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

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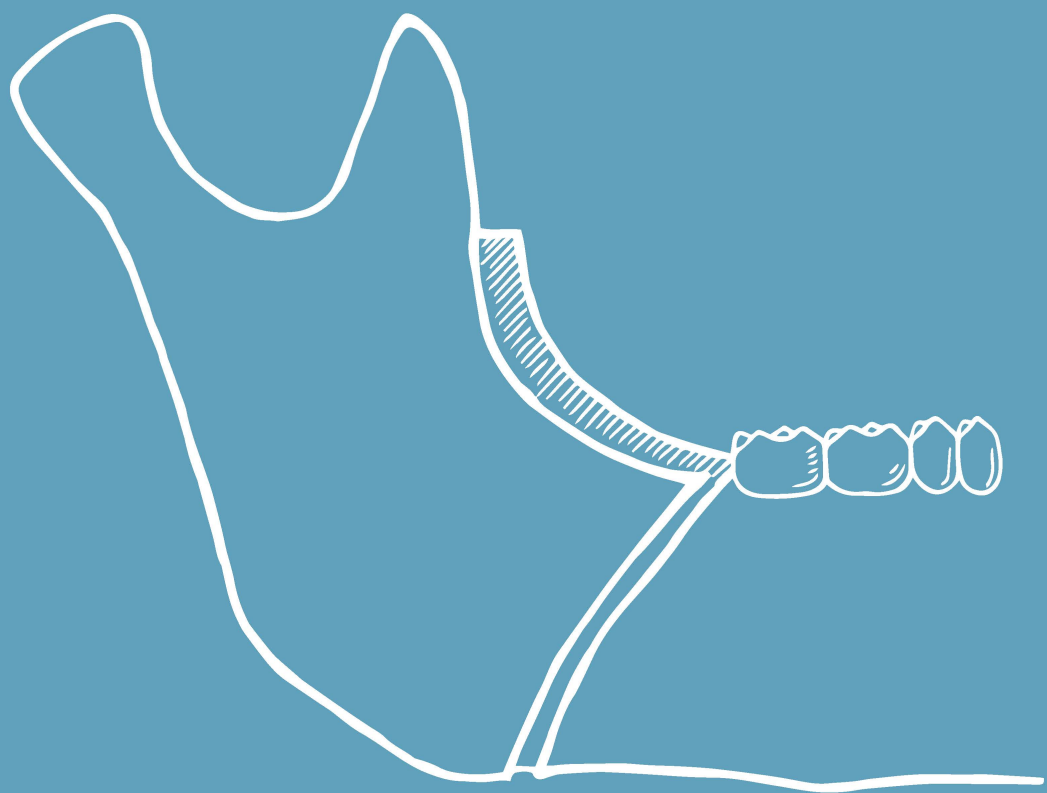


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CHAPTER 9

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:

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

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 Pont² advanced the buccal bone cut towards the second molar to increase bony contact between the mandibular segments. Hunsuck³ 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 Hunsuck³ (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.

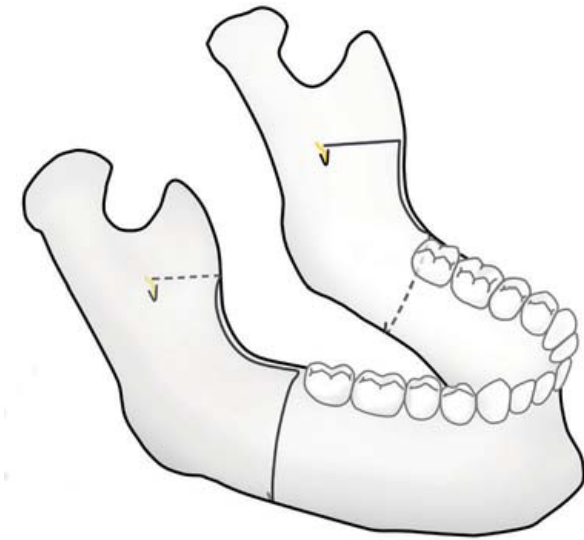


Figure 1a: A schematic of the conventional osteotomy design described by Hunsuck.



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.

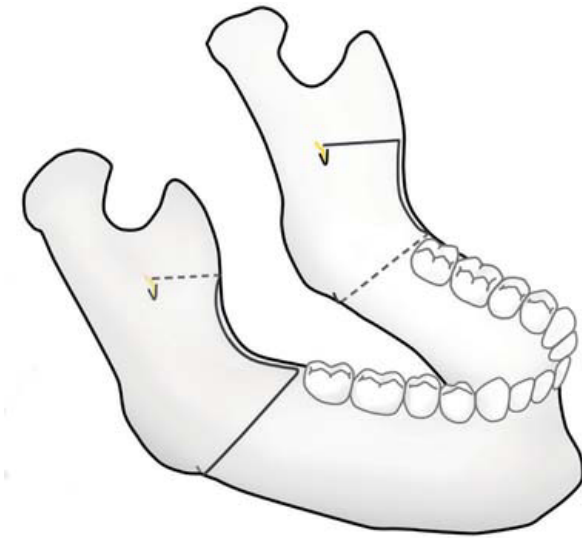


Figure 2a: A schematic of the angled osteotomy design. A modified buccal bone cut is placed towards the anterior border of the masseteric tuberosity, with a posteriorly aimed inferior border cut.



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 Plooiij 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 into 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.

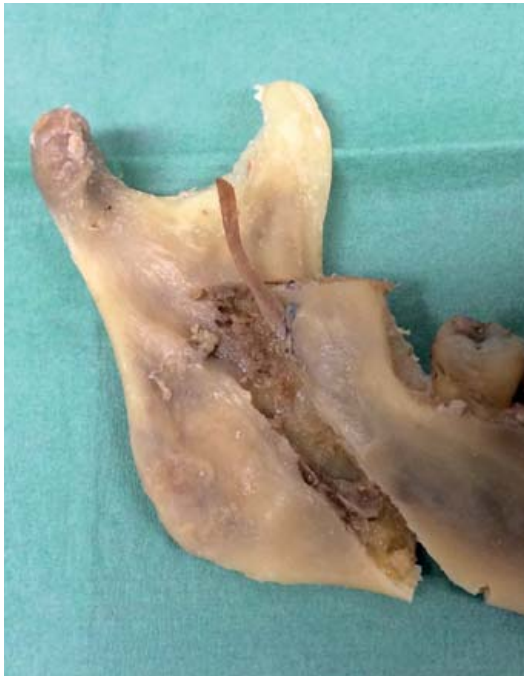


Figure 4: Lingual fracture after conventional bilateral sagittal split osteotomy. It is classified as an LSS3 fracture, which progresses completely through the mandibular canal.



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. Plooiij 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 obviously 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. Wyatt⁴ 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. Wyatt⁴ 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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