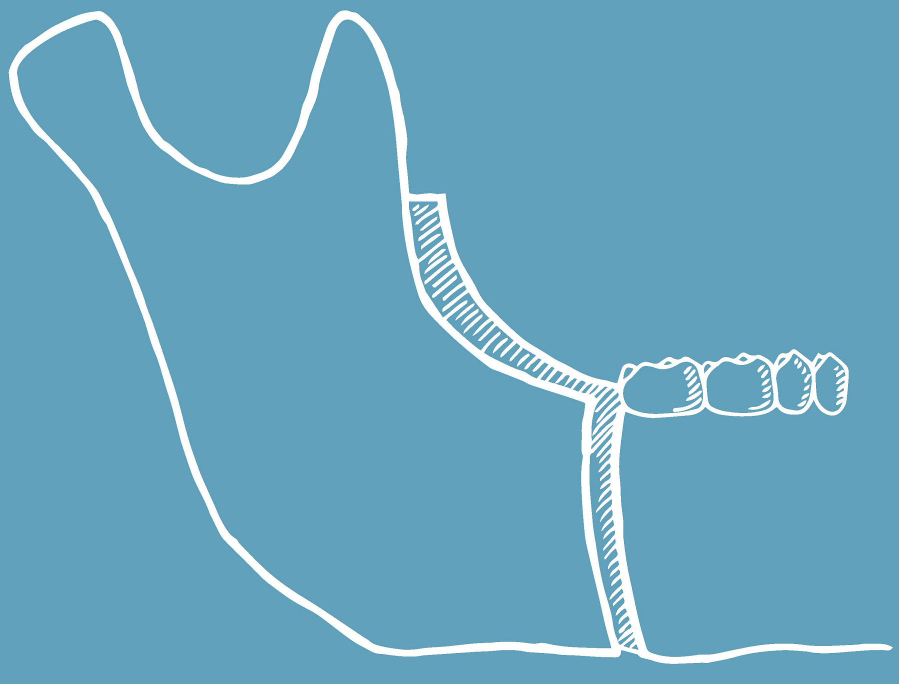

CHAPTER 2

Risk factors for common complications associated with bilateral sagittal split osteotomy, a literature review and meta-analysis

This chapter is based on the manuscript:

Verweij JP, Houppermans PNWJ, Gooris PJJ, Mensink G, van Merkesteyn JPR

Risk factors for common complications associated with bilateral sagittal split osteotomy, a literature review and meta-analysis

Journal of Cranio-Maxillofacial Surgery 2016; 44: 1170-1180.

ABSTRACT

The most common complications that are associated with bilateral sagittal split osteotomy are: bad splits, postoperative infection, removal of osteosynthesis material, and neurosensory disturbances of the lower lip. Particularly in elective orthognathic surgery, it is important that surgeons inform their patients about the risk of these complications and attempt to minimise these risks. The purpose of this literature review and meta-analysis is to provide an overview of these common complications and their risk factors.

After a systematic electronic database search, 59 studies were identified and included in this review. For each complication, a pooled mean incidence was computed. Both the pooled study group and the pooled 'complication group' were analysed.

The mean incidences for bad split (2.3% per sagittal split osteotomy; SSO), postoperative infection (9.6% per patient), removal of the osteosynthesis material (11.2% per patient), and neurosensory disturbances of the lower lip (33.9% per patient) are reported. Regularly reported risk factors for complications were the patient's age, smoking habits, presence of third molars, the surgical technique and type of osteosynthesis material. This information may help the surgeon to minimise the risk of these complications and inform the patient about the risks of complications associated with bilateral sagittal split osteotomy.

INTRODUCTION

Bilateral sagittal split osteotomy (BSSO) is an orthognathic surgical technique used to treat mandibular deformity. It was first described by Trauner and Obwegeser in 1957.[1, 2] Soon after its introduction, several important and widely used modifications had been suggested by Dal Pont, Hunsuck, and Epker.[3-5] Since then, this well-designed and valuable technique has become an important cornerstone of maxillofacial surgery. Nevertheless, it is associated with several complications, such as unfavourable fracture patterns (bad splits), postoperative infection, the need for postoperative removal of osteosynthesis material, and neurosensory disturbances (NSD) of the lower lip.[6-9] Because of the elective nature of BSSO, it is important to reduce the risk of complications as much as possible. Furthermore, preoperative counselling and informing the patient are considered to be of paramount importance in surgery. The surgeon therefore should know the general incidence of common complications associated with the procedure and should be aware of the possible risk factors for these complications. This allows for patient-specific counselling prior to performing BSSO and enables surgeons to evaluate their work critically and maximise the chance of success.

The aim of this review is to provide an evidence-based overview of the incidence of common complications associated with BSSO and to discuss the risk factors related to these complications. This review includes the occurrence of bad splits, postoperative infection, removal of symptomatic osteosynthesis material, and permanent neurosensory disturbances of the lower lip. The impact of common risk factors, such as the patient's age, gender, smoking habits, the presence of mandibular third molars, and concomitant procedures, were analysed and discussed. This information could help surgeons to prevent these complications.

MATERIAL AND METHODS

This review was registered on http://www.crd.york.ac.uk/PROSPERO as CRD4201502034 and conducted in accordance with the PRISMA statement.[10]

Study identification

An electronic search of Pubmed, Embase, and World of Science databases was performed. Keywords were used with their truncations and the corresponding Medical Subject Heading (MeSH) terms in various combinations. Keywords included: risk, risk factors, complication, intraoperative complications, postoperative complications, orthognathic surgery, mandibular advancement, sagittal ramus split, sagittal split osteotomy, BSSO, bad split, unfavourable fracture, lingual split pattern, lingual fracture line, infection, device removal, removal of osteosynthesis material, screws, plates, inferior alveolar nerve, neurosensory disturbances, hypoesthesia, and sensory function.

Prospective and retrospective original research papers describing clinically observed intra-operative or post-operative complications associated with BSSO (bad splits, infection, removal of osteosynthesis material, and neurosensory disturbances) were included. In vitro studies and animal studies were excluded. Letters to the editor and conference abstracts were excluded because of the lack of detail in the description of materials and methods. Non-English articles were also excluded.

This review aimed to analyse BSSO performed according to modern surgical techniques. Therefore, articles published before 1985, using less modern techniques, were excluded. Postoperative infection and removal of hardware were investigated after BSSO with rigid fixation, using titanium osteosynthesis material. Studies that investigated other non-standard fixation techniques or that used bioresorbable fixation materials were excluded. If the operative technique was not clear, or if different orthognathic operative techniques were analysed together without identifying the BSSO-specific outcome, the paper was excluded.

In order to prevent inclusion of small, less coherent studies, the minimum number of patients for inclusion in this review was 25 subjects (50 SSOs) for assessing short-term complications (bad splits, infection, and removal of osteosynthesis material) and 50 subjects (100 SSOs) with a minimal follow-up of 1 year for assessing long-term complications (neurosensory disturbances). With regard to neurosensory disturbances, studies using subjective tests (such as questionnaires, light-touch detection, etc.) were included, as these are reported to show the highest sensitivity for detecting neurosensory disturbances. Studies using only quantitative analyses of NSD (i.e., threshold tests) were excluded.

Data extraction

Articles that were identified through the electronic database search were first screened based on title and abstract. If the title or abstract mentioned one of the aforementioned postoperative complications associated with BSSO, the full-text article was obtained. Studies that met the inclusion criteria were analysed. The reference lists of the included studies were searched for possible additional relevant papers.

All data were recorded in an individual summary of the study and subsequently entered in a database. Demographic data of the patient groups were collected, including the number of patients, their mean age (with age range), distribution of gender, and smoking habits. Details of the surgical procedure, including the presence of mandibular third molars, the surgical technique used, and the method of fixation applied, were also noted. The incidences of different complications (bad splits, infection, removal of osteosynthesis material, and neurosensory disturbances) were recorded. Intra-operative complications (bad splits) were reported as the incidence per SSO. Postoperative complications were reported both as the incidence per SSO and the incidence per patient. When a specific risk factor for one of the abovementioned complications was discussed in the study of interest, this was recorded in the summary of this study, and is subsequently reported in this review.

Quality assessment of the studies

The methodological index for non-randomised studies (MINORS) tool was used to assess the quality of the selected studies.[11] Information regarding the methodological items for non-randomised studies was recorded on predesigned forms. This included the aim of the study, the method for inclusion and follow-up of patients, the protocol used for data collection, the method used for evaluation of the endpoints, the risk of bias, and the study size, including loss to follow-up. For comparative studies, the equivalence of the compared groups and statistical analyses were also evaluated. Each item was scored as 0 (not reported), 1 (reported but inadequate) or 2 (reported and adequate). The maximum MINORS score was 16 points for non-comparative studies and 24 points for comparative studies.

Meta-analysis

The patient groups of the included studies were analysed. A subdivision was made based on the four complications of interest (bad splits, infection, removal of osteosynthesis material, and NSD of the lower lip). Data from the study groups were pooled to compute a mean pooled incidence for each complication. A Forest plot was computed for the reported incidence of bad split per SSO, and for the incidences of infection, removal of osteosynthesis material, and NSD per patient.

For each study group, the mean age of the patients, distribution of gender, presence of third molars, and smoking habits were reported. Surgical specifications, such as the surgical technique and the type of fixation material used, were also noted in the database when they were reported in the included studies.

The distribution of age, gender, presence of third molars, and smoking was reported for the pooled study group and for the 'complication-group' in order to facilitate a simple comparison of the distribution of possible risk factors for each complication. The individual studies and their findings regarding risk factors for complications of interest are discussed.

RESULTS

Literature search

The initial database search identified 2537 articles. From these papers, 2443 could be excluded based on the title or abstract. The full-texts of 94 possibly relevant articles were then obtained. Searching the reference lists of these papers revealed no additional eligible articles. After strict application of the exclusion criteria, a total of 59 articles were included for analysis in our review. These papers were then subdivided based on the four complications of interest. Ten papers described more than 1 subject of interest. A flowchart summarising the literature search for this review and the subdivision in terms of subjects of interest is shown in Figure 1.

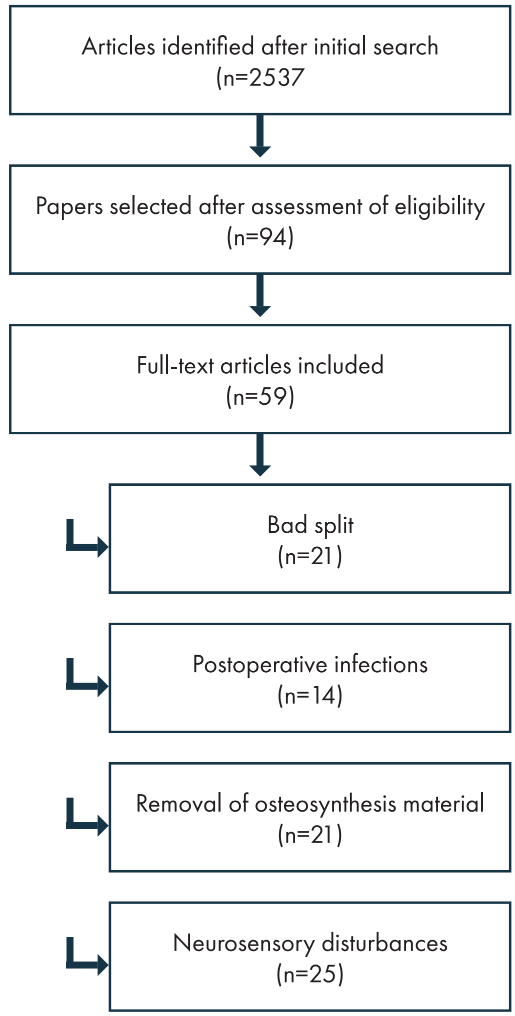

Figure 1: Flowchart summarising the approach followed in the literature search for studies describing risk factors for common complications after bilateral sagittal split osteotomy (BSSO). Several papers described more than one subject of interest to this study.

Quality assessment

A total of 15 prospective and 44 retrospective studies were included in this review. Of the 39 non-comparative studies, 8 were prospective and 31 were retrospective. Of the 20 comparative studies, 7 were prospective and 13 were retrospective.

The MINORS scores of the included studies were assessed. For non-comparative studies, one study scored 8 points, ten studies scored 9 points, six studies scored 10 points, fourteen studies scored 11 points, seven studies scored 12 points and one study scored 13 points. For comparative studies, one study scored 14 points, three studies scored 15 points, four studies scored 16 points, one study scored 17 points, five studies scored 18 points, three studies scored 20 points and three studies scored 21 points. The range of MINORS scores thus ranged from 8 to 13 points (out of 16 points) for non-comparative studies and from 14 to 21 points (out of 24 points) for comparative studies.

Methodological flaws included an incomplete description of the protocol used for data collection or evaluation of the outcome, absent or incomplete description of statistical methods, absence of baseline equivalence of the groups, and loss to follow-up of more than 5% of cases. Exclusion of specific studies or a subdivision based on risk-of-bias was found to be unnecessary, as there were no important methodological flaws that would relevantly influence the analysis.

Bad splits

Eighteen retrospective and three prospective papers describing bad splits were included. Two papers reported on the same patient group and were therefore analysed as one. The studies reported on 8225 patients that received 16359 SSOs in total. A total of 381 bad splits were reported. The pooled incidence of bad split was 2.3% per SSO (Figure 2). The reported incidences of bad split varied between 0.5% and 14.6% per SSO (Table 1).

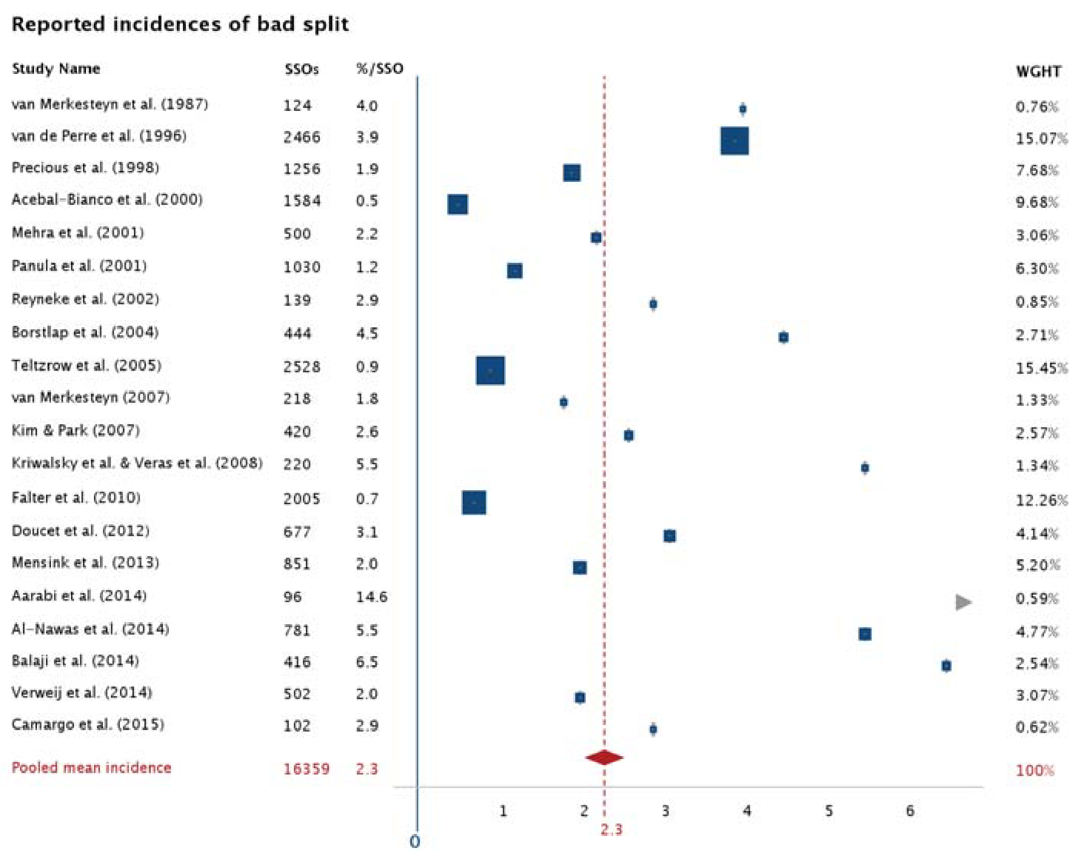

Figure 2: Forest plot for the reported incidence of bad splits per SSO.

Authors	Year	Patients	SSOs	Incidence (%/SSO)
Van Merkesteyn et al.[12]	1987	62	124	4.0
Van de Perre et al.[13]	1996	1233	2466	3.9
Precious et al.[14]	1998	633	1256	1.9
Acebal-Bianco et al.[15]	2000	802	1584	0.5
Mehra et al.[16]	2001	262	500	2.2
Panula et al.[17]	2001	515	1030	1.2
Reyneke et al.[18]	2002	70	139	2.9
Borstlap et al.[19]	2004	222	444	4.5
Teltzrow et al.[20]	2005	1264	2528	1.0
Van Merkesteyn et al.[21]	2007	109	218	1.8
Kim & Park[22]	2007	210	420	2.6
Kriwalsky et al.[23] & Veras et al.[24]	2008 2008	110	220	5.5
Falter et al.[25]	2010	1008	2005	0.7
Doucet et al.[26]	2012	339	677	3.1
Mensink et al.[27]	2013	427	851	2.0
Aarabi et al.[28]	2014	48	96	14.6
Al-Nawas et al.[29]	2014	400	781	5.5
Balaji[30]	2014	208	416	6.5
Verweij et al.[31]	2014	251	502	2.0
Camargo et al.[32]	2015	52	102	2.9

Table 1: The reported incidence of bad splits during BSSO.

The patients in the study groups consisted of 1% males and 65.9% females, with a mean age of 25.1 years (range 12.1-68.0). The relationship between gender and bad split was reported in eight articles, with 40.5% males and 59.5% females in the bad split group. The mean age of the bad split group was mentioned in nine articles, resulting in a pooled mean age of 30.3 years (SD: 6.7 years; range 15.0-61.0). The presence of third molars was mentioned in ten articles comprising 5110 SSOs. In 75 of 2172 SSOs (3.3%) involving third molars, a bad split occurred, in comparison to 72 of 2938 SSOs (2.4%) not involving third molars.

Male and female patients were reported to be at similar risk of bad split.[14, 19, 25-28, 30-32] With regard to the influence of age on the occurrence of unfavourable fractures, reports varied.[14, 25, 27, 30-32] Some authors found that older age was a risk factor for bad splits.[23, 26, 28] Other authors, however, reported that younger patients have an increased risk for bad splits.[16, 18]

The presence of mandibular third molars during BSSO is the most frequently reported risk factor for bad splits.[14, 16, 18, 27, 31] Nevertheless, some authors found no significant association between third molars and bad splits.[19, 23, 26, 32] Reyneke et al.[18] reported age as a factor in the risk of bad splits associated with third molars. Mehra et al.[16] found that the risk of bad split was increased in younger patients (< 20 years) with third molars and in older patients (> 40 years) without third molars. This is in accordance with the findings by Camargo et al.[32], who reported that third molars do not increase the risk of bad splits in patients aged 30 years or older. Balaji[30] investigated the spatial position of unerupted third molars and reported that the type of impaction, degree of third molar development, and root morphology significantly influenced the risk of bad splits. In their study, the occurrence of unfavourable fractures was reported to be more likely when third molars with a distoangular/vertical orientation or divergent roots were present.[30]

The surgeon's expertise has also been reported to be of importance.[18] Doucet et al.[26] reported that more bad splits occurred when BSSO was performed by residents. Borstlap et al.[19] considered that the relatively high incidence of bad splits in their study was due to trainees performing BSSO in a teaching hospital. Al-Nawas et al.[29] reported more bad splits when BSSO was performed by inexperienced surgeons, although they did not report a significant difference. Falter et al.[25] described that increasing expertise of surgeons had no effect, but their study protocol prescribed that third molars should be removed six months before BSSO as standard practice, making the procedure more straightforward.

Mandibular morphology has been reported to influence both the difficulty of the procedure and the risk of bad splits. Mehra et al.[16] reported no increased risk of bad splits relative to the occlusal plane angle or posterior mandibular height. Aarabi et al.[28] showed that the risk of bad splits was increased in buccolingually thinner and vertically smaller mandibles.

Some reports found that the osteotomy design influenced the risk of unfavourable fractures. An osteotomy procedure using an inferior border cut (Hunsuck modification) has been reported to result in significantly fewer bad splits than the traditional Obwegeser-Dal Pont techniques.[29] The use of either a splitter and separators or a mallet and chisels is reported to both result in a similar incidence of bad splits.[27]

Infection

Ten retrospective and four prospective papers, describing postoperative infection after BSSO, were included in our review. All the prospective papers compared patient groups with different antibiotic treatments. The studies reported on 4123 patients in total. Postoperative infection occurred in 333 patients, and the reported incidences range from 2.0%-25.9% per patient (Table 2). The pooled incidence of postoperative infection was 9.6% per patient (Figure 3). Ten studies described infection rates per SSO. These studies described 5129 SSOs and postoperative infection occurred at 318 sites, resulting in a pooled incidence of 6.2% per SSO (range 1.0%-15.6%).

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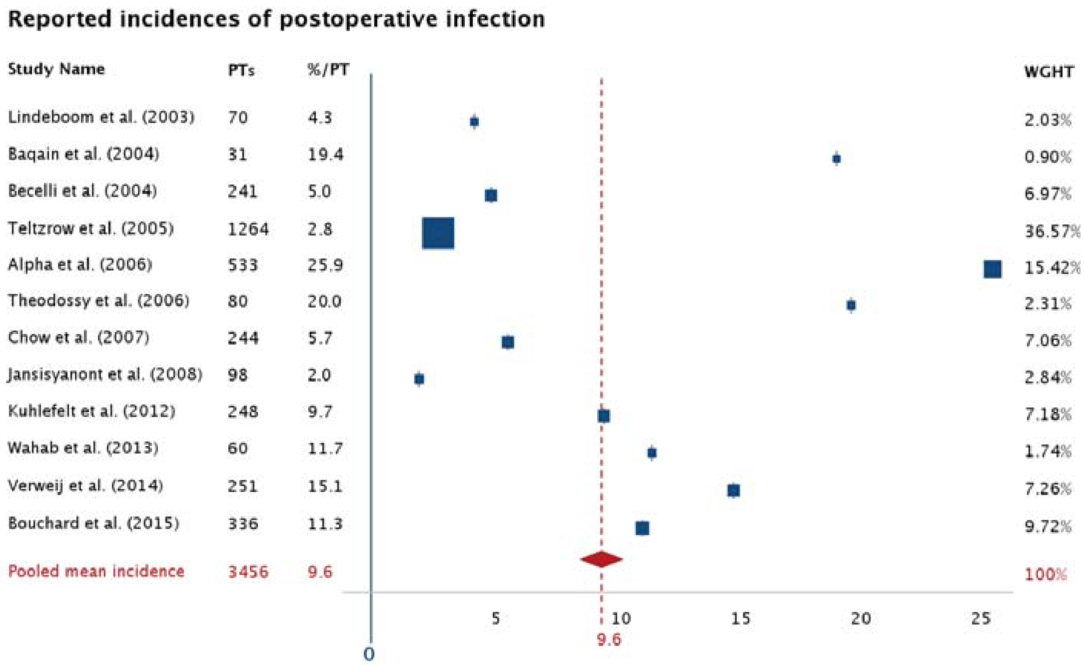

Figure 3: Forest plot for the reported incidence of postoperative infection per patient.

Authors	**SSOs**	**Incidence (%/SSO)**	**Patients**	**Incidence (%/patient)**
Bouwman et al.[33]	1334	1.12	667	-
Lindeboom et al.[34]	140	2.14	70	4.29
Baqain et al.[35]	62	9.68	31	19.35
Becelli et al.[36]	482	2.49	241	4.98
Spaey et al.[37]	1067	4.40	-	-
Teltzrow et al.[20]	-	-	1264	2.77
Alpha et al.[38]	1066	15.01	533	25.89
Theodossy et al.[39]	160	15.63	80	20.00
Chow et al.[40]	-	-	244	5.74
Jansisyanont et al.[41]	196	1.02	98	2.04
Kuhlefelt et al.[42]	-	-	248	9.68
Wahab et al.[43]	120	5.83	60	11.67
Verweij et al.[31]	502	8.17	251	15.14
Bouchard et al.[44]	-	-	336	11.31

Table 2: The reported incidence of infection after BSSO.

The patients in the study groups consisted of 33.4% males and 66.6% females with a mean age of 26.0 years (range 13.0-68.0 years). Five studies reported on the relationship between infection and gender, with 35.2% males and 64.8% females in the patient groups that experienced postoperative infection. The mean age of the patients with postoperative infection was mentioned in 3 studies, showing a mean age in the infection group of 29.7 years (range 14.6-51.0 years).

Three studies investigated the influence of smoking on postoperative infection in 71 smokers and 878 non-smokers. The incidence of infection after BSSO was 32.4% per patient in the smokers group and 19.3% in the non-smokers group.

Six studies reported on the influence of mandibular third molar removal during BSSO on infection. Of the 421 sites involving a third molar, 49 sites developed postoperative infection (11.6% per SSO), and of the 1730 sites without a third molar, 208 sites developed postoperative infection (12.0% per SSO).

Male and female patients were generally reported to have the same risk of postoperative infection.[31, 34, 35, 38-40, 42, 44] Younger and older patients also exhibit similar infection rates in most articles.[31, 34, 38, 40, 42] Bouchard et al.[44] and Theodossy et al.[39] however reported more infections with increasing age. Alpha et al.[38] reported that the intra-operative removal of third molars can influence the risk of postoperative infection, but most authors found no increased risk of infection when mandibular third molars were removed during surgery.[31, 39, 44]

Several authors reported that smokers have an increased risk of postoperative infection after oral surgery, as compared to non-smokers.[38, 42, 44] Systemic conditions, such as diabetes, were also reported to increase the risk of infection and to delay wound healing.[38]

Procedures in the mandible were found to result in a greater risk of postoperative infection as compared to other maxillofacial procedures.[37, 42, 43] The supero-anterior part of the buccal cortex is reported to be at risk for sequestration after BSSO, due to the poor blood supply of this area.[33, 36] Moreover, the use of a drain has been reported to increase the risk of infection.[37]

A total surgical time of more than 3 hours has been found to be a risk factor for infection in one study.[39] However, other clinical studies did not find a significant association between surgical time and infection.[34, 35, 40, 42]

Removal of osteosynthesis material

Eleven studies described removal of osteosynthesis material, due to symptoms, after BSSO (Table 3). All studies were retrospective, except for 1 prospective study, which compared titanium and bioresorbable plate fixation. Of this prospective paper, only the results related to titanium fixation were included in our study. The studies reported on a total of 2809 patients. Removal of osteosynthesis material was necessary in 240 patients and the incidence ranged from 0.0% to 25.8% per patient (Table 3). The pooled incidence of removal of osteosynthesis removal was 11.2% per patient (Figure 4). Seven studies described removal of osteosynthesis material per SSO. The pooled incidence of removal of osteosynthesis material was 5.1% per site (range 0.0%-18.3%), as it was required for 200 of 3928 sites.

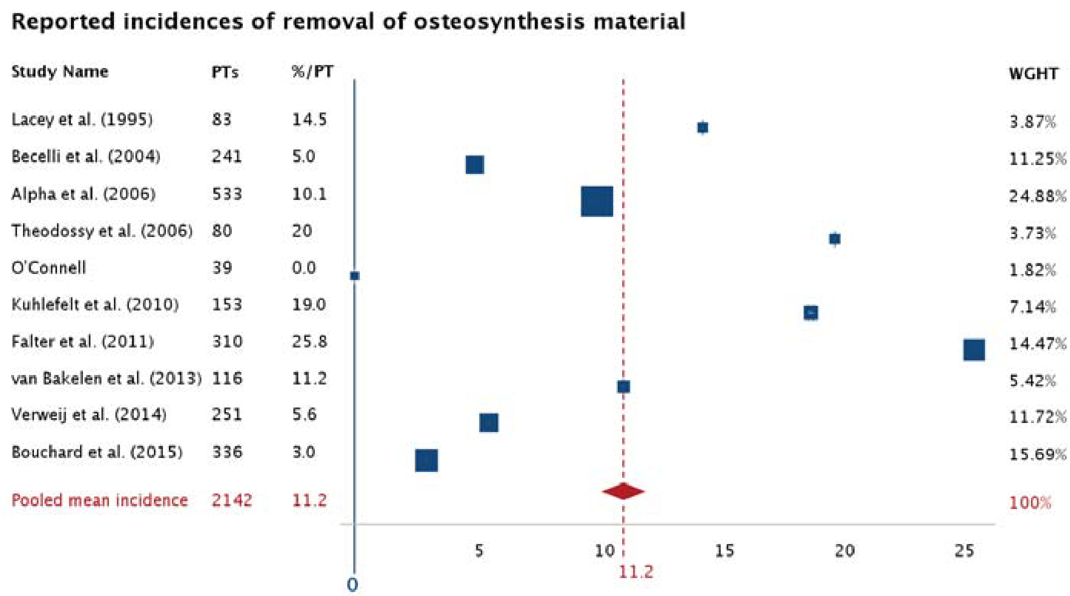

Figure 4: Forest plot for the reported incidence of removal of osteosynthesis material per patient.

Authors	**Type of fixation**	**SSOs**	**Incidence (%/SSO)**	**Patients**	**Incidence (%/patient)**
Bouwman et al.[33]	S	1334	1.5	667	-
Lacey et al.[45]	S	-	-	83	14.5
Becelli et al.[36]	S	482	2.5	241	5.0
Alpha et al.[38]	P	1066	6.6	533	10.1
Theodossy et al.[39]	P	160	15.6	80	20.0
O'Connell et al.[46]	P	78	0.0	39	0.0
Kuhlefelt et al.[47]	P	306	18.3	153	19.0
Falter et al.[48]	P	-	-	310	25.8
Van Bakelen et al.[49]	P	-	-	116	11.2
Verweij et al.[50]	S	502	3.4	251	5.8
Bouchard et al.[44]	S	-	-	336	3.0

Table 3: The reported incidence of removal of osteosynthesis material after BSSO.
S = Bicortical screw fixation, P = Miniplate fixation

The patients in the study group consisted of 32.6% males and 67.4% females, with a mean age of 27.3 years (range 13.0-68.0 years). Three studies reported on removal of osteosynthesis material and gender, with 31.6% males and 68.4% females in the group in which osteosynthesis material needed to be removed. Five studies reported on the relationship between age and removal of osteosynthesis, and found that the group in which osteosynthesis material needed to be removed had a mean age of 29.7 years (range 15.0-65.0 years).

With regard to the smoking habits of the patients, 3 studies reported that removal of osteosynthesis material was necessary in 15 of 40 smokers (37.5%) compared to 30 of 193 non-smokers (15.5%); thus, smokers more frequently required removal of osteosynthesis material. In the five studies that described the presence of third molars during BSSO, removal of osteosynthesis material was performed at 23 of 342 sites (6.7%) with third molars present during surgery and 84 of 634 sites (13.3%) without third molars during surgery. In five studies, miniplates were used as fixation material, and in six studies, bicortical screws were used. Removal of osteosynthesis material was necessary in 192 of 1225 patients (15.7%) with miniplate fixation and in 68 of 1578 patients (4.3%) with screw fixation.

Gender was not reported as a significant factor in removal of osteosynthesis material in most previous studies, although Falter et al.[48] did report an increased rate of plate removal for non-infectious symptoms in women.[38, 44, 47, 50] Most studies reported no effect of increased age of the patient, although Theodossy et al.[39] and Bouchard et al.[44] reported that removal of osteosynthesis material was more frequently required in older patients.[47, 48, 50] Lacey et al.[45] reported a higher rate of infected screws after third molar removal during BSSO and described exposed hardware in the socket as a possible reason for this. Other studies found no significant correlation between the presence of mandibular third molars during BSSO and removal of osteosynthesis material.[39, 44, 50]

Risk factors for postoperative infection, such a smoking, have been reported to increase the need for removal of osteosynthesis material.[47] Placing the fixation near the inferior border of the mandible has been reported to prevent hardware removal, because of infectious symptoms, because of a poor blood supply to the supero-anterior part of the buccal cortex.[33, 36, 38] The removal rates for monocortical miniplates and bicortical screws were markedly different.[50] No randomised studies comparing the removal rates after plate- or screw-fixation during BSSO were found.

Neurosensory disturbance

Sixteen retrospective and nine prospective papers reported subjective assessment if NSD of the inferior alveolar nerve persisting at least one year after BSSO and were included in our study. Two papers described the same patient group and were analysed as one. The studies reported on 3230 patients and 5408 SSOs in total. The reported incidences of NSD are described in Table 4. The pooled mean incidence of NSD was 33.9% per patient (range 0.0%-71.0%) and 21.7% per SSO (range 0.0%-48.8%). Figure 5 shows the Forest plot with the pooled mean incidence of permanent NSD per patient.

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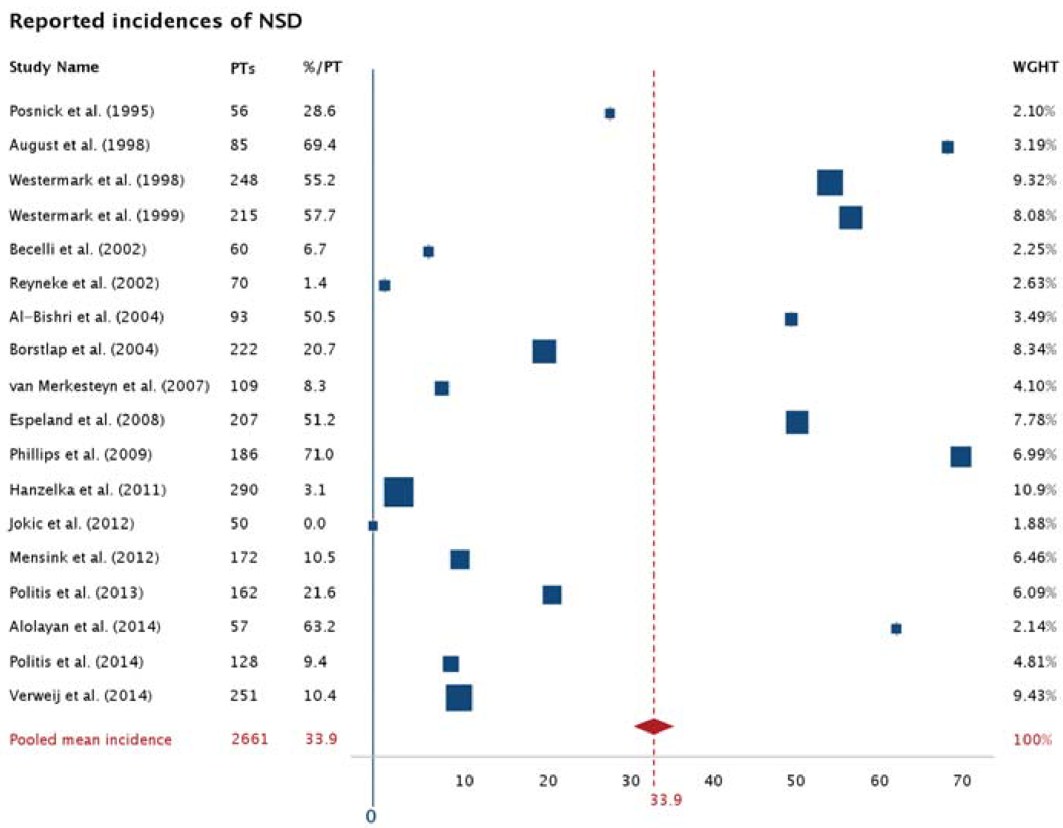

<u>Figure 5</u>: Forest plot for the reported incidence of permanent neurosensory disturbance (NSD) per patient.

Authors	SSOs	Incidence (%/SSO)	Patients	Incidence (%/patient)
Scheerlinck et al.[51]	206	17.0	103	-
Posnick et al.[52]	112	18.8	56	28.6
August et al.[53]	-	-	85	69.4
Westermark et al.[54] & Westermark et al.[55]	496	40.3	248	55.2
Westermark et al.[56]	430	40.5	215	57.7
Becelli et al.[57]	120	5.0	60	6.7
Reyneke et al.[18]	-	-	70	1.4
Bothur et al.[58]	160	48.8	80	-
Al-Bishri et al.[59]	185	36.8	93	50.5
Borstlap et al.[19]	444	13.1	222	20.7
Nesari et al.[60]	136	31.6	68	-
Van Merkesteyn et al.[21]	218	4.1	109	8.3
Espeland et al.[61]	-	-	207	51.2
Phillips et al.[62]	-	-	186	71.0
D'Agostino et al.[63]	100	48.0	50	-
Hanzelka et al.[64]	-	-	290	3.1
Jokic et al.[65]	100	0.0	50	0.0
Mensink et al.[66]	344	5.8	172	10.5
Bruckmoser et al.[67]	206	22.8	103	-
Gilles et al.[68]	102	2.0	51	-
Politis et al.[69]	324	15.1	162	21.6
Alolayan et al.[70]	-	-	57	63.2
Politis et al.[71]	-	-	128	9.4
Verweij et al.[31]	502	5.4	251	10.4

Table 4: The reported incidences of permanent NSD after BSSO.

The patients in the study groups consisted of 33.6% males and 66.4% females, with a mean age of 26.8 years (range 12.6-72.4 years). The patient characteristic that was reported most often as an important predictor of NSD is increasing age.[19, 31, 53, 54, 56, 58, 60-62, 66-70] The risk of permanent NSD after BSSO has been reported to increase with approximately 5% per year.[66, 69] Patients over 30 years of age have been described as being vulnerable to nerve damage and subsequent permanent NSD.[56, 60] These older patients have also been reported to experience an increased burden due to NSD, and were subsequently found to be less satisfied after BSSO.[53, 61, 62, 72] Bothur et al.[58] and Bruckmoser et al.[67] reported female patients were at greater risk for NSD. In most studies, however, the patient's gender was found to have no significant influence on the risk of NSD.[18, 31, 54, 56, 59, 60, 62, 65, 66, 69, 70] Third molar removal during surgery has been reported to increase the difficulty of the sagittal split, but not the risk of NSD.[18, 31, 53, 66] Intra-operative complications, such as a bad split or bleeding have not been reported as a cause of NSD.[19, 31, 53, 58]

Some authors reported no influence of nerve manipulation during surgery.[18, 53, 64] Several other authors however reported that nerve encounters during the split does increase the risk of NSD.[19, 31, 55, 60, 66, 67, 71] The risk of NSD was reported to be increased particularly when the nerve had to be released from the lateral segment.[31, 60, 66, 71] Several authors propose using sagittal splitters or ultrasonic osteotomes to minimise the chance of iatrogenic nerve damage.[31, 66, 68]

Some studies have described less NSD after setback surgery.[21, 63, 65] However, other studies found no difference between patients with a class II or class III malocclusion.[31, 59, 64, 67, 69] Large advancements/setbacks (> 7 mm) have been reported to increase the risk of NSD by increasing the difficulty of the procedure or the vulnerability of the patient by stretching the nerve.[55, 73] Additional procedures in the upper jaw (i.e. Le Fort I osteotomy) have not been reported to influence the risk of NSD after BSSO. Several authors reported that genioplasty combined with BSSO increased the incidence of NSD.[21, 31, 52, 55, 66, 69] Others did not find a significant increase of NSD due to genioplasty.[53, 58, 59, 62, 67] Rigid fixation with either bicortical position screws or monocortical miniplates has been reported to result in a similar incidence of NSD with either technique.[53, 58, 60, 67]

DISCUSSION

This systematic literature review and meta-analysis aimed to provide a mean complication rate that summarises the current literature regarding the most common complications associated with BSSO, such as bad splits; postoperative infection; removal of osteosynthesis material; and NSD of the lower lip.

Bad splits

Soon after the development of the BSSO technique, bad splits were described as a common intra-operative complication.[6-8, 12, 74-76] There is, however, still no consensus in the literature about what incidence of this complication is considered acceptable and which risk factors increase the risk of unfavourable fractures. We found a mean pooled incidence of 2.3% per SSO by analysing the literature.

In their review, Chrcanovic et al.[77] reported an incidence of bad splits ranging between 0.21% and 22.72% per patient. The lowest incidence of bad splits in their review was reported in a letter to the editor, without description of study design or methods.[78] The highest incidence of bad splits was reported in papers published before 1980, which used traditional Obwegeser techniques.[7, 74] In the current review, we have attempted to estimate a more contemporary, representative mean incidence of bad splits per SSO. Although the incidence of bad splits per patient is not reported consistently, bilateral bad splits are relatively rare, so that the incidence per patient can be assumed to be approximately double the incidence per SSO.

We found that the presence of third molars is regularly reported as a risk factor for bad splits, possibly in combination with the patient's age.[18, 26] The spatial positioning of the third molar and experience of the surgeon might also play a role in this association.[30] It is plausible that the presence of third molars could increase the difficulty of the procedure, and therefore the risk of bad splits, particularly for less experienced surgeons.[79]

Apart from patient-related risk factors, the occurrence of bad splits during BSSO probably depends first and foremost on the execution of the BSSO technique by the surgeon. Plooij et al.[80], Muto et al.[81], and Song et al.[82] showed that a horizontal and vertical bone cut in the osteotomy design and incomplete osteotomies can influence the lingual fracture pattern and therefore predispose to bad splits.

Infection

Postoperative infection is a common complication after any form of surgery. We report a mean pooled incidence of infection of 9.6% per patient. Smoking was reported as an important risk factor for infection.

In their Cochrane systematic review regarding the use of antibiotics in relation to orthognathic surgery, Brignardello-Petersen et al.[83] concluded that long-term antibiotic prophylaxis (before/during surgery and more than 1 day after surgery) probably decreases the risk of infection at the surgical site, and the information provided was insufficient to show whether any specific antibiotic was better than another. Therefore, it could be advisable to use long-term antibiotic prophylaxis, particularly in patients undergoing a surgical procedure that exceeds 3 hours and in patients who smoke. The exact preferred amount and type of prophylactic antibiotic to use exceeds the scope of this review.

Furthermore, possible precautions can be taken to prevent infection. Patients should be encouraged to stop smoking.[42] Additionally, the occurrence of infection could possibly be further reduced by specific surgical precautions, such as using fibrin glue in the wound, instead of a drain.[37] When postoperative infection does occur, it is practically always effectively treated using a regiment of amoxicillin-clavulanate or clindamycin.[83]

Removal of osteosynthesis material

The introduction of rigid fixation for BSSO has been an important development for this type of orthognathic surgery and has almost completely eliminated the need for intermaxillary fixation after BSSO.[84-86] Removal of the titanium osteosynthesis material after BSSO can nevertheless be indicated because of the presence of several symptoms. We found a mean pooled incidence for removal of such material of 11.2% per patient.

When postoperative infection is present at the surgical site, it often requires removal of the hardware. Smoking is an important risk factor for removal of osteosynthesis material, based on infection. A thin layer of soft tissue covering the hardware could be more prone to result in wound dehiscence with subsequent infection. However, removal of osteosynthesis material can also be necessary because of subjective discomfort, palpability of the plates, or breakage of the material. There is thus some overlap between hardware removal and infection, but removal of osteosynthesis material is identified as a separate complication, requiring an additional surgical procedure.

After a comparison of studies reported in the literature, we found that removal of bicortical screws (4.3%) was necessary markedly less often than removal of titanium miniplates (15.7%). Possible explanations for this finding could be the fact that the design, size, and morphology of implanted material influences the risk of material-related infection or other complaints.[50] Miniplates, with monocortical screws, present much more 'foreign body material' than bicortical screws. This enlarges the area for bacterial colonisation, which increases susceptibility of infection.[87] The size and position of miniplates also increase the chance that the material will be palpable, or other subjective complaints, which are indications for hardware removal. Based on the literature, we would therefore advise the use of bicortical screws to stabilise mandibular segments. If miniplates are used, it may be advisable to place the hardware closer to the caudal mandibular border to minimise the risk of complaints or wound healing problems.[38]

Neurosensory disturbance

If any type of altered sensation is present one year after BSSO, it is considered permanent. These permanent NSD of the lower lip are probably the most important complication associated with BSSO. Many different subjective and objective tests are used in neurosensory examination.[88] In their literature review, Agbaje et al.[89] concluded that this lack of standardised assessment procedures results in a wide variation in the reported incidence of inferior alveolar nerve injury. The wide range of methods used also complicates the comparison between studies. Because this review aimed to provide a patient-focused approach to complications associated with BSSO, only studies reporting subjectively assessed NSD were included. We found a mean pooled incidence of 33.9% NSD per patient.

In their literature review, Ow et al.[90] reported persistent subjective IAN disturbance in 27.8% of cases, based on 14 articles, which is similar to our mean pooled incidence. Colella et al.[91] reviewed seven studies, in which both objective and subjective neurosensory tests were used. They found an objective incidence of permanent NSD in 12.8% and a subjective incidence of 23.8%.[91] Subjective assessment of NSD should thus be part of postoperative examination in order not to underestimate the incidence of neurosensory disturbances.

Based on the literature, age is probably the most important patient-related risk factor for NSD. Other characteristics of patients with NSD were unfortunately rarely mentioned in the previous papers, making further characterisation of the NSD group difficult. Some important factors could nevertheless help the surgeon in an attempt to prevent NSD after BSSO. Manipulation of the nerve during the surgical procedure generally increases the risk of NSD and should therefore be prevented.[71] In their review, Mensink et al.[92] investigated the risk of nerve damage due to the use of chisels along the buccal cortex and found higher reported rates of NSD after BSSO was performed with chisels instead of splitters and separators. Furthermore, after a successful sagittal split, it is advised that sharp bony spicules and trabeculae on the inside of the mandibular segments are carefully removed to prevent puncturing of the nerve during fixation. When fixating the proximal and distal mandibular segment, pressure that can crush the nerve should also be prevented.[93] These factors, combined with careful handling of the nerve by the surgeon during surgery, could help the surgeon minimise the risk of NSD as much as possible.

CONCLUSION

In conclusion, this systematic literature review and meta-analysis provides an overview of important common complications associated with BSSO. Pooled mean incidences were computed for bad splits (2.3% per SSO), postoperative infection (9.6% per patient), removal of osteosynthesis material (11.2% per patient), and NSDs of the lower lip (33.9% per patient). Regularly reported risk factors for complications are the patient's age, smoking habits, presence of third molars, the surgical technique and the type of osteosynthesis material.

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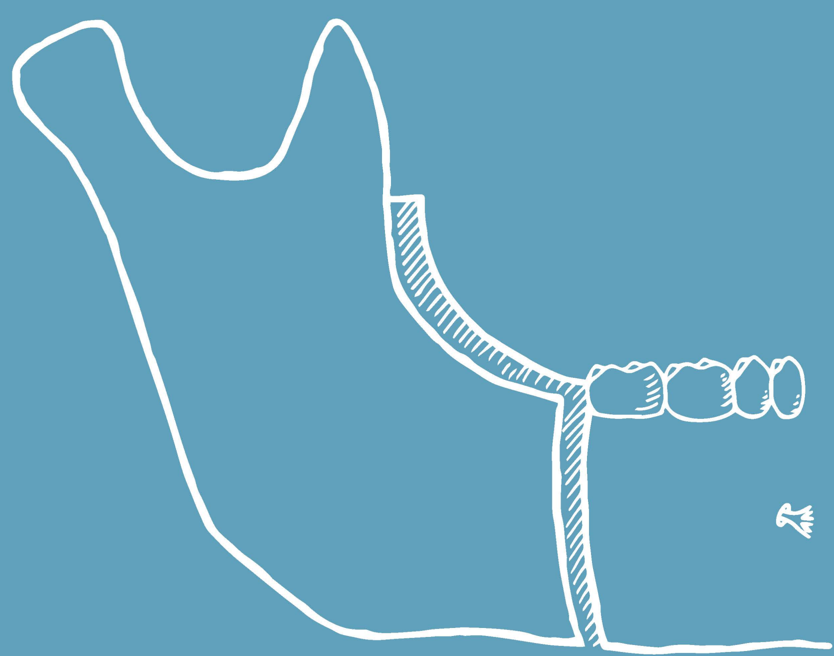

CHAPTER 3

Incidence and recovery of neurosensory disturbances after bilateral sagittal split osteotomy in different age groups: a retrospective study of 263 patients

This chapter is based on the manuscript:

Verweij JP, Mensink G, Fiocco M, van Merkesteyn JPR

Incidence and recovery of neurosensory disturbances after bilateral sagittal split osteotomy in different age groups: a retrospective study of 263 patients

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ABSTRACT

This study aimed to investigate the incidence of neurosensory disturbance (NSD) after bilateral sagittal split osteotomy (BSSO) in different age groups and assess the probability of sensory recovery in patients aged <19 years, 19–30 years and >30 years.

We subjectively and objectively assessed hypoaesthesia in the lower lip immediately, 1 week and 1, 6 and 12 months after BSSO. Hypoaesthesia was considered permanent if it was present one year after BSSO.

In older patients, the frequency of NSD immediately after surgery was significantly higher. The cumulative incidence of recovery at 1 year was lower and mean time to recovery was longer in the older patients, although these differences were not statistically significant. Older age was a significant risk factor for permanent hypoaesthesia with an incidence of 4.8% per patient <19 years; 7.9% per patient 19-30 years; and 15.2% per patient > 30 years.

The findings show that the risk of NSD after BSSO is significantly higher in older patients. These results can aid surgeons in pre-operative patient counselling and deciding the optimal age to perform BSSO.

INTRODUCTION

Neurosensory disturbance (NSD) of the inferior alveolar nerve (IAN) is one of the most frequently occurring complications of bilateral sagittal split osteotomy (BSSO). The most common manifestation is numbness of the lower lip (hypoaesthesia). In many patients, NSD resolves within several months after surgery.[1] However, if it is still present a year after surgery, it is considered permanent. This permanent hypoaesthesia leads to significant morbidity and is therefore an important complication of the elective BSSO procedure that should be explained to the patient before obtaining informed consent.[2]

During mandibular surgery, iatrogenic nerve damage and subsequent NSD can occur because of several factors. For example, IAN bruising can be caused by nerve compression during soft tissue dissection near the mandibular foramen, excessive nerve manipulation during splitting, the use of sharp instruments (chisels) during BSSO or the incorrect placement of screws.[3-5] Large mandibular advancements and increasing age have also been described as risk factors for NSD.[3, 4, 6, 7]

In our clinic, we perform BSSO using a sagittal splitter and separator (without the use of chisels) in an attempt to minimise the risk of hypoaesthesia.[8] This retrospective study analysed the incidence of hypoaesthesia and time to recovery from hypoaesthesia after the use of this BSSO technique in different age groups.

The purpose of this study was to report the incidence of NSD of the IAN after BSSO in different age groups (<19 years, 19-30 years and >30 years) and further investigate NSD in these different age groups in order to provide information that will aid surgeons in explaining age-specific risks to patients and deciding the optimal age to perform BSSO.

MATERIAL AND METHODS

We conducted a retrospective cohort study, including patients who had undergone BSSO alone or bimaxillary procedures at the Leiden University Medical Center (LUMC). The patients' clinical records were screened for details of sex, age at surgery, pre-operative diagnosis and concomitant procedures. The surgical reports were reviewed to assess the intra-operative status of the IAN, which was classified as follows: not visible in the distal segment, less than half visible in the distal segment, more than half visible in the distal segment, prepared from the proximal segment either blunt or with a burr, and visibly damaged. The patients were divided into three groups on the basis of age: group A (<19 years); group B (19–30 years) and group C (>30 years).

Prospective collection of data regarding NSD after the BSSO procedure had started in our centre in 2004, so we included all consecutive patients undergoing BSSO between January 2004 and January 2014.[3] Exclusion criteria included concomitant genioplasty, previous mandibular surgery and pre-existing hypoaesthesia. A minimum follow-up of six months was necessary for inclusion in this study.

The medical files of 320 patients were retrospectively reviewed. From this series, a total of 57 patients were excluded: 37 who required concomitant genioplasty, one with a previous history of orthognathic surgery, one with pre-existing hypoaesthesia and 18 who could be followed up for less than 6 months. All patients were treated according to the same procedures and the same clinical care was applied for all patients.

BSSO was performed using a sagittal splitter and separator according to the standard protocol in our centre.[3, 8, 9] Fixation of the mandibular segments was performed with three bicortical position screws through the upper border of the buccal cortex into the lingual cortex (superior of the mandibular canal and nerve). BSSO was performed by one of seven maxillofacial surgeons on one side and by a resident under close supervision of the surgeon on the other side. All patients were discharged within a week after surgery and scheduled for clinical and radiographic evaluations at 1, 2 and 3 weeks and 1, 6 and 12 months after surgery. Although principally the last evaluation was performed 1 year after BSSO, not all patients wished to return after the 6 month evaluation moment. If patients experienced any NSD 6 months postoperatively, they were however always evaluated 1 year after surgery.

Neurosensory function was tested preoperatively, immediately after surgery and at clinical evaluation at 1 week and 6 and 12 months after BSSO. Hypoaesthesia was considered permanent if it was present 1 year after surgery. Neurosensory testing was performed in a standardised manner, using sensory testing methods that are most widely used in osteotomy studies.[10] Sensory function was subjectively assessed by questioning the patient about altered sensation in the lower lip and by comparing contralateral sides. Light-touch detection was performed by the maxillofacial surgeon. It consisted of the surgeon softly touching the lower lip with cotton swabs and evaluating if the patient experienced reduced or altered sensation at the lower lip area. NSD was interpreted in as a binary outcome measure (absent/present). If any disturbance or altered sensation was noticed, hypoaesthesia was recorded as present.

This study was performed in accordance with the guidelines of our institution and followed the Declaration of Helsinki on medical protocol and ethics. Because of the retrospective nature of this study, it was granted a written exemption by the institutional review board of Leiden University Medical Center.

Statistical analysis

Statistical analyses were performed using SPSS version 20.0 for Windows (SPSS Inc., Chicago, IL, USA) and R version 18 (The R Foundation, Vienna, Austria). Descriptive statistics were performed. Chi-squared tests and Student's t-tests were used when appropriate. Mixed models (GLMM) were used to study the effect of age group on the status of the nerve and the status of the third molar. The same model has been applied to investigate the effect of third molar status and nerve status on permanent hypoaesthesia. These models are required since the status of the nerve and the status of the third molar were assessed per side and mixed models are necessary to account for the correlated nature of the left and right side measurement within each patient.[11]

The three age groups were retrospectively compared in this study, no control group was present. NSD was assessed at the patient level and therefore a univariate logistic regression model was employed to assess the effect of the three age groups on NSD after BSSO.

To study the effects of sex, type of malocclusion and concomitant Le Fort I osteotomy on the occurrence of NSD at the patient level, univariate logistic regression models are estimated.

To investigate the effects of age (age groups) on the time to recovery of nerve function, a Cox regression proportional hazards model was used. Recovery was defined as the absence of any sensory dysfunction. Therefore, the outcome was analysed on the patient level (NSD per patient). There was thus no correlated nature of the data (left and right side within one patient) in this analysis.

RESULTS

The study group comprised 263 patients (104 men and 159 women) who underwent 526 sagittal split osteotomies (SSOs/sites). Orthognathic surgery was performed to correct class II malocclusion in 226 patients (85.9%) and class III malocclusion in 37 patients (14.1%). In 86 patients (32.7%), BSSO was combined with Le Fort I osteotomy (bimaxillary procedure). Mandibular third molars were present at 196 sites (37.2%). The mean follow-up duration was 427.9 days (SD, 159.4; range, 188–1465 days).

	Group A (< 19 years)	**Group B (19 – 30 years)**	**Group C (> 30 years)**
Total number of patients	63 (24.0)	101 (38.4)	99 (37.6)
Mean (SD) age, age range (years)	17.1 (1.3), 13.8-18.9	22.7 (3.1), 19.0-29.8	40.6 (6.5), 30.1-55.6
Gender			
Male	19 (30.2)	50 (49.5)	35 (35.4)
Female	44 (69.8)	51 (50.5)	64 (64.6)
Malocclusion class			
II	54 (85.7)	78 (77.2)	94 (94.9)
III	9 (14.3)	23 (22.7)	5 (5.1)
Third molars			
Present (%/site)	94 (74.6)	69 (34.2)	33 (16.7)
Absent (%/site)	32 (25.4)	133 (65.8)	165 (83.3)
Bimaxillary procedure	19 (30.2)	40 (39.6)	27 (27.3)
Mean (SD) follow-up time, range (days)	418.5 (136.2), 188-856	434.1 (194.9), 188-1465	427.6 (131.5), 212-904

Table 1: Groups' characteristics. Data represent the number of patients (%) unless otherwise indicated.

	Group A (< 19 years)	Group B (19-30 years)	Group C (> 30 years)
Total number of sites	126	202	198
IAN not visible in the distal segment	21 (16.7)	36 (17.8)	24 (12.1)
Less than half of the IAN visible in the distal segment	30 (23.8)	35 (17.3)	27 (13.6)
More than half of the IAN visible in the distal segment	52 (41.2)	98 (48.5)	93 (47.0)
IAN prepared blunt from the proximal segment	11 (8.7)	15 (7.4)	31 (15.7)
IAN prepared with burr from the proximal segment	10 (7.9)	18 (8.9)	20 (10.1)
IAN visibly damaged	2 (1.6)	0 (0.0)	3 (1.5)

Table 2: Status of the nerve during BSSO for the different groupsData represent the number of surgical sites (%).

The characteristics of the patients in groups A, B and C are presented in Table 1. The status of the nerve during BSSO in each group is represented in Table 2. There was a significant statistical association between the three age groups with regard to the presence of mandibular third molars ($p < 0.01$) and status of the nerve ($p = 0.035$). There was no significant effect of third molar status ($p = 0.433$) on hypoaesthesia. If the nerve was prepared from the proximal segment (either blunt or with a burr) or was visibly damaged during surgery, the risk of permanent NSD was significantly higher ($p = 0.01$).

Univariate logistic regression models for NSD at the patient level have been estimated. Risk factors used were sex (OR, 1.06; CI, 0.58–1.89; $p = 0.87$), type of malocclusion (OR, 1.12; CI, 0.51–2.49; $p = 0.77$), concomitant Le Fort I osteotomy (OR, 0.91; CI, 0.49–1.68; $p = 0.76$). The risk factors showed no significant association with permanent NSD.

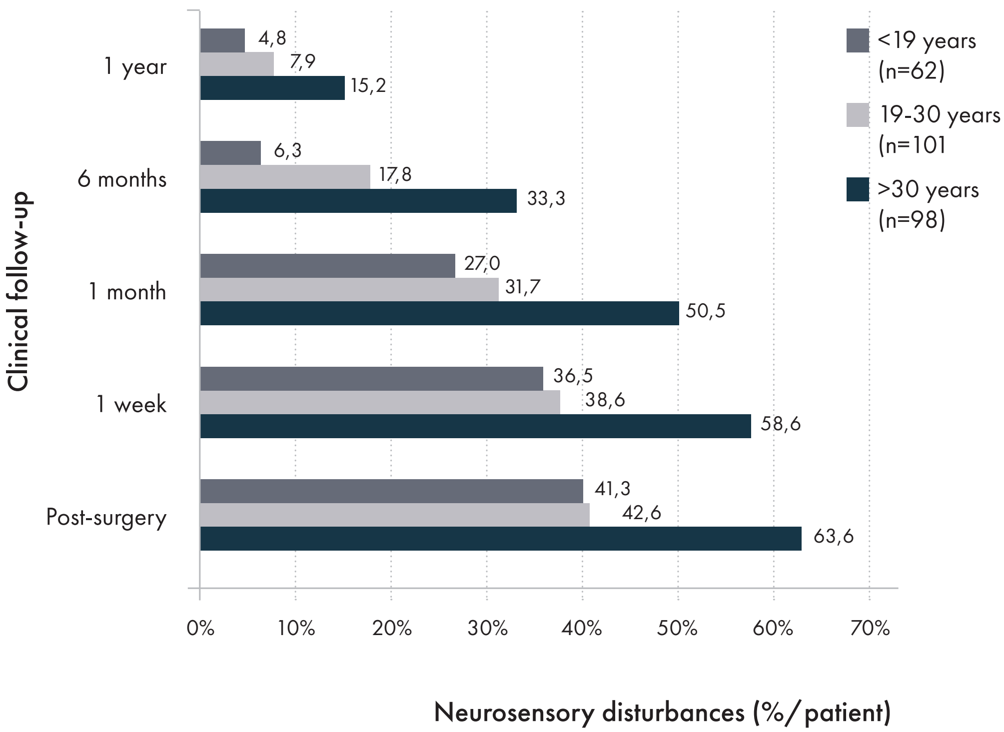

Figure 1: Bar chart showing the incidence of neurosensory disturbance in different age groups directly after BSSO and during clinical follow-up at 1 week, 1 month, 6 months and 1 year postoperatively.

The incidence of NSD in the three age groups during the clinical follow-up is represented in Figure 1. Immediately after BSSO, NSD was present in 132 patients (50.2%): 26 in group A (13 left side, eight right side, five bilateral), 43 in group B (12 left side, 15 right side, 16 bilateral) and 63 in group C (19 left side, 24 right side, 20 bilateral). Accordingly, the incidence of immediate post-operative NSD was 41.3% per patient in group A, 42.6% per patient in group B and 63.6% per patient in group C.

Logistic regression analysis to investigate the effects of age group on the occurrence of NSD immediately after BSSO was used. A significant association between age and NSD was found ($p < 0.01$). With group A as a reference group, the ORs for groups B and C were 1.06 (CI, 0.56–2.00) and 2.49 (CI, 1.30–4.76), respectively.

One year after BSSO, hypoaesthesia was observed in 26 patients (9.9%): three in group A (two left side, one right side), eight in group B (three left side, four right side, one bilateral) and 15 in group C (six left side, nine right side). Accordingly, the incidence of permanent hypoaesthesia was 4.8% per patient in group A, 7.9% per patient in group B and 15.2% per patient in group C. Logistic regression analysis to study the association between age group and permanent hypoaesthesia was employed. A significant association between age and permanent NSD was found ($p = 0.05$). With group A as a reference group, the ORs for groups B and C were 1.72 (CI, 0.44–6.74) and 3.57 (CI, 1.00–12.89), respectively.

The cumulative incidence of recovery at 1 year after BSSO was 0.833%, 0.702% and 0.593%, respectively, in groups A, B and C. The cumulative incidence of post-operative sensory recovery in each age group is shown in Figure 2. The hazard ratio decreased with increasing age, implying that the older group experienced recovery at a later stage compared with the younger groups. However, the difference among groups was not statistically significant ($p = 0.33$). The hazard ratios and mean time to recovery in each age group are shown in Table 3.

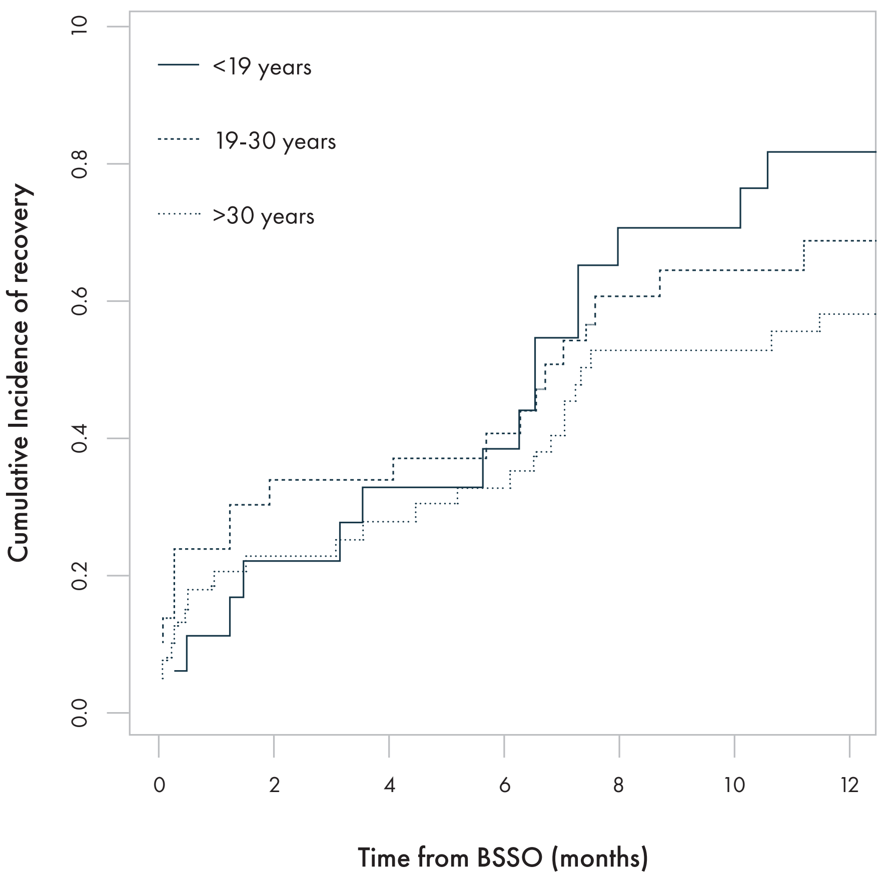

Figure 2: Graph of the cumulative incidence of recovery of nerve function in different age groups, showing a lower cumulative incidence of recovery one year after BSSO in the older groups.

	Group A (<19 years)	**Group B (19-30 years)**	**Group C (> 30 years)**
Hazard ratio for recovery (95% CI)	reference category	0.95 (0.50-1.80)	0.74 (0.17-3.18)
Mean time to recovery (days) (95% CI)	83.69 (38.47-128.91)	99.30 (68.13-130-46)	203.83 (26.36-152.16)

Table 3: Recovery hazard ratios and mean time to recovery along with 95% CI corresponding to the three age groups.

DISCUSSION

This study aimed to analyse the incidence of NSD after BSSO in different age groups and investigate the time to recovery of nerve function. In the older patients, we found a significantly higher incidence of NSD immediately after surgery and permanent NSD. Although a trend for slower recovery and a lower probability of recovery was observed for the older patients 1 year after BSSO, this difference was not statistically significant.

During the assessment of NSD, both objective and subjective assessments are used to evaluate sensory function and the possibility of hypoaesthesia. In this study, we recorded hypoaesthesia if either objective or subjective tests indicated altered sensation in the lower lip area, in order to avoid underestimation of the incidence of NSD. We found that the overall incidence of permanent hypoaesthesia was 9.9% per patient (5.1% per site). In the literature, the reported incidence of permanent hypoaesthesia after BSSO varies between 0% and 85% patient.[12] Few studies have reported an incidence below 10%.[4, 5, 13, 14] We speculate that the relatively low incidence of NSD in our study was due to our technique, which involved the use of sagittal splitters and separators to perform BSSO without the use of chisels.[3]

The frequency of NSD immediately after surgery was significantly higher in the oldest patient group (>30 years). This indicates that the difference between younger and older patients is already established during surgery. With increasing age, neurons show axonal atrophy and degeneration.[15] Therefore, we believe that the loss of nerve fibres in older patients can play a role in the increased risk of nerve damage, and older patients are inherently more prone to iatrogenic damage during surgery. Furthermore, a lower probability of recovery and a longer time to recovery were observed in the older patients. Although this difference in recovery between age groups was not statistically significant, the trend was apparent. Functional recovery of nerve function depends on the survival of injured neurons and functional re-innervation of target tissue. Older patients have been reported to show decreased nerve regeneration and re-innervation.[15] It may be hypothesised that older patients exhibit not only a higher risk of NSD after surgery but also decreased recovery, even though this study does not prove the latter part of this hypothesis.

The incidence of permanent NSD in specific age groups is rarely reported in the literature. Age-specific incidences are important and clinically relevant for the surgeon, particularly for pre-operative counselling of individual patients about the risk of permanent hypoaesthesia. In our study, the incidence of permanent hypoaesthesia was 4.8% in patients aged <19 years, 7.9% in those aged 19–30 years and 15.2% in those aged >30 years.

Several different authors have reported a significant association between increasing age and an increased risk of permanent NSD. Westermark et al.[16] reported that an older age significantly influenced IAN dysfunction. Ylikontiola et al.[6] showed that hypoaesthesia was significantly associated with age, distance of mandibular movement and manipulation of the nerve. Van Sickels et al.[7] also reported older age as a risk factor for NSD, particularly in patients undergoing large mandibular advancements or genioplasty. Borstlap et al.[4] reported a significant effect of age on nerve recuperation, with the mean age of patients without and with hypoaesthesia being 24 and 31 years, respectively. Mensink et al.[3] showed that the frequency of hypoaesthesia is higher in older patients, with a mean increased risk of 1.07 per year of increasing age. Politis et al.[17] showed an increased risk of self-reported hypoaesthesia by 5% per year in his patients. All these findings are in concordance with the findings of our study. Therefore, we strongly believe that older age is an important risk factor for NSD. This information can also prove important for patients with obstructive sleep apnoea requiring BSSO, considering these patients are generally older.

Some authors also reported older age to be associated with an increased risk of other clinical complications after BSSO, such as bad splits, infection and non-union.[18-20] These reports are, however, not always in concordance with other findings.[4, 21] Therefore, the effects of age on clinical complications other than NSD remain unclear.

When investigating the influence of age on complications, it is important to consider any possible confounding factors that can hinder accurate interpretation of the observations, particularly when dealing with a complication that is difficult to assess, such as NSD. We decided to exclude patients who underwent additional genioplasty, because several authors have reported an increased risk of permanent hypoaesthesia due to genioplasty.[3, 17] Some authors even reported associations among genioplasty, age and sensory deficits, confirming that genioplasty can be a confounding factor in the relationship between age and NSD.[7]

The status of the nerve during BSSO is another important factor for the development of permanent hypoaesthesia.[3, 14, 21] This can also be associated with the surgical technique and osteotomy design. Therefore, BSSO was performed using the same technique in all patients.[22] In this study, preparation of the nerve from the proximal segment was significantly associated with an increased risk of permanent NSD and the age groups were different with regard to the status of the IAN during BSSO. Increased manipulation of the nerve could therefore partially explain increased NSD in older patients. The anatomical position of the IAN in the ramus and body area was not assessed in this study, because earlier findings had shown no significant association between the position of the nerve in the ramus and body area and NSD.[23] Other surgical factors, such as duration of the procedure and experience of the surgeon have shown to not significantly influence NSD and were therefore not included in this study.[21]

Different authors have reported contradicting findings regarding the association between the presence of third molars and hypoaesthesia.[24, 25] However, most authors reported no correlation between the presence of third molars and NSD.[4, 21, 24] In our study group, the three age groups differed significantly with regard to the pre-operative presence of third molars. It is understandable that third molars are more often present in younger patients.[21] Nevertheless, there was no significant association between the presence of third molars and the status of the nerve or NSD. We therefore believe that the presence of third molars did not significantly influence the incidence of hypoaesthesia in the different age groups. Other possible risk factors, such as sex, type of malocclusion and additional Le Fort I osteotomy showed no significant association with permanent hypoaesthesia in this study and were not considered influential in the development of NSD. Note that other confounding factors such as comorbidities or the use of medication could have influenced the outcomes in the different age groups; however, this was not investigated.

Permanent hypoaesthesia after BSSO negatively affects the patient's perceived quality of life and results in decreased patient satisfaction.[2, 14] Therefore, it is one of the most important complications of BSSO. Older patients are considered more likely to experience interferences in daily life activities due to altered sensations after BSSO and are also at an increased risk of neuropathic pain, which is again responsible for patient dissatisfaction after BSSO.[14,26]

Although the results of this study advocate the performance of BSSO at a younger age, the risk of relapse should also be considered. Borstlap et al.[4] performed a prospective study and reported that a younger age (mean, 20.7 years) was a strong risk factor for the relapse of malocclusion. However, Den Besten et al.[27] reported no significant differences in skeletal stability after BSSO in patients under 18 years of age. In their literature review, Joss et al.[28] concluded that skeletal relapse after BSSO is multi-factorial and dependant on factors such as the amount of advancement, mandibular plane angle, soft tissue and muscles, future growth and pre-operative age. Therefore, BSSO can be performed in younger patients under certain circumstances; for example, when the amount of mandibular advancement required is less than 6 mm and/or when patients exhibit a low mandibular plane angle. Further research is necessary to investigate important considerations such as the possibility of relapse in specific (younger) patients and the risk of (permanent) hypoaesthesia after BSSO.

In conclusion, the results of this study suggest that the incidence of NSD immediately after surgery and permanent NSD is lower in younger patients than in older patients. Furthermore, younger patients tend to exhibit a shorter recovery time and a higher hazard ratio for recovery. This information can aid surgeons in pre-operative counselling about the risk of hypoaesthesia and deciding the optimal age for BSSO.

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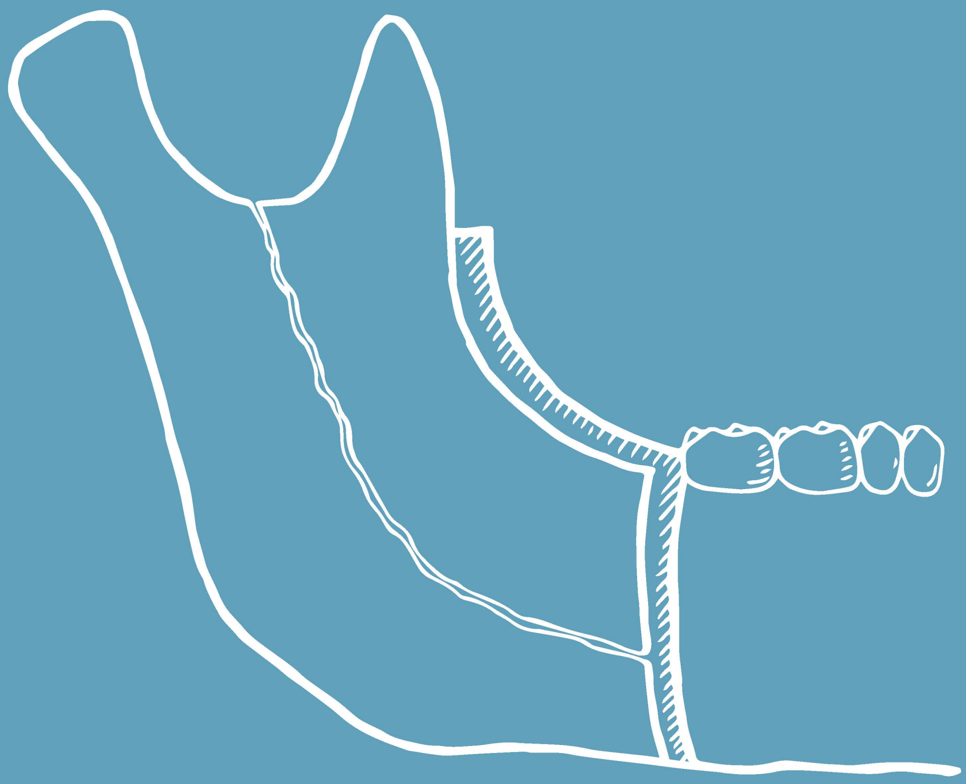

CHAPTER 4

Bad split during bilateral sagittal split osteotomy of the mandible performed with separators: retrospective study of 427 patients

This chapter is based on the manuscript:

Mensink G, Verweij JP, Frank MD, Bergsma JE, van Merkesteyn JPR

Bad split during bilateral sagittal split osteotomy of the mandible performed with separators: a retrospective study of 427 patients

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ABSTRACT

An unfavourable fracture, known as a bad split, is a common intra-operative complication in bilateral sagittal split ramus osteotomy (BSSO). The reported incidence of this complication ranges from 0.5 to 5.5% per site. Since 1994 BSSO has been performed in our clinic with sagittal splitters and separators, instead of chisels, in an attempt to prevent post-operative hypoesthesia. Theoretically, a higher percentage of bad splits could be expected with this technique. This retrospective study aimed to determine the incidence of bad splits associated with BSSO performed with splitters and separators. Furthermore, we assessed different risk factors for bad splits.

The study group consisted of 427 consecutive patients. The incidence of bad splits in this group was 2.0% per site. This is well within the range reported in the literature. The only predicting factor for a bad split was the removal of third molars concomitant with BSSO. There was no significant association between bad splits and age, sex, occlusion class, or the experience of the surgeon.

We believe that BSSO, performed with splitters and separators instead of chisels, does not increase the risk of a bad split and is therefore a safe technique with predictable results.

INTRODUCTION

Bilateral sagittal split osteotomy (BSSO) is one of the most frequently used operative techniques for correcting mandibular deformities.[1] Efforts to reduce complications associated with the procedure have led to several modifications, since it was first described by Trauner and Obwegeser.[2] However, the procedure still presents a certain degree of technical difficulty and is associated with several potential complications.

One such intra-operative complication associated with BSSO is an irregular osteotomy pattern or unfavourable fracture, known as a bad split.3 The reported incidence of bad split at a sagittal split osteotomy (SSO) site ranges from 0.5 to 5.5%.[4-20] This unwanted fracture is normally located in either the distal (lingual plate fracture) or proximal cortical plate (buccal plate fracture) of the mandible and more rarely affects the coronoid process or the condylar neck. When a bad split is adequately treated, the chances of functional success are good, though some limitations can occur.[21] Therefore, the number of bad splits should be minimised.

Our clinic abandoned the use of chisels to minimise post-operative hypoesthesia.[22] Instead, sagittal splitters and separators (i.e. elevators) are used.[8] Theoretically, this technique could result in a higher percentage of bad splits. The purpose of this study is to retrospectively review bad splits of the mandible associated with BSSO using sagittal split separators, in a single centre over 17 years.

MATERIAL AND METHODS

We retrospectively analysed the clinical records and radiographs of 427 consecutive patients who underwent BSSO at our institution between July 1994 and December 2011. In 1994, we started to perform BSSO with sagittal splitters and separators instead of chisels. All planned BSSOs, single procedures, and those associated with other procedures were included (Table 1).

Procedure(s)	Patients	%
BSSO	229	53.6
BSSO + Le Fort I	124	29.0
BSSO + genioplasty	31	7.3
BSSO + Le Fort I + genioplasty	43	10.1

Table 1: Distribution of concomitant procedures in 427 patients. Data are presented as number (%) of operations.

The patients' medical files and orthopantomographs were screened for the patient's sex, age at surgery, pre-operative diagnosis, BSSO procedure (unilateral or bilateral), concomitant procedures, and presence of third molars. The status of third molars was classified as follows: absent at first consultation; removed prior to BSSO; removed concomitant with BSSO; or present after surgery. If third molars were left in situ, they were in occlusion with maxillary antagonists. Furthermore, we noted whether the BSSO was performed by a specialist or a resident, the occurrence of a bad split during surgery and type of bad split, the incidental use of chisels, and the method of postoperative fixation.

The patient sample consisted of 150 males and 277 females. The age at surgery ranged from 13.8 to 55.6 years (mean age, 27.3 [SD, 9.8 years]). In 363 cases, the mandible was moved ventrally to correct a class II malocclusion. A class III malocclusion was present in 59 patients, resulting in posterior movement of the mandible. Indications for BSSO are summarised in Table 2. Indications other than class II/III malocclusion (e.g. condylar hyperplasia or cleft lip and palate) were present in 5 cases.

Category	Patients	%
Class II malocclusion	363	85.0
Class III malocclusion	59	13.8
Other	5	1.2

Table 2: Indications for BSSO in our patients. Data are presented as number (%) of patients

BSSO was performed without the use of chisels, as first described by van Merkesteyn et al.[8,22] Splitting forceps (Smith Ramus Separator 12 mm, Walter Lorentz Surgical, Jacksonville, FL, USA) and elevators were used. The procedures were performed while patients were under general anaesthesia. To reduce bleeding, the surgical area was infiltrated with epinephrine 1:160 000 (Ultracaine D-S, Aventis Pharma, Hoevelaken, The Netherlands). The mandibular ramus was exposed and the mandibular foramen was located. A periosteal elevator was placed subperiosteally just above the mandibular foramen, and the horizontal bone was cut with a Lindemann burr (2.3 × 22 mm) approximately 5 mm above the mandibular foramen. Subsequently, the sagittal and vertical cuts were made with a short Lindemann burr (1.4 × 5 mm). The inferior border was cut perpendicularly through the inferior cortex, just reaching the medial side. Splitting was done with an elevator positioned in the vertical bone cut and the splitting forceps in the sagittal bone cut. Once the superior aspect of the mandible started to split, the elevator was repositioned at the inferior end of the vertical cut, and splitting was completed. Care was taken to be certain that the inferior alveolar nerve was in the distal segment when the split was completed. A chisel was only used when a small bridge of cortical bone between the buccal and lingual segments remained at the inferior border of the mandible, well below the level of the mandibular canal.

After mobilisation, the mandible was placed into the new intermaxillary relationship using a wafer, and intermaxillary wire fixation was applied. When possible, 3 bicortical screws (Martin GmbH, Tuttlingen, Germany; 9, 11, or 13 mm in length; 2.0 mm in diameter) were placed in the upper border of the mandible on both sides. Other fixation methods, such as Champy plates or upper wire fixation, were used if screw fixation was not optimal because of fragile bone, after removal of third molars or after a bad split. The temporary intermaxillary fixation was then removed, and the occlusion was checked. No elastic bands were used. Permanent intermaxillary fixation with upper border wiring was only used after a bad split or intra-oral vertical ramus osteotomy (IVRO).

All patients were discharged from the hospital within a week after the operation and were scheduled to return for evaluation approximately 1, 6, and 12 months after the discharge.

Statistical methods

All statistical analyses were performed with SPSS 16.0 for Windows (SPSS, Inc.; Chicago, IL, USA). Crosstabs, Pearson's chi-square test, and logistic regression were used to assess associations between parameters. All statistical associations are reported with odds ratios (ORs) and 95% confidence intervals (CIs). A p-value smaller than 0.05 was considered statistically significant.

RESULTS

Out of 851 sagittal splits (427 patients), 17 bad splits occurred (2.0%). All the bad splits were unilateral, localised as 11 buccal plate fractures (64.7%), 5 lingual plate fractures (29.4%) and 1 condylar neck fracture (5.9%) (Figure 1 and 2). Although BSSO was planned in all cases, unilateral sagittal split osteotomy (USSO) was performed in 3 (0.7%) patients. One patient eventually underwent IVRO on both sides, after a large buccal plate fracture occurred during the first initial sagittal split. In 1 patient, a sagittal split was performed on one side and IVRO on the contralateral side, because of a very high mandibular foramen. In the third case, the operation was terminated after the first sagittal split, and fixation was completed without translocation of the mandible because of a large buccal plate fracture. The buccal plate was fixated and both lower third molars were removed. A successful BSSO was performed 6 months after the initial procedure.

The bad splits occurred in 6 males and 11 females (mean age, 29.3 years; range, 14.83–53.89 years). Sex ($p = 0.988$, OR 1.01, 95% CI 0.363–2.711) and older age ($p = 0.399$, OR 0.980, 95% CI 0.935–1.027) had no statistically significant association with bad splits during BSSO; however, bad splits occurred more in females than in males. Preoperative occlusion class was not a statistically significant factor either; bad splits occurred in 14 patients having a class II malocclusion and 2 patients having a class III malocclusion ($p = 0.862$, OR 1.143).

We analysed the duration between preoperative removal of third molars and bad splits. The preoperative status of third molars is summarised in Table 3. In 180 patients (328 sites), one or both third molars were absent at first consultation, making it impossible to determine the time of removal. Third molars were removed preoperatively in 177 patients (301 sites), with time of removal ranging from 1 month to 15 years prior to surgery (mean 10.4 months). Third molars were removed during BSSO in 120 patients (219 sites) and remained present after surgery in 4 patients (6 sites). The duration between removal of third molars and bad split had no statistically significant association with bad split ($p = 0.149$, OR 0.998, 95% CI 0.998–1.001). However, the removal of third molars concomitant with BSSO was positively associated with bad split ($p = 0.041$, OR 2.637). In 8 of the 17 bad splits, a third molar was present at the site of the split.

Category	Left side	%	Right side	%
Absent at first consultation	169	39.6	159	37.2
Removed prior to BSSO	148	34.7	153	35.8
Removed concomitant with BSSO	107	25.1	112	26.2
Present after surgery	3	0.7	3	0.7

Table 3: Status of lower third molars in our patients. Data are presented as number (%) of patients.

All patients were operated on by either experienced senior staff or a resident assisted by a senior staff member. In 165 (38.6%) patients, the sagittal splits on both sides were performed by senior staff; in 252 (59.1%) patients, senior staff performed the sagittal split on one side and a resident on the other side; and in 10 (2.3%) patients, a resident, supervised by senior staff, operated on both sides. The occurrence of bad splits was not associated with the residents' experience level ($p = 0.472$, OR 1.514, 95% CI 0.489–4.687).

Out of the 17 patients with a bad split, 2 patients (11.7% of the patients) experienced persistent neurosensory disturbances after at least 1 year.

In 403 (94.4%) patients, BSSO was performed with only spreaders and separators. A chisel was necessary in only 24 (5.6%) patients, because of a small bridge of cortical bone remaining at the inferior border of the mandible.

Bilateral screw fixation was used for postoperative mandibular fixation in 414 (97.4%) patients. In this group, 4 (0.9%) cases involved combined fixation with mini-plates, and 2 (0.4%) patients underwent screw fixation in combination with intermaxillary fixation (IMF). In 5 (1.2%) patients, unilateral plate fixation on 1 side was combined with screw fixation on the contralateral side, and bilateral plate fixation was used in 1 patient (0.2%). Plate fixation was used because of a bad split in 4 (0.9%) patients and fragile cortical bone in the other 6 (1.4%). Intermaxillary fixation was used on 9 (2.1%) patients (7 times after a bad split and twice after the IVRO).

All patients eventually recovered with good functional and aesthetic results.

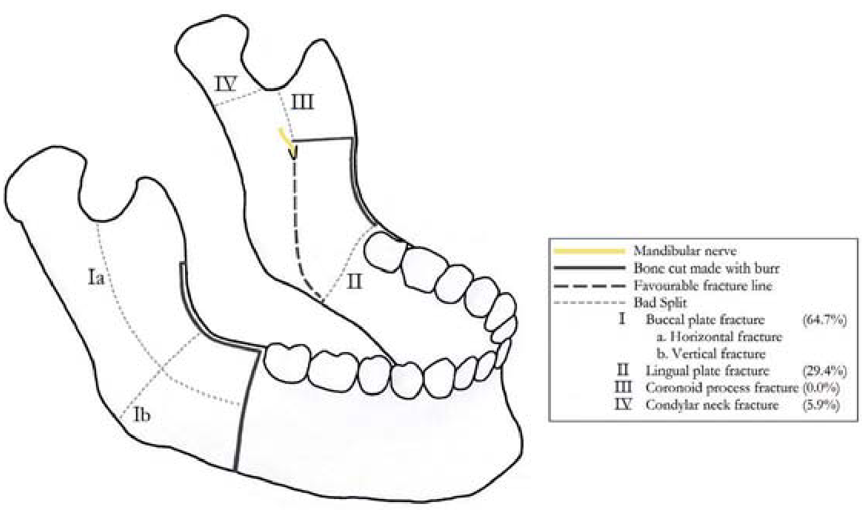

Figure 1: The fracture lines and cuts of a BSSO including the most common unfavourable fractures. The incidence of the different types of bad splits in this study are mentioned in percentages.

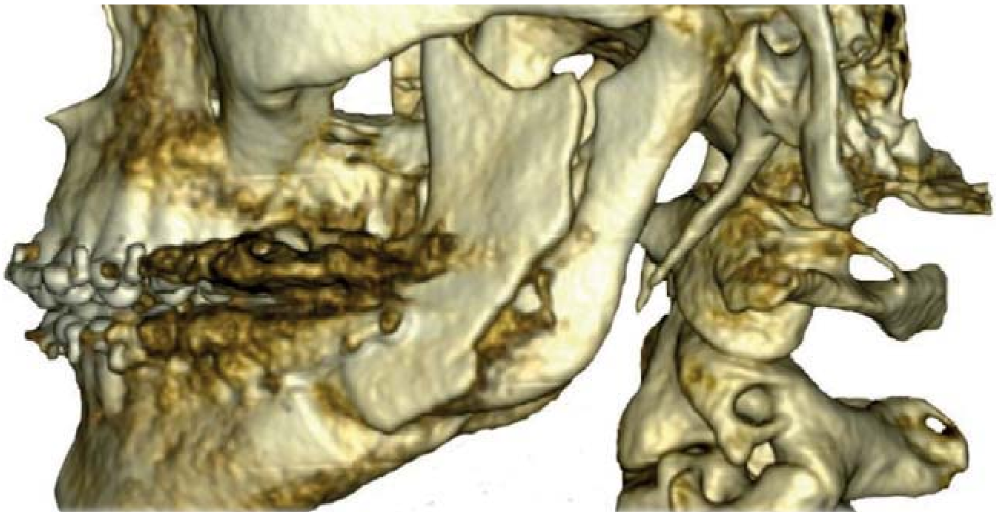

Figure 2: Cone Beam Computed Tomography (CB-CT) scan of a horizontal buccal plate fracture of the left side of the mandible during a BSSO, reaching the incisura semilunaris (figure 1; type Ia). The proximal and distal segment of the mandibula were eventually fixated with two bicortical screws on the lower border of the mandible (in this CB-CT hidden behind the buccal segment), combined with plate fixation to attach the buccal segment.

DISCUSSION

The exact combination of factors resulting in bad split is unknown. Reported predictors for bad split are the presence of third molars and age at surgery. Advanced age has been reported to increase the risk of bad split.[6] In our patients, age was not considered a complicating factor; we found no relationship between age and bad split.

No association between bad split and patient sex or surgeon experience has been reported, and our findings are consistent with the literature in this regard.[10,11,12]

The removal of third molars before BSSO is controversial. Some suggest that if third molar removal is required, it should be done at least 6 months prior to orthognathic surgery.[11,13,23] Other authors advise removal of third molars concomitant with surgery and describe fewer postoperative complications, like hypoesthesia, associated with this method.[4,15,24] In our patients, there were significantly more bad splits during BSSO among those who had concomitant removal of the third molars.

Although one could expect that more healing time would reduce the risk of a bad split, our retrospective study did not allow us to infer an optimal timing for removing third molars prior to BSSO. In our clinic, most third molars that were present during the last five years before surgery were removed at the time of BSSO. This is because separate third molar removal is estimated to increase the risk of inferior alveolar nerve damage, and separate surgery was also more inconvenient for the patient as he/she would have to undergo multiple procedures instead of just one combined procedure.

One would expect bad splits to occur more often with less experienced surgeons, like residents. However, no such differences were found between senior staff members and residents, most likely because the latter were closely supervised during BSSO and corrected when necessary.

	Year of publication	Number of bad splits	SSO's (n)	Patients (n)	Incidence per site (%)	Incidence per patient (%)
Doucet et al[10]	2011	21	677	339	3.1	6.2
Falter et al[11]	2010	14	2005	1008	0.7	1.4
Kriwalsky et al[12]	2007	12	220	110	5.5	10.9
Kim and Park[13]	2007	11		214		5.1
Van Merkesteyn et al[14]	2007	2	222	111	0.9	1.8
Teltzrow et al[15]	2005	12	2528	1264	0.5	0.9
Borstlap et al[16]	2004	20	444	222	4.5	9.0
Reyneke et al[17]	2002	4	139	70	2.9	5.7
Panula et al[18]	2001	12		515		2.3
Mehra et al[19]	2001	11	500	262	2.2	4.2
Acebal-Bianco et al[20]	2000	8		802		1.0
Precious et al[21]	1998	24	1256	633	1.9	3.8
Van de Perre et al[22]	1996	97	2466	1233	3.9	7.9
Turvey[23]	1985	9	256	128	3.5	7.0
Martis[24]	1984	5		258		1.9
Macintosh[25]	1981	16		236		6.8
Behrmann[26]	1972	10		600		1.7
White et al[27]	1969	1	32	17	3.1	5.9

Table 4: Reported incidences of bad split during BSSO

In our study sample, a bad split occurred in 17 of 851 sagittal splits, which is consistent with the average reported in the literature (Table 4). Therefore, the use of splitters and separators without chisels does not lead to a higher risk of bad splits. The bad splits were localised as 11 (64.7%) buccal plate fractures, 5 (29.4%) lingual plate fractures, and 1 condylar neck fracture (Figure 1 and 2). When a bad split occurred, additional fixation was usually necessary. Buccal and lingual plate fractures could be fixated with screws and/or plates and sometimes IMF, depending on the fracture lines. The condylar neck fracture resulted from a bad split of the buccal segment, with the condylar neck attached to the distal segment. Therefore, the condylar process was purposely removed from the distal segment and fixation to the proximal segment was attempted. Because fixation to the proximal segment was not possible eventually upper border wiring and IMF were required. This procedure was almost similar, although accidently, to the recently discussed supraforaminal horizontal oblique osteotomy.[25]

Although BSSO was planned in all patients, the procedure was converted to IVRO in 3 patients. IVRO is only possible during a setback and requires IMF, making it a suboptimal option. However, when a safe sagittal split is not possible, IVRO can be helpful in treating these difficult cases.

Since our goal in using splitters and separators was to reduce postoperative neurosensory disturbances after BSSO, the percentage of neurosensory disturbances after a bad split should not be increased. The incidence of persistent neurosensory disturbances after a bad split was 11.7% per patient in this study. Our reported incidence of neurosensory disturbances in previous studies using this technique was 10.5% per patient.[22] Therefore bad splits using this technique do not introduce significantly more postoperative neurosensory disturbances.

The chances of good functional success after a bad split are high, and as such bad splits are regarded as complications without long-term consequences.[5,21] Nevertheless, the number of bad splits should always be minimised because of negative short-term consequences, such as longer operation time, loss of surgeon concentration, use of intermaxillary fixation, and reoperation or conversion to IVRO with IMF. All patients in our group, including the patients with a bad split, functioned well after the operation(s).

CONCLUSION

The proportion of bad splits occurring during BSSO performed with splitting forceps and elevators is similar to the proportion of bad splits during conventional BSSO, performed with chisels. In our study, the only complicating factor that was predictive of a bad split was the removal of third molars concomitant with BSSO. The use of sagittal splitters and separators does not increase the risk of bad splits and is therefore a safe and predictable technique.

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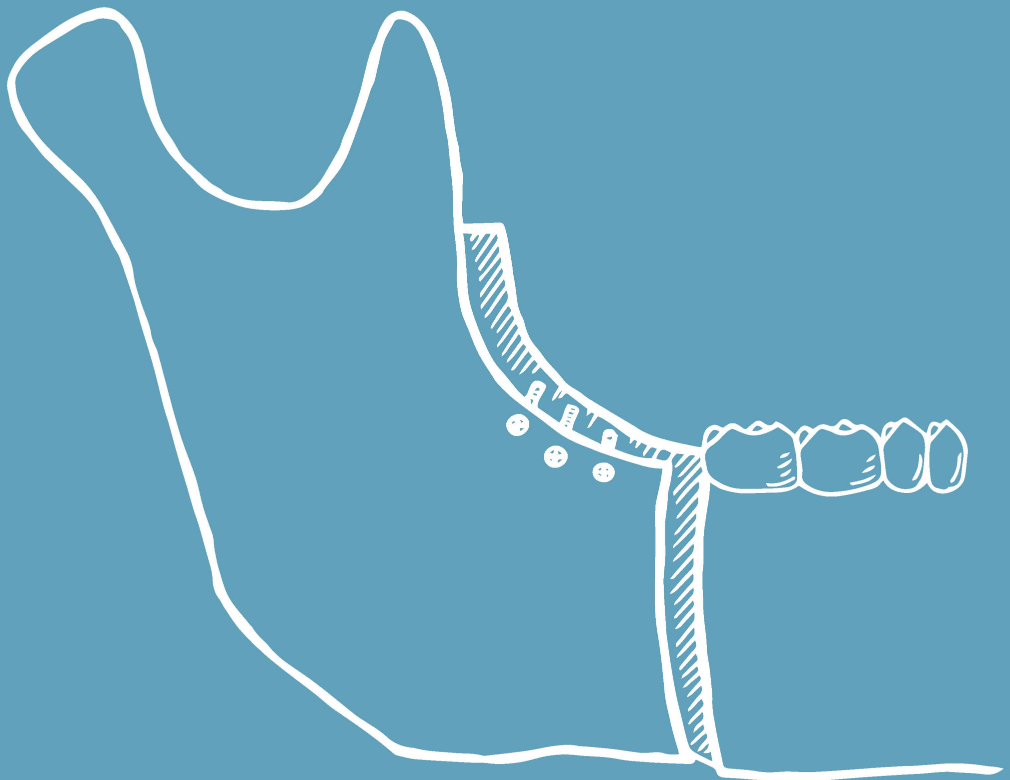

CHAPTER 5

Removal of bicortical screws and other osteosynthesis material that caused symptoms after bilateral sagittal split osteotomy: a retrospective study of 251 patients, and review of published papers

This chapter is based on the manuscript:

Verweij JP, Houppermans PNWJ, Mensink G, van Merkesteyn JPR

Removal of bicortical screws and other osteosynthesis material that caused symptoms after bilateral sagittal split osteotomy: a retrospective study of 251 patients, and review of published papers

British Journal of Oral and Maxillofacial Surgery 2014; 52: 756-760.

ABSTRACT

Rigid fixation with either bicortical screws or mini-plates is the current standard to stabilise the mandibular segments after bilateral sagittal split osteotomy (BSSO). Both techniques are widely used and the superiority of any one method is still under debate. One complication of rigid fixation is the need to remove the osteosynthesis material, due to associated complaints. The aim of this retrospective study was to analyse the incidence of symptomatic removal of bicortical screws after BSSO in our clinic. By reviewing the literature, we furthermore investigated the reported rates of screw and mini-plate removal. The mean (SD) follow-up duration of 251 patients (502 sites) was 432 (172) days. Incidence of bicortical screw removal in our clinic was 2.9% (14/486 sites). Alternative methods of fixation were used at 16 sites. No significant association was noted between bicortical screw removal and age, gender, presence of third molars, or bad splits. In the literature, reported rates of removal of bicortical screws and mini-plates are 3.1–7.2% and 6.5–22.2% per site, respectively. These findings show bicortical screw fixation after BSSO is associated with a low rate of symptomatic removal of the osteosynthesis material. Reported incidences in the literature imply a lower removal rate with screw fixation compared to miniplates.

INTRODUCTION

Bilateral sagittal split osteotomy (BSSO), first described by Trauner and Obwegeser[1], is a frequently used technique in orthognathic surgery. Dal Pont, Epker, and Hunsuck subsequently described widely used modifications of the original operative technique.[2-4] Initially, the proximal and distal mandibular segments were fixed with a wire looped around the ramus, combined with jaw immobilisation and intermaxillary fixation (IMF).[1] In 1974, Spiessl introduced rigid fixation with lag screws, avoiding IMF.[5] A few years later, Lindorff advocated placing position screws without compression, to prevent entrapment of the inferior alveolar nerve (IAN).[6] Rigid fixation with mini-plates was popularised by Champy and has since become another method of choice for stabilising the mandibular segments after BSSO.[7]

Although rigid fixation has many advantages over the earlier techniques, post-operative complications associated with the osteosynthesis material can occur.[8-10] One complication is the need to remove the osteosynthesis material because of related infection or irritation, or wound dehiscence. Although long-term consequences are rare, removal of the osteosynthesis material causes morbidity. Therefore, its incidence should be minimised, especially considering the elective nature of orthognathic surgery.

The aims of this retrospective study were to analyse the incidence of bicortical screw removal after BSSO in our clinic and compare in the literature reported rates of bicortical screw and mini-plate removal.

MATERIAL AND METHODS

The clinical records and radiographs of 259 consecutive patients who had undergone either BSSO or bimaxillary osteotomy, with or without genioplasty, were reviewed. The procedures had been performed between January 2004 and December 2011.

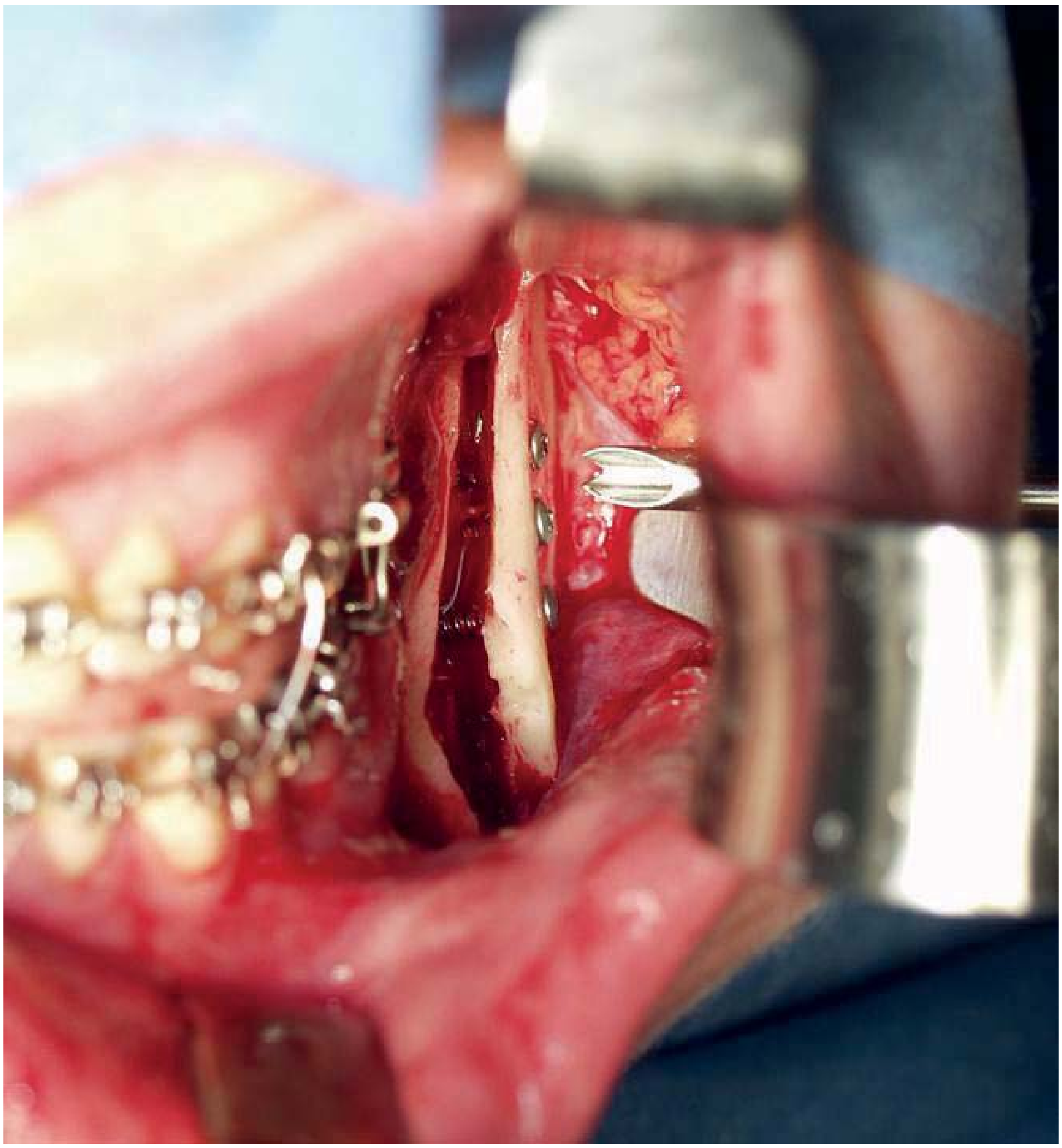

Figure 1: Intraoral view of the buccal cortex showing bicortical screw placement after BSSO.

The same procedures and clinical care had been applied in all cases. Preoperatively, the patients had received single-shot antimicrobial prophylaxis (penicillin, 1 × 106 units intravenously) and steroids (methylprednisolone intravenously, 2 × 25 mg on day 1, 2 × 12.5 mg on day 2, and 1 × 12.5 mg on day 3). Three senior staff surgeons operated in all cases, supervising a resident on the other side in almost all patients. BSSO had been performed with sagittal splitter and separators, without the use of chisels.[11,12] After the sagittal split procedure, the mandible had been placed in the new intermaxillary relationship and rigid fixation with 3 bicortical screws (Martin GmbH, Tuttlingen, Germany; 9, 11, or 13 mm in length and 2.0 mm in diameter) had been planned (Fig.1). If fixation with bicortical screws had been unfavourable, mini-plates (Martin GmbH; 4- or 6-hole Champy mini-plates) had been used. The patients had been discharged 2 days after surgery and instructed to return to the clinic if they had any complaints. Clinical and radiographic evaluation had been planned at 1, 2, and 3 weeks and 3, 6, and 12 months post-operatively.

The patients' medical files were reviewed for information on the patients' gender, age, pre-operative diagnosis, the status of the mandibular third molars, other simultaneous procedures, method of fixation, and post-operative removal of bicortical screws. If the osteosynthesis material had been removed, the reason had been noted: infection at the osteosynthesis site with inflamed tissue, granulation tissue, or intraoral fistula; wound dehiscence with visible osteosynthesis material; or radiographic bone loss around the material without symptoms. The osteosynthesis material could also be removed on the patient's request, usually because of irritation or tenderness at the osteosynthesis site without infectious symptoms.

Statistical analysis

Statistical evaluation was performed with SPSS version 20.0 for Windows software (IBM Corporation, Armonk, NY, USA). Cross tabulation, Pearson's chi-square test, Fisher's exact test, and logistic regression were used, as appropriate, to assess the significance of differences among the variables. All statistical associations are reported with the odds ratio (OR) and 95% confidence interval (CI). P-values less than 0.05 were considered significant.

RESULTS

Of the 259 patients enrolled in the study, the records of 8 patients were excluded because of incomplete data. Therefore, the final study group comprised 251 patients. Their characteristics are listed in Table 1. The mean (SD) follow-up period was 432 (172) days. Twenty-one patients had not attended the clinical evaluation at 12 months and had been contacted by telephone.

Category	No of patients (%)	Mean (SD)	Range
Sex			
Male	90 (35.9)		
Female	161 (64.1)		
Age (years)		28 (11)	14-56
Occlusion Class			
II	219 (87.3)		
III	32 (12.7)		
Third molars (right side)			
Absent prior to BSSO	165 (65.7)		
Present during BSSO	86 (34.3)		
Third molars (left side)			
Absent prior to BSSO	168 (66.9)		
Present during BSSO	83 (33.1)		
Procedure			
BSSO	146 (58.2)		
+ Le Fort I	63 (25.1)		
+ genioplasty	11 (4.4)		
+ Le Fort I + genioplasty	31 (12.4)		
Follow-up time (days)		432 (172)	163-1465

Table 1: Patient characteristics.

Sagittal split osteotomy had been performed at 502 sites. Screw fixation had been performed in 246 patients (98.0%), bilaterally in 240 patients and unilaterally in 6 patients, with mini-plate fixation on the contralateral side. Mini-plates had been fixed on the right side in 5 patients and combined with one bicortical screw on the left side in 1 patient. The reasons for unilateral mini-plate fixation were bad splits (n = 3), decreased lingual cortical bone volume after third molar extraction (n = 1), a small mandibular body with possible danger to the IAN by bicortical screw fixation because of its anatomical position (n = 1), and burr malfunction and mini-plate fixation with other equipment (n = 1). Two patients (0.8%) had undergone bilateral mini-plate fixation because of decreased lingual cortical bone volume after third molar extraction. Three patients had undergone IMF because of bad splits.

	Patients	Sites
Screw fixation	246	486
Removal indicated (%)	12 (4.9)	14 (2.9)
Plate fixation	8	10
Removal indicated (%)	2 (25.0)	3 (30.0)
IMF	3	6

Table 2: Modes of fixation after BSSO with incidence of removal of osteosynthesis material. Removal of osteosynthesis material is indicated as number (%) of either patients or sites.

The different methods of fixation and incidence of removal of the osteosynthesis material are shown in Table 2. Removal of bicortical screws had been necessary at 14 of 486 sites. The incidence of screw removal was 2.9% per site. At 11 sites (78.6%), the reason for removal was related infection, including intraoral fistula in 6 cases. The screws at 3 sites had been removed on the patient's request, because of related irritation or tenderness. Of the 10 sites with mini-plates, removal of the osteosynthesis material had been necessary at 3 sites (2 patients). In one patient, bilateral mini-plates had been removed because of related infection with intraoral fistula on the left side. In the other patient, unilateral mini-plate fixation had been combined with one bicortical screw. The mini-plate had been removed because of intraoral fistula originating from the material, and the unaffected bicortical screw had been retained. In total, removal of the osteosynthesis material had thus been necessary in 14 of 248 patients (5.6%) at 17 of 496 sites (3.4%). All the patients had recovered well after removal of the osteosynthesis material.

Risk factors for screw removal were analysed between the removal and the non-removal groups of patients. Screw removal was indicated in 7 male and 5 female patients. The mean age in the removal group was 26.7 years (range, 15.0–37.7 years), compared with 27.8 years (range, 13.8–55.6 years) in the non-removal group. Gender (OR, 0.38; 95% CI, 0.12–1.23; $p = 0.10$) and age (OR, 0.99; 95% CI, 0.93–1.05; $p = 0.71$) were not significantly associated with removal of the osteosynthesis material. Further, pre-operative occlusion did not differ significantly in the removal group, consisting of 9 and 3 patients with class II and III malocclusions, respectively (OR, 2.87; 95% CI, 0.85–9.72; $p = 0.08$).

The association between presence of third molars during BSSO and post-operative removal of screws was also analysed. On the right side, screws had been removed at 7 sites, and third molars were present at 2 of these sites. On the left side, screw removal was indicated at 7 sites, but none of them contained third molars during BSSO. Presence of third molars was not significantly associated with screw removal (OR, 0.97; 95% CI, 0.92–1.03; $p = 0.37$).

Bad splits had occurred at 9 of the 502 sites (1.8%). These were sometimes an indication for an alternative method of fixation, but no osteosynthesis material had been removed in any of these patients.

DISCUSSION

In this study, the incidence of symptomatic removal of the osteosynthesis material after BSSO was analysed and compared with the reported rates of bicortical screw and mini-plate removal in the literature. The study showed a low incidence of symptomatic removal of bicortical screws (2.9% per site).

Rigid fixation has evident advantages over IMF in terms of function, patient comfort, stability, and relapse.[13] Therefore, rigid fixation with bicortical screws or mini-plates and monocortical screws is the treatment of choice after BSSO and IMF is solely used if stabilisation of the bony segments cannot be achieved in another way. The superiority of any of these two fixation methods is controversial.[14,15] Many different factors play a role in the choice for one osteosynthesis material and specific conditions sometimes require the application of one fixation technique instead of the other. The primary fixation method of choice in our clinic had been the placement of three bicortical positional screws in the superior border of the mandibular segments. In our opinion this provides a reliable rigid fixation specifically designed to fixate osteotomies. Bicortical screws seem to provide a more rigid fixation than mini-plates. Some authors therefore prefer screw fixation in asymmetric mandibles, although others specifically favour plate fixation in these cases.[15] Further, a more natural seating of the condyle is achievable during bicortical screw fixation, because mini-plates could reduce the degree of adaption and thus induce changes in the condylar position. However, less rigid fixation with mini-plates creates less torque on the condylar process and minor occlusal discrepancies are probably adjusted more easily after surgery. Patients with mini-plates also tend to recover their masticatory function faster.[16] Mini-plate fixation is furthermore indicated at sites with thin lingual cortex, such as after third molar extraction or bad splits.[17]

In this study, the patients had been scheduled to undergo rigid fixation with bicortical screws, which had been performed in almost all cases (96.8%). Fixation with mini-plates had been used when screw fixation had not been possible, for example, because of difficulty in achieving proper configuration of bicortical screws due to the mandibular anatomy or (in most cases) lack of the lingual cortex of the distal segment after third molar extraction or bad splits. IMF had been applied only after bad splits. The incidence of symptomatic removal of bicortical screws was 2.9% per site in our group. At three out of 10 sites, plate removal was necessary. The patients receiving plate fixation were however a small biased group, selected on the inability to use bicortical screws. Therefore, only screw removal was further analysed in our study.

First author	Year of publication	Number of patients	Number of sites	Screw removal (per patient)	Screw removal (per site)	Incidence per patient (%)	Incidence per site (%)
Bouwman[7]	1995	667	-	20	-	3.0	-
Lacey[17]	1995	83	166	12	12	14.5	7.2
Becelli[8]	2004	241	482	15	15	6.2	3.1
Verweij	Present study	246	486	12	14	4.9	2.9

Table 3: Reported incidence of screw removal.

First author	Year of publication	Number of patients	Number of sites	Plate removal (per patient)	Plate removal (per site)	Incidence per patient (%)	Incidence per site (%)
Brown[9]	1989	-	18	-	4	-	22.2
Theodossy[18]	2006	80	160	16	25	20	15.6
Alpha[19]	2006	533	1066	54	70	10	6.5
Kuhlefelt[20]	2010	159	306	29	56	18.6	18.2
Falter[21]	2011	310	-	80	-	25.8	-

Table 4: Reported incidence of plate removal.

In the literature, the incidence of screw removal after BSSO varies between 3.1% and 7.2% per site (Table 3).[8,9,18] The reported incidence of mini-plate removal after BSSO varies between 6.5% and 22.2% per site (Table 4).[10,19-22] Infection is the main reason for removal of both screws and mini-plates.[8-10,18-22] In the literature reported incidences of screw removal are remarkably lower than those of mini-plate removal. Research in the field of traumatology has shown that the design, size, and morphology of an implanted material influences the incidence of post-operative infection.[23] Mini-plates have multiple concavities and holes and are larger than screws. Their morphology thus enlarges the area for bacterial colonisation, increasing susceptibility to infection. If mini-plates are positioned too high in relation to the superior border of the mandible, necrosis and sequestration cranial to the material can occur.[14] Furthermore, palpability of mini-plates could lead to irritation or sensitivity.

Removal of the osteosynthesis material is however only one measure of surgical outcome after BSSO and the key measures evidently are final occlusion and patient satisfaction. Moreover, other factors govern the choice between screw and mini-plate fixation after BSSO. After orthognathic surgery with rigid fixation, the condylar position in the glenoid fossa changes, leading to condylar remodelling and resorption.[24,25] Bicortical screw fixation could increase the torque on the condyle. However, no comparative studies have been performed and the reported risk of condylar resorption after both fixation methods is similar.[24]

The stab incision to place bicortical screws is not needed in mini-plate fixation, so no extra-oral scar can form and localised skin burns are avoidable. However, in our experience, the stab incision results in a small extra-oral scar, which is inconspicuous to the patient. Skin burns occur only because of the use of poor technique and are avoidable. Bouwman et al. reported a higher incidence of neurosensory disturbance with bicortical screw fixation than with IMF.[8] Therefore, in bicortical screw fixation, care should be taken during screw placement with consideration of the IAN. Furthermore, the mandibular segments should be fixed with gentle force to prevent entrapment of the nerve, which can occur when the cortices are forcefully pressed together. These technical aspects depend mainly on the skill of the surgeon. Use of bicortical screws with the proper technique has been shown to be associated with a low incidence of neurosensory disturbances.[11,12] However, the possibility of nerve injury remains; mini-plate fixation had been performed in one case to avoid this problem.

In conclusion, the findings of our retrospective review show that rigid fixation with 3 bicortical screws after BSSO is a reliable method with a low rate of post-operative removal of the osteosynthesis material. Reported incidences in the literature indicate a lower removal rate of bicortical screws compared to miniplates. These findings could help the surgeon to choose the appropriate method of fixation in the (controversial) decision between mini-plates and bicortical screws.

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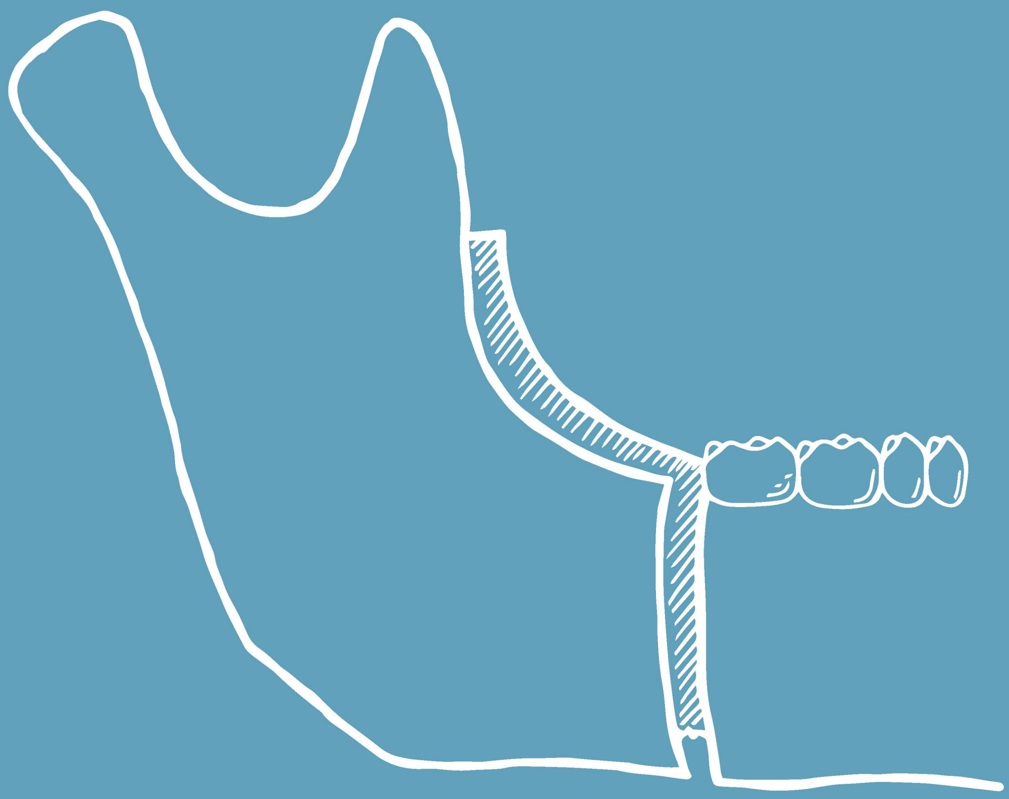

CHAPTER 6

Are there risk factors for osseous mandibular inferior border defects after bilateral sagittal split osteotomy with splitter and separators?

This chapter is based on the manuscript:

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Are there risk factors for osseous mandibular inferior border defects after bilateral sagittal split osteotomy with splitter and separators?

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ABSTRACT

Bone defects of the inferior mandibular border (osseous inferior border defects) can cause unaesthetic postoperative outcomes after bilateral sagittal split osteotomy (BSSO). The aim of this study was to estimate the frequency of osseous inferior border defects after BSSO and identify risk factors for this complication.

This retrospective study included consecutive patients who underwent BSSO for mandibular retrognathia. The primary outcome was the presence/absence of osseous inferior border defects. Predictors included the mandibular movement, rotation of the occlusal plane, postoperative proximal segment position, pattern of the lingual fracture, occurrence of bad split, and presence of third molars.

The study sample consisted of 200 patients (mean follow-up of 13 months). The mean mandibular advancement and rotation was respectively 5.8 millimeters and 5.4 degrees clockwise. Osseous inferior border defects were present in 7.0% of splits and 12.5% of patients. Significant risk factors for inferior border defects included increased advancement, increased clockwise rotation, cranial rotation of the proximal segment, and a split originating in the lingual cortex.

In conclusion, osseous inferior border defects occur significantly more often in cases with large mandibular advancement, increased clockwise rotation of the occlusal plane, malpositioning of the proximal segment, and a split originating in the lingual cortex.

INTRODUCTION

Bilateral sagittal split osteotomy (BSSO) is a widely used orthognathic surgical technique for the correction of mandibular deformities. The main purpose of this elective procedure is the establishment of a class I occlusion with good function. Surgeons should also aim to establish a harmonious maxillofacial profile with good facial esthetics.

BSSO is associated with some well-known postoperative complications, including damage to the inferior alveolar nerve, bad split, postoperative infection, and symptomatic removal of the osteosynthesis material.[1] A less common postoperative complication of BSSO advancement is the occurrence of osseous mandibular inferior border defects. These bone defects occur at the inferior border of the mandible, near the vertical osteotomy site of the sagittal split.[2, 3] They can cause visible and palpable dimples at the inferior border of the mandible and can result in an unaesthetic outcome of BSSO, leading to patient dissatisfaction.[2, 4, 5] Inferior border defects can sometimes even necessitate secondary reconstruction using bone products or allogeneic implants.[2, 4] These secondary procedures not only cause patient discomfort, but also pose a significant risk of iatrogenic damage.

Previously reported risk factors for the occurrence of osseous inferior border defects after BSSO include older age, increased extent of mandibular advancement, and inclusion of the full thickness of the mandibular inferior border in the split.[2] However, few studies have investigated this subject.

Surgeons should always attempt to avoid the occurrence of inferior border defects in order to increase patient satisfaction and minimize the risks associated with secondary procedures.

This study investigates the risk of osseous inferior border defects after BSSO according to the Hunsuck modification with sagittal splitter and separators. The investigators hypothesized that increased mandibular advancement, significant (clockwise) rotation of the occlusal plane, malpositioning of the proximal segment, the pattern of the lingual fracture, the occurrence of bad splits, and presence of third molars could play a role in the development of osseous inferior border defects. The specific aims of the study were to estimate the incidence of osseous inferior border defects and identify relevant risk factors associated with this complication.

MATERIAL AND METHODS

Study design/sample

To address the research purpose, the investigators designed and implemented a retrospective cohort study. The study population was composed of consecutive patients presenting for evaluation and management of retrognathia between July 2006 and March 2015 at the Department of Oral and Maxillofacial Surgery of the Leiden University Medical Center, the Netherlands. To be included in the study sample, patients had to have a class II malocclusion that was treated with BSSO according to the Hunsuck modification with sagittal splitter and separators. Single BSSO procedures as well as procedures combined with Le Fort I osteotomy and/or genioplasty were included in this study. Patients were excluded from this study if clinical follow-up was less than six months or radiographic evaluation was not available.

Surgical protocol

The BSSO procedures were performed by one of six consultant maxillofacial surgeons (specialists), usually closely supervising a resident operating on the contralateral side of the patient. All surgeons performed surgery according to the same surgical protocol, using the same osteotomy design and surgical technique, as reported in previous papers.[6, 7] Residents performed surgery only under close supervision of the surgeon.

BSSO was performed according to the Hunsuck[8] modification, using a sagittal splitter (Smith Ramus Separator 12 mm, Walter Lorentz Surgical, Jacksonville, FL, USA) and separators (Smith Sagittal Split Separators, curved, Walter Lorentz Surgical, Jacksonville, FL, USA). A short medial cut was placed just above the mandibular foramen. Subsequently, a sagittal cut was made over the anterior side of the ascending ramus towards the distal border of the second molar. The vertical osteotomy was always performed at the distal border of the second molar, perpendicular to the inferior border of the mandible. An inferior border cut was made completely passing through the inferior cortex and reaching the lingual cortex. The sagittal split was then performed using a splitter and separators without the use of chisels. The splitter was placed in the sagittal bone cut and the separator in the vertical bone cut, in order to guide the split. After successful splitting, the distal segment was fixed in its new position using an intermaxillary wafer. A small horizontal bone cut was performed in the medial side of the proximal segment, approximately at the midpoint of the vertical bone cut, and this mandibular segment was secured in its correct position using a Luniatschek ligature tucker. This technique was used to correctly secure the condyles in the glenoid fossa and, subsequently, position the proximal mandibular segment in line with the distal mandibular segment. The proximal segment was aligned with the distal segment by aligning the inferior mandibular border of both segments. Rigid fixation was then applied. Standard follow-up included clinical and radiographic evaluations at 1 week, 1 and 6 months, and 1 year after surgery.

Variables

The primary outcome variable in this study was the presence/absence of osseous inferior border defects. Osseous inferior border defects were defined as a bone defect in the inferior border of the mandible near the vertical osteotomy site. The occurrence of osseous inferior border defects was categorized on both sides of the patient as: 1) inferior mandibular border without relevant contour changes; 2) large contour changes of the inferior border equivalent to approximately one thickness of the inferior cortex; or 3) large contour changes of the inferior border corresponding to more than one cortical thickness. If a large contour change of the inferior border of more than one cortical thickness (category 3) was observed, an osseous inferior border defect was defined as 'present' during further analyses.

A set of predictor variables was used to investigate risk factors for osseous inferior border defects, including both operative and radiographic variables. Operative predictor variables included the presence/absence of third molars during surgery, and the presence/absence of bad splits. Radiographic predictor variables included the amount of mandibular movement (mm), the rotation of the occlusal plane (degrees), the postoperative position of the proximal segment, and the pattern of the lingual fracture. The position of the proximal segment was subcategorized as good anatomical position of the proximal segment, slight rotation of the proximal segment of less than one cortical thickness, or significant rotation of the proximal segment of more than one cortical thickness. If the proximal segment was aligned with the distal segment in a continuous line with the inferior mandibular border, this was defined as a good anatomical position of the proximal segment. The pattern of the lingual fracture was defined as either a type I or a type II split. A type I split (Figure 1) was defined when the inferior border had split on the lingual and buccal side with the cortical bone of the caudal cortex in both the proximal and distal segments. A type II split (Figure 2) was defined by a split originating in the lingual cortex (including the full thickness of the inferior border), leaving the complete bilateral caudal cortex attached to the proximal segment.

Patient and procedural characteristics were recorded. These characteristics included the age and sex of the patients, type of procedure (i.e., BSSO or bimaxillary procedure with or without genioplasty), and whether the procedure was performed by a specialist or by a resident under the close supervision of a specialist.

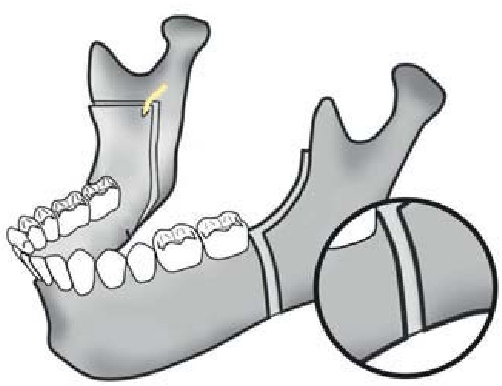

Figure 1: Type I split, with the lingual cortex attached to the distal mandibular segment.

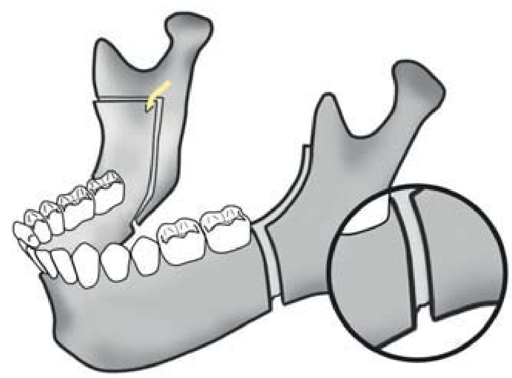

Figure 2: Type II split, with the full thickness inferior cortex completely attached to the proximal mandibular segment.

Data collection methods

The occurrence of osseous inferior border defects was analyzed using preoperative radiographs and postoperative radiographs (orthopantomographic images) acquired at the latest follow-up (minimally 6 months after BSSO) (Figure 3). In the most recent orthopantomogram, a tangential line to the inferior mandibular border was visualized to assess if a contour change was present near the vertical osteotomy site. This contour change of the inferior mandibular border was measured relative to the thickness of the inferior cortex (i.e. more/less than one cortical thickness).

The presence/absence of third molars and the occurrence of bad splits during surgery had been recorded in surgical reports. The extent of mandibular advancement and the rotation of the occlusal plane were calculated from the pre- and postoperative lateral cephalograms by cephalometric measurement. The amount of mandibular advancement was measured as the distance (mm) between reference point pogonion in the pre- and postoperative cephalogram. In case of a genioplasty, a reference point just above the chin-osteotomy was used. This distance between pogonion preoperatively and postoperatively was measured after precise superposition of the mandibular condyle and occlusal plane. The rotation of the occlusal plane was analyzed by superposing static reference points (mandibular condyle, sella, and nasion) and subsequently measuring the angle between the occlusal plane in the pre- and postoperative cephalogram. The assessment of the position of the proximal segment was performed through subjective evaluation by the surgeon, using orthopantomographic or cone-beam computed tomography (CBCT) images acquired one week after surgery. The type of split was analyzed using orthopantomographic images that were recorded one week after surgery.

The findings are reported according to the STROBE guidelines for reporting on observational studies.[9] The entire study was performed in accordance with the guidelines of our institution and followed the Declaration of Helsinki on medical protocol and ethics. Because of the retrospective nature of this study, it was granted an exemption by the Leiden University Medical Center institutional review board.

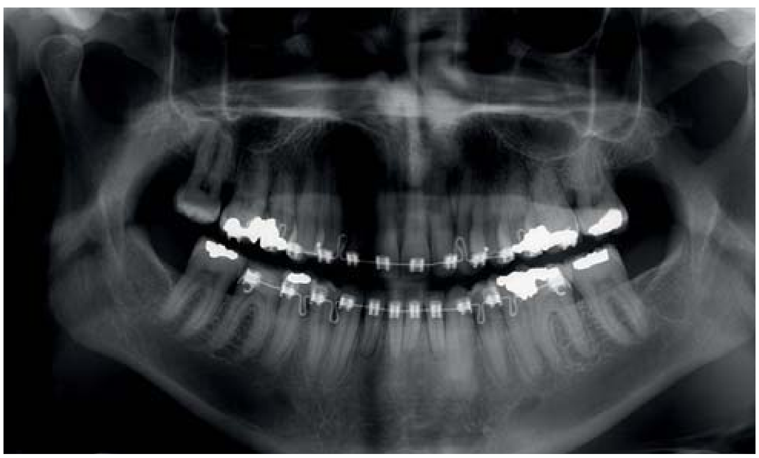

Figure 3a: Preoperative orthopantomographic image acquired a month before bilateral sagittal split osteotomy (BSSO).

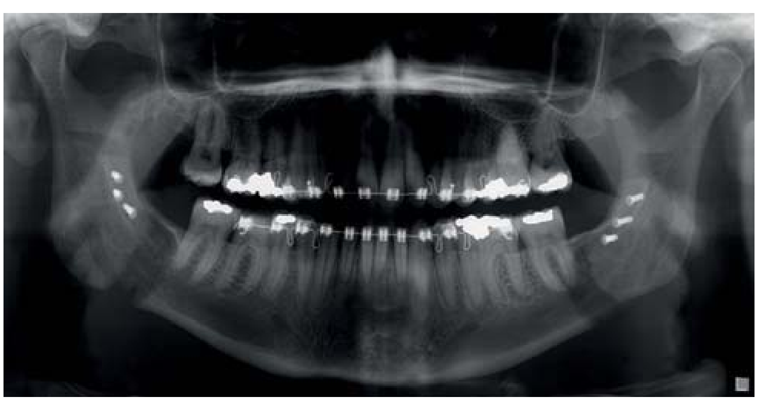

Figure 3b: Orthopantomographic image acquired 2 days after BSSO, showing a defect on the right side. Note that the full thickness of the inferior cortex is attached to the proximal segment on the right side (type II split) and the proximal segment is positioned downwards and backwards (in line with the distal segment). On the left side, a type I split was present, and a forward and upward (cranial) rotation of the proximal segment is observed.

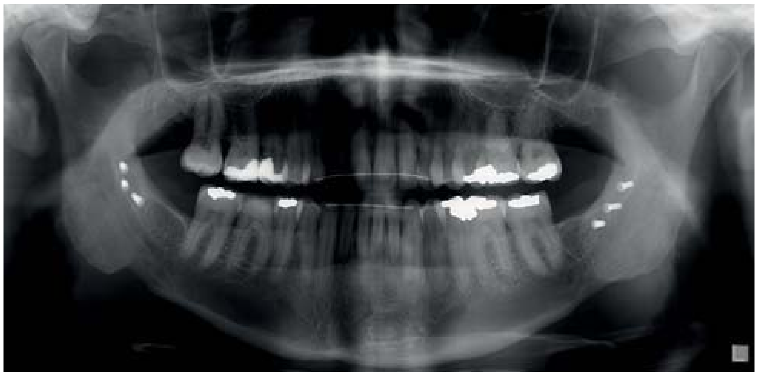

Figure 3c: *Orthopantomographic image acquired a year after BSSO, showing an osseous inferior border defect on the right side.*

Data analyses

Statistical analysis was performed with using the Statistical Package for Social Sciences (SPSS version 23.0 for Mac; IBM, Armonk, NY, USA). Descriptive analyses of the patient characteristics and specifics of the surgical procedures were performed first. The association between the risk factors and incidence of osseous inferior border defects was evaluated using generalized linear mixed models (GLMM) in order to account for the correlated nature of the data: repeated measures design involving the measurement of both the sagittal split osteotomy (SSO) on the right and left sides of each patient. Probabilities less than 0.05 were considered statistically significant.

RESULTS

The medical records of 219 patients were evaluated, leading to the inclusion of 200 patients in this study. The exclusion of 19 patients was necessary because of follow-up durations of less than 6 months (10 patients) or absence of postoperative radiographs (9 patients). The patient characteristics of the final study group are represented in Table 1. The mean follow-up duration was 13 months (standard deviation [SD], 5 months; range, 6–38 months).

Category	n (%)
Sex	
Male	78 (39.0%)
Female	122 (61.0%)
Mean age (years)	29.7
SD, range	12.0, 13.8–55.6
Procedures	
BSSO	141 (70.5)
BSSO + Le Fort I osteotomy	40 (20.0)
BSSO + genioplasty	5 (2.5)
BSSO + Le Fort I osteotomy + genioplasty	14 (7.0)
Operating surgeon (SSO)	
Specialist	220 (55%)
Resident	180 (45%)
Mean mandibular advancement (mm)	5.8
SD, range	1.8, 1–11
Clockwise rotation (degrees)	5.4
SD, range	2.5, 0–13

Table 1: Patient characteristics. Data are represented as the number of patients (%) unless otherwise specified; SD, standard deviation; BSSO, bilateral sagittal split osteotomy.

The incidence of osseous inferior border defects is represented in Table 2. Third molars were present during surgery at 163 SSO (40.8%) and absent at 237 SSO (59.3%). During surgery, bad splits occurred at 9 of 400 SSO (2.3% per SSO). Buccal plate fractures of the lateral cortex accounted for 5 of the 9 bad splits and lingual plate fractures of the medial cortex accounted for the remaining 4. No bilateral bad splits were recorded. Rigid fixation was performed using bicortical screws in 380 splits and monocortical miniplates in 16 splits; intermaxillary fixation was necessary because of a bad split in 2 patients.

	No. of SSO, n (%)
Inferior mandibular border without relevant contour changes	317 (79.3)
Large contour change of the inferior border	55 (13.8)
Inferior border defect	28 (7.0)

Table 2: Incidence of inferior border defects. Data are represented as the number of SSO (%).

Postoperative radiography findings revealed a good anatomical position of the proximal mandibular segment at 272 SSO (68.0%). Slight cranial rotation of the proximal mandibular segment (less than one cortical thickness) was observed at 114 SSO (28.5%) and significant cranial rotation of the proximal segment at 14 SSO (3.5%). The results of analysis of the origin of the split revealed type I splits in 344 SSO (86.0%), wherein the sagittal split originated in the caudal cortex, running through the inferior border with the buccal and lingual cortices attached to respectively the proximal and distal segment. The remaining 56 splits (14.0%) were classified as type II splits, indicating splits originating in the lingual cortex, leaving the complete bilateral caudal cortex attached to the proximal segment.

Using GLMM, no significant association was observed between the incidence of inferior border defects and the presence of third molars ($p = 0.14$) or bad splits ($p = 0.38$). Statistically significant associations were observed between the incidence of inferior border defects and increased extent of mandibular advancement ($p < 0.01$) as well as increased clockwise rotation ($p = 0.012$). Similarly, the occurrence of inferior border defects was found to be statistically significantly associated with the cranial rotation of the proximal segment ($p < 0.01$) as well as the presence of a type II split ($p < 0.01$).

DISCUSSION

The purpose of this study was to estimate the incidence of osseous inferior border defects after BSSO according to the Hunsuck modification with splitter and separators. Risk factors for this complication are furthermore assessed. In the current study group of 200 patients, the overall incidence of osseous inferior border defects was 12.5% per patient and 7.0% per SSO. Significant risk factors for osseous inferior border defects were larger mandibular advancements, increased clockwise rotation, cranial rotation (malposition) of the proximal segment, and a type II split originating in the lingual cortex (including the full thickness of the inferior cortex).

In a recent study, Agbaje et al.[2] reported a 36.5% incidence of inferior border defects per SSO after BSSO, which is significantly higher in comparison to the 7% incidence identified in our study. The discrepancy between the findings of these two studies could be related to the greater amount of mandibular advancement (10.7 mm vs. 5.8 mm) and higher percentage of type II splits (28% vs. 14%) in the study group of Agbaje, et al.[2] A smaller bone gap between the proximal and distal segment of the mandible could be less than the critical size defect, allowing healing of the bony gap, decreasing the evidence of inferior border defects. However, differences in the technique and the position of the vertical bone cut could also play a role in the different findings. Agbaje et al.[2] performed the vertical bone cut between the first and second molar as opposed to our technique, where the vertical bone cut was performed just distally of the second molar.

Advantages of placings the vertical bone cut distally of the second molar include a short (and therefore predictable) lingual fracture distance, and thus no need for an inferior border osteotomy.[10] With this technique, the masseter muscle could furthermore cover inferior border defects, preventing a visible unaesthetic inferior border defect.[5] Clinical studies show that BSSO according to this technique is associated with a low incidence of neurosensory disturbances.[6, 7, 11, 12] However, placing the vertical bone cut behind the second molar could also have several disadvantages like: a limited maximum amount of advancement, and no additional control of the vertical position of the proximal segment.[4, 5, 13]

Although the present study differed from the study by Agbaje et al.[2] with regard to the incidence of osseous inferior border defects, both studies identified a significant association between inferior border defects and large mandibular advancements or a type II split. This association between the extent of mandibular advancement and osseous inferior border defects could be explained by the basic principles of bone healing as well as the interference of the soft tissue during the healing process.[14] The higher risk for osseous inferior border defects following increased clockwise rotation of the occlusal plane is explained by the angle of the inferior border of the mandible created after the rotation. This angle is located near the vertical osteotomy site and, therefore, causes a contour change and sometimes even a slight dimple. Regular bone healing will not alter this angulation defect. Compromised bone healing in these cases would, however, rapidly lead to a noticeable inferior border defect.

Proximal segment positioning during BSSO remains an important part of surgery. In the present study, care was taken during surgery to secure the proximal segment correctly in the glenoid fossa and position the proximal segment in line with the distal mandibular segment. However, the results of our study indicated that, despite these precautions, 3.5% of the sagittal splits still showed significant cranial rotation of the proximal segment. Various authors have proposed different techniques to ensure correct positioning of the proximal segment before fixation of the mandibular segments after a successful split. Wolford[4] describes a stepwise sagittal cut, fixed with a Z-plate, to ensure correct positioning of the proximal segment. The use of additional positioning devices remains questionable.[15] The results of the present study indicate that the presence of malpositioned proximal segments is significantly associated with an increased risk of osseous inferior border defects, which is probably caused by the differences in the orientation of the cortex on both sides of the vertical osteotomy, thereby increasing the gap.

In this study, the presence of a type II split, wherein the full thickness of the inferior cortex is completely attached to the proximal mandibular segment, was found to be a significant risk factor for the occurrence of osseous inferior border defects. In a type I split, the lingual inferior cortex is attached to the distal mandibular segment, while the buccal inferior cortex is attached to the proximal segment, which results in the presence of a continuous cortical bone of the inferior border of the mandible after advancement. A bone defect will, therefore, only occur in the case of bone resorption. However, in a type II split, the complete inferior cortex is attached to the proximal segment, resulting in a gap in the inferior border of the mandible after advancement. A bone defect can, therefore, easily result in case of insufficient bone healing. This study found that the risk of inferior border defects after BSSO is reduced when the sagittal split originates in the inferior cortex (i.e. a type I split), which is in line with the results of previous studies by Wolford et al.[4, 16] and Agbaje et al.[2, 3]

Whether a type I or type II split is preferable nevertheless remains debatable.[4, 5, 13, 17] Some surgeons prefer a split that starts in the lingual cortex (i.e., type II split), so as to ensure safe splitting with a minimal chance of a bad split.[17] Performing an inferior border cut could contribute to the development of this kind of split. Other authors, however, prefer a split traversing the inferior cortex (i.e., type I split), so as to ensure maximal bony contact of the mandibular segments.[3, 4]

In a recent study, Agbaje et al.[3] described a surgical technique that develops the inferior part of the vertical bone cut towards the mandibular angle. This technique appears somewhat similar to the inferior border osteotomy described by Wolford et al.[16] However, in their technique, Agbaje et al.[3] only partially cut the inferior border using an ultrasonic Piezo device, unlike the much longer inferior border osteotomy with a reciprocating saw described by Wolford et al.[16] With their new technique, Agbaje et al.[3] reported occurrence of inferior border defects in 5% of the operated mandibular sites, which is in sharp contrast to their earlier findings.[2] The low incidence of osseous inferior border defects reported in their study coincides with that identified in the present study.

The findings of this study with regard to osseous inferior border defects help identify a scarcely described surgical complication of BSSO. Nevertheless, several disadvantages of the current study need to be mentioned. The retrospective nature of this study is evidently a disadvantage, especially since 19 patients had to be excluded because of insufficient data or loss to follow-up. Since there were no remarkable differences between the excluded patients and the patients included in the study group, we however believe the exclusion did not significantly affect the outcome of the study. BSSO was performed by one of six maxillofacial surgeons usually closely supervising a resident operating on the contralateral side of the mandible. All surgeons and residents performed BSSO according to the same surgical protocol, using the same technique and materials. However, small differences based on the surgeon/resident could be present because of the number of different physicians.

Further research is required for the investigation of the clinical consequences of the present findings and to assess the clinical importance of inferior border defects.

CONCLUSION

The overall incidence of osseous inferior border defects in the present study was found to be 12.5% per patient and 7.0% per SSO. Significant risk factors for osseous inferior border defects included large mandibular advancement, increased rotation of the occlusal plane, cranial rotation of the proximal segment, and a type II mandibular split. These findings could help surgeons increase the aesthetic outcome of BSSO and minimize the risks of secondary procedures.

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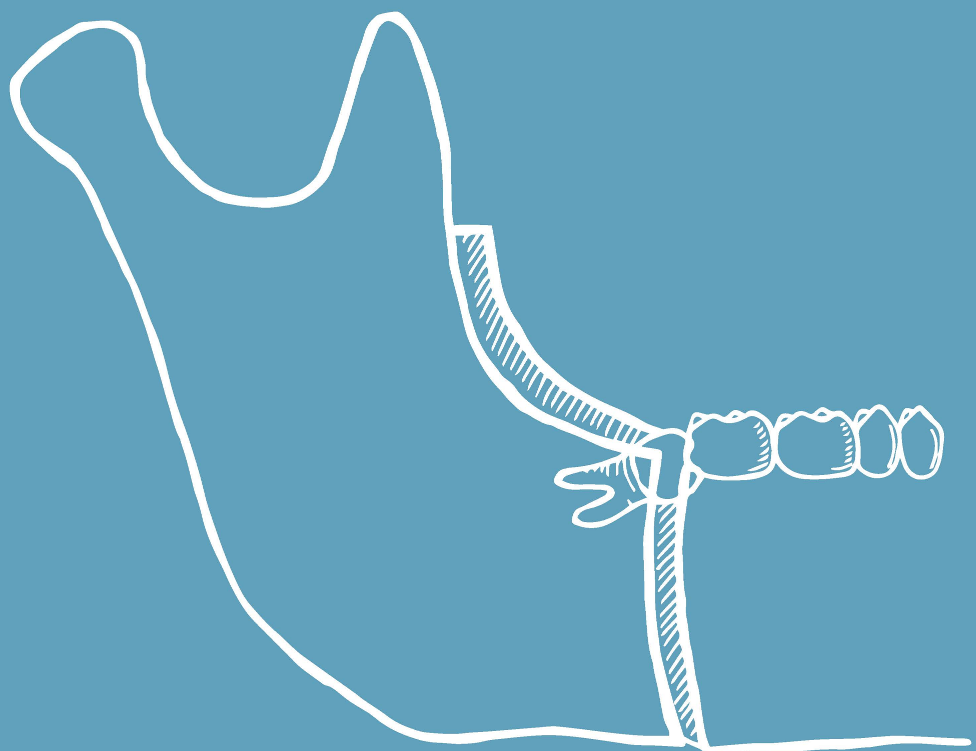

CHAPTER 7

Presence of mandibular third molars during bilateral sagittal split osteotomy increases the possibility of bad split but not the risk of other post-operative complications

This chapter is based on the manuscript:

Verweij JP, Mensink G, Fiocco M, van Merkesteyn JPR

Presence of mandibular third molars during bilateral sagittal split osteotomy increases the possibility of bad split but not the risk of other post-operative complications

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ABSTRACT

Timing of third molar removal in relation to bilateral sagittal split osteotomy (BSSO) is controversial, especially with regard to postoperative complications. We investigated the influence of mandibular third molar presence on complications after BSSO with sagittal splitters and separators by a retrospective record review of 251 patients (502 surgical sites).

Mandibular third molars were present during surgery at 169 sites and removed at least 6 months preoperatively in 333 sites. Bad splits occurred at 3.0 % (5/169) and 1.5% (5/333) of the respective sites. Presence of mandibular third molars significantly increased the risk of bad splits (OR 1.08, CI 1.02-1.13, $p < 0.01$). The mean incidences of permanent neurosensory disturbances, postoperative infection, and symptomatic removal of the osteosynthesis material were 5.4% (OR, 0.89; 95% CI, 0.79–1.00; $p = 0.06$), 8.2% (OR, 1.09; 95% CI, 0.99–1.20; $p = 0.63$), and 3.4% (OR, 0.97; 95% CI, 0.92–1.03; $p = 0.35$) per site, respectively, without a significant influence of mandibular third molar status.

In conclusion, the presence of mandibular third molars during surgery increases the possibility of bad splits, but does not affect the risk of other complications. Therefore, third molars can be removed concomitantly with BSSO using sagittal splitters and separators.

INTRODUCTION

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Bilateral sagittal split osteotomy (BSSO) is one of the most popular techniques in orthognathic surgery nowadays. Since it was first described by Trauner and Obwegeser (1957), many attempts have been made to improve this technique in order to minimise post-operative complications.[1-6] The most common complications associated with BSSO are: an unfavourable fracture pattern during osteotomy, termed 'bad split'; neurosensory disturbances of the inferior alveolar nerve (IAN), resulting in altered sensation of the lower lip; infection at the surgical site; and symptomatic removal of the osteosynthesis material.[7]

BSSO is often performed to correct malocclusion in relatively young patients.[8, 9] These patients generally have third molars at the first consultation. If indicated, mandibular third molar removal is recommended at least 6 months before BSSO.[10] Although concomitant removal with BSSO is also possible, the influence of this procedure on the incidence of post-operative complications is still under debate.[11, 12] Therefore, timing of third molar removal in relation to BSSO is controversial.[13, 14]

The aim of this retrospective study was to investigate the association between third molar status during and common complications after BSSO with sagittal splitters and separators.

MATERIAL AND METHODS

Patients and surgical procedures

We reviewed the medical files and radiographs of 259 consecutive patients who had undergone BSSO at our centre between 2004 and 2011. Eight patients were excluded from this study due to incomplete records, so data concerning 251 patients were analysed.

BSSO was performed according to the Hunsuck modification with sagittal splitters and separators, without using chisels.[5, 15] Additional procedures included Le Fort I osteotomy and/or genioplasty. Maxillary third molars were removed if indicated. Mandibular third molars were left in situ if they occluded with maxillary second molars, because of absent mandibular premolars or second molars. If mandibular third molar removal was indicated, the patients could choose removal at least 6 months before or concomitant with BSSO. The possibility of bad splits due to the presence of third molars during BSSO was explained.[16]

All the patients were discharged within a week after surgery. Follow-up examinations were performed at 1, 2, and 3 weeks and 3, 6, and 12 months. The patients were instructed to return to the clinic if they had any complaints.

Outcomes

The primary outcome variables were complications of BSSO: bad split, neurosensory disturbances of the IAN, infection at the surgical site, and symptomatic removal of the osteosynthesis material. The secondary outcome variables were intra-operative factors: IAN status, operative time, and blood loss. Independent variables were third molar status during BSSO, patient age and gender, and preoperative malocclusion class.

A bad split was defined as an irregular or unfavourable fracture pattern in the distal or proximal part of the mandible after osteotomy; it was recorded as present or absent. Neurosensory disturbances of the IAN were evaluated by objective tests and subjective assessment. The disturbances were considered permanent if they were present one year after BSSO. IAN status during BSSO was recorded as not visible in the distal segment, less than half visible in the distal segment, more than half visible in the distal segment, prepared out of the proximal segment with blunt instruments, or prepared out of the proximal segment with burr. Infection at the surgical site was defined as infectious symptoms (swelling with granulation tissue, pus, or intraoral fistula) treated with antibiotics. Osteosynthesis material was removed because of infection, wound dehiscence, or irritation/tenderness at the osteosynthesis site.

Statistical analysis

Statistical analyses were performed with SPSS version 20.0 for Windows (IBM, Armonk, NY, USA). Descriptive analyses concerning the study population were performed at first. To study the effect of mandibular third molar status on bad splits, neurosensory disturbances, infection and removal of osteosynthesis material, respectively, a multivariate generalised linear mixed model had been employed to account for information on the left and right sides within the same patient. Gender, age at surgery and occlusion class had been incorporated in the mixed model. Linear regression models, adjusting for gender and age at surgery, were used to investigate the association of mandibular third molar status with operative time and blood loss.

RESULTS

General findings

In total, 502 sagittal split osteotomies (sites) were performed in 251 patients. The study population consisted of 90 male and 161 female patients, with a mean age of 27.7 years (SD, 10.8 years; range, 13.8–55.6 years). The surgical indications were mandibular advancement and setback for class II and III malocclusions in 219 and 32 patients, respectively. BSSO was performed singly in 146 patients and combinatorially with genioplasty, Le Fort I osteotomy, or Le Fort I osteotomy and genioplasty in 11, 74, and 20 patients, respectively. Mandibular third molars were present during surgery at 169 sites (Figure 1) ; they were congenitally absent or removed at least 6 months preoperatively at 333 sites (Table 1). The mean follow-up duration was 432 days (SD, 172 days; range, 163–1465 days).

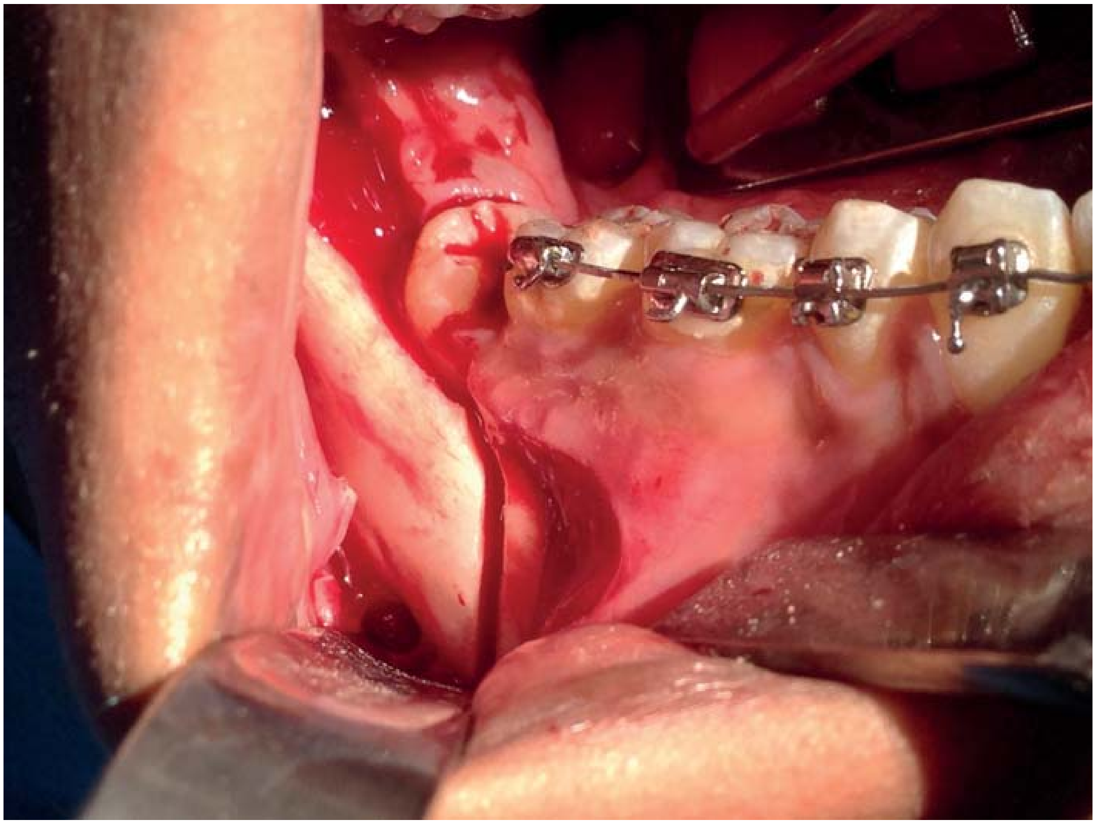

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Figure 1: *Intra-operative photograph of a sagittal split osteotomy with the third molar present during the split.*

The mean incidences (per site) of the complications of BSSO were as follows: bad splits, 2.0%; permanent neurosensory disturbances of the IAN, 5.4%; infection at the surgical site, 8.2%; and symptomatic removal of the osteosynthesis matetrial, 3.4%.

Status	**Mandibular third molars**		**Maxillary third molars**	
	Right	*Left*	*Right*	*Left*
Absent at first consultation	97 (38.6)	102 (40.6)	99 (39.4)	96 (38.2)
Removed >6 months preoperatively	68 (27.1)	66 (26.3)	49 (19.5)	54 (21.5)
Removed during BSSO	84 (33.5)	81 (32.3)	67 (26.7)	66 (26.3)
Present after BSSO	2 (0.8)	2 (0.8)	36 (14.3)	35 (13.9)

Table 1: *Status of third molars in the study population. Data represent the number of teeth (%).*

Group characteristics

Groups with and without mandibular third molars during BSSO were compared. No significant differences have been found, but patients' age (Table 2). Patients with mandibular third molars during BSSO were significantly younger. Table 3 shows the incidences of the complications in both groups, with and without third molars.

Parameter	Third molars present	Third molars absent	Significance*
Total number of patients	93 (37.1)	158 (62.9)	
Mean (SD) age, age range (years)	21.5 (8.1), 13.8–52.9	31.6 (10.5), 16.9–55.6	<0.01
Gender			0.52
Male	31 (33.3)	59 (37.3)	
Female	62 (66.7)	99 (62.7)	
Malocclusion class			0.65
II	80 (86.0)	139 (88.0)	
III	13 (14.0)	19 (12.0)	
Additional procedures			0.20
BSSO	62 (66.7)	84 (53.2)	
BSSO + Le Fort I osteotomy	21 (22.6)	53 (33.5)	
BSSO + genioplasty	4 (4.3)	7 (4.4)	
BSSO + Le Fort I osteotomy + genioplasty	6 (6.5)	14 (8.9)	

Table 2: Groups' characteristics with and without mandibular third molars during BSSO.
Data represent the number of patients (%) unless otherwise indicated.
**p-values of less than 0.05 were considered statistically significant.*

Complication	Third molars present	Third molars absent
Bad splits (%)	3.0	1.5
Neurosensory disturbances of the IAN (%)	3.6	6.3
Infection at the surgical site (%)	10.7	6.9
Symptomatic removal of osteosynthesis material (%)	2.4	3.9

Table 3: Incidence of post-operative complications per site in the groups with and without mandibular third molars during BSSO.

Bad split

Bad splits occurred at five of the 169 sites with mandibular third molars (3.0%) and five of the 333 sites (1.5%) without mandibular third molars. Bilateral bad splits did not occur. A generalised mixed model had been employed to account for patient's information on the right and left side, adjusting for age and gender. Presence of mandibular third molars significantly increased the risk of bad splits (OR, 1.08; 95% CI, 1.02–1.13; $p < 0.01$). Age (OR, 1.03; 95% CI, 0.98–1.09; $p = 0.22$) and gender (OR, 1.01; 95% CI, 0.97–1.05; $p = 0.61$) did not significantly influence the occurrence of bad splits.

IAN status and neurosensory disturbances

The IAN was visibly damaged unilaterally in seven patients; bilateral damage did not occur (Table 4). No significant association was present between mandibular third molar status and IAN status (OR, 1.00; 95% CI, 0.68–1.48; p = 0.98), with adjustment for age and gender.

IAN status	Third molars present	Third molars absent
Total number of surgical sites	169	333
IAN not visible in the distal segment	33 (19.5)	56 (16.8)
Less than half of the IAN visible in the distal segment	29 (17.2)	47 (14.1)
More than half of the IAN visible in the distal segment	74 (43.8)	148 (44.4)
IAN prepared blunt from the proximal segment	17 (10.1)	36 (10.8)
IAN prepared with burr from the proximal segment	12 (7.1)	43 (12.9)
IAN visibly damaged	4 (2.4)	3 (0.9)

Table 4: IAN status at the surgical sites with and without mandibular third molars during BSSO. Data represent the number of surgical sites (%).

Permanent neurosensory disturbances were present at six of the 169 sites (3.6%) with mandibular third molars and 21 of the 333 sites (6.3%) without mandibular third molars. No significant difference in neurosensory disturbances was found between the groups (OR, 0.89; 95% CI, 0.79–1.00; p = 0.06). As before, patient's age and gender had been incorporated in the model. Further analysis revealed an increased risk of neurosensory disturbances when the IAN was prepared from the proximal segment (OR, 1.14; 95% CI, 1.05–1.23; p < 0.01). Increasing age was also a significant risk factor for nerve dysfunction (OR, 1.05; 95% CI, 1.02–1.08; p < 0.01). Gender (OR, 1.37; 95% CI, 0.74–2.54; p = 0.31) and bad split status (OR, 0.90; 95% CI, 0.61–1.35; p = 0.62) were not significantly associated with permanent neurosensory disturbances.

Infection

Infection was present at 18 of the 169 sites (10.7%) with mandibular third molars and 23 of the 333 sites (6.9%) without mandibular third molars. Two patients with mandibular third molars and one patient without mandibular third molars developed infection bilaterally. Presence of mandibular third molars did not significantly increase the risk of infection at the surgical site, adjusting for gender and age (OR, 1.09; 95% CI, 0.99–1.20; p = 0.09). Age (OR, 0.99; 95% CI, 0.97–1.03; p = 0.72), gender (OR, 1.02; 95% CI, 0.95–1.09; p = 0.63), and bad split status (OR, 1.01; 95% CI, 0.72–1.41; p = 0.94) showed no significant association with the development of infection.

Removal of the osteosynthesis material

Symptomatic removal of the osteosynthesis material was indicated at 17 sites, including four of the 169 sites (2.4%) with mandibular third molars and 13 of the 333 sites (3.9%) without mandibular third molars. No significant association was found between mandibular third molar status and symptomatic removal of the osteosynthesis material (OR, 0.97; 95% CI, 0.92–1.03; p = 0.35), with adjustment for age and gender. Age (OR, 0.99; 95% CI, 0.93–1.05; p = 0.71) and gender (OR, 0.38; 95% CI, 0.12–1.23; p = 0.10) were not significantly associated with removal of osteosynthesis material.

Operative time and blood loss

The mean operative time and blood loss during BSSO in the groups with and without mandibular third molars are listed in Table 5. Mandibular third molar status had no significant influence on the total operative time (p = 0.80) and blood loss during surgery (p = 0.09).

Surgery	Third molars present				Third molars absent			
	Operative time (min)		Blood loss (ml)		Operative time (min)		Blood loss (ml)	
	Mean (SD)	*Range*	*Mean (SD)*	*Range*	*Mean (SD)*	*Range*	*Mean (SD)*	*Range*
BSSO	147 (45)	60–295	349 (200)	40–900	131 (34)	65–221	360 (338)	50–2500
BSSO + genioplasty	192 (46)	140–235	335 (255)	150–690	158 (76)	105–300	358 (291)	100–900
BSSO + Le Fort I osteotomy	269 (48)	185–353	719 (347)	250–1600	271 (58)	161–397	858 (357)	250–1800
BSSO + Le Fort I osteotomy + genioplasty	315 (70)	210–408	992 (641)	150–1700	268 (68)	180–408	835 (484)	400–2000

Table 5: Operative time and blood loss during various surgical procedures.

DISCUSSION

Some authors advocate third molar removal during BSSO to avoid an additional surgical procedure and minimise unwanted post-surgical consequences.[11, 13, 17] However, presence of third molars during surgery increases the surgical difficulty and third molar removal concomitant with BSSO is challenging even for experienced surgeons.[10, 18] Other authors therefore recommend removal of third molars at least 6 months preoperatively.[14, 19, 20] In this study, we analysed the influence of third molar status on the common complications of BSSO performed with sagittal splitters and separators. We found that the presence of mandibular third molars during BSSO significantly increased the risk of bad splits but not that of neurosensory disturbances of the IAN, infection at the surgical site, or symptomatic removal of the osteosynthesis material.

Mandibular third molar removal during BSSO significantly increased the risk of bad splits in our study. Third molar removal during surgery can weaken the bony cortex or cause bone defects near the alveolus, predisposing to a bad split. The patients with mandibular third molars during BSSO were significantly younger, but patient age did not have a significant influence on the incidence of bad splits. Age and gender have been included in all multivariate generalised mixed models to account for possible confounding effects, due to the significant difference in age between both groups. Reyneke et al. and Mehra et al. recorded an increased incidence of bad splits when third molars were present, especially in younger patients.[10, 12] Further, Mensink et al. reported a significant association between presence of third molars and occurrence of bad splits independent of patient age.[16] Other authors, however, reported no clinical influence of peri-operative third molar removal on the occurrence of bad splits. Kriwalsky et al. reported older age as a risk factor for bad splits without an association with third molar removal.[21] Doucet et al., Precious et al. and Tucker et al. also found no significant association between the presence of third molars and the occurrence of bad splits.[11, 17, 22] Patients generally recover well after a bad split.[16] In our study, bad splits had no impact on patient recovery and all the patients had good functional outcomes one year after BSSO.

The IAN was manipulated during BSSO, but presence of mandibular third molars did not influence IAN status. This is in concordance with the findings of Doucet et al. who also reported no significant association between third molar removal and nerve manipulation.[23] In contrast, Reyneke et al. reported slightly more frequent manipulation of the nerve in patients with third molars.[10] IAN manipulation is an important factor, because it increases the possibility of permanent neurosensory disturbances after BSSO.[24] In our study group the incidence of IAN manipulation of the nerve was similar between the patients with and without mandibular third molars during surgery, therefore being no influencing factor in the possible post-operative neurosensory disturbances.

The incidence of permanent neurosensory disturbances of the IAN was lower in the group with mandibular third molars (3.6% per site) than in the group without mandibular third molars (6.3% per site). Patients in the group without mandibular third molars were, however, significantly older, predisposing to neurosensory disturbances. The difference between these groups was not significant after adjusting for age and gender. Contradicting earlier findings, Doucet et al. and August et al. reported significantly less neurosensory dysfunction of the lip and chin area when third molars were removed concomitantly with BSSO.[23, 25] Six months post-operatively, the reported incidence of neurosensory disturbances in their study was 32.1% per patient without third molars and 9.5% per patient with third molars during surgery.[23] The authors hypothesised that the presence of a third molar could result in distal positioning of the IAN, avoiding nerve manipulation during surgery. Given our findings, an association of mandibular third molar status with direct manipulation of the nerve seems unlikely.

The relationship between third molar removal concomitant with BSSO and post-operative infection has scarcely been examined. We noted a lower incidence of infection at the surgical site when mandibular third molars were absent before BSSO. However, this association was not significant. Lacey et al. reported increased incidence of infection associated with osteosynthesis material after third molar removal concomitant with surgery.[26] They hypothesised that the empty alveolus increases exposure of bicortical screws to bacteria, thus increasing the infection rate.

Bicortical screws were removed in only a few cases. Mandibular third molar status did not affect the incidence of symptomatic removal of the osteosynthesis material, in contrast with the findings of Lacey et al.[26] The osteosynthesis material was removed mainly because of infection, irritation, and tenderness.

Operative time and blood loss during surgery did not differ significantly between the patients with and without mandibular third molars. Other authors also report no clinically significant influence on the time to accomplish the osteotomy and peri-operative blood loss.[10, 11]

CONCLUSION

We found only a slightly increased risk of bad splits when mandibular third molars were present during BSSO, without long-term consequences. Presence of mandibular third molars did not increase the risk of other post-operative complications. These results imply that mandibular third molar removal can be performed concomitantly with BSSO with sagittal splitters and separators; its timing depends on the surgeon's discretion and patient's choice.

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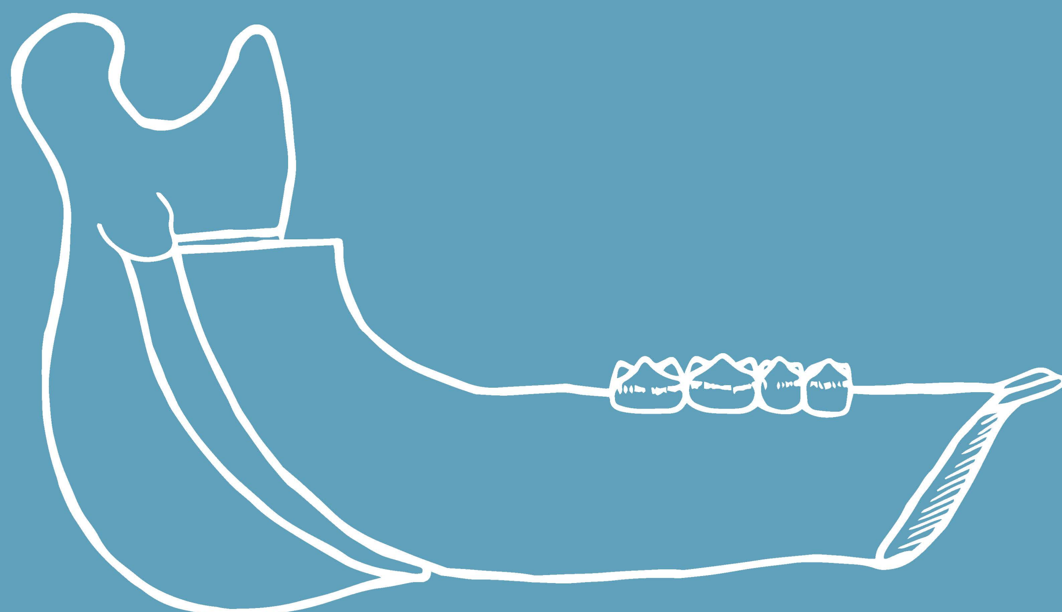

CHAPTER 8

Investigation of the influence of mallet and chisel techniques on the lingual fracture line and comparison with the use of splitter and separators during sagittal split osteotomy in cadaveric pig mandibles

This chapter is based on the manuscript:

Verweij JP, Mensink G, Houppermans PNWJ, Frank MD, van Merkesteyn JPR

Investigation of the influence of malle tand chisel techniques on the lingual fracture line and comparison with the use of splitter and separators during sagittal split osteotomy in cadaveric pig mandibles

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ABSTRACT

In bilateral sagittal split osteotomy the proximal and distal segments of the mandible are traditionally separated using chisels. Modern modifications include prying and spreading the segments with splitters. This study investigates the lingual fracture patterns and status of the nerve after sagittal split osteotomy (SSO) using the traditional chisel technique and compares these results with earlier studies using the splitter technique.

Lingual fractures after SSO in cadaveric pig mandibles were analysed using a lingual split scale and split scoring system. Iatrogenic damage to the inferior alveolar nerve was assessed.

Fractures started through the caudal cortex more frequently in the chisel group. This group showed more posterior lingual fractures, although this difference was not statistically significant. Nerve damage was present in three cases in the chisel group, but was not observed in the splitter group.

A trend was apparent, that SSO using the chisel technique instead of the splitter technique resulted in more posterior lingual fracture lines, although this difference was not statistically significant. Both techniques resulted in reliable lingual fracture patterns. Splitting without chisels could prevent nerve damage. Therefore, we propose a spreading and prying technique with splitter and separators. However, caution should be exercised when extrapolating these results to the clinic.

INTRODUCTION

Bilateral sagittal split osteotomy (BSSO) is commonly used in human orthognathic surgery. Since the introduction of this technique by Trauner and Obwegeser[1], several modifications have been suggested to maximise its safety and reliability.[2-5] Traditional surgical techniques are based on the use of chisels to separate distal and proximal segments of the mandible.[1-4, 6] Compression of the inferior alveolar nerve (IAN) during splitting with chisels has been shown to reduce sensory nerve reactions.[7] Along with other authors, we therefore advocate prying and spreading of the segments of the mandible.[5, 8, 9] BSSO with a sagittal splitter and separators is associated with less postoperative nerve dysfunction compared with splitting with chisels and mallets.[5, 10] The use of a sagittal splitter and separators does not increase the incidence of bad splits.[11] However, little is known about fracture patterns with different techniques and avoiding chisels could promote a different splitting pattern on the lingual side of the mandible. Precise control of the lingual fracture is difficult and the concealed nature of this lingual fracture line makes it impossible to evaluate this aspect during surgery.[12]

To better understand the split patterns and possible side effects, investigation of the lingual fracture pattern and possible nerve damage with different BSSO techniques is important. This study is a continuation of earlier research published by Mensink et al.[†], investigating the lingual fracture line after sagittal split osteotomy (SSO) with sagittal splitter and separators. In this study, we aimed to further analyse the lingual fracture patterns and status of the nerve after SSO, comparing the traditional chisel technique with the splitter technique. We compared the risk of direct visible damage to the IAN associated with each splitting technique.

MATERIAL AND METHODS

Sagittal split osteotomy was performed on cadaveric pig mandibles. The mandibles were obtained from female pigs aged 6–7 months, with a mean weight of approximately 100 kg and a mixed dentition phase. Soft tissues were used for consumption, and the mandibles were boiled to remove any soft tissue residues. Mandibles were cut in the midline, and then refrigerated at 1–3°C. The average length of the hemimandibles was 20 cm (range, 17–23 cm), and they contained at least one unerupted molar, two erupted molars and two erupted premolars. The pig mandibles were scheduled for destruction, therefore we did not need to obtain approval from our institution to use them in our study. One mandible, used as a splitting control, was not boiled and the soft tissues were removed from it by hand.

Sagittal split osteotomy (SSO) was performed as described by Hunsuck.[3] Since only intra-mandibular forces were applied, the mandibles were easily stabilised by hand. Horizontal, sagittal and vertical bone cuts were performed with a long Lindemann burr (2.3 ´ 22.0 mm; Meisinger, Neuss, Germany). The horizontal cut was made approximately 3–5 mm above the mandibular foramen, ending in the deepest point of the concavity of the mandibular foramen. The vertical cut was made just posterior to the most distal erupted molar, perpendicular to the caudal border of the mandibular body. Subsequently, the sagittal cut and the inferior cortex cut through the caudal border, reaching 1–2 mm in the lingual cortex, were made with a short Lindemann burr (1.4 ´ 5.0 mm, Meisinger).

SSO was performed according to the traditional chisel technique, using a 7 mm wide chisel (Seward Thackray, Rhymney, Gwent, UK). Chisels were used as described by Bruckmoser et al.[6] First, the horizontal bone cut was chiselled to achieve better definition. Subsequently, the sagittal bone cut was chiselled to 5–10 mm in depth. The chisel was torqued in the sagittal cut, to see if the proximal segment split accordingly. Then, at the distal end of the sagittal cut, an elevator was slid along the inner side of the buccal cortex, to separate the cortex from the inner side of the mandible. Using a mallet, a chisel was directed along the vertical bone cut through the inferior cortex, again keeping close contact with the inner side of the buccal cortex to avoid damaging the IAN. This was repeated until the inferior cortex had split approximately 20 mm. The split was completed by applying moderate pressure with curved Obwegeser elevators (Stryker Leibinger, Pusignan, France) to separate the segments. If required, the remaining part of the (dorsal) inferior border was split under direct visibility of the IAN, with the additional use of a chisel.

We investigated fracture patterns after SSO according to the traditional technique with chisels and mallets. Lingual fracture patterns were evaluated based on their origin, relation to the mandibular canal and completion of the fracture lines. The lingual split scale (LSS) described by Plooij et al.[†]was used to categorise the different lingual splitting patterns. In that scale, LSS1 represents a 'true Hunsuck' lingual fracture inferior to the mandibular canal, LSS2 describes a more posterior fracture line through the caudal and dorsal border of the ramus ('Obwegeser' split) and LSS3 describes a more anterior fracture line through the mandibular canal. Unfavourable fracture patterns and impact on the IAN were also examined. To further assess our primary outcome variable (the lingual fracture pattern), we designed a split scoring system (SSS) to distinguish between more anterior or posterior splitting patterns (Figure 1). The start of the split was defined as either extending from the inferior border cut in the lingual cortex (3 points) or through the inferior cortex (0 points). Relation to the mandibular canal was scored as completely through the canal (4 points), less than 1/3 inferior to the canal (3 points), 1/3–2/3 inferior to the canal (2 points), predominantly inferior to the canal (1 point) or entirely inferior to the canal (0 points). The end of the split was defined as either in the mandibular foramen (1 point) or ending more dorsally (0 points).

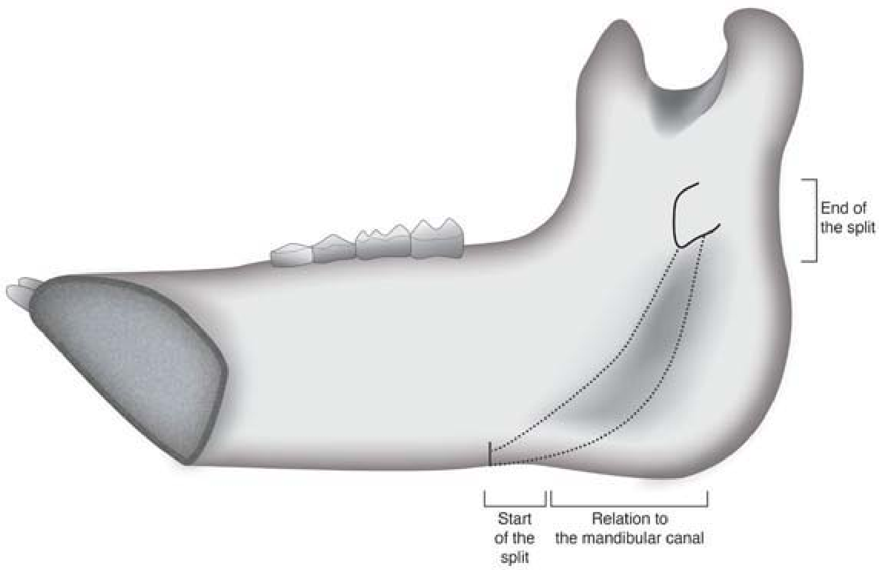

Figure 1: A drawing of the pig mandible model. An anterior lingual fracture line originating from the inferior border cut and extending through the mandibular canal into the mandibular foramen is shown, as is a posterior lingual fracture line starting from the inferior border, continuing inferior to the mandibular canal and ending in the concavity of the mandibular foramen.

The fracture patterns with the traditional technique after SSO with chisels were subsequently compared with fracture patterns after SSO with splitter and separators, as described by Mensink et al.[13] In this second group, SSO was performed using a similar technique with the same horizontal, sagittal and vertical bone cuts, but instead of chisels a sagittal splitter and curved Smith Ramus separators (Walter Lorentz Surgical, Jacksonville, Florida, USA) were used.[14] Both groups each consisted of 20 hemimandibles: 10 left-sided and 10 right-sided SSOs. We further evaluated the fracture patterns with the sagittal split scale and assessed possible iatrogenic nerve damage after SSO with both techniques.

This study was performed in accordance with the guidelines of our institution and followed the Declaration of Helsinki on medical protocol and ethics. Due to the ex-vivo nature of this study, it was granted an exemption in writing (reference number P14.189) by the Leiden University Medical Center institutional review board.

Data analysis

Statistical analyses were performed with SPSS version 21.0 for OSX (IBM, Armonk, NY, USA). Descriptive analyses of the different aspects of the fracture patterns and nerve status were performed. Student's t-test was used to calculate differences between the two techniques investigated. Associations between the fracture patterns and the outcome of the SSS were analysed using linear regression techniques. Associations between the techniques investigated and nerve damage were calculated with a logistic regression model. A p-value of <0.05 was considered significant.

RESULTS

Chisel group

Regarding the start of the split, in the chisel group 40% of splits originated directly from the inferior border cut in the lingual cortex, without splitting the caudal cortex, and 60% continued through the caudal border of the mandible. The mean length of the fracture line in the caudal cortex was 19.5 mm (range, 9.0–43.0 mm). The subsequent pattern of lingual fractures in relation to the mandibular canal was: 40% directly through the mandibular canal; 35% initiating inferior to the mandibular canal and extending through the canal; and 25% continuously inferior to the mandibular canal. The lingual split patterns in the chisel group were 60% LSS1 and 40% LSS3.

One impending unfavourable fracture was avoided, when the chisel was hit through the buccal cortex. Retracting the chisel and carefully replacing it closer to the inferior cortex successfully completed this split. The IAN was also visible after all splits. In three cases (15%), the IAN was visibly affected after chiselling through the inferior cortex, resulting in partial laceration of the IAN.

One additional mandible was not boiled or otherwise prepared, and BSSO was performed on this 'fresh' mandible as a control for preparation effects. Subjective evaluation by the operator confirmed there was no clear difference between the fresh mandible, and the cooked and refrigerated mandibles.

Splitter group

In the splitter group, 60% of the splits originated from the sagittal cut in the lingual cortex, and 40% originated from the caudal border and continued through it. The mean length of the fracture line in the caudal cortex was 17.9 mm (range, 7.0–34.0 mm). The lingual fracture pattern originated from the mandibular canal and continued through it in 60% of cases; originated inferiorly and extended through the canal in 35%; and remained predominantly inferior to the canal in 5%. Of these fracture patterns, 40% were LSS1 and 60% were LSS3. All but one (95%) of the lingual fracture lines ended in the concavity of the mandibular foramen. The only lingual fracture line not ending in the concavity of the mandibular foramen was an unfavourable fracture, originating from the inferior border cut, crossing the mandibular canal and ending ventral to the mandibular foramen. The IAN was visible after all splits, with no laceration of the nerve in any cases in the splitter group.

Lingual fracture pattern	Split scoring system (points)		Splitter group	Chisel group	Significance
			Total score (mean)	*Total score (mean)*	*p value*
Start of split	From inferior border cut	(3)	36 (1.80)	24 (1.20)	0.22
	Continuing through inferior cortex	(0)			
Relation to mandibular canal	Directly through canal	(4)	63 (3.15)	50 (2.50)	0.10
	Through canal from first 1/3	(3)			
	Through canal from second 1/3	(2)			
	Through canal in last 1/3	(1)			
	Remaining inferior to canal	(0)			
End of split	In mandibular foramen	(1)	20 (1.00)	19 (0.95)	0.32
	Behind mandibular foramen	(0)			
Total score (mean)			119 (5.95)	93 (4.65)	0.14

Table 1: Split scoring system for lingual fracture patterns, showing total score per group for each aspect of the lingual fracture line. A higher score indicates a more anterior fracture pattern.

Chisel group vs. splitter group

Logistic regression showed no significant difference between the types of fractures (LSS1 or LSS3) in the two groups ($p = 0.12$; OR = 2.79; 95% CI, 0.77–10.05). The SSS, designed to distinguish between anterior and posterior fracture patterns, recorded lower scores for each aspect of the split in the chisel group compared with the splitter group (Table 1). In the chisel group, 12 out of 20 fracture lines scored 0–4 points, corresponding to a relatively posterior split (Figure 2) and the other eight fracture lines scored 4–8 points indicating a more anterior split. In the splitter group, eight 'posterior splits' (0–4 points) and 12 'anterior splits' (4–8 points) were recorded (Figure 3). Linear regression showed no significant difference ($p = 0.14$; 95% CI, -0.46 to 3.06) in mean or median total score between the groups (Figure 4). Although increased scores were observed for the relation to the mandibular canal after SSO with splitters, the difference between the groups was not significant ($p = 0.10$; 95% CI, -0.14 to 1.44). Iatrogenic nerve damage occurred only with the chisel technique, but the difference in incidence between the groups was not significant ($p = 0.07$; OR = 1.17; 95% CI, 0.71–1.02).

The reliability and reproducibility of the two techniques investigated did not differ significantly, with no significant difference in the mean ($p = 0.35$), comparable standard deviations (2.89 vs. 2.56) and comparable variances (8.35 vs. 6.68).

Figure 2: Photograph of a posterior lingual fracture line in a cadaveric pig mandible, after sagittal split osteotomy with a chisel and mallet.

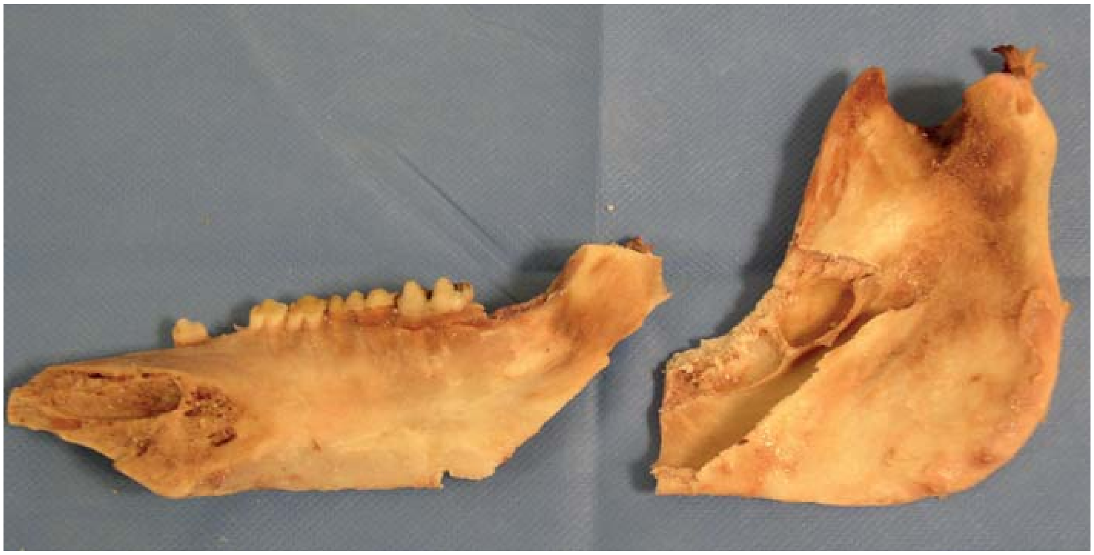

Figure 3: Photograph of an anterior lingual fracture line in a cadaveric pig mandible, after sagittal split osteotomy with a sagittal splitter and separators.

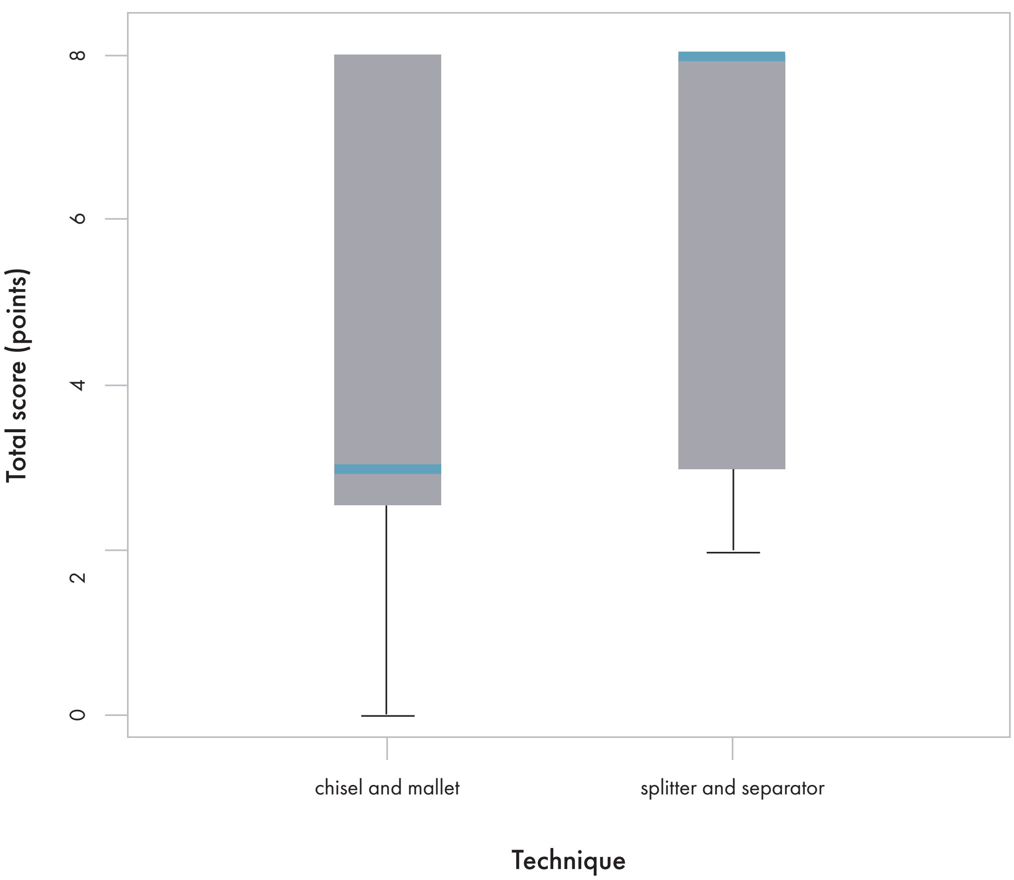

Figure 4: Boxplot of the mean total scores in the chisel and splitter groups, showing no statistically significant difference between the groups, but a trend of higher scores in the splitter group (a more anterior fracture pattern).

DISCUSSION

This study aimed to analyse the lingual fracture patterns after SSO in cadaveric pig mandibles, with the chisel and mallet technique. The traditional chisel technique was furthermore compared with the widely used splitter technique. Although statistical analysis revealed no significant difference between the techniques, a tendency for a more posterior splitting pattern was observed after SSO with a chisel and mallet, compared with SSO with a splitter and separators. Assessment of possible nerve damage revealed three cases of visible iatrogenic nerve damage in the chisel group and no visible nerve damage in the splitter group.

Our findings showed a tendency of the fracture line through the caudal border to be longer in the chisel group than in the splitter group. This difference could be due to chiselling through the inferior cortex in the chisel group resulting in a longer fracture line through the caudal border. In the splitter group, more fracture lines extended through the mandibular canal or crossed the canal, than in the chisel group. This could be due to the more anterior centre of rotation in the splitting process when using the sagittal splitter and separators. With the splitter technique, the sagittal splitter is used to apply force to the superior cortex in the sagittal bone cut, and a separator is placed in the buccal bone cut (near the inferior cortex) to guide the split. The primary leverage is near the separator at the inferior part of the buccal bone cut. No intra-mandibular instruments are used. The centre of rotation with this technique is between the superior aspect of the mandibular body and the buccal bone cut. With the chisel technique, the chisel is placed in the sagittal split and chiselled along the inside of the buccal plate, up to 1–2 cm dorsally through the inferior cortex. Therefore, the centre of rotation during the splitting procedure using chisels is situated more towards the mandibular angle, particularly when elevators are placed between the proximal and distal segment to complete the split.

In their clinical study, Plooij et al.[12] attempted to achieve a dorsally placed 'true Hunsuck' split (LSS1) after BSSO with a chisel. The lingual fracture line, however, progressed more anteriorly (LSS3) than was intended, in one third of all cases. This variability shows that the lingual fracture line is not precisely controlled, possibly due to the limited accessibility and visibility of this fracture line during the procedure. A path of least resistance could also be hypothesised, through the mylohyoid groove or mandibular canal, resulting in relatively more 'anterior' lingual fractures independent of the technique; however, this has not been confirmed.[15] Nevertheless, when running through the mylohyoid groove and/or the mandibular canal, it has been reported that there is a six-fold greater incidence of LSS3 than when it is not running through this groove and/or canal.[13, 15]

Muto et al.[16] investigated the influence of the bone cuts in SSO on the lingual splitting pattern. Favourable fracture patterns were achieved with a short horizontal bone cut just above the lingula, and an inferior border cut reaching into the lingual cortex. In our study, similar bone cuts were made in the chisel and splitter groups, so the bone cuts did not influence the lingual fracture patterns differently in the two groups.

Bockmann et al.[17] and Schoen et al.[18] demonstrated the use of an added osteotomy at the inferior border of the mandible. The aims of this added osteotomy were reduction of the torque required to complete the split, and a splitting pattern through the inferior border. In this current study, 70% and 60% of the fracture lines in the splitter and chisel groups respectively continued through the inferior cortex, without an added osteotomy. All other fracture lines originated from the superior extension of the inferior lingual border cut. In our opinion, it is therefore not necessary to perform this (difficult) added osteotomy.

It could be suggested that a more posterior lingual fracture is favourable, because a more anterior fracture line decreases the bony contact between the proximal and distal segment. Sufficient contact surface of the cortical plates was present in all the mandibles in our study, even in the mandibles with the most anteriorly positioned lingual fracture line. In our clinic, rigid fixation with three bicortical screws is applied after BSSO with a sagittal splitter and separators. No cases of insufficient bony contact have occurred in our clinic, and this technique reportedly results in good skeletal stability and few complications.[19] Some authors advocate a more posterior lingual split, to facilitate distal repositioning of the mandible.[17] In our opinion, persisting bone at the dorsal part of the mandible could in theory create difficulties, but this does not seem to form any impediment in the clinic. This was also the case in our study, and setback of the mandible seemed possible in all mandibles of both groups.

Although the operation technique with a sagittal splitter and separators thus possibly affects the lingual fracture pattern, it reportedly does not increase the risk of a bad split.[20, 21] Unfavourable fracture patterns (bad splits) are an important complication of the BSSO procedure. In this study, with the chisel technique one impending buccal plate fracture could be saved and with the splitter technique one unfavourable fracture line ended just in front of the mandibular foramen. It could be hypothesised that the chisel technique is more prone to buccal plate fractures, because the fracture line runs through the inferior cortex and the risk of running the chisel through the buccal cortex is present; as opposed to the splitter technique being more prone to lingual plate fractures, due to the force exerted on lingual cortex during the split and a more anterior lingual fracture pattern.

Wolford et al.[8] described the basic principles of the prying and spreading technique to decrease the risk of unfavourable fracture patterns. This design innovation placed modified preliminary bone cuts, directed toward strengthening the posterior aspect of the distal segment and decreasing the risk of a vertical fracture in the lingual cortex. The modification furthermore emphasised the importance of an inferior border cut completely through the inferior cortex and 2–3 mm into the lingual cortex, in order to prevent buccal plate fractures. This is similar to the findings by Muto et al.[22] Wolford et al.[8] further minimised the risk of a buccal bad split by applying the majority of pressure with an osteotome at the inferior border, similar to the split performed with our splitter-technique. In a later publication, Wolford et al.[23] reported another modification, adding an inferior border osteotomy with a reciprocating saw, to improve predictable splitting of the inferior mandibular border. This inferior border osteotomy is similar to the modification described by Bockmann et al.[17] and Schoen et al.[18], which was discussed earlier. In our study the preliminary bone cuts were the same in the chisel group and the splitter group, to prevent the osteotomy design influencing the lingual fracture patterns and the occurrence of bad splits.

It has been reported previously that the use of a splitter and separators results in a low incidence of neurosensory disturbances (5.1% per side).[14] In our study, visible nerve damage occurred in three cases in the chisel group. One explanation for the higher incidence of nerve dysaesthesia with the chisel technique might be the possibility of nerves coming into contact with the chisel when chiselling near the IAN, and subsequent nerve damage. The technique using a sagittal splitter and separators did not result in any visible nerve damage in our study, probably because they were not used near the IAN. Fiamminghi and Aversa[24] provided the first evidence for the risk of IAN lesions after the use of chisels in an experimental study. In a clinical study, Teerijoka et al.[7] showed that laceration of the nerve can occur during BSSO with chisels, resulting in disturbed IAN conduction. Ylikontiola et al.[25] demonstrated a strong correlation between manipulation of the nerve and neurosensory disturbances after BSSO. Although nerve manipulation between both segments of the mandible can occur during BSSO with a sagittal splitter and separators, no intra-mandibular instruments are used with this technique, thus preventing direct iatrogenic nerve damage.

Pig mandibles have proven to be a useful model in dental and orofacial research.[26] Study designs using cadaveric pig mandibles for maxillofacial research have been used successfully in many studies.[13, 17, 18, 27] Pig mandibles, nevertheless, differ from human mandibles in several ways and caution must be exercised when extrapolating results based on this fundamental research model to a clinical setting. Pig mandibles are longer, and contain more teeth. Fully-grown pig mandibles contain three molars, four premolars, one canine and three incisors. In our study, all the mandibles contained one unerupted molar and two erupted molars. The follicular space of the unerupted third molar had a bony margin. Although unerupted molars are part of the surgical field during BSSO, in the clinical setting their presence does not influence the splitting pattern or nerve damage.[12, 28] In this study, none of the splits fractured near the bony margin, therefore the fracture patterns were not influenced by unerupted molars. In pig mandibles, the mandibular canal is larger than it is in human mandibles. In our study, the IAN was visible in the proximal segment in all mandibles, making clinical evaluation of nerve damage possible in all cases. The larger canal may affect the risk of nerve involvement during BSSO, nevertheless this does not account for the nerve laceration associated with the chisel technique in this study. Our operating technique incorporated the Hunsuck modification[3] with the horizontal bone cut reaching as far as the concavity of the mandibular foramen (and not further towards the dorsal border), which promotes the ending of lingual fracture lines near the foramen. The more robust cortical bone in the angle region and dorsal border of pig mandibles as compared with human mandibles may also contribute to preventing a more dorsal pattern of the lingual fracture line during BSSO.

In this study, the preparation of the mandibles included a short boiling process to remove soft tissues, after which the mandibles were refrigerated at 1–3°C. The potential effects of the preparation process on bones were considered, and were described previously by Mensink et al.[13] No effect of the preparation can be expected. This was confirmed by the subjective evaluation of BSSO on a fresh mandible.

Thus, while pig mandibles are a useful and informative basic research model for the study of fracture patterns, these results must be regarded as a first step in acquiring knowledge about lingual fracture lines after BSSO. The assumptions and conclusions must be interpreted with caution, because this model does not refer to the clinical situation in living human individuals. Therefore, care must be taken when extrapolating these results to the clinic and evidently further research, for example on human mandibles, is necessary to confirm and clarify our findings.

CONCLUSION

In this study, performing SSO with a chisel did not result in a significantly more posterior lingual fracture line compared with SSO with a splitter, however, that tendency was observed. The technique with chisels and the technique with splitters both resulted in a reliable and reproducible lingual fracture pattern. Furthermore, splitting without the classic ‘mallet and chisel’ technique may prevent direct iatrogenic damage to the IAN. Therefore, we propose a spreading and prying technique, for example with a sagittal splitter and separators.

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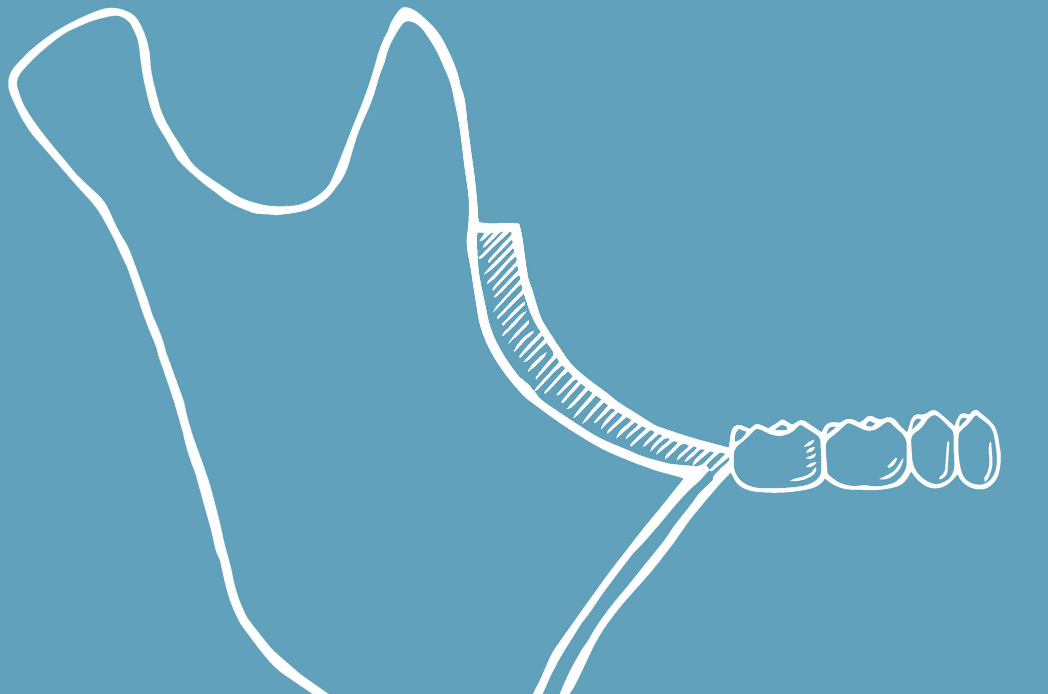

CHAPTER 9

Angled osteotomy design aimed to influence the lingual fracture line in bilateral sagittal split osteotomy: a human cadaveric study

This chapter is based on the manuscript:

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Angled osteotomy design aimed to influence the lingual fracture line in bilateral sagittal split osteotomy: a human cadaveric study

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ABSTRACT

The traditional osteotomy design in bilateral sagittal split osteotomy includes a horizontal lingual bone cut, a connecting sagittal bone cut and a vertical buccal bone cut perpendicular to the inferior mandibular cortex. The buccal bone cut extends as an inferior border cut into the lingual cortex.

This study investigated a modified osteotomy design including an angled oblique buccal bone cut that extended as a posteriorly aimed inferior border cut near the masseteric tuberosity.

We implemented a randomised controlled study. The study sample comprised 28 cadaveric dentulous mandibles. The primary outcome variable was the pattern of lingual fracture induced using the conventional (n = 14) and modified osteotomy (n = 14) designs. The secondary outcome variables included the incidence of bad splits and status of the inferior alveolar nerve (IAN). Descriptive and bivariate statistics were computed.

The angled osteotomy design resulted in a significantly higher number of lingual fractures originating from the inferior border cut (OR 1.54; 95%CI 1.27–1.86; $p < 0.01$), with a significantly more posterior relation of the fracture line to the mandibular canal (OR 2.11; 95%CI 1.22–3.63; $p < 0.01$) and foramen (OR 1.99; 95%CI 1.28–3.08; $p < 0.01$). No bad splits occurred with the angled design, whereas three bad splits occurred with the conventional design, although this difference was not statistically significant (OR 1.11; 95%CI 0.99–1.25; $p = 0.07$). IAN status was comparable between designs, although the nerve more frequently required manipulation from the proximal mandibular segment when the conventional design was used (OR 1.21; 95%CI 0.99–1.47; $p = 0.06$).

The results suggest that the angled osteotomy design promotes a more posterior lingual fracture originating from the inferior border cut and a trend was apparent that this may also possibly decrease the incidence of bad splits and IAN entrapment. These results must be carefully extrapolated to the clinical setting, with future studies clarifying our findings.

INTRODUCTION

Bilateral sagittal split osteotomy (BSSO) is a popular orthognathic surgical technique introduced by Trauner and Obwegeser.[1] Initially, the sagittal split of the ramus was induced by placing a horizontal bone cut in the lingual cortex just above the mandibular foramen and a parallel bone cut in the buccal cortex approximately 25 millimeters (mm) below the posterior mandibular border. These bone cuts were connected by sawing the ramus in the sagittal plane, thus completing the split.

Subsequently, modifications in the osteotomy pattern were suggested to increase the reliability of this technique. Dal Pont[2] advanced the buccal bone cut towards the second molar to increase bony contact between the mandibular segments. Hunsuck[3] suggested a shorter horizontal lingual bone cut and an inferior border cut completely through the inferior mandibular cortex, completing the sagittal split with a lingual fracture between these bone cuts.

These modifications included all the components of the contemporary osteotomy design.[4] This conventional osteotomy design includes three preliminary bone cuts: a horizontal lingual cut ending just posterior to the mandibular foramen, a connecting sagittal bone cut down the anterior border of the ascending ramus and a vertical buccal bone cut just distal to the second molar, running perpendicular to the inferior mandibular border. The buccal bone cut progresses as an inferior border cut through the inferior cortex, making an angle of 90° with the inferior cortex and reaching into the lingual cortex. Since the last modification by Hunsuck in 1968, the introduction of rigid fixation has further increased the stability and success rate of BSSO.[5-7] Furthermore, different instruments and techniques have been suggested to successfully complete the split, minimising complications.[8-10] Although these developments improved the BSSO technique, the osteotomy design remains mostly consistent.

We developed a modified osteotomy design aimed at increasing the predictability and reliability of the lingual fracture and minimising complications. This angled osteotomy design differs from the conventional design in that it includes an oblique buccal bone cut originating at the distal border of the second molar and ending inferiorly near the masseteric tuberosity. This angled buccal bone cut extends as a posteriorly aimed inferior border cut into the lingual cortex, making an angle of approximately 45° with the inferior cortex.

In this study, we aimed to analyse the lingual fracture patterns, incidence of bad splits and status of the inferior alveolar nerve (IAN) after BSSO using the conventional design and our modified design in cadaveric mandibles.

MATERIAL AND METHODS

This randomised controlled study included a total of 28 cadaveric dentulous mandibles randomised into the conventional osteotomy and angled osteotomy groups. All mandibles were fully grown and contained an adult dentition. They were obtained from anonymous post-mortem donors who had donated their bodies for research purposes. The donors' bodies were embalmed in formaldehyde for preservation purposes. The mandibles were surgically resected and soft tissues were separated by hand. Before surgery, the status of individual teeth and the mandibular dimensions, including mandibular body height and -width in the second molar region and the ramus breadth at the level of the mandibular foramen were recorded.

Mandibles from both groups were randomly divided between two surgeons, performing BSSO using a sagittal splitter and separator as described by Mensink et al.[10] In the conventional osteotomy group, BSSO was performed as described by Hunsuck[3] (Figures 1a and 1b). The horizontal lingual bone cut was placed approximately 3–5 mm above the mandibular foramen, ending in the deepest point of the concavity of the mandibular foramen. The sagittal connecting bone cut was placed to extend down the anterior border of the ascending ramus towards the distal border of the second molar, passing just medial to the lateral oblique ridge. The vertical buccal bone cut was a straight cut, perpendicular to the inferior mandibular border and just distal to the second molar. The inferior border cut was placed perpendicular to the inferior cortex, just extending into the lingual cortex.

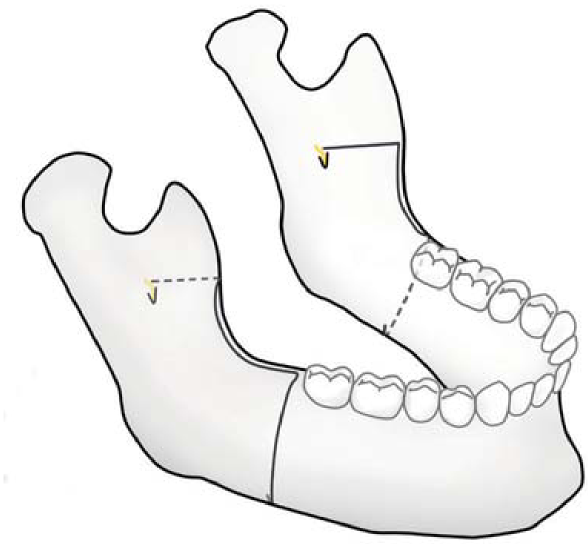

Figure 1a: *A schematic of the conventional osteotomy design described by Hunsuck.*

Figure 1b: *Bone cuts placed during conventional bilateral sagittal split osteotomy.*
A vertical buccal bone cut perpendicular to the inferior border of the mandible progresses as an inferior border cut perpendicular to the inferior mandibular cortex.

In the angled osteotomy group, our modified osteotomy design was used (Figures 2a and 2b), which included the same horizontal lingual and connecting sagittal bone cuts. The modification was the use of an angled vertical buccal bone cut making an angle of approximately 45° with the inferior border of the mandible. This angled buccal bone cut originated from the distal border of the second molar, extending towards the mandibular angle and ending near the masseteric tuberosity. The inferior border cut was therefore positioned near the masseteric tuberosity and was subsequently aimed in a posterior direction.

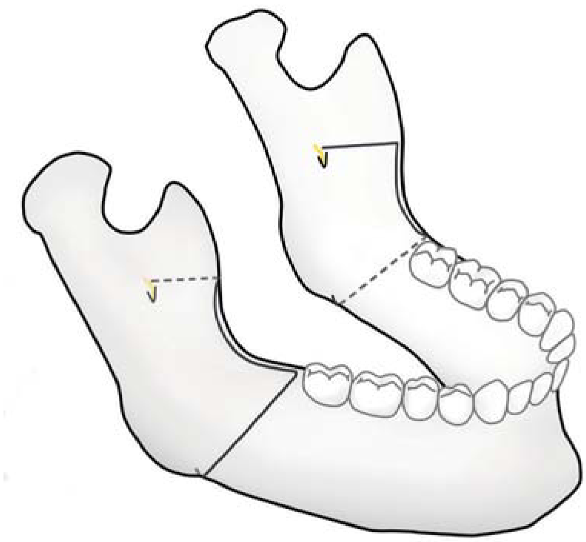

Figure 2a: A schematic of the angled osteotomy design. A modified buccal bone cut is placed towards the anterior border of the masseteric tuberosity, with a posteriorly aimed inferior border cut.

Figure 2b: Bone cuts placed during angled bilateral sagittal split osteotomy. An oblique buccal bone cut originating from the second molar and progressing towards the masseteric tuberosity, extending as an inferior border cut making an angle of approximately 45° with the inferior cortex.

Care was taken that both groups were to the greatest extent possible similar with regard to all other aspects of the osteotomy design such as for example the length of the medial horizontal osteotomy into the retrolingular fossa and the depth of the inferior border osteotomy in the lingual depression of the mandible. In both groups, the buccal bone cut was bevelled to enhance easy splitting of the mandible. The splitting technique with sagittal splitter and separator was the same in both groups.

The pattern of lingual fracture was evaluated in both groups. The start of the split was assessed as either originating from the inferior border cut and coursing through the lingual cortex or originating within and running through the inferior mandibular cortex. In the latter case, the mean length of the inferior cortex fracture was measured. The progressing lingual fracture line was analysed in relation to the mandibular canal and categorised as follows: coursing through the entire length of the canal, progressing through approximately two-thirds of the canal, progressing through approximately one-third of the canal and remaining posterior to the mandibular canal. The end of the split was recorded in relation to the mandibular foramen and defined to be either within the mandibular foramen or posterior to the mandibular foramen. We also categorised the fracture lines using a lingual split scale, previously described by Plooij et al.[11] In this scale, LSS1 represent a true Hunsuck fracture that remains posterior to the mandibular canal, LSS2 represents an even more posterior Obwegeser fracture that passes through the posteroinferior mandibular border, LSS3 represents a more anterior fracture that passes through the mandibular canal or mylohyoid groove and LSS4 represents unfavourable fractures, also known as bad splits.

We analysed the incidence of bad splits and assessed the status of the inferior alveolar nerve (IAN). The visibility of the nerve was defined as follows: not visible, less than 50% visible in the distal segment, more than 50% visible in the distal segment and completely visible in the proximal mandibular segment. If the IAN required manipulation from the proximal segment, this was recorded, and we assessed visible damage to the IAN in such cases.

This study was performed in accordance with the guidelines of our institution and followed the Declaration of Helsinki on medical protocol and ethics. Due to the ex-vivo nature of this study, it was granted an exemption in writing by the Leiden University Medical Center institutional review board.

Data analysis

Statistical analyses were computed using Statistical Package for Social Sciences (SPSS version 21.0 for OSX, IBM, Armonk, NY, USA) software. Descriptive analyses were used to evaluate the different aspects of the lingual fracture lines, the incidence of bad splits and the IAN status. Pearson's chi-squared tests and Student's t-test were used to assess associations between the two techniques. Generalised linear mixed models (GLMMs) were used to analyse significance of differences between the techniques, taking into account the repeated measurement design (left and right measurement within one mandible). Odds ratios (ORs) with 95% confidence intervals (CIs) were calculated. A probability value of less than 0.05 was considered statistically significant.

RESULTS

Sample characteristics

The mean number of teeth in each mandible was 11.8 (SD, 3.5; range, 4–16). There was no significant difference in the number of individual teeth between the two groups (Table 1). Third molars were included in 10 SSOs in the conventional osteotomy group and five SSOs in the angled osteotomy group; there was no significant difference between groups (OR, 0.39; 95% CI, 0.11–1.35; $p = 0.13$).

The mean height and width of the mandibular body were 23.7 mm (SD, 4.2; range, 15.0–35.0) and 14.3 mm (SD, 2.3; range, 8.0–19.0) and the mean breadth of the ramus was 7.7 mm (SD, 1.4; range, 5.0–11.0). No significant difference in mandibular dimensions was recorded between the two groups (Table 1). The mandibles were similar with regard to the horizontal lingual bone cut intro the retrolingular fossa, the sagittal connecting bone cut and the depth of the inferior border cut.

	Conventional osteotomy	**Angled osteotomy**	**p-value**
Number of teeth (n)	11.50	12.07	0.67
Incisors	3.29	3.93	0.10
Cuspids	2.00	2.00	1.00
Premolars	3.29	3.71	0.27
Molars	2.79	2.43	0.68
Body height (mm)	23.07	24.34	0.26
Body width (mm)	13.88	14.68	0.19
Ramus breadth (mm)	7.93	7.55	0.31

Table 1: Mean number of individual teeth and mean mandibular dimension values in the conventional osteotomy and angled osteotomy groups.

Conventional osteotomy design

After splitting according to the conventional osteotomy design, the lingual fracture line originated from the inferior border cut and coursed through the lingual cortex in 15 fractures, while it originated within the inferior mandibular cortex in 13. The mean length of the fracture through the inferior cortex was 10.42 mm (SD, 4.76; range, 3.00–18.00). Progression of the lingual fracture in relation to the mandibular canal was as follows: completely through the canal in 10 cases, originating inferiorly and subsequently progressing through at least two-thirds of the canal in seven cases, progressing through one-third of the canal in four cases and remaining posterior to the canal in six cases. Twenty-one fractures ended in the mandibular foramen and six ended posterior to the foramen. A total of 12 and 13 lingual fracture lines were classified as LSS1 and LSS3, respectively. Three bad splits (LSS4) occurred, including two lingual plate fractures and one buccal plate fracture originating within the inferior cortex and extending to the semilunar incisure (Figure 3).

The IAN was not visible in two cases, less than 50% visible in the distal segment in four cases and more than 50% visible in 14 cases. The nerve had to be manipulated from the proximal segment in seven cases.

Figure 3: A bad split after conventional bilateral sagittal split osteotomy.
It appears as a buccal plate fracture originating within the inferior cortex of the mandible and extending to the semilunar incisure.

Angled osteotomy design

In the angled osteotomy group, the lingual fracture line of 27 fractures originated from the inferior border cut and coursed through the lingual cortex. One lingual fracture originated within the inferior cortex and extended for a length of 5.00 mm. The progression of the split in relation to the mandibular canal was as follows: completely through the canal in four cases, originating inferiorly and progressing through at least two-thirds of the canal in two cases, progressing through one-third of the canal or less in 13 cases and remaining posterior to the canal in nine cases. Four fractures ended in the mandibular foramen and 24 posterior to the foramen. A total of 23 lingual fracture lines were classified as LSS1 and five fracture lines were classified as LSS3. No bad splits occurred.

The IAN was less than 50% visible after 11 splits and more than 50% visible after 15 splits. The nerve had to be prepared from the proximal segment after two splits.

Conventional vs. angled osteotomy design

In the angled osteotomy group, a significantly higher number of lingual fracture lines originated from the inferior border cut and coursed completely through the lingual cortex (OR, 1.54; 95% CI, 1.27–1.86; $p < 0.01$). Furthermore, the lingual fracture subsequently progressed posterior to the mandibular canal in a significantly higher number of splits in this group (OR, 2.11; 95% CI, 1.22–3.63; $p < 0.01$). The end of the fracture line was posterior to the foramen in a significantly higher number of splits in the angled osteotomy group (OR, 1.99; 95% CI, 1.28–3.08; $p < 0.01$). The lingual split scale identified a significantly higher number of LSS1 splits in the angled osteotomy group (OR, 2.44; 95% CI, 1.53–3.89; $p < 0.01$), while the conventional osteotomy group showed a greater number of LSS3 splits (Figures 4 and 5).

Three bad splits occurred in the conventional osteotomy group as opposed to none in the angled osteotomy group, although this difference was not statistically significant (OR, 1.11; 95% CI, 0.99–

1.25; p = 0.07). There was no significant difference in IAN visibility between the two techniques (OR, 1.34; 95% CI, 0.92–1.94; p = 0.12). Although the nerve required manipulation from the proximal segment more frequently in the conventional osteotomy group, there was no significant difference between groups (OR, 1.21; 95% CI, 0.99–1.47; p = 0.06). There was no visible damage to the IAN in both groups.

Figure 4: Lingual fracture after conventional bilateral sagittal split osteotomy. It is classified as an LSS3 fracture, which progresses completely through the mandibular canal.

Figure 5: Lingual fracture after angled bilateral sagittal split osteotomy. It is classified as an LSS1 split or a true Hunsuck split, which progresses posteriorly to the mandibular canal.

DISCUSSION

This randomised preclinical trial using cadaveric mandibles analysed the lingual fracture pattern and IAN status after BSSO using the angled osteotomy design and the conventional osteotomy design.

Our hypothesis was that a change in the angle of the buccal bone cut in BSSO could give a more predictable outcome with a posteriorly developing lingual fracture pattern. We found that the lingual fracture was more posteriorly located with the angled osteotomy design, as shown by the significantly more posterior relation of the fracture line to the mandibular canal and -foramen and the occurrence of more true Hunsuck (LSS1) splits. The use of the angled buccal bone cut, which resulted in a more distally placed (angled) inferior border cut, could explain this difference. With both osteotomy designs, the inferior border cut is placed at the end of the buccal bone cut progressing through the inferior cortex into the lingual cortex. However, with the angled osteotomy design, the inferior border cut through the inferior cortex is placed near the masseteric tuberosity and is aimed in a posterior direction. It makes sense that the fact that this osteotomy through the inferior cortex is located more posteriorly, could explain the lingual fracture pattern subsequently developing more posteriorly. The position and angulation of the bone cut thus resulted in a more posterior origin of the split, explaining the more posterior lingual fracture pattern.

With the angled osteotomy design, all but one lingual fracture originated from the inferior border cut (96.4%), compared with slightly more than 50% with the conventional osteotomy design (53.6%). When the sagittal split does not originate from the inferior border cut, but originates and courses through the inferior cortex, it provides the advantage of additional bony contact between both mandibular segments. Furthermore, it decreases the probability of creating a defect at the inferior mandibular border.[12] Especially with the Dal Pont lateral cut, where an inferior border cut is placed at a 90 degrees angle reaching into the lingual cortex, there is an increased risk the technique will result in this unaesthetic defect. However, a fracture through the inferior cortex is accompanied by the risk of the fracture line turning towards the buccal cortex, resulting in a buccal plate fracture. This occurred in one case in the conventional osteotomy group in this study (Figure 3). With the conventional osteotomy design, a total of three bad splits occurred, as opposed to none in the angled osteotomy group. Clinical studies have shown that conventional BSSO using sagittal splitter and separators does not result in a higher number of bad splits compared with other techniques.[12] It can be hypothesised that the angled osteotomy design further decreases the incidence of bad splits, thus increasing the reliability of the technique. In this study, a trend was apparent that the angled osteotomy could result in less bad splits but this difference was not statistically significant. Although the splits originated from the inferior border cut in almost all cases in the angled osteotomy group, this design can also decrease the risk of inferior border defects because the inferior border cut is placed more posteriorly (near the masseteric tuberosity). Therefore, the masseter muscle can mask unaesthetic defects, preventing visible inferior border defects in the masseter muscle region.

We hypothesised a more posterior lingual fracture with the angled osteotomy design, which can prevent IAN entrapment in the proximal segment. If the fracture develops more posteriorly it should involve the mandibular canal (and therefore the nerve) less than with a more anterior lingual fracture pattern. In this study we found no significant difference between the two groups regarding the visibility of the IAN after the split. Although the nerve had to be manipulated from the proximal segment less frequently with the angled osteotomy design, the difference was not statistically significant.

Several authors have described the influence of the osteotomy design on the lingual fracture line. Plooij et al.[11] showed that a longer horizontal lingual bone cut ending behind the anterior border of the mandibular foramen resulted in more LSS1 splits, i.e. a more posterior splitting pattern. In both groups in our study, we placed similar horizontal lingual bone cuts in the concavity of the foramen that ended behind the anterior border of the foramen. The horizontal lingual bone cuts were therefore the same with both the conventional and angled osteotomy design. Muto et al.[13] investigated the influence of the lateral (buccal) bone cut on the splitting pattern and reported a favourable split in the lingual cortex when the lateral bone cut extended through the inferior border into the lingual cortex, similar to the inferior border cut used in this study. Muto et al.[13] and Song et al.[14] further showed that a lateral bone cut remaining in the buccal cortex increased the risk of bad splits by causing unfavourable buccal plate fractures. In both osteotomy designs used in this study, the lateral bone cut did not remain in the buccal cortex but extended into the lingual cortex. With both the conventional and the angled osteotomy design, care was taken to make sure the inferior border cut completely reached into the lingual cortex and the buccal bone cut was bevelled exactly the same in both groups to prevent confounding effects of the different bone cuts in the osteotomy design.

Mensink et al.[15] hypothesised a path of least resistance through the mylohyoid groove, although they could not confirm this hypothesis. In their study, they performed conventional BSSO using sagittal splitters and separators in cadaveric mandibles16 and reported that 72.5% lingual fractures ended in the mandibular foramen; this value was 75% in our study. Other aspects of the splits were also roughly similar. Mensink et al.[16] also reported a reliable splitting pattern after BSSO using sagittal splitters and separators, without an increased risk of bad splits, which was confirmed by clinical studies.[12, 17]

The conventional osteotomy design has been used since 1968.[1-3] Over the years, several modifications in this design have been suggested. In 1987, Wolford et al. suggested that the horizontal lingual bone cut should be placed close to the lingula because increased medullary bone between the buccal and lingual cortical plates at this level could facilitate an easier split.[18] Furthermore, they advanced the buccal bone cut towards the distal border of the first molar to minimise the probability of encountering a nerve near the buccal cortex and to increase bony contact between the mandibular segments. We also advocate a horizontal lingual bone cut close to the lingula, preferably 3–5 mm above the lingula and ending in the concavity of the mandibular foramen. However, it remains controversial whether the advanced buccal bone cut, which leads to increased bony contact, is necessary to enhance the success of the procedure. This is particularly questionable when rigid fixation is used, which oissubly reduces the need for increased bony contact. A reliable and predictable result is expected with rigid fixation using either mini-plates or bi-cortical screws inserted through the superior border of the mandibular body.[19] An example, where the advanced buccal bone cut could be useful is when a BSSO procedure with the angled osteotomy design requires a large advancement of the proximal mandibular segment. It could be hypothesised that a more posteriorly located inferior border cut could limit the amount of possible advancement. In these BSSO cases with large advancements of the mandible the surgeon could consider using an advanced buccal cut towards the distal border of the first molar to facilitate the advancement.

In a later publication, Wolford et al.[8] suggested a parallel bone cut through the inferior cortex using a reciprocating saw to enhance the split through the inferior border. Schoen et al.[20] later reported a similar bone cut to decrease the magnitude of resistance encountered during splitting. The goal of using this additional bone saw in the inferior cortex was to increase the predictability and control of the split. This is supposedly accomplished by the decreased distance between the end of the inferior bone cut and the end of the horizontal bone cut, which results in an easy lingual fracture with little force. A similar mechanism resulting in a more predictable split because of a decreased distance between the preliminary bone cuts is observed with the angled osteotomy design. Wyatt[4] later advocated the extension of the buccal bone cut further anteriorly over the external oblique ridge, curving inferiorly near the first molar–second bicuspid region. The rationale for this anteriorly placed buccal bone cut was a wider mandibular body and a more lingual location of the IAN in this region, thus preventing nerve encounter and subsequent damage (as earlier mentioned by Wolford et al.[18]). A more anterior position of the buccal bone cut can also be considered with the angled osteotomy design; however, it is not necessary. Wyatt[4] advocated the use of a fine, flexible cement spatula chisel in all areas, thus increasing the need to prevent a nerve encounter with this sharp chisel. The requirement of this advanced buccal bone cut during BSSO using sagittal splitters and separators without any sharp instruments is therefore debatable.

Keeping the abovementioned modifications in mind, some authors advocated the use of the original horizontal mandibular osteotomy.[21, 22] This supraforaminal horizontal osteotomy includes an oblique bone cut through the ramus, placed above the mandibular foramen to prevent damage to the IAN. The most evident disadvantage of this challenging technique is the short proximal segment, making effective condylar positioning difficult and decreasing reliability. We therefore prefer BSSO as the treatment of choice in orthognathic surgery.

During BSSO using the angled osteotomy design, the buccal bone cut should be cautiously placed just through the buccal cortex without extending into the medullary bone to prevent damage to the IAN, which can be positioned near the buccal cortex as mentioned earlier. Additional pre-operative three-dimensional cone-beam computed tomography can be considered to assess the position of the IAN in relation to the buccal cortex. Furthermore, surgeons should cut completely through the inferior cortex. We prefer using Piezo-electric surgery to cut the inferior cortex, which prevents damage to the IAN and allows for an inferior border cut that extends completely into the lingual cortex. With the angled osteotomy design, we aim the inferior border cut in a posterior direction to achieve a posterior lingual fracture (LSS1 or true Hunsuck split).

The results of cadaveric studies should be carefully interpreted in relation to the actual clinical setting. Extrapolating these preclinical results based on a cadaveric study with fixation artefacts and bone behaviour differences to the clinic is always difficult. Cadaveric mandibles are formalinised for preservation purposes and have furthermore an increased visibility of the mandibular foramen because of the absence of soft tissues, thus making the clinical conditions easier. We tried to maximise the reliability of this study by using only dentulous mandibles in a simulated clinical setting. We therefore believe this study to be a suitable pilot for investigating the angled osteotomy design and we believe the observations are valuable for the clinician performing mandibular orthognathic surgery.

In conclusion, the angled osteotomy design promotes a reliable posteriorly developing lingual fracture pattern originating from the inferior border cut and furthermore a trend (although not statistically significant) was apparent suggesting this may decrease the incidence of bad splits and IAN entrapment. Further studies in the clinic, for example using cone-beam computed tomography, are required to evaluate the pattern of lingual fractures after BSSO and associated complications. This will eventually increase the reliability of the procedure and further decrease the complications of BSSO, such as bad splits and neurosensory disturbance caused by IAN damage.

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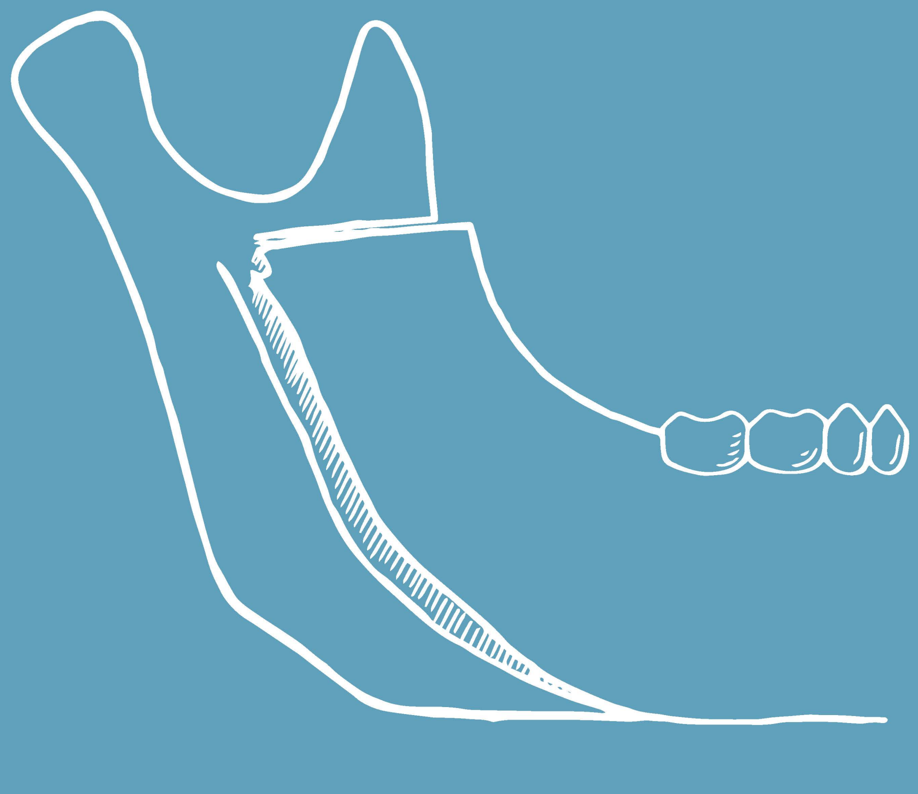

CHAPTER 10

Influence of the inferior border cut on lingual fracture pattern during bilateral sagittal split osteotomy with splitter and separators: a prospective observational study

This chapter is based on the manuscript:

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Influence of the inferior border cut on lingual fracture pattern during bilateral sagittal split osteotomy with splitter and separators: a prospective observational study

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ABSTRACT

Bilateral sagittal split osteotomy (BSSO) is a widely used orthognathic surgery technique. This prospective observational study investigated the correspondence between the planned inferior border cut and the actually executed inferior border cut during BSSO. The influence of the performance of the inferior border cut on lingual fracture patterns was also analysed.

Postoperative cone beam computed tomography (CBCT) scans of 41 patients, representing 82 sagittal split osteotomies were investigated. The inferior border cut was intended to penetrate completely through the caudal cortex. Descriptive statistics were used to analyse the planned and executed inferior border cuts. Mixed models were employed to investigate the influence of independent variables as the surgeon's experience on the inferior border cut and secondarily the inferior border cut on lingual fracture patterns and the incidence of bad splits.

The inferior border cut reached the caudal cortex in all cases, but only reached the lingual cortex in 38% of the splits. There was no significant relationship between the inferior border cut and a specific lingual fracture line.

In this study, postoperative CBCT analysis revealed that the bone cuts during BSSO were often not placed exactly as planned. Despite this, no significant relationship between the inferior border cut and lingual fracture patterns or bad splits was detected. Further research is needed to identify factors that could make the sagittal split more predictable.

INTRODUCTION

Orthognathic procedures are widely used for the correction of maxillofacial deformities. One of the most popular techniques is the bilateral sagittal split osteotomy (BSSO). The technique originates from Schuchardt[1] (1942), who introduced a modification of the horizontal subcondylar osteotomy previously described by Blair[2] in 1907. This modification consisted of two horizontal cortex osteotomies in the mandibular ramus, with the aim of bilaterally splitting the mandibular ramus. The first horizontal cut was placed just above the mandibular foramen at the lingual side of the ramus, and the second cut was positioned approximately 10 mm caudally at the buccal side.[1] This first version of the BSSO was subsequently popularised and further developed by Trauner and Obwegeser[3] in 1957. They extended the horizontal cut at the buccal side more caudally, so the distance between the bone cuts was approximately 25 mm.

Since then, several modifications have been suggested to improve the technique. Dal Pont[4] extended the buccal bone cut more ventrally towards the second molar, in order to increase bony contact and stability. Hunsuck[5] proposed a shorter horizontal bone cut at the medial side in order to achieve a controlled fracture in the lingual cortex, and was the first to complete the sagittal split by performing a controlled lingual fracture. Epker[6] later emphasised the importance of an inferior border cut that extended completely through the inferior cortex, for ease of splitting. Several authors subsequently advocated a cut through the inferior cortex of the mandible.[7-9] With this technique the full thickness of the lower border of the mandible remains on the proximal segment. The aim of this is to strengthen the proximal segment and thereby increase control of the lingual fracture and prevent unfavorable splits.[10]

The influence of the osteotomy design and orientation of the bone cuts on the lingual fracture pattern during BSSO have been the subject of recent research.[11-13] Modification of the osteotomy design can increase the predictability of the sagittal split.[12] An altered orientation of the bone cuts or incomplete bone cuts can, on the other hand, increase the risk of a bad split.[14, 15] Recent reports show that accomplishing the bone cuts completely as planned is a challenge, due to limited visibility during BSSO.[11, 14, 15] The course of the lingual split results from the design and the extent of the cortical bone cuts, including the type of manipulation during the splitting technique. Evaluation of the position of the bone cut as a factor in the sagittal split procedure is therefore important. Visualisation of the lingual part and inferior border of the mandible is compromised during surgery, and is only possible using (postoperative) cone beam computed tomography (CBCT) scanning. The chance of an incomplete bone cut due to limited visibility could therefore be high when performing the inferior border cut that was proposed by Epker.[6]

In this study, the position of the inferior border cut was investigated and secondarily the influence of this inferior border cut on lingual fracture patterns and unfavorable fractures was analysed.

MATERIAL AND METHODS

Study group

This study prospectively observed a consecutive group of 43 patients who received a BSSO alone or bimaxillary procedures either with or without genioplasty. The procedures were performed between January 2013 and July 2014 at the Department of Oral and Maxillofacial Surgery of the Leiden University Medical Center. The procedure was always performed by one of four experienced surgeons, usually supervising a resident on the contralateral side. All procedures were performed according to the same treatment protocol that included the use of postoperative CBCT as part of standard clinical follow-up.

The patients' medical files were screened for age at surgery, gender, malocclusion class, and simultaneous procedures (i.e. Le Fort I osteotomy or genioplasty). The postoperative CBCT scan was used to evaluate the position of the mandibular segments and the lingual fracture pattern within the first week after BSSO.

All consecutive patients that received BSSO in the aforementioned time period were included. Patients were excluded when alternative surgical techniques were used and in the case of incomplete data, for example when postoperative scans were not performed correctly and the bone cuts or fracture lines could not be visualised adequately.

The main outcome variable in this study was the position of the inferior bone cut, defined as either in the buccal cortex, in the inferior border or through the inferior border reaching into the lingual cortex. Secondary outcome variables were the lingual split pattern and the occurrence of a bad split possibly influenced by the inferior border cut.

Evaluation of the CBCT

A postoperative CBCT scan (Planmeca Promax®3D Max, 96 kV, 11 mA) was performed within the first week after BSSO. The patients' CBCT images were uploaded into Osirix v.5.7.1 32 in the form of DICOM files in order to generate a 3D reconstruction of the mandible. The view settings used were: WL/WW; CT bone, CLUT; 16 bit CLUT, opacity; linear table.

The mandible was separated from the scan and positioned in a symmetrical position by aligning the inferior borders, occlusal plane, and temporomandibular joints. A crop cube was generated and aligned with the inferior border of the mandible (Figure 1). The caudal position of the crop cube and the aligned mandible were not changed. The cube and mandible where subsequently rotated 90 degrees in order to get a perpendicular view of the caudal side of the mandible. This view was exported and subsequently used to derive measurements at the inferior border. The crop cube was then aligned with the buccal and lingual cortex of the distal segment and rotated to achieve a view perpendicular to the buccal and lingual side of the mandible. Once aligned, the region of interest was further explored by using the crop tool. Points of interest were specified in the CBCT and checked from the different views. Acquired projections were exported in standard format and subsequently used to derive further measurements. Contrast corrections were only used when difficulties involving split pattern tracing were present.

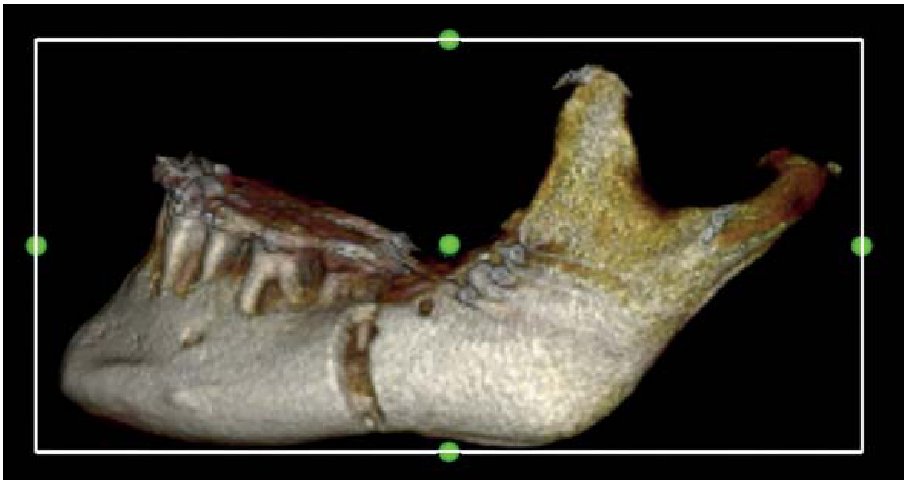


Figure 1: Alignment of the inferior borders, occlusal plane, and temporomandibular joints of the mandible in the crop cube.

Measurements

The inferior border cut was categorised as either ending in the buccal cortex, in the caudal cortex, or in the lingual cortex. If the inferior border cut was performed completely through the caudal cortex and extended into the lingual cortex, the length of the inferior border cut in the lingual cortex was measured.

The postoperative CBCT was evaluated in the abovementioned standardised lingual view, caudal view, and buccal view. First, the lingual view (constructed perpendicular to the lingual cortex, with the inferior borders exactly aligned) was assessed. When the inferior border cut was visible from the lingual view, the lingual corticalis was thus affected and the inferior border cut was categorised as ending in the lingual cortex. Second, the caudal view (constructed perpendicular to the tangent to the caudal border) was assessed. When the inferior border cut was not visible from the lingual view, but was visible in the caudal view, the cut was categorised as ending in the caudal cortex. When the inferior border cut was not visible from the lingual and caudal view, and thus did not reach into the caudal cortex, it was categorised as a cut ending in the buccal cortex.

The measurement of the inferior border cuts that extended into the lingual cortex was performed in the standardised lingual view (Figure 2). This measurement was defined as the distance in the cranial dimension from the inferior border of the distal segment to the end of the cut. In cases where difficulties were encountered in differentiating between the end of the cut and the beginning of the split in the perpendicular views, the reconstructed mandible was rotated in different directions to get a clear view of the end of the cut and beginning of the split. In unclear cases, the axial, coronal, and transversal views of the plain CBCT scans could furthermore be consulted in order to define this transition. A point of interest was placed at the end of the inferior border cut of the reconstructed mandible. This point was automatically transferred to all standardised views of the reconstructed mandible and enabled exact positioning of the end of the inferior border cut.

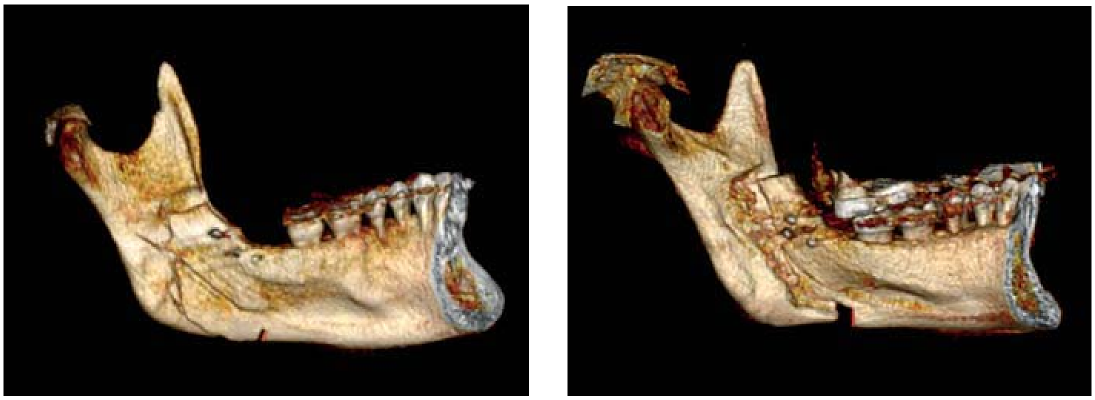


Figure 2: Measurement of the inferior border cut in the lingual cortex. (a) LSS1 fracture pattern that did not initiate from the (end of the) inferior border cut, but started from the caudal cortex, extending dorsally before reaching the lingual cortex. The red line represents the measured length of the inferior border cut. (b) LSS3 fracture pattern that initiated from the end of the inferior border cut. A clear transition from the inferior border cut into the lingual fracture is visible. The red line represents the measured length of the inferior border cut.

The lingual fracture line was evaluated using the lingual split scale (LSS).[11] A LSS1 split was defined as a fracture line originating through the caudal cortex and progressing caudal and dorsal to the mandibular canal ('true' Hunsuck). A LSS2 split was defined as a fracture line through the caudal and posterior cortex of the ramus. A LSS3 split was defined as a fracture line originating from the inferior border and progressing through the mandibular canal. A LSS4 split was defined as any other (unfavorable) fracture pattern (Figures 3 and 4). The lingual fracture patterns were scored by two observers, who evaluated the lingual fractures of every scan separately. Differences were subsequently discussed and classified based on a consensus between both investigators. If a consensus could not be reached, a third observer could be consulted.

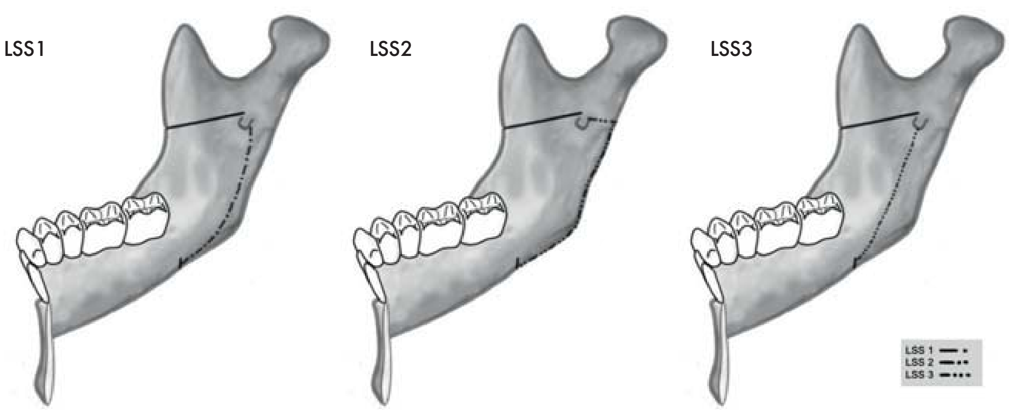
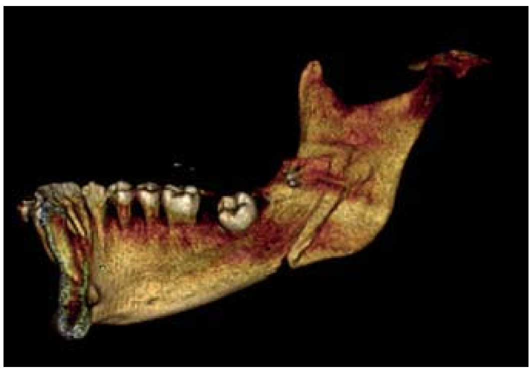


Figure 3: Different lingual fracture patterns according to the lingual split scale (LSS), as previously described by Plooij et al. (a) LSS1 fracture line originating from the caudal cortex and progressing through the caudal cortex, caudally and dorsally of the mandibular canal ('true" Hunsuck). (b) LSS2 fracture line through the caudal and posterior cortex of the ramus. (c) LSS3 fracture line originating from the inferior border (cut) and progressing through the mandibular canal.

Figure 4: 3D reconstructed models of the mandible from a lingual view. (a) LSS1 fracture line. In this case the inferior border cut was not visible from this lingual view as it ended in the caudal cortex.



(b) LSS3 fracture line progressing through the mandibular canal. The inferior border cut is not visible as it ended in the caudal cortex.

(c) LSS4 fracture line, or unfavorable split. Although the inferior border cut reached in the caudal cortex, the initiation of the fracture line was in the buccal cortex.

Surgical procedure

All BSSOs were performed according to the same treatment protocol, using the same surgical technique that was previously described by van Merkesteyn et al.[16] Splitting forceps and separators (Smith ramus separator, sagittal separators curved left and right, Walter Lorentz Surgical, Jacksonville, FL, USA) were used to perform all BSSO procedures without the use of chisels. The procedures were performed under general anesthesia, and local anesthetic was infiltrated (1:160000 Ultracaine D-S; Aventis Pharma, Hoevelaken, Netherlands).

The medial side of the ramus was exposed and a periosteal flap was elevated with a periosteal elevator to identify the mandibular foramen. The first bone cut was performed with a long Lindemann burr (2,3 mm x 22 mm), approximately 5 mm above the mandibular foramen and just dorsal of the mandibular foramen. The subsequent sagittal and vertical bone cuts were performed with a short Lindemann burr (1,4 mm x 5 mm). Based on surgical preference either a Lindemann burr or a Piezo

(Mectron, Piezosurgery 3) was used for the inferior border cut. The inferior border cut was aimed perpendicular to the caudal cortex of the mandible. In all cases, the surgeon attempted to perform the inferior border cut completely through the inferior cortex and reaching into the lingual cortex. A dental probe was used to check the extent of the inferior border cut.

To initiate the split, the splitting forceps and separator were placed in the vertical and sagittal cut respectively. First, the mobility of the fragments was checked vertically and horizontally by spreading the sagittal splitter and rotating the separator. Subsequently, the sagittal separator was replaced at the inferior border of the mandible and rotated again. The sagittal split was completed with the alternating use of the splitter and the separator.

When the inferior alveolar nerve was attached to the proximal segment, it was freed with blunt instruments or with the help of either a burr or Piezo. The nerve was always released before completing the sagittal split. Care was taken to prevent nerve damage by sharp bony spicules or instruments. Sharp bony spicules or edges of the mandibular canal were thoroughly removed via a round burr. Chisels were not used to perform BSSO, unless a small bridge of cortical bone at the inferior border between the proximal and distal segment was present.

After mobilisation of the mandibular segments, the mandible was placed into its new intermaxillary position using a wafer. Rigid fixation was performed with three bicortical screws in the upper border of the mandible (Martin GmBH, Tuttlingen, Germany: 9, 11, 13, or 15 mm long; diameter 2.0 mm). Champy plates (Martin GmBh, Tuttlingen Germany) where only used in the cases with a lingual fracture or fragile lingual bone due to removal of third molars.

Patients were discharged from our clinic within 2-4 days after surgery. Standard follow-up consisted of evaluations at 1 week, 3 weeks, and 6, and 12 months after BSSO.

Ethical statement

This study was performed in accordance with the guidelines of our institution and followed the Declaration of Helsinki on medical protocol and ethics. The study protocol was reviewed by the institutional review board (IRB) of the Leiden University Medical Center and because of the observational nature of this study, it was granted exemption in writing from IRB approval.

Statistical methods

Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS version 22.0 for Mac, SPSS inc., Chicago, IL, USA). Descriptive statistics were performed. Generalised linear mixed models (GLMM) were used to study the effect of the surgeon's experience on the classification of the inferior border cut, lingual fracture pattern, and the occurrence of a bad split. The same models were employed to study the effect of the classification of the inferior border cut on the lingual fracture pattern and the occurrence of bad splits. As all factors were assessed per side, mixed models were required to account for the correlated nature of the left and right side measurements within each patient. Probabilities of less than 0.05 were considered statistically significant.

RESULTS

A total of 43 consecutive patients were prospectively included in this study. Two patients were excluded, because BSSO was performed by a (guest) surgeon using alternative techniques. The total study group was thus comprised of 41 patients.

The 82 sagittal split osteotomies were performed by a specialist on 40 sides (48.8%) and by a resident under close supervision of a specialist on 42 sides (52.2%). The inferior border cut was performed with Piezo in 36 (43,9%) sagittal spits and with Lindemann burr in 46 (56,1%) sagittal splits. Patient characteristics are shown in Table 1.

	n (%)
Age (years)	26.8 (10.6), 14.2-55.4
Mean (SD), range	
Gender	
Male	20 (48.8)
Female	21 (51.2)
Malocclusion class	
II	33 (80.5)
III	8 (19.5)
Procedures	
BSSO	28 (68.3)
BSSO + Le Fort I	12 (29.3)
BSSO + Le Fort I + genioplasty	1 (2.4)

Table 1: Patient characteristics. The data represent the number of patients (%), unless otherwise specified.

CBCT revealed 51 inferior border cuts (62.2%) remaining in the caudal cortex and 31 inferior border cuts (37.8%) cutting completely through the caudal cortex and reaching into the lingual cortex. Of the 31 inferior border cuts in the lingual cortex, 19 (61.3%) were performed with Piezo and 12 (38.7%) were performed with a Lindemann burr. None of the bone cuts remained in the buccal cortex.

Of the cases where the inferior border cut reached into the lingual cortex, the mean length of the cut was 1.0 mm (SD 0.7, range 0.1–2.4). Of the 82 lingual fractures, 39 splits (47.6%) were classified as LSS1, 40 (48.8%) were classified as LSS3, and 3 (3.7%) were unfavorable fracture patterns classified as LSS4. No LSS2 fractures occurred (Table 2). In two sagittal splits, additional (partial) lingual fracture lines were recorded. The three LSS4 splits that were classified as bad splits all ran through the buccal cortex of the proximal mandibular segment. No bilateral bad splits occurred. No additional measures (i.e. different fixation methods) were necessary in any of the cases of a bad split. All sagittal splits were completed successfully. All lingual fracture patterns were classified from the CBCT images based on a consensus between the two primary investigators. The third observer did not need to be consulted.

	LSS1	LSS3	LSS4	Total
Inferior border cut in the lingual cortex	16	13	2	31 (37,8%)
Inferior border cut in the caudal cortex	23	27	1	51 (62,2%)
Total	39 (47,6%)	40 (48,8%)	3 (3,7%)	82 (100%)

Table 2: Lingual fracture patterns. The data represent the number of sagittal splits (%).

GLMMs were employed to investigate the influence of different factors while adjusting for the correlated nature of the data (left and right side within each patient). The experience of the surgeon was not statistically significantly associated with the classification of the inferior border cut (p = 0.59) or the lingual fracture pattern (p = 0.28). Bad splits occurred on the specialist's side in one patient, and on the resident's side in two patients. The surgeon's experience was not significantly associated with the occurrence of bad splits (p = 0.08).

Inferior border cut classification was not statistically significantly associated with lingual fracture pattern (p = 0.53). Bad splits occurred with the inferior border cut ending in the caudal cortex in one patient, and with the inferior border cut extending lingually in two patients. There was no significant association between inferior border cut classification and bad splits (p = 0.31).

DISCUSSION

This study aimed to assess the location of the inferior border cut during BSSO.

Subsequently, the association between the end of the inferior border cut and the lingual split pattern after BSSO was investigated. A complete inferior border cut was attempted in all patients, but achieved in little over 40% of the sagittal splits. When the inferior border cut did reach the lingual cortex, this did not significantly influence the lingual fracture pattern or the occurrence of bad splits.

To date, the investigation of human fracture patterns associated with BSSO has been limited to cadaveric studies, because of the concealed nature of the lingual fracture.[11] The use of CBCT now facilitates clinical evaluation of the different patterns of lingual fractures in living patients. Plooij et al.[11] recently described a lingual split scale to differentiate between a 'true Hunsuck' fracture (LSS1), a posterior 'Obwegeser' fracture (LSS2), an anterior lingual fracture line (LSS3), and an unfavorable fracture line (LSS4).

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Using this scale, we evaluated lingual fracture patterns and found no significant association between them and the inferior border cut. We believe this is mainly due to the fact that none of the inferior border cuts remained in the buccal cortex, and all cuts ended in either the caudal cortex or extended through the caudal cortex into the lingual cortex of the mandible. Thus, the buccal cortex was cut completely in all cases. In a previously published study by Muto et al.[14], the occurrence rate of bad splits was 15%, and in all of those cases the vertical cut ended in the buccal cortex without extending into or through the caudal cortex. This is concordant with Song et al.[15], who reported no bad splits if the inferior border cut ran through the caudal cortex and into the lingual cortex, and they also detected bad splits only when the inferior border cut was not thoroughly placed through the inferior cortex.

In a recently published report by Agbaje et al.[10], the authors suggest performing an inferior border cut into the caudal cortex that does not extend into the lingual surface, to prevent possible inferior border defects. However, we believe that with alternative osteotomy designs, a complete inferior border cut is possible especially when the cut is placed more dorsally near the masseter, and soft tissue can camouflage possible inferior border defects.[12] Further studies investigating inferior border defects are needed to clarify these findings.

In the current study, the inferior border cut was placed through the caudal cortex as planned in approximately 40% of the sagittal splits. In the other cases the completeness, orientation, or location of the inferior border cut was not precisely in accordance with the standard planning of this bone cut. Plooij et al. 11 described a comparable outcome for the medial bone cut in their study. They planned this horizontal bone cut just dorsal of the mandibular foramen, but actually placed this cut more ventrally in 66% of the cases. This disparity between the planned and actual placement of the bone cuts in BSSO is probably due to limited visibility during surgery, and emphasises the importance of postoperative CBCT usage in the contexts of both research and education. In this study a dental probe was used to check the extent of the inferior border cut as a tool to overcome the limited visibility. In this current study a complete inferior border cut through the caudal cortex was only observed in approximately 40% of the sagittal splits, which makes the use of the dental probe at least questionable.

Plooij et al.[11] also reported a significant association between the end of the medial bone cut and the split pattern. In that study, a horizontal bone cut ending just in front of the mandibular foramen resulted in LSS1 ('true Hunsuck') in 45% of cases, and LSS3 in 43%. A horizontal bone cut ending dorsal to the mandibular foramen resulted in LSS1 in 63% of cases, and LSS3 in 11%. In the current study, we attempted to place the horizontal bone cut just dorsal of the mandibular foramen, and observed 47.6% LSS1 fractures and 48.8% LSS3 fractures. Our technique using sagittal splitters and separators may account for the differences in fracture patterns.[16]

An association between the split pattern and third molar presence has been reported by both Reyneke et al.[17] and Kriwalsky et al.[18]. Furthermore, Verweij et al.[19] reported a significantly increased risk of bad splits when third molar removal was performed during BSSO. Zamiri et al.[20] reported that a smaller buccolingual thickness of the ramus was a risk factor for an unfavorable fracture in the lingual surface. Hou et al.[21] investigated cortical bone thickness dorsal to the mandibular canal, and reported that 75.38% of their splits proceeded as described by Hunsuck[5]. They also classified the shapes of the mandibular ramus in the axial plane into three categories, half-crescent moon, sim-triangle, and a well distributed shape. In that study, they reported that the half-crescent moon and sim-triangle shapes were associated with more splits, as was reported by Hunsuck[5], and that the well distributed shape was associated with more LSS2 splits as was reported by Plooij et al.[11] Hou et al.[21] showed that a split in mandibles with a high mandibular angle is more likely to progress as described by Hunsuck[5] (i.e., LSS1), and mandibles with a low mandibular angle showed more LSS2 split patterns.[11]

This study evaluated the position of the inferior border cut using postoperative CBCT scans. The development of the lingual fracture from the end of this bone cut can however cause a smooth transition impeding the exact definition of the end of the inferior border cut. When evaluating the sagittal views of the plain CBCT-scans, the differentiation between the end of the bone cut and the beginning of the fracture seemed difficult. In the reconstructed mandible, the transition from bone cut to lingual fracture was however clearly visible in almost all cases. The standardised views of the reconstructed mandible could be combined with the sagittal, coronal, and axial views of the plain CBCT-scans. If difficulties in the interpretation of the end of the bone cut were encountered in one view, the different views always clearly showed the exact position of the end of the inferior border cut and this point of interest could be indicated in the reconstructed mandible.

The visibility of the cuts on the lingual, caudal and buccal side of the reconstructed mandible is dictated by the orientation of the reconstructed mandible. To avoid measurement errors, the reconstructed mandible was symmetrically placed in a crop cube and the different views of the mandible were standardised according to the crop cube. By rotating the crop cube, the mandible was rotated simultaneously and could easily be placed in a perpendicular lingual, caudal and buccal view. A simple reproducible view was obtained by using this method.

This study revealed slightly more inferior border cuts extending through the lingual cortex by using Piezo compared with a Lindemann burr, (61.3% and 38.7% respectively). This could suggest that Piezo predisposes a complete inferior border cut into the lingual cortex. Although this relevant topic exceeds the scope of this study, future research should include the investigation of the influence of surgical instruments (e.g. Piezo versus burr) on the inferior border cut and subsequent lingual fracture patterns.

Based on the results of the current study, it is questionable whether or not an inferior border cut extending into the lingual cortex increases the predictability of a sagittal split. A potential explanation for these findings is that the bone cuts are often not performed as planned and an inferior border cut extending into the lingual cortex does not necessarily extend completely through the full thickness of the caudal cortex.

In conclusion, this study shows that postoperative CBCT imaging can facilitate the visualisation of concealed parts (e.g. the inferior border and lingual split patterns), and reveals discrepancies between planned bone cuts and actual bone cuts. The study also suggests that an inferior border cut extending through the lingual cortex does not necessarily lead to higher predictability of a split in BSSO.

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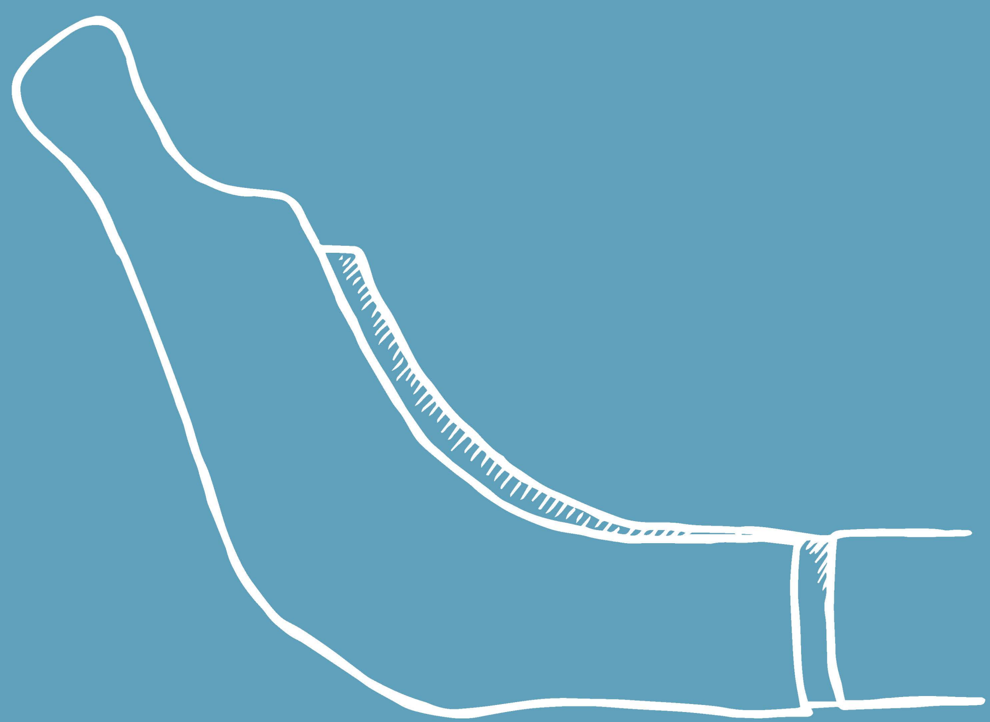

CHAPTER 11

Bilateral sagittal split osteotomy in a mandible previously reconstructed with a non-vascularized bone graft

This chapter is based on the manuscript:

Mensink G, Verweij JP, Gooris PJJ, van Merkesteyn JPR

Bilateral sagittal split osteotomy in a mandible previsouly reconstructed with a non-vascularized bone graft

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ABSTRACT

This case reports of a bilateral sagittal split osteotomy (BSSO) in a reconstructed mandible. A 28-year old woman underwent a segmental mandibulectomy, due to a multicystic ameloblastoma in the left jaw. After primary plate reconstruction, final reconstruction was performed with a left posterior iliac crest cortico-cancellous autograft. Because of a pre-existing Class II malocclusion, the patient was analysed for combined orthodontic-surgical treatment. Subsequently, after one year of orthodontic treatment, the BSSO was planned. The sagittal split was performed in the remaining right mandible and on the left side in the iliac crest cortico- cancellous autograft. Ten months later, oral rehabilitation was completed with implant placement in the neo-mandible as well. Follow-up showed a Class I occlusion, with good function. The patient was very satisfied with the functional and aesthetic results. This shows that a BSSO can be performed in a reconstructed mandible, without side effects and with good functional and aesthetic results.

INTRODUCTION

The bilateral sagittal split osteotomy (BSSO) is a frequent procedure in correcting a Class II malocclusion. Although the technique still presents a certain degree of technical difficulty, it has become a reliable procedure in orthognatic surgery. Reports of BSSO in a mandible, reconstructed with a non-vascularised bone graft, after hemimandibulectomy (because of an ameloblastoma), have not been published previously.

Multicystic ameloblastoma (MA) is an uncommon benign odontogenic neoplasm of the jaws. This cystic tumour is most often found in the mandible in the region of the molars and ramus. Ameloblastoma usually progresses slowly, but are locally invasive and, uncontrolled, may cause significant morbidity and sometimes death. The MA is the most common ameloblastoma and is considered the most aggressive variant. As curative treatment segmental mandibulectomy with a 1- to 1.5 cm linear bony margin is the treatment of choice in these cases.[1]

After (partial) resection of mandible, due to large benign tumours, reconstruction is necessary. Several reconstructive procedures, such as vascularised and non-vascularised bone flaps, can be considered.[2,3] A common technique is reconstruction with a non-vascularised iliac crest bone graft.[4]

After mandibular reconstruction, oral rehabilitation can be completed with implant placement. High survival and success rates after implant placement in autogenous bone grafts are reported, with an excellent prognosis of implant-supported prostheses.[5]

This study reports a case of a bilateral sagittal split osteotomy, in combination with implant rehabilitation in the non-vascularised iliac crest bone graft in a 33-year old woman after hemimandibulectomy, due to a multicystic ameloblastoma.

CASE REPORT

A healthy, 28-year old, female patient was diagnosed with a follicular type multicystic ameloblastoma in the body of the mandible, near the mandibular angle on the left side (Figure 1). The patient underwent a segmental mandibulectomy, starting between the first and second premolar to the ramus, with preservation of the left condyle.

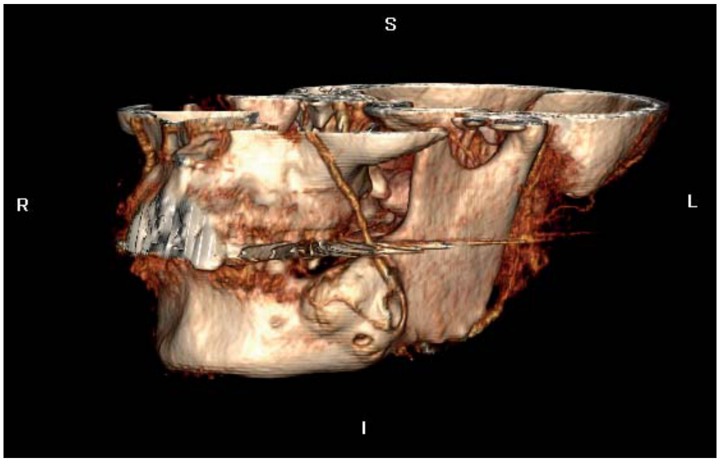

Figure 1: Three-dimensional image of the multicystic ameloblastoma in the body and angle of the left hemimandible.

Primary reconstruction was performed with a plate (UniLOCK Plate 2.4, angled, TiCP, SYNTHES, Oberdorf, Germany). Seven months later, after recovery and confirmation of clear pathologic margins, the mandible was reconstructed as described by Marx.4 Restoration of the left hemimandible was performed with a left posterior iliac crest cortico-cancellous autograft. The defect of the mandible was measured (17 mm by 56 mm) preoperatively, using an orthopantomogram (OPT). Via extra-oral approach the initial reconstruction plate was visualised and freed, because it had been fractured, due to trauma. A new similar plate was placed to support and fixate the bone graft. The cortico-cancellous graft was adjusted to the lingual side of the plate and kept in place by primary closure of the soft tissues in several layers. Recovery was uneventful and the graft consolidated in a slightly inferior position (Figure 2).

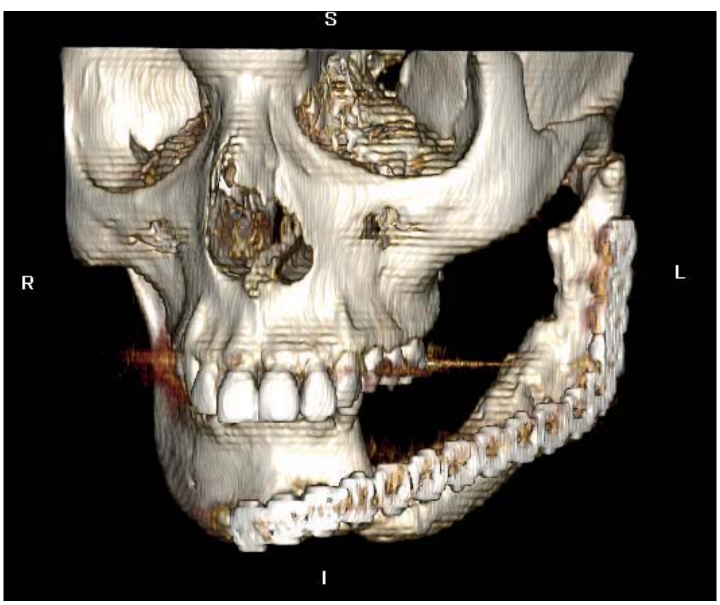

Figure 2: Three-dimensional image of the mandible after reconstruction with a plate and autologous bone from the left posterior iliac crest. The cortico-cancellous autograft consolidated in a slightly inferior position.

Postoperative follow-up showed a pre-existing Class II malocclusion with traumatic gingival recession in the maxillary incisors and generalised periodontitis (Figure 3 and 4). The second molar in the upper left jaw was absent. The second premolar and first molar of the upper left jaw showed no occlusion because of missing antagonists, after the hemimandibulectomy.

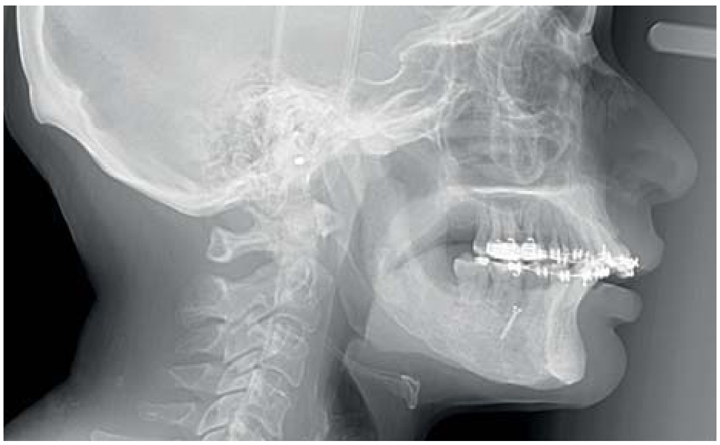

Figure 3: Lateral cephalogram taken one month before bilateral sagittal split osteotomy, showing a pre-existing class 2 malocclusion.

Figure 4: Photograph taken before BSSO, showing the contour of the successfully reconstructed mandible, resulting in a class II profile, with a shortened vertical length of the face.

Due to her Class II malocclusion with palatal soft tissue trauma, she was analysed for a combined orthodontic-surgical treatment and occlusal rehabilitation with implants. Radiographic examination in preparation for BSSO showed a bony union of the cortico-cancellous graft, diffuse periodontal reduction of bone and an impacted third molar in the right mandible. Initial treatment of the periodontitis was started.

Preceding the orthognatic surgery, one year previous to BSSO, the reconstruction plate was removed, combined with remodelling of the left hemimandible with autogenous bone from the right anterior iliac crest and removal of the impacted third molar (Figure 5). After successful treatment and stabilisation of the periodontitis, staged orthodontic and surgical treatment was initiated to restore occlusion and prevent further palatal and periodontal trauma.

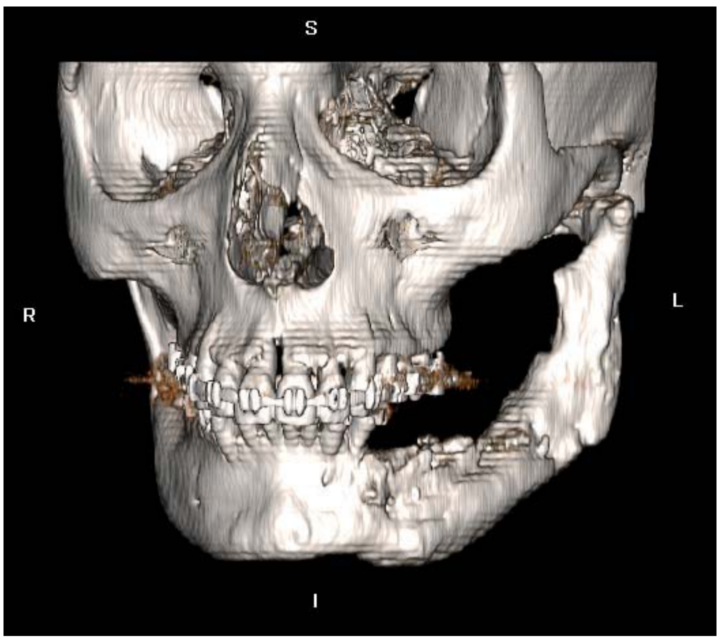

Figure 5: Three-dimensional image of the reconstructed mandible after removing the reconstruction plate and remodelling of the left hemimandible with autologous bone from the right anterior iliac crest.

After uneventful healing the patient was planned for orthognatic treatment, five years after the first operation. The bilateral sagittal ramus split on the right side was performed, with the use of sagittal splitters and separators instead of chisels, as first described by Van Merkesteyn and Mensink.[6,7] In the neomandible, the distal end of the iliac crest graft was found to be the site with the highest bone quality and quantity, therefore the split was planned in this section of the mandible. Horizontal, sagittal and vertical cuts were made with a saw (sagittal cut) and Lindemann burr (horizontal and vertical cut) and the split was completed with chisels in combination with sagittal splitters and separators. Chisels were necessary due to the small consistent cortical bone and could be used, because of the absence of the inferior alveolar nerve after hemimandibulectomy. After complete mobilisation of the proximal and distal parts, the mandible was placed into the new intermaxillary relationship using a wafer and intermaxillary wire fixation was applied.

After precise placement of the proximal segments, with normal clinical support of the temporomandibular joints, the right side was fixated with three bicortical screws in the upper border of the mandible. Then the iliac crest graft was subsequently fixated with two bicortical screws. After removal of the temporary intermaxillary fixation a new symmetrical Class I occlusion was created (Figure 6 and 7).

Figure 6: Lateral cephalogram showing a class 1 occlusion after bilateral sagittal split osteotomy and subsequent implant placement.

Figure 7: Photograph taken after BSSO, showing a class I profile as a result of the operation, with a normalized vertical length of the face.

Three months after BSSO, the initial stage of implant treatment took place. Two submucosal implants (length 13 mm, diameter 3.8 mm, Branemark, Nobel biocare, Houten, the Netherlands) were placed in the position of the former second premolar and first molar of the left mandible. Seven months after implant placement, the implants were recovered to place 2 healing abutments. Subsequently the prosthetic phase started, after healing of the wound.

From the first operation to the Class I occlusal rehabilitation took about six years. At the last follow-up the patient had a good function and was satisfied with the result.

DISCUSSION

The different treatment options for patients with ameloblastoma range from enucleation and curettage to more radical surgical management, such as marginal or segmental resection. Multicystic ameloblastomas (MA) are more aggressive and associated with a higher rate of recurrence in comparison with unicystic or peripheral ameloblastoma.[1] MA of the follicular type shows the highest percentage of recurrence. Because this patient was diagnosed with a MA of the follicular type, radical surgical management was indicated. Segmental mandibulectomy with histopathologically clear bony margins is the most effective in preventing recurrence and was therefore the treatment of choice in this case.[1]

After segmental resection of the mandible, different methods of reconstruction can be chosen. The two most frequently used techniques are reconstruction with a vascularized bone flap (VBF) or a non-vascularized bone graft (NVBG). VBF, often in the form of a vascularized fibular free flap, is the most commonly used technique for reconstruction, with high success rates and high endosseous implant success.[8] In patients with prior radiation therapy or very large defects (>60 mm), reconstruction with a VBG is the therapy of choice, because these factors significantly decrease success rates of NVBG.[9]

However, NVBG are widely used as well and can be very useful, especially in secondary reconstructions. Non-vascularized bone grafts allow for an easier reconstruction, with higher functional success and create a better contour and bone volume for facial aesthetics and subsequent implant insertion than VBF.[9,10] In this case, no prior radiation therapy was necessary because of the nature of the tumor and the mandibular defect was less than 60 mm. Primary reconstruction with a plate was performed in order to be able to confirm histopathologically clear bony margins before secondary reconstruction. Because of the mentioned advantages, secondary reconstruction was subsequently done with a non-vascularized iliac crest posterior autograft.

The most common complication after BSSO is damage to the inferior alveolar nerve, resulting in neurosensory disturbances of the lip and/or chin, also known as hypoesthesia. In this patient hypoesthesia was already present on the left side, due to the previous hemimandibulectomy. This made the use of chisels in addition to our conventional technique favorable, because of small cortical bone in the iliac crest autograft. On the right side the inferior alveolar nerve was not damaged using only sagittal splitters and separators and no hypoesthesia was present after BSSO. Other complications after BSSO, such as bad splits, infection, non-union, bleeding complications and osteomyelitis are not very frequent and were not present in this patient.

Oral rehabilitation with implant placement is often an important part of the dental reconstruction after mandibular reconstruction and helps prevent recurrence of malocclusion. High success and survival rates after implant placement in bone grafts have been reported.8 Dental implants placed in a non-vascularized bone graft provide a reliable basis for dental rehabilitation.5 The moment of implant placement is normally several months (3-4 months) after bone augmentation or reconstruction. In this case implant placement concomitant with BSSO was considered, but postoperative implant placement was preferred, because of the altered position of the mandible after BSSO. When the patient discovered she was pregnant, placement of dental implants was delayed. Dental implant placement was nevertheless necessary, because of the proceeding bone reduction and was thus commenced later than planned, after more than five months of pregnancy.

In our patient, occlusion class I remained present after BSSO, with good functional and aesthetic results. Hypoesthesia on the left side was pre-existent after hemimandibulectomy and hypoesthesia was absent on the right side. No other complications after BSSO were present and successful implant placement resulted in full oral rehabilitation. This shows the bilateral sagittal split osteotomy can be performed in a reconstructed mandible, with no side effects and a good result.

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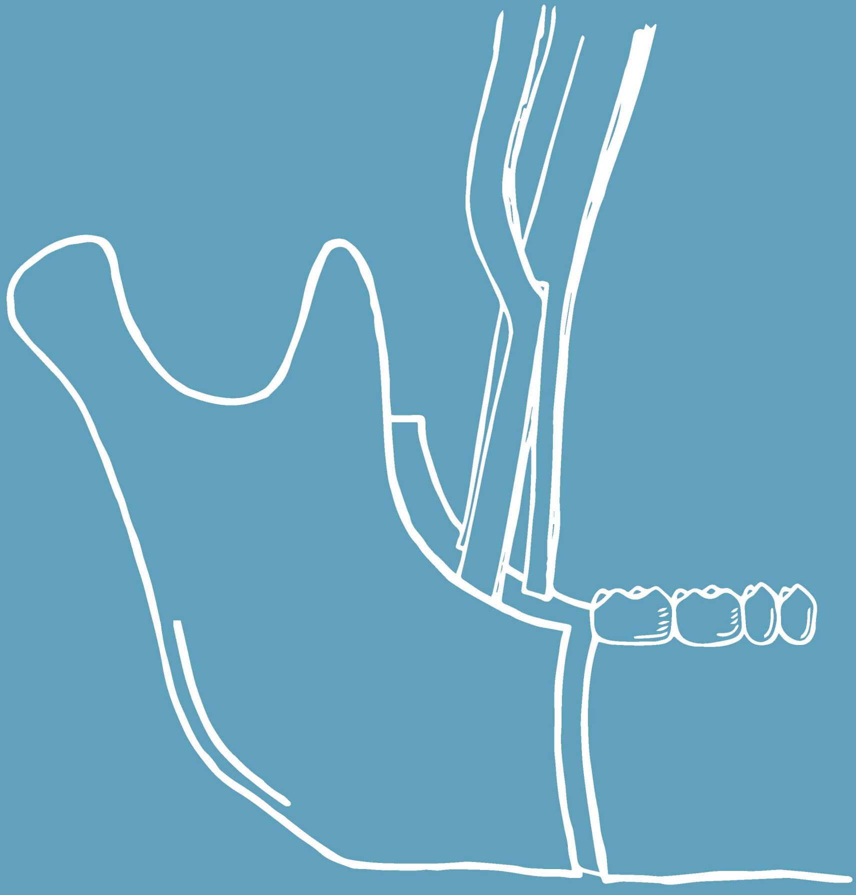

CHAPTER 12

Discussion and future perspectives

DISCUSSION AND FUTURE PERSPECTIVES

Aims of the thesis

This thesis aimed to investigate the risk of complications associated with bilateral sagittal split osteotomy (BSSO), performed with a splitter and separators. Specific risk factors for intra- and postoperative complications as well as factors influencing the predictability of the technique were analysed in order to increase predictability of the split and minimise the risk of complications.

The elective nature of BSSO demands a reliable and predictable procedure with minimal risk of complications. Individual patient counselling using patient-specific information regarding the benefits and risks of the procedure are also vital in this process.

In this thesis, risk factors for common complications associated with BSSO were assessed through a systematic review of the literature. Furthermore, the occurrence of complications with the splitter-separator technique and risk factors for these complications were investigated through retrospective studies. The patterns of lingual fractures during BSSO and the predictability of the lingual fracture with our splitter-separator technique was investigated and compared with techniques using other instruments (i.e. mallet and chisels) or other osteotomy designs (i.e. angled osteotomy design) in cadaveric studies.

General considerations regarding the technique

In the research that was conducted in this thesis, BSSO was performed according to the Hunsuck[1] modification using a sagittal splitter and separators.[2, 3] Rigid fixation was usually performed using three bicortical screws unless the use of miniplates was indicated.

When the BSSO technique was introduced by Schuchardt[4] and Obwegeser[5], the sagittal split was performed with a mallet and chisels. Since then, different modifications of the osteotomy design have been proposed. Dal Pont[6] suggested advancing the buccal bone cut towards the distal border of the second molar to increase bone contact surface between the mandibular segments. Hunsuck[1] modified the lingual bone cut and was the first to complete the sagittal split with a controlled lingual fracture instead of completely chiselling through the mandible. In this design, an inferior border cut through the caudal cortex was performed. The importance of this bone cut in the caudal mandibular cortex, aimed to promote predictable splitting, as well as the importance of biological factors, such as minimal periosteal elevation, were subsequently emphasised by Epker[7]. With these improvements, the basic components of the contemporary osteotomy design for the sagittal split were in place.[8] However, important innovations were still to come.

The first decades after its introduction, BSSO was fixed using wires and intermaxillary fixation.[1, 4-7] Innovations in fixation techniques, however, introduced the use of rigid fixation by bicortical screws or monocortical miniplates.[9-11] This minimised the need for intermaxillary fixation, thereby reducing patient discomfort and making the procedure much more patient friendly. Rigid fixation furthermore improved the stability and reliability of the outcome after BSSO.[9-11]

The introduction of BSSO using prying and spreading techniques meant another important innovation for the procedure.[2] The most important reason for this improvement was the risk of iatrogenic damage to the inferior alveolar nerve when using chisels during BSSO.[12] Different instruments can be used in these prying and spreading techniques.[13, 14] In our opinion and experience, the sagittal splitter and separator are the most well-designed instruments to perform a prying and spreading technique.[3]

Nevertheless, complete control over the lingual fracture during BSSO is still not achieved and complications do still occur. This thesis aims to elucidate the factors influencing the lingual fracture and common complications associated with BSSO.

Neurosensory disturbances

Permanent neurosensory disturbance of the lower lip is one of the most important complications associated with BSSO, especially since neurosensory alteration has a serious impact on the patient's daily life.[15] It presents as either dysesthesia (pain), paresthesia (altered sensation), hypoesthesia (reduced sensation) or anesthesia (no sensation), of which hypoesthesia is the most common presentation.[16] In most cases, normal sensation returns shortly after BSSO.[17] If neurosensory disturbances are still present one year after surgery, they are considered permanent.[18]

Altered sensation is a side effect of BSSO that was described shortly after the introduction of the technique.[19, 20] The inferior alveolar nerve (IAN) runs through the mandible and therefore the risk of iatrogenic nerve damage during splitting of the mandible was soon evident. Early techniques performed the sagittal split with chisels, which is still the norm in several clinics today.[21-23] The use of sharp instruments near the mandibular canal is associated with a risk of direct iatrogenic nerve damage, especially when tapping chisels along the inner side of the buccal cortex.[24, 25] Sudden forces that are exerted on the mandible when hitting an instrument through the bone, can furthermore cause indirect damage to the IAN.[26] More subtle prying and spreading techniques cause less sudden forces around the nerve and minimise the risk of altered sensation.[2, 3] These prying and spreading techniques are generally accompanied by a lower risk of permanent neurosensory disturbance after BSSO.[12]

Nevertheless, the occurrence of neurosensory disturbances after BSSO is multifactorial. Important surgical factors that can cause nerve damage include: stretching of the IAN during medial dissection near the mandibular foramen, laceration of the IAN during the vertical bone cut when the nerve is positioned near the buccal cortex, puncturing of the IAN due to sharp bone spicules between the mandibular segments, or compression on the IAN due to rigid fixation.[27, 28] The surgeon should be aware of these important factors in order to prevent neurosensory disturbances as much as possible.

Several patient factors might also play a role in the development of altered sensation. These factors are furthermore vital in individual patient counselling, when informing patients about their risk of complications associated with BSSO. Specific mandibular morphology, for example a long mandibular angle or low body height, could predispose neurosensory disturbance of the IAN.[28-30] However, the most frequently mentioned risk factor for altered sensation after BSSO is the patient's age. Older patients report significantly more neurosensory disturbance after BSSO than younger patients.[31-33] Older patients have furthermore been reported to experience more burden in daily life because of persisting neurosensory disturbance.[34] The effect of age on the risk of altered sensation after BSSO is clearly demonstrated in Chapter 3. The incidence of neurosensory disturbances after BSSO was especially low in patients that were younger than 19 years (4.8% per patient).[35] Therefore considering BSSO at a young age can be advocated, in an attempt to reduce the risk of this complication. These findings furthermore enable correct preoperative counselling and provides patient-specific information.

Bad splits

Unfavourable fracture patterns, also known as bad splits, can complicate the sagittal splitting procedure.[19, 20, 36, 37] This can be frustrating for the surgeon, but usually causes no long-term consequences for the patient.[38] Bad splits do however frequently necessitate additional fixation techniques, including intermaxillary fixation in rare cases.[38, 39] Seldom, the operation even has to be ceased and re-BSSO can be performed at least six months later.

Bad splits are subdivided in relatively frequently occurring buccal- or lingual plate fractures, and more infrequently occurring fractures of the coronoid process or condylar neck with possible extension into the condyle. Buccal- and lingual plate fractures are further subdivided in horizontal or vertical fractures.[40]

The surgical technique plays an important role in the development of bad splits.[41] Careful application and subsequent control of the bone cuts is necessary to assess the completeness of the performed bone cuts before using the splitting forceps.[42] An incompletely cut inferior border or too high horizontal bone cut could predispose bad splits. It could furthermore be hypothesised that the surgical technique with splitter and separators is accompanied with a different risk of bad split than traditional techniques with chisels. This thesis therefore investigated the incidence of bad split after BSSO with splitter and separators. Chapter 4 showed that the splitter-separator technique is associated with an incidence of bad split of 2.0% per sagittal split osteotomy (SSO). This is well within the range that is reported in the literature (0.5-5.5% per SSO).[43] BSSO with splitter and separators is thus associated with a risk of bad split that is similar to the risk of bad split with other techniques.

Several risk factors for bad splits have been reported. Increasing age has been reported as a risk factor for bad splits.[39] However, there is still no robust evidence that patient age influences the risk of bad split.[42] The presence of third molars has also frequently been identified as a risk factor for bad split during BSSO. The presence of a third molar makes the surgical procedure more difficult. In Chapter 7, third molars were found to increase the risk of bad split but not the risk of other complications.[44] Nevertheless, other authors found no relation between the presence of third molars and bad split.[42] Therefore, the choice to remove third molars prior to surgery remains debatable. Some authors advocate the removal of third molars at least six months prior to BSSO, in order to facilitate an easy and predictable procedure.[45] Other authors, however, propose removing third molars during BSSO to spare the patient one or two unpleasant additional surgical procedures before BSSO.[46] Factors that could influence this decision of third molar removal either during BSSO or six months preoperatively include the patient's age, the experience of the surgeon, and the spatial positioning of the third molars.[39, 47-51]

Removal of osteosynthesis material

Rigid fixation has been introduced in the 1970's.[9, 10] Since then, it has become standard to fix the mandibular segments after BSSO with either bicortical screws or monocortical miniplates. This eliminated the routine need for intermaxillary fixation. One common complication after BSSO is the need to remove this titanium osteosynthesis material because of symptoms, such as infection, palpability of the hardware, or other subjective complaints.[52-54] These symptoms cause significant morbidity for the patient and result in additional procedures after BSSO.[55] Therefore, removal of osteosynthesis material should be minimised as much as possible.

Chapter 5 reported a comparison of the removal rates for screw fixation and plate fixation, showing that bicortical screws are removed remarkably less than monocortical plates.[56]

These findings could be a reason to perform fixation after BSSO with bicortical screw fixation instead of monocortical plate fixation. However, other aspects of the two techniques are also important.[57, 58] Favourable aspects of plate fixation are that it can be fixed intra-orally without the need for a stab incision in the skin, plates require less precaution to avoid excessive rotation of the proximal segment, and there is no risk of damaging the inferior alveolar nerve with monocortical fixation.[58] On the other hand, favourable aspects of bicortical screws are the fact that they are less expensive than miniplates, and the risk of palpability of the hardware or chronic irritation is lower.[57] When bicortical screws are used, it is important to perform position fixation without compression of the mandibular segments. Lag screw fixation has been shown to cause compression of the inferior alveolar nerve between the mandibular segments and subsequently predispose neurosensory disturbances.[59]

Osseous mandibular inferior border defects

Mandibular inferior border defects are an unaesthetic complication, wherein a bone defect postoperatively develops at the caudal end of the vertical bone cut.[60] BSSO is aimed to restore a class I occlusion with good function, but usually also improves facial harmony and aesthetics. It is evident that in this process, the occurrence of inferior border defects should be avoided.[61]

Several risk factors can predispose osseous inferior border defects, such as large mandibular advancements and inclusion of the full thickness of the mandibular border in the split (i.e. a type II split).[60] Chapter 6 confirmed these earlier reported risk factors and furthermore showed that increased clockwise rotation of the occlusal plane and significant cranial rotation of the proximal mandibular segment were relevant risk factors for inferior border defects.

The surgical technique could also play a role in the occurrence of osseous inferior border defects.[61, 62] Chapter 8 showed that in BSSO, the chisel-technique and splitter-separator technique result in different lingual fracture patterns (i.e. type of split). Fractures started through the caudal cortex more frequently when using chisels compared to splitter and separators. The splitter-separator technique could therefore facilitate type II splits and subsequently predispose osseous inferior border defects.

The clinical consequences and unaesthetic effects of these complications are yet to be determined. When an unaesthetic mandibular inferior border defect is present, secondary reconstruction techniques to correct the contour of the mandibular border can be performed, for example using Medpore implants or using autologous bone or bone substitutes with a (titanium-reinforced) membrane.

Lingual fracture patterns and predictability of the split

In the traditional osteotomy design, a lingual, sagittal, and buccal bone cut are placed just through the cortical bone in order to perform a controlled fracture in the lingual cortex.[1] Several authors furthermore propose performing an inferior border cut through the caudal cortex extending to the lingual side in order to predispose a start of the fracture line in the lingual cortex.[7, 63, 64] Subsequently, the proximal and distal mandibular segments are mobilised.

Different variations of the osteotomy design are used in BSSO, and the (horizontal) lingual bone cut and (vertical) buccal bone cut can be modified with regard to the length and angulation of the bone cuts.[65] Some authors even advocate performing an additional inferior border osteotomy towards the mandibular angle.[61, 66, 67]

Establishing the optimal osteotomy design by rearranging the bone cuts or even adding additional bone cuts could reduce the risk of bad split and improve the predictability of the technique.[61, 68] These differences in the bone cuts of the osteotomy design of BSSO can furthermore result in different lingual fracture patterns. Plooij et al.[69] categorised these fracture patterns in their lingual split scale (LSS). They described a 'true Hunsuck' vertical fracture line to the inferior border of the mandible (LSS1), an 'Obwegeser-Dal-Pont' horizontal fracture line to the posterior border of the ramus (LSS2), and a fracture line through the mandibular canal to inferior border of the mandible (LSS3). Unfavourable fracture patterns were categorised as LSS4 splits.

Furthermore, during BSSO the bone cuts are not always performed completely as planned, because of limited visibility and little workspace on the lingual side of the mandible.[69] The complete performance of the bone cuts of the osteotomy design is an important factor in the development of the lingual fracture and the risk of bad splits.[69-71] When the vertical bone cut is performed incompletely and ends in the buccal cortex, it has shown to predispose bad splits.[70, 71] When the bone cut either ends in the caudal cortex or an inferior border cut extending into the lingual cortex is performed, the risk of bad split is relatively low.[70] In Chapter 10 of this thesis, in a prospective observational cone-beam computed tomography study, the different lingual fracture patterns after

BSSO were examined. There was no significant association between the length of the inferior border cut in the lingual cortex and the lingual fracture patterns. More research is needed to further investigate the exact association between the osteotomy design and the lingual fracture to increase the predictability of the BSSO technique.

Future perspectives

This thesis investigated different risk factors for complications associated with the BSSO technique with sagittal splitter and separators. Nevertheless, complications do still occur and further research should be aimed at increasing the predictability of the technique and reduce the risk of adverse outcomes even more.

The splitter-separator technique is associated with a low incidence of permanent neurosensory disturbances after BSSO. Future clinical research should however aim for further reduction of this important complication of BSSO, as neurosensory disturbances cause the most morbidity and dissatisfaction for patients. Innovations such as CBCT-analysis and piezo-surgery might help minimize the risk of neurosensory disturbances as a result of BSSO.

The development of different lingual fracture patterns remains largely unexplained. Future research aimed to identify predictors for specific lingual fracture lines could help to improve the predictability of the technique and help better understand the occurrence of bad splits. Patient-specific planning with regard to the osteotomy design could also help promote an easy, predictable splits and prevent complications. Prospective research exploring the ideal orientation and arrangements of the bone cuts in BSSO, and the relation between the lingual fracture patterns and complications could further increase the success of BSSO.

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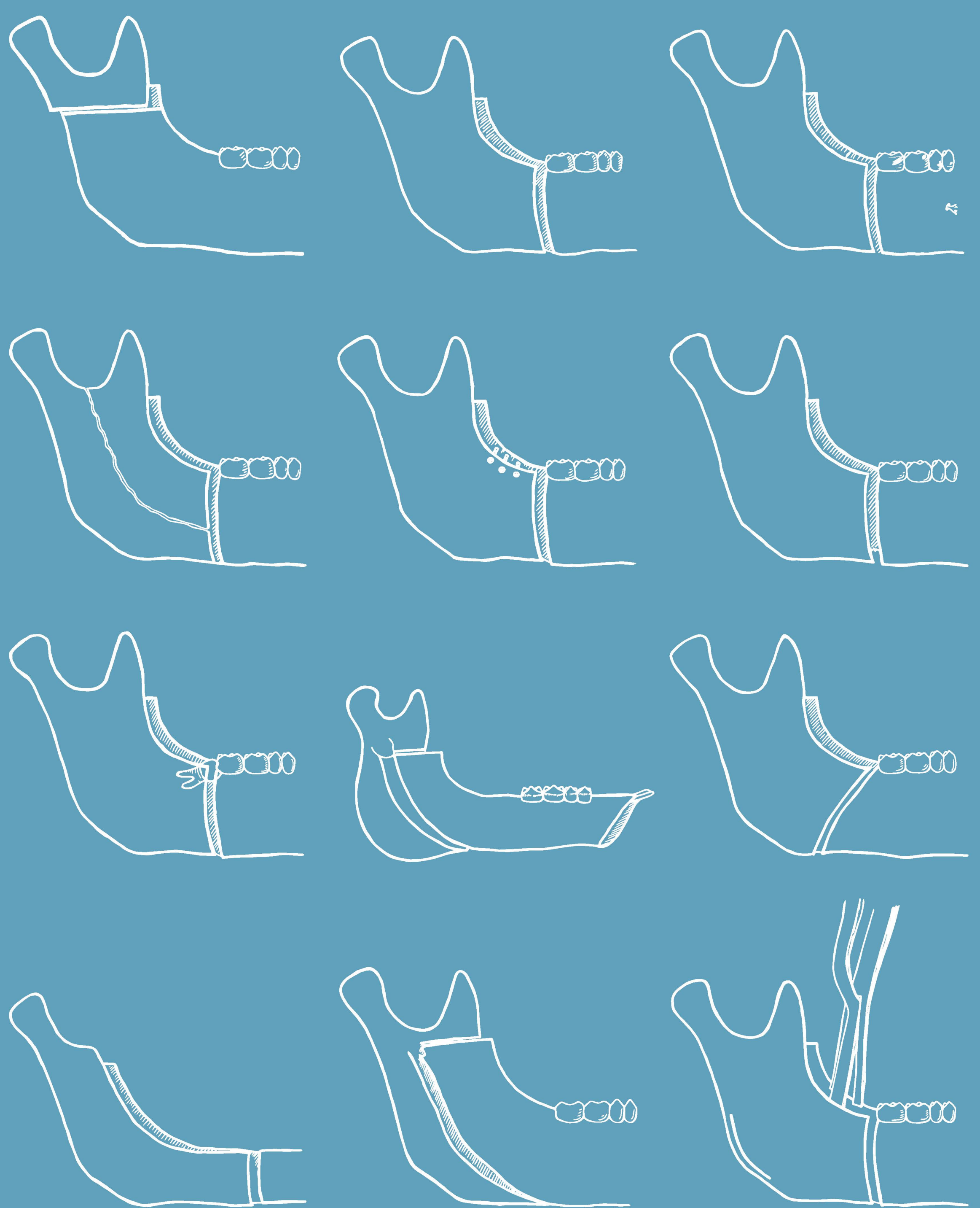


CHAPTER 13

Summary

SUMMARY

Chapter 1 provides a general introduction about bilateral sagittal split osteotomy (BSSO). The history and development of the technique are described. Clinical complications that frequently occur within the first postoperative year are discussed, including neurosensory disturbances of the lower lip, unfavourable fractures, postoperative infection, removal of osteosynthesis material and osseous mandibular inferior border defects.

This thesis aims to investigate the risk of complications associated with BSSO, performed with a splitter and separators. Specific risk factors for intra- and postoperative complications as well as factors influencing the predictability of the technique are analysed.

The purpose of this research is to enable individual counselling of patients before BSSO, and help maxillofacial surgeons attempt to minimise the risk of complications associated with this procedure.

In *Chapter 2*, a systematic review and meta-analysis of the literature regarding risk factors for common complications associated with BSSO is provided. After a systematic electronic database search, 59 studies could be included. For each complication, a pooled mean incidence was computed.

The mean incidences are reported for bad split (2.3% per site), postoperative infection (9.6% per patient), removal of the osteosynthesis material (11.2% per patient), and neurosensory disturbances of the lower lip (33.9% per patient). Relevant risk factors such as age, smoking habits, presence of third molars, the surgical technique and type of osteosynthesis material are discussed.

This information could help the surgeon to reduce the risk of these complications and inform the patient about the complication risks associated with BSSO.

In *Chapter 3*, the incidence of neurosensory disturbances (NSD) of the lower lip and chin after BSSO with splitter and separators is investigated in different age groups. The probability of sensory recovery is furthermore assessed in patients aged <19 years, 19–30 years and >30 years.

In this retrospective study, we subjectively and objectively assessed hypoaesthesia in the lower lip immediately postoperatively, 1 week and 1, 6 and 12 months after BSSO. Hypoaesthesia was considered permanent if it was present one year after BSSO.

In older patients, the frequency of NSD immediately after surgery was significantly higher. The cumulative incidence of recovery at 1 year was lower and the mean time to recovery was longer in older patients, although these differences were not statistically significant. Older age was a significant risk factor for permanent hypoaesthesia with an incidence of 4.8% per patient <19 years; 7.9% per patient 19-30 years; and 15.2% per patient > 30 years.

This shows that the risk of NSD after BSSO is significantly higher in older patients. The results can aid surgeons in pre-operative counselling specific age groups and help decide the optimal age to perform BSSO.

In *Chapter 4*, the occurrence of bad split after BSSO with splitter and separator is investigated. An unfavourable fracture pattern, known as bad split, is a common intra-operative complication in BSSO. The reported incidence of this complication with traditional techniques ranges from 0.5 to 5.5% per site.

Since 1994, BSSO is performed with splitter and separators instead of chisels in our clinic. In this retrospective cohort study of 427 consecutive patients (851 sites), the incidence of bad split was 2.0% per site. This is well within the range reported in the literature. The removal of third molars concomitant with BSSO was a significant risk factor for bad split. There was no significant association between bad splits and the patient's age, gender, occlusion class, or the experience of the surgeon.

In conclusion, BSSO performed with splitter and separators instead of chisels does not increase the risk of a bad split.

In *Chapter 5*, the removal of bicortical screws and other osteosynthesis material that caused symptoms is analysed. Rigid fixation with either bicortical screws or mini-plates is the current standard to stabilise the mandibular segments after BSSO. However, one complication of rigid fixation is the need to remove the osteosynthesis material because of associated complaints.

In our clinic, fixation after BSSO is performed with three bicortical screws unless otherwise indicated. Retrospective analysis of 251 consecutive patients (502 sites) showed the incidence of bicortical screw removal in our clinic was 2.9% per site. No significant association was noted between bicortical screw removal and age, gender, presence of third molars, or bad splits. Alternative methods of fixation were used at 16 sites. In the literature, reported rates of removal of bicortical screws and mini-plates are 3.1–7.2% and 6.5–22.2% per site, respectively.

These findings show that bicortical screw fixation after BSSO is associated with a low rate of symptomatic hardware removal. Reported incidences in the literature imply that the need of removal of bicortical screws is remarkably lower than the need of removal of mini-plates.

In *Chapter 6*, the occurrence of osseous inferior border defects after BSSO is retrospectively investigated using the pre- and postoperative radiography of 200 consecutive patients. Bone defects of the inferior border of the mandible can cause an unaesthetic postoperative result and in rare cases even necessitate secondary surgical procedures.

In this study, osseous inferior border defects were present at 28 out of 400 sides (7.0%/side) in 25 out of 200 patients (12.5%/patient). Significant risk factors for inferior border defects were increased mandibular advancement, more clockwise rotation of the occlusal plane, rotation of the proximal mandibular segment, and a type II split initiating in the lingual cortex. The presence of third molars and occurrence of bad splits were not significantly associated with inferior border defects.

These findings could help the surgeon to maximise the result of BSSO, increase patient satisfaction and minimise the risk of secondary procedures.

In *Chapter 7*, the influence of mandibular third molar removal during BSSO with splitter and separators is discussed. Timing of third molar removal in relation to BSSO is controversial, especially with regard to postoperative complications.

We performed a retrospective record review of 251 patients (502 sites). Mandibular third molars were present during surgery at 169 sites and removed at least 6 months preoperatively in 333 sites. Bad splits occurred at 3.0% and 1.5% of the respective sites. Presence of mandibular third molars significantly increased the risk of bad splits. The mean incidences of permanent neurosensory disturbances, postoperative infection, and symptomatic removal of the osteosynthesis material were 5.4%, 8.2%, and 3.4% per site respectively, without a significant influence of mandibular third molar status.

The presence of mandibular third molars during surgery increased the possibility of bad split, but did not affect the risk of other complications. Third molar removal concomitant with BSSO can save the patient additional preoperative procedures to remove third molars before surgery. Therefore, third molar removal can be advised concomitantly with BSSO performed with splitter and separators.

In *Chapter 8*, the lingual fracture pattern and status of the nerve after BSSO with the prying and spreading technique (splitter and separators) are compared to the traditional technique (mallet and chisels). Lingual fractures after sagittal split osteotomy in cadaveric pig mandibles were analysed using a lingual split scale and split scoring system. Iatrogenic damage to the inferior alveolar nerve was assessed.

Fractures started through the caudal cortex more frequently in the chisel group. This group also showed more posterior lingual fractures, although this difference was not statistically significant. Nerve damage was present in three cases in the chisel group, but was not observed in the splitter group.

A trend was apparent, that BSSO using the chisel technique instead of the splitter technique resulted in more posterior lingual fracture lines, although this difference was not statistically significant. Both techniques resulted in reliable lingual fracture patterns. Splitting without chisels could prevent nerve damage, which is why we propose a spreading and prying technique with splitter and separators.

In *Chapter 9*, further research is performed regarding lingual fractures, bad split and nerve status after BSSO with splitter and separator.

The conventional osteotomy design in BSSO includes a horizontal lingual bone cut, a connecting sagittal bone cut and a vertical buccal bone cut perpendicular to the inferior mandibular cortex. This buccal bone cut extends as an inferior border cut into the lingual cortex. This study investigated a modified osteotomy design including an angled oblique buccal bone cut that extended as a posteriorly aimed inferior border cut near the masseteric tuberosity.

The study sample comprised 28 cadaveric dentulous human mandibles. The angled osteotomy design resulted in a significantly higher number of lingual fractures originating from the inferior border cut, with a significantly more posterior relation of the fracture line to the mandibular canal and foramen. No bad splits occurred with the angled design, whereas three bad splits occurred with the conventional design, although this difference was not statistically significant. Inferior alveolar nerve (IAN) status was comparable between designs, although the IAN more frequently required manipulation from the proximal mandibular segment when the conventional design was used.

These results suggest that the angled osteotomy design promotes a more posterior lingual fracture originating from the inferior border cut. A trend was apparent that this might also possibly decrease the incidence of bad splits and IAN entrapment.

In *Chapter 10*, a clinical prospective observational study regarding the lingual fracture patterns after BSSO with splitter and separators is performed. This study investigated the correspondence between the planned inferior border cut and the actually executed inferior border cut during BSSO through postoperative cone-beam computed tomography (CBCT). The influence of the performance of the inferior border cut on lingual fracture patterns was analysed.

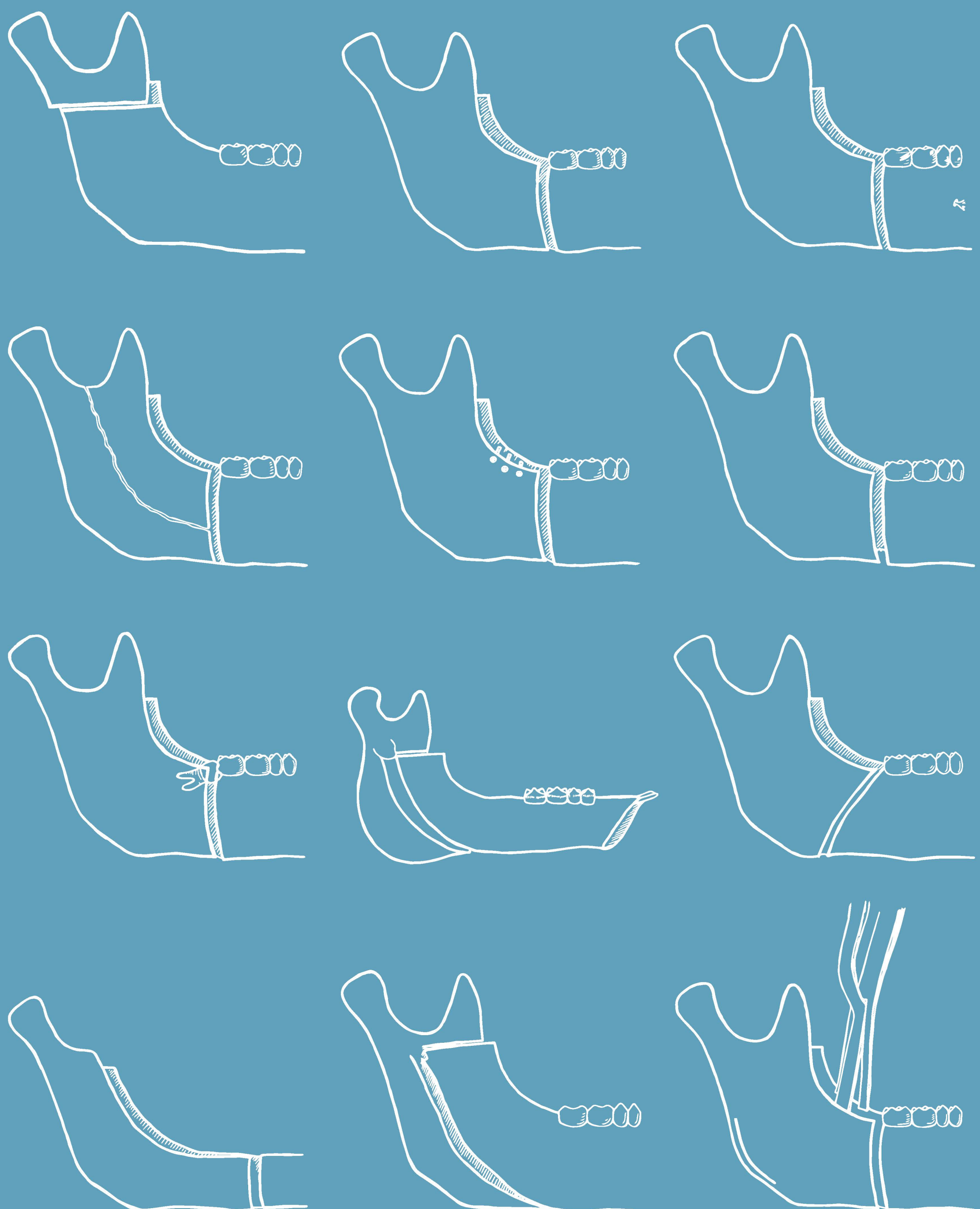
The inferior border cut reached the caudal cortex in all cases, but only reached the lingual cortex in 38% of the splits. There was no significant relationship between the inferior border cut and a specific lingual fracture line.

Postoperative CBCT analysis revealed that the bone cuts during BSSO were often not placed exactly as planned. Despite this, no significant relationship between the inferior border cut and lingual fracture patterns or bad splits was detected. Further research is needed to identify factors that could make the sagittal split more predictable.

In *Chapter 11*, a case is presented of BSSO in a reconstructed mandible. A 28-year old woman underwent a segmental mandibulectomy, due to a multicystic ameloblastoma in the left jaw. After primary plate reconstruction, final reconstruction was performed with a left posterior iliac crest cortico-cancellous autograft. Because of a pre-existing Class II malocclusion, the patient was analysed for combined orthodontic-surgical treatment. After one year of orthodontic treatment, the BSSO was planned. The sagittal split was performed in the remaining right mandible and on the left side in the iliac crest cortico- cancellous autograft. Ten months later, oral rehabilitation was completed with implant placement in the neo-mandible. Follow-up showed a Class I occlusion, with good function. The patient was very satisfied with the functional and aesthetic results.

This shows that BSSO can be performed in a reconstructed mandible, without side effects and with good functional and aesthetic results.

Chapter 12 discussed conclusions, clinical implications and future perspectives for the subjects of this thesis.



CHAPTER 14

Samenvatting

SAMENVATTING

Hoofdstuk 1 begint met een algemene inleiding over het onderwerp van dit proefschrift: de bilaterale sagittale splijtingsosteotomie (BSSO). De geschiedenis en ontwikkeling van de techniek worden beschreven. Frequent voorkomende complicaties worden besproken, waaronder gevoelsstoornissen van de onderlip, ongewenste fractuurpatronen (bad split), postoperatieve infectie, verwijdering van osteosynthesemateriaal en botdefecten van de onderrand van de mandibula.

Dit proefschrift evalueert de veiligheid en voorspelbaarheid van BSSO met splijttang en splijthevels. Klinische complicaties, die frequent voorkomen in het eerste jaar na de operatie, worden onderzocht. Het doel van dit onderzoek is om goede preoperatieve counseling en individuele informatievoorziening aan patiënten mogelijk te maken, en om de MKA-chirurg te helpen het risico op complicaties bij BSSO met splijttang en splijthevels te minimaliseren.

In *Hoofdstuk 2* wordt geanalyseerd welke risicofactoren voor complicaties na BSSO worden beschreven in de onderzoeksliteratuur. Een systematisch literatuuronderzoek en meta-analyse werden uitgevoerd met inclusie van 59 studies. Voor de verschillende complicaties, werd een gemiddelde incidentie berekend.

De gemiddelde gerapporteerde incidentie was 2.3% per sagittale splijtingsosteotomie (SSO) voor bad split, 9.6% per patiënt voor postoperatieve infectie, 11.2% per patiënt voor verwijdering van osteosynthesemateriaal en 33.9% per patiënt voor gevoelsstoornissen van de onderlip. Relevante risicofactoren zoals leeftijd, rookgewoonten, aanwezigheid van verstandskiezen, de chirurgische techniek en het type osteosynthesemateriaal zijn geassocieerd met deze complicaties.

Deze informatie kan de chirurg helpen het risico op de genoemde complicaties te reduceren en kan helpen bij het informeren van de patiënt over het risico op complicaties bij BSSO.

In *Hoofdstuk 3* wordt de incidentie van gevoelsstoornissen van de onderlip na BSSO onderzocht in drie verschillende leeftijdsgroepen: <19 jaar, 19-30 jaar en >30 jaar. Herstel van de sensibiliteit wordt tevens onderzocht in deze drie leeftijdscategorieën.

In deze retrospectieve studie worden gevoelsstoornissen van de onderlip subjectief en objectief geanalyseerd, direct na de operatie, 1 week en 1, 6 en 12 maanden na BSSO. Gevoelsstoornissen werden beschouwd als permanent wanneer zij een jaar na BSSO nog steeds aanwezig waren omdat volledig herstel dan niet meer te verwachten is.

Bij oudere patiënten was de frequentie van gevoelsstoornissen significant hoger direct na de operatie. Het totale herstel was minder en de tijd tot herstel van gevoelsstoornissen duurde langer bij oudere patiënten, hoewel deze verschillen niet statistisch significant waren. Hogere leeftijd was een significante risicofactor voor permanente gevoelsstoornissen van de onderlip, gemeten één jaar na BSSO. De incidentie van gevoelsstoornissen was 4.8% per patiënt <19 jaar; 7.9% per patiënt 19-30 jaar; en 15.2% per patiënt >30 jaar.

Deze resultaten tonen aan dat het risico op gevoelsstoornissen na BSSO significant hoger is voor oudere patiënten. De bevindingen zijn van belang ten behoeve van goede preoperatieve voorlichting van patiënten van verschillende leeftijden en draagt bij aan het bepalen van de optimale leeftijd om BSSO uit te voeren.

In *Hoofdstuk 4* wordt de incidentie van bad split tijdens BSSO met splijttang en splijthevels onderzocht. Een ongewenst fractuurpatroon, bad split genoemd, is een frequente intra-operatieve complicatie bij BSSO. De gerapporteerde incidentie van bad split na BSSO met traditionele technieken varieert tussen 0.5% en 5.5% per SSO.

Sinds 1994 wordt in onze kliniek BSSO met splijttang en splijthevels uitgevoerd. In deze retrospectieve cohort studie van 427 patiënten (851 SSO) was de incidentie van bad split 2.0% per SSO. Dit is binnen het bereik dat genoemd wordt in de onderzoeksliteratuur. De verwijdering van verstandskiezen tijdens BSSO was een significante risicofactor voor een bad split. Er was geen significante associatie tussen het optreden van bad split en leeftijd, geslacht, occlusieklasse, of de ervaring van de chirurg.

Concluderend leidt het gebruik van splijttang en splijthevels in plaats van beitels niet tot een verhoogde kans op bad split.

In *Hoofdstuk 5* wordt verwijdering van bicorticale schroeven en ander osteosynthesemateriaal vanwege klachten bij de patiënt, geanalyseerd. Rigide fixatie met bicorticale schroeven of monocorticale miniplaten is sinds decennia de standaard voor fixatie van de mandibula-segmenten na BSSO. Desalniettemin, komt het regelmatig voor dat het titanium fixatiemateriaal verwijderd moet worden wegens klachten bij de patiënt.

In onze onderzoeksgroep werd fixatie na BSSO uitgevoerd met behulp van drie bicorticale schroeven tenzij ander fixatiemateriaal geïndiceerd was. Retrospectieve analyse van 251 patiënten (502 SSO) toonde aan dat de incidentie van schroefverwijdering in onze kliniek 2.9% per SSO was. Er was geen significante associatie aanwezig tussen schroefverwijdering en leeftijd, geslacht, aanwezigheid van verstandskiezen tijdens de operatie of bad splits. Alternatieve fixatiemethoden waren noodzakelijk na 16 splijtingen. In de onderzoeksliteratuur, varieert de incidentie van schroefverwijdering en miniplaatverwijdering tussen respectievelijk 3.1-7.2% en 6.5-22.2% per SSO.

Deze resultaten tonen aan dat fixatie met bicorticale schroeven bij BSSO gepaard gaat met een lage incidentie van verwijdering van het osteosynthesemateriaal. De gerapporteerde incidentie van schroef- en plaatverwijdering impliceren dat bicorticale schroeven aanzienlijk minder vaak verwijderd dienen te worden dan miniplaten.

In *Hoofdstuk 6* wordt de incidentie van botdefecten van de onderrand van de mandibula na BSSO onderzocht middels de pre- en postoperatieve röntgenonderzoeken van 200 patiënten. Onderranddefecten kunnen onesthetische postoperatieve resultaten veroorzaken en in zeldzame gevallen zelfs secundaire procedures noodzakelijk maken.

In deze studie waren onderranddefecten aanwezig aan 28 van de 400 zijden (7.0% per kant) in 25 van de 200 patiënten (12.5% per patiënt). Significante risicofactoren voor onderranddefecten waren grote verplaatsing van de mandibula, grote rotaties van het occlusievlak, rotatie van het proximale segment, en een type II splijting die in de linguale cortex begint. De aanwezigheid van verstandskiezen tijdens de splijting en het optreden van bad splits was geen significante risicofactor voor onderranddefecten.

Deze bevindingen kunnen helpen het resultaat van BSSO te maximaliseren, patiënttevredenheid te verhogen en het risico op secundaire procedures te minimaliseren.

In *Hoofdstuk 7* wordt de invloed van verstandskiesverwijdering tijdens BSSO met splijttang en splijthevels nader onderzocht. De beste timing van verstandskiesverwijdering vóór of tijdens de BSSO procedure is nog onduidelijk.

Deze retrospectieve studie beschrijft 251 patiënten (502 SSO). In de onderkaak waren verstandskiezen aanwezig tijdens de operatie in 169 SSO. In 333 SSO waren de verstandskiezen minstens zes maanden voor de operatie verwijderd. Bad splits kwamen voor in respectievelijk 3.0% en 1.5% van de SSO. De aanwezigheid van verstandskiezen tijdens de operatie was een significante risicofactor voor bad split. De gemiddelde incidentie van gevoelsstoornissen, infectie en verwijdering van osteosynthesemateriaal was respectievelijk 5.4%, 8.2% en 3.4% per SSO, zonder significante associatie met de verwijdering van verstandskiezen tijdens BSSO.

De aanwezigheid van verstandskiezen tijdens BSSO verhoogde het risico op bad split, maar had geen significante invloed op het risico op andere complicaties. Verstandskiesverwijdering tijdens BSSO kan de patiënt aanvullende preoperatieve behandelingen besparen. Zodoende is verstandskiesverwijdering tijdens BSSO met splijttang en splijthevels een goede behandeloptie.

In *Hoofdstuk 8* wordt het linguale fractuurpatroon en de status van de nervus alveolaris inferior (NAI) tijdens BSSO met splijttechnieken (splijttang en splijthevels) vergeleken met de klassieke technieken (hamer en beitels). Linguale fracturen werden geanalyseerd met behulp van een 'lingual split scale' en 'split scoring system'. Mogelijke iatrogene schade aan de NAI werd tevens geanalyseerd.

De start van de linguale fracturen verliep frequenter door de caudale cortex in de beitel-groep. Deze groep vertoont ook meer posterieure linguale fracturen, hoewel dit verschil niet statistisch significant was. Zenuwschade was zichtbaar in drie SSO van de beitel-groep en werd niet geobserveerd in de splijttang-groep.

Hoewel het verschil tussen de groepen niet significant was, werd een trend geobserveerd dat BSSO met de beiteltechniek in plaats van de techniek met splijttang resulteert in een meer posterieur fractuurpatroon. Beide technieken resulteerden in een betrouwbare splijting. Het uitvoeren van BSSO met splijttang in plaats van beitel kan mogelijk directe iatrogene zenuwschade voorkomen.

In *Hoofdstuk 9* wordt nader onderzoek uitgevoerd naar de linguale fractuurpatronen, bad splits en status van de zenuw tijdens BSSO met splijttang en splijthevels.

Het conventionele design van de BSSO bestaat uit een horizontale boorsnede, een verbindende sagittale boorsnede en een verticale boorsnede, loodrecht op de onderrand van de onderkaak. Deze buccale boorsnede loopt door in een 'inferior border cut' tot in de linguale cortex. Dit onderzoek vergelijkt dit design met het 'angled osteotomy design', waarbij de buccale boorsnede schuin naar achter richting de angulus verloopt en ook de 'inferior border cut' naar dorsaal gericht is.

Dit post-mortem onderzoek werd uitgevoerd in 28 dentate humane kaken. Het 'angled osteotomy design' resulteerde in significant meer linguale fracturen vanuit de 'inferior border cut' dan het conventionele design. Het fractuurpatroon verliep significant meer dorsaal van de canalis en het foramen mandibulare. Bad splits kwamen niet voor bij het 'angled osteotomy design' en drie bad splits werden geobserveerd bij het conventionele design, hoewel dit verschil niet statistisch significant was. De status van de IAN was vergelijkbaar bij beide designs, hoewel de nervus vaker vrij geprepareerd moest worden bij het conventionele design.

Deze resultaten suggereren dat het 'angled osteotomy design' een meer dorsale linguale fractuur veroorzaakt, die regelmatig initieert uit de 'inferior border cut'. Een trend werd geobserveerd dat dit design mogelijk ook de incidentie van bad splits reduceert.

In *Hoofdstuk 10* wordt een klinische prospectieve observationele studie naar de linguale fractuurpatronen na BSSO met splijttang en splijthevels uitgevoerd. De studie onderzoekt de overeenkomst tussen de geplande inferior border cut en de daadwerkelijk uitgevoerde inferior border cut middels postoperatieve CBCT. De invloed van de uitgevoerde inferior border cut op linguale fractuurpatronen werd verder geanalyseerd.

De inferior border cut bereikte de caudale cortex in alle gevallen, maar bereikte de linguale cortex in slechts 38% van de splijtingen. Er was geen significante relatie tussen de positie van de inferior border cut en specifieke linguale fractuurpatronen.

Postoperatieve CBCT-analyse toonde aan dat de inferior border cut-zaagsnede tijdens BSSO vaak niet exact uitgevoerd was, zoals deze gepland was. Desalniettemin was er geen significante associatie tussen de inferior border cut en linguale fractuurpatronen of ongewenste fractuurpatronen. Meer onderzoek is geïndiceerd om factoren te identificeren, die de splijting meer voorspelbaar zouden kunnen maken.

In *Hoofdstuk 11* wordt een casus beschreven, waarbij BSSO is uitgevoerd in een gereconstrueerde onderkaak. Een 28-jarige vrouw onderging een segmentele mandibulectomie wegens een multicystisch ameloblastoom in het linker deel van haar onderkaak. Na primaire reconstructie met een osteosynthese-plaat, werd secundaire reconstructie uitgevoerd met bot uit de linker crista iliaca posterior. Vanwege een pre-existente klasse II malocclusie, werd de patiënte geanalyseerd voor een chirurgisch-orthodontisch behandeltraject. Na een jaar orthodontische behandeling, werd een BSSO uitgevoerd. De sagittale splijting werd enerzijds rechts uitgevoerd in de overgebleven onderkaak. Aan de linker zijde vond de splijting plaats in het gereconstrueerde deel van de onderkaak. Tien maanden later werd de orale rehabilitatie voltooid met de plaatsing van twee implantaten in de gereconstrueerde onderkaak. Tijdens de latere controles functioneerde de patiënte volledig met een klasse I occlusie. De patiënte was zeer tevreden met het functionele en esthetische resultaat.

Dit toont aan dat BSSO uitgevoerd kan worden in een gereconstrueerde onderkaak zonder een verhoogd risico op complicaties met een goed functioneel en esthetisch resultaat.

Hoofdstuk 12 beschrijft conclusies, klinische implicaties en toekomstperspectieven bij dit proefschrift..

List of publications

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Autotransplantation of teeth with the aid of computer-aided rapid prototyping using a 3D replica of the donor tooth: a systematic literature review

Verweij JP, Jongkees FA, Anssari Moin D, Wismeijer D, van Merkesteyn JPR
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Curriculum Vitae

Jop Verweij werd geboren op 6 september 1988 in Bergen op Zoom. Na het behalen van zijn VWO-diploma aan R.K. Gymnasium 't Juvenaat, studeerde hij van 2006 tot 2013 geneeskunde met een minor Human Osteoarchaeology aan de Universiteit Leiden. In dezelfde periode was hij lid bij studentenvereniging L.S.V. Minerva en heeft hij van 2007 tot 2011 bij de stichting BISLIFE gewerkt als uitvoerend operateur en teamleider bij de explantatie van hartklepweefsel ten behoeve van postmortale weefseldonatie.

Vervolgens studeerde hij van 2013 tot 2016 tandheelkunde voor artsen aan de Radboud Universiteit te Nijmegen. Hij heeft in 2015 als tandarts algemeen practicus (in opleiding) gewerkt in Den Haag en tandheelkundig vrijwilligerswerk gedaan met de stichting NOHS in Samara, Nepal. Daarnaast was hij actief bij de stichting Medical Business als organisator van de Medical Business Masterclass en eindredacteur van het boek 'Artsen met verstand van zaken. Medisch leiderschap, financiën en organisatie in de zorg'.

In 2016 startte Jop met de opleiding tot specialist Mondziekten, Kaak- en Aangezichtschirurgie in het Leids Universitair Medisch Centrum te Leiden (opleider: Prof. Dr. J.P.R. van Merkesteyn). Naast zijn opleiding tot MKA-chirurg is hij actief als voorzitter van de Vereniging van Arts-Assistenten van het Leids Universitair Medisch Centrum. Zijn hobby's zijn tekenen, hockey, golf en hardlopen.