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

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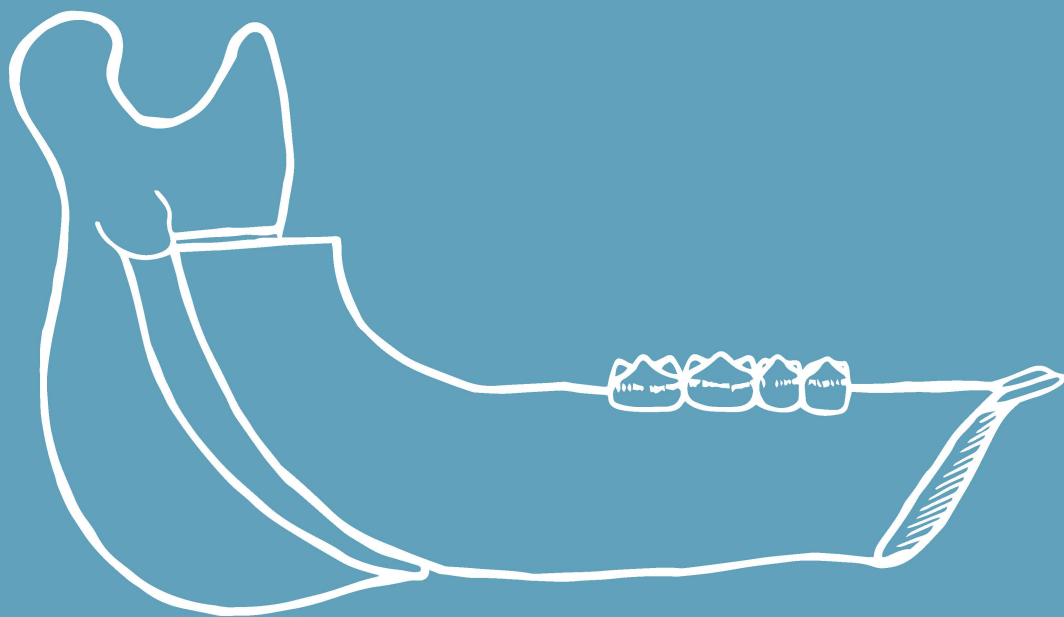


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CHAPTER 8

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 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

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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 Obwegeser¹, 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.¹, 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.⁴ 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).

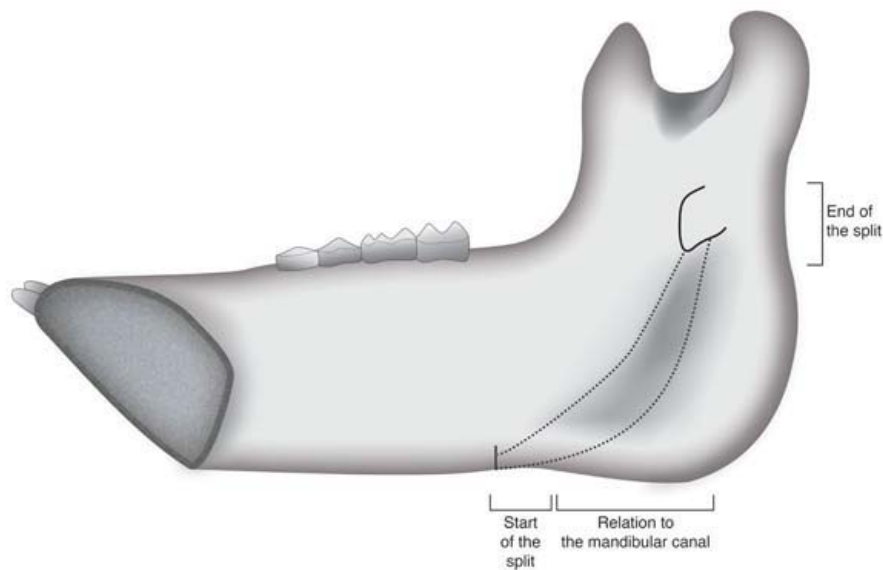


Figure 1: A drawing of the pig mandible model. An anterior lingual fracture line originating from the inferior border cut and extending through the mandibular canal into the mandibular foramen is shown, as is a posterior lingual fracture line starting from the inferior border, continuing inferior to 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 Total score (mean)	Chisel group Total score (mean)	Significance 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).

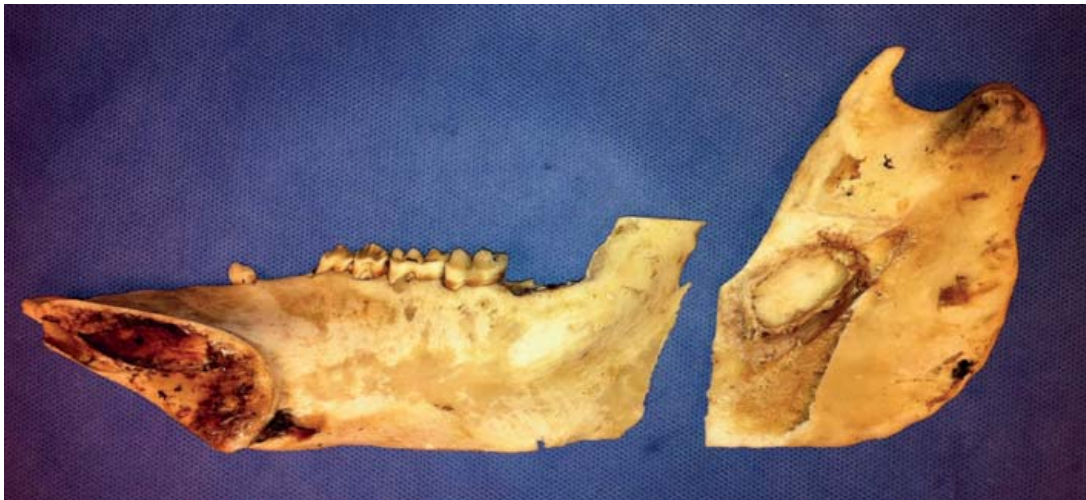


Figure 2: Photograph of a posterior lingual fracture line in a cadaveric pig mandible, after sagittal split osteotomy with a chisel and mallet.

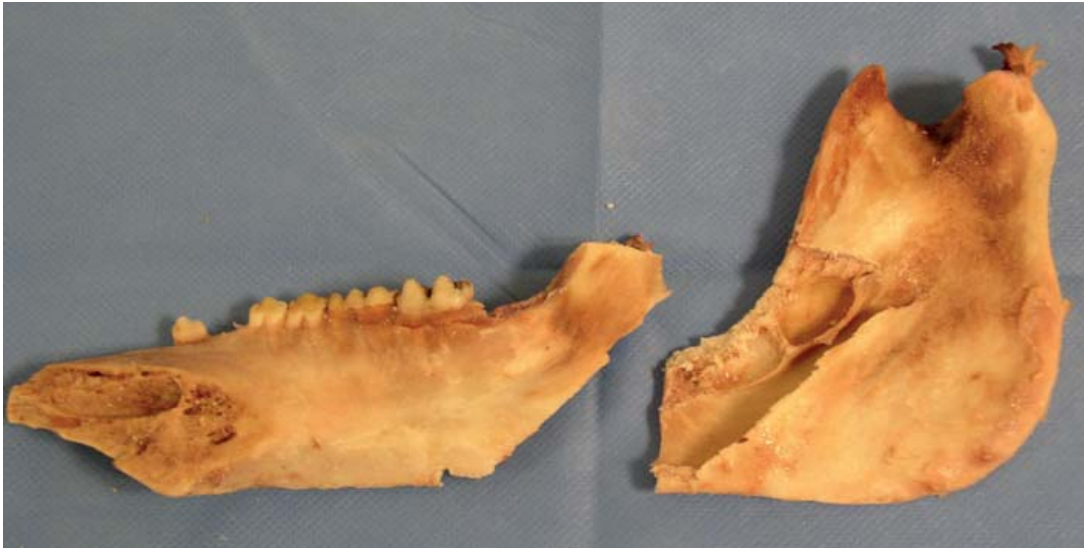


Figure 3: Photograph of an anterior lingual fracture line in a cadaveric pig mandible, after sagittal split osteotomy with a sagittal splitter and separators.

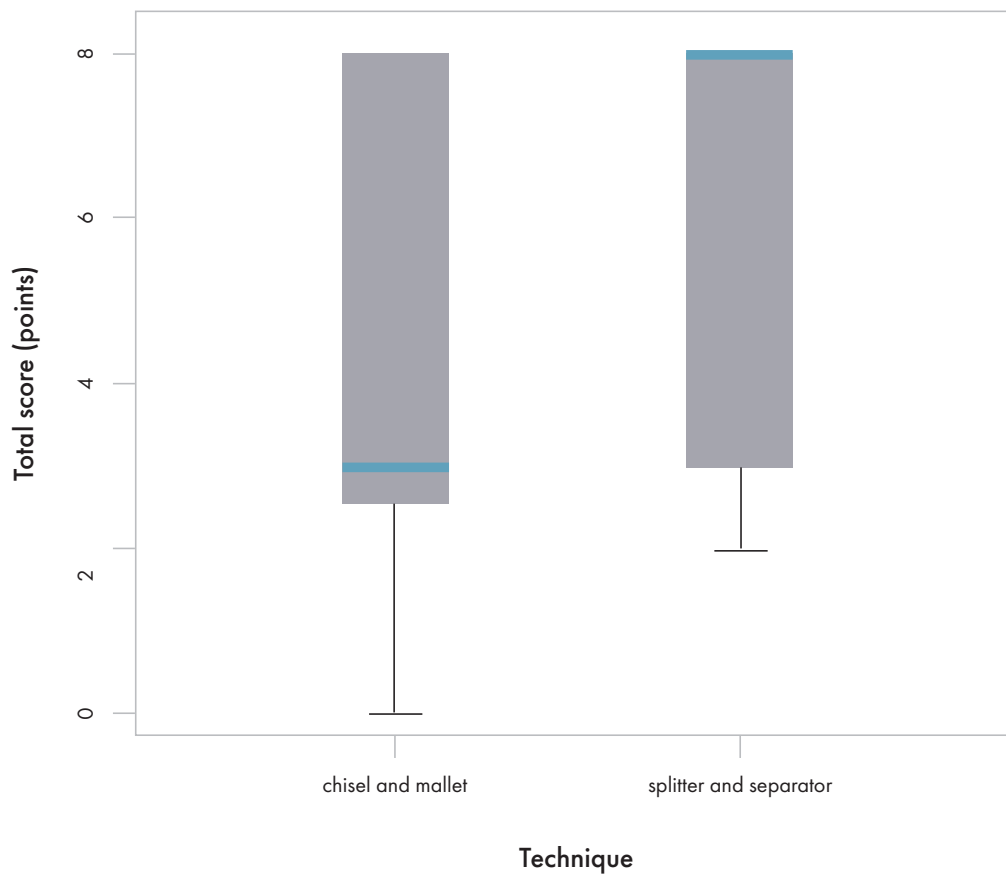


Figure 4: Boxplot of the mean total scores in the chisel and splitter groups, showing no statistically significant difference between the groups, but a trend of higher scores in the splitter group (a more anterior fracture pattern).

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 Aversa²⁴ 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 modification³ 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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