Bilateral sagittal split osteotomy by the splitter-separator technique: technical aspects, safety, and predictability

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Is the lingual fracture line influenced by the mandibular canal and/or the mylohyoid groove during a bilateral sagittal split osteotomy? A human cadaveric study

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Abstract

Purpose: Although the bilateral sagittal split osteotomy (BSSO) is a routinely performed procedure, the exact control of the lingual fracture line remains problematic. The purpose of this study was to determine the various lingual splitting patterns in cadaveric human mandibles after a BSSO and the possible influence of the mandibular canal and the mylohyoid groove on the lingual fracture line.

Methods: The investigators designed and implemented a case-series to compare the different lingual fracture lines. A standardized SSO was performed on 40 cadaveric hemi-mandibles with the use of elevators and splitting forceps. The primary outcome variable during this study was the lingual fracture pattern possibly influenced by independent variables: the mandibular canal, the mylohyoid groove and the dental status. Descriptive and analytic statistics were computed for each study variable.

Results: Most of the lingual fractures (72.5%) ended in the mandibular foramen. Only 25% of the fractures were a "true" Hunsuck fracture and no "bad splits" occurred. Meanwhile, 35% of the lingual fractures ran more than half or entirely through the mandibular canal, while only 30% of the fractures ran along the mylohyoid groove. However, when the lingual fracture ran along this groove, it had a 6-fold greater chance of ending in the mandibular foramen.

Conclusion: The hypothesis that the mandibular canal and/or the mylohyoid groove will function as the path of least resistance was only partly confirmed. The use of splitters and separators did not increase the incidence of bad splits compared with the literature.

Introduction

The inferior alveolar nerve (IAN) is an important structure during a bilateral sagittal split osteotomy (BSSO), and nerve damage is probably the most common complication of this type of surgery, causing hypoesthesia of the innervation region of the IAN.[1,2] Because BSSO is an elective surgery, it remains important to minimize these sequalae.

Before entering the mandibular canal, the IAN gives off a small mylohyoid branch that enters a shallow groove (or sometimes a partial canal, which is also described as mylohyoid bridging on the medial surface of the mandible) called the mylohyoid groove. This mylohyoid branch follows a course roughly parallel to its parent nerve (Figure 1),[3] and is primarily a motor nerve to innervate the mylohyoid muscle and the anterior belly of the digastrics muscle. Moreover, it provides a few filaments to supply the skin submentally over the point of the chin, sometimes including the lower incisor teeth (up to the first lower premolar).[4-6] Damage to the cutaneous branches of the mylohyoid nerve could also be responsible for causing (partial) hypoesthesia of the skin of the chin or even up to the lip.[5,7]

The nerve fibers of the IAN can be injured during a BSSO through surgical manipulation, including by stretching or crushing during the operation or by compression of the nerve bundle within the mandibular canal, or secondarily through hypoxia and edema caused by this manipulation. The injuries from surgical manipulation and the secondary effects can result in a combination of neuropraxia (bruising, such as damage to the myelin sheath) and partial axonotmesis (nerve fiber damage, such as sectioning of the axon).[8,9]

One of the potential causes of unwanted side effects, especially damage to the IAN, is that the classical technique used for splitting involves the use of mallet and chisels (i.e., a technique driving the chisels along the IAN to the inferior border of the mandible to split the proximal and distal parts) .[10-13] Hence, we believe a splitting technique without chisels but with sagittal splitters and elevators could potentially minimize the risk of injuries to the IAN without introducing other negative side effects.[1,2,14] In a previous pig cadaveric study, we suggested the mandibular canal and the mylohyoid groove or canal could function as a path of least resistance during the creation of a lingual fracture during BSSO.[14] If so, the use of this technique with sagittal splitters and elevators could lead to a higher predictability in the creation of a less forced lingual fracture and thereby could eventually lead to a lower percentage of patients with persistent hypoesthesia of the IAN.[15]

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Figure 1 Image shows bridging (black arrow A) of the mylohyoid groove (black arrow B) and the mandibular foramen (white arrow).

The purpose of this study was to assess the lingual fracture line running through the mylohyoid groove and the mandibular canal and to determine the possible influence of this mandibular canal and mylohyoid groove on various lingual splitting patterns in cadaveric human mandibles after a BSSO. The investigators hypothesize that the lingual fracture during a BSSO is running through the mylohyoid groove or the mandibular canal, as a proposed weakest point of the mandible, with the lingual split subsequently ending in the mandibular foramen (Figure 2). We want to estimate a predictable "natural" fracture path of the lingual fracture using sagittal splitters and separators, without forced chiseling of the inferior border and identify possible other sequelae of this technique (ie. bad splits).

Materials and Methods

To address the research purpose, the investigators designed and implemented a case-series to compare the different lingual fracture lines. The study population was composed of 40 cadaveric hemi-mandibles. No sex or age characteristics were available. All mandibles with or without teeth were included. The presence of molars was reported, because of the possible influence during the splitting procedure. Mandibles with possible foreign bodies related to the bone (e.g. implants, metal plates) were excluded. First, the mandibles were excised out of formalinized cadaveric heads. After the mandible was excised, the soft tissue was stripped away, including the periosteum, with only the bony mandible remaining. The mandibles were split in

Figure 2 Image shows a lingual fracture line running through the mandibular canal and mylohyoid groove together as hypothesized. The lingual fracture line runs directly from the inferior border and will eventually end in the mandibular foramen as shown in 72,5% of the cases (LSS 3 fracture pattern).

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a left and right mandible. Care was taken to preserve the IAN and the mylohyoid nerve. Pre-mortally, informed consent was given by all individuals to use their remains for scientific purposes. Therefore, we did not need to obtain approval from our institution to use the mandibles in our study. Parts of the heads had already been used for other scientific purposes.[16,17]

A standardized BSSO was performed on the cadaveric mandibles as reported by Hunsuck.[18] However, no chisels were used in the procedure, and the horizontal medial cut started just cranially of the mandibular foramen and ended in the deepest point of the concavity of the mandibular foramen, as reported before in our clinical setting.[1,2,14] No attempt was made to force a lingual fracture dorsally of the mandibular foramen. Instead, the primary focus was to end it exactly in the mandibular foramen and thereby to create a lingual fracture through the mandibular foramen, as in our previously reported pig pilot study.[14] First, a horizontal bone cut was performed

with a Lindemann bur (2.3 × 22 mm) approximately 5 mm cranially of the entrance point of the IAN until the trabecular bone was visible and was ended precisely at the deepest point of the concavity of the mandibular foramen. Subsequently, the vertical cuts and the sagittal bone cut, which connected the horizontal and vertical bone cuts, were made with a short Lindemann bur (1.4 × 5 mm). The vertical cut was placed just behind the second molar or its estimated location. The inferior border was cut perpendicular through the inferior cortex, just reaching the medial side running vertical to the lingual cortex (about 2 mm), to show the trabecular bone (Figure 2). After the bone cuts, the splitting was performed with an elevator positioned in the vertical bone cut and the splitting forceps in the sagittal bone cut. When the superior aspect of the mandible started to split, the elevator was repositioned at the inferior border of the vertical cut, and the splitting was completed.

Study Variables

The 2 primary outcome variables during this study were first the lingual fracture line running through the mylohyoid groove and/or mandibular canal and secondly the lingual fracture pattern (according to the Lingual Splitting Scale (LSS) by Plooij et al.[15]) possibly influenced by 3 independent variables: the mandibular canal, the mylohyoid groove and the presence of molars in the cadaveric mandible.

Secondary outcome variables were entrapment of the IAN in the distal part of the mandible after a SSO and the inferior border fracture.

Lingual splitting pattern

First the aspect of the lingual split in relation to the mylohyoid groove and the mandibular canal was examined (Figure 2). The lingual fracture was categorically assessed as running entirely through the mandibular canal; running more than half through the mandibular canal; extended through less than half of the proximal area of the mandibular canal; or as no relation to the mandibular canal.

Subsequently, the lingual splitting pattern in the mandible was categorically examined using the lingual splitting scale (LSS) developed by Plooij et al.[15] The LSS categorizes the lingual splitting patterns as splitting behind the mandibular foramen ("true" Hunsuck; LSS 1), splitting to the posterior border ("Obwegeser split"; LLS 2), splitting through the mandibular foramen (LSS 3) and other patterns, such as bad splits (LSS 4; Figure 3, Table 1).

Entrapment of the IAN

After completion of the split, the mandible was twice examined to determine whether the IAN was present either in the proximal or in the distal part of the mandible. If the IAN was still present in the proximal part of the mandible, it was established whether the IAN had to be freed either with or without additional bone surgery.
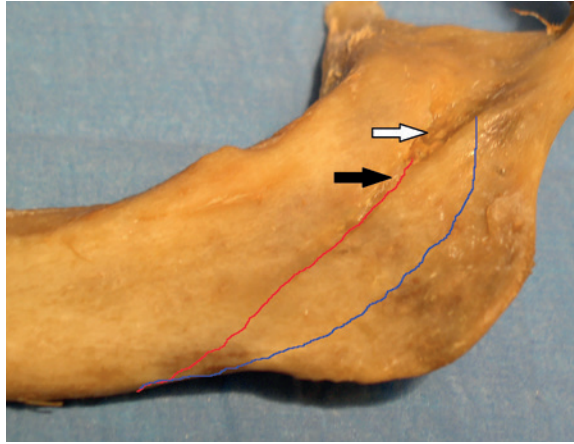
Figure 3 Illustration of the scoring system of the lingual fracture patterns. Red line: hypothesized fracture line through the mylohyoid groove ending in the mandibular foramen. Blue line: "classic" fracture pattern more posteriorly (Hunsuck fracture). Black arrow: mylohyoid groove. White arrow: indicates mandibular foramen.

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Inferior border fracture

In addition to the splitting patterns, the distance and characteristics of the fractures running along the mandibular border were categorical evaluated to provide possible information about bad splits (e.g., a split starting buccally and creating a buccal plate fracture) and bony contact after advancement of the mandible. The fractures running along the mandibular border were categorized in 4 groups: 1) not running through the inferior border but directly more cranially on the lingual side of the mandible; 2) running 1–10 mm through the inferior border; 3) running more than 10 mm through the inferior border; 4) not starting lingually but buccally.

Data analyses

All statistical data were carried out with SPSS software program, version 18.0 for Windows (SPSS Inc., Chicago, USA). Descriptive statistics were computed for each study variable. Bivariate analyses (Crosstabs, the Pearson chi-square tests, logistic regression) were computed to measure the association between the primary fracture outcome with the 3 variables of interests. The variables measured were adjusted for correlation by logistic regression, because 2 observations (left and right side of a mandible) were derived within one subject. Values of $p < 0.05$ were considered statistically significant.

Results

The hemi-mandibles varied from completely dentate to completely edentulous (95% were at least edentulous posterior to the premolars). None of the mandibles contained an impacted third molar. Thirty-four hemi-mandibles (85%) had a mylohyoid groove, while 4 (10%) showed bridging of the mylohyoid groove. Two hemi-mandibles (5%) had neither a mylohyoid groove nor mylohyoid bridging (Figure 1; Table 2).

There were 40 sagittal split osteotomies (SSO) performed. None of the splits resulted in a bad split. Eleven sites (27.5%) required instrumentation to release the IAN from the proximal part of the mandible.

Lingual splitting patterns using the LSS

As evaluated using the LSS, the majority of lingual fracture lines (29 sites; 72.5%) ended in the concavity of the mandibular foramen (LSS3) (Figure 3). Meanwhile, 1 lingual fracture (2.5%) ended at the posterior border as a "Obwegeser" split (LSS2), while 10 (25%) ended just posterior to the mandibular foramen ("true" Hunsuck, LSS1). Because no bad splits occurred, no LSS4 splitting patterns were seen (Table 1).

Table 1 Comparison of LSS between the present study and the study of Plooij et al.[15].

LSS category	The present study	Plooij et al.[15]
LSS1 ("true" Hunsuck)	25%	51%
LSS2 ("Obwegeser" split)	2.5%	13%
LSS3 (split through the mandibular foramen)	72.5%	33%
LSS4 (other splitting type; i.e., bad split)	0%	3%

Relationship of the fractures to the mylohyoid groove and the mandibular canal

Twelve (30%) of the lingual fracture lines had a relation with the mylohyoid groove and ran through the mylohyoid groove (Figure 2). After leaving the inferior border, 15 (37.5%) of the lingual fracture lines ran parallel and inferior to the mylohyoid groove to the horizontal bur cut. Meanwhile, 3 (7.5%) ran parallel and superior to the mylohyoid groove, whereas 7 (17.5%) crossed the mylohyoid groove and ran to the horizontal bur cut. Two of the mandibles did not have a mylohyoid groove, and there was 1 "Obwegeser" split. When we evaluated whether a lingual fracture line running through the mylohyoid groove correlated with it ending in the foramen, instead of behind the

Table 2 Presence of a mylohyoid groove or bridging of the mylohyoid groove.

40 hemi-mandibles	total (percentages)
Mylohyoid groove	34 (85%)
Mylohyoid bridging	4 (10%)
No Mylohyoid bridging or groove	2 (5%)

mandibular foramen (LSS3), we observed a nonsignificant trend of the lingual fracture ending in the foramen (LSS3) when the fracture ran through the mylohyoid groove (odds ratio = 6.11; 95% confidence interval, 0.685–54.506; p = .105).

With respect to the mandibular canal, 7 (17.5%) of lingual fractures ran entirely through the mandibular canal; 7 (17.5%) ran through more than half of the mandibular canal; 13 (32.5%) extended through less than half of the proximal area of the mandibular canal; and 13 (32.5%) had no relation to the mandibular canal. When we evaluated whether a lingual fracture line running through the mandibular canal correlated with it ending in the mandibular foramen (LSS 3), no correlations could be computed between these 2 parameters.

The dental status (ie. hemi-mandibles containing molars) could not be correlated to a certain fracture patterns. Only 2 hemi-mandibles contained molars and no LSS variations were present within this group.

Inferior border fractures

Thirteen fracture lines (32.5%) ran directly to the lingual side; 13 splits (32.5%) ran less than 10 mm; and 14 splits (35%) ran more than 10 mm through the mandibular inferior border (Table 3.). Hence, the fracture lines running along the inferior border were almost equally divided among these 3 categories. One split showed an unexpected "Obwegeser" split and ran entirely along the inferior border; this split was included in the final of these 3 categories. None of the splits ran buccally. When the fracture ran through the inferior mandibular border, the distance varied from 2.5–22 mm (mean ± SD, 11 ± 6.5 mm).

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Table 3 Divisions of groups of the lingual fracture lines running along the inferior border of the mandible. (1 split showed an unexpected 'obwegeser' split an ran entirely along the inferior border, included in group 3)

Lingual fracture line running along the inferior mandibular border divided in groups. *(range 2,5-22 mm; mean 11 mm; SD 6,5 mm)*	Amount of splits (percentages)
Group 1 *(Not running through the inferior border, but directly to the horizontal medial cut)*	13 (32,5%)
Group 2 *(Running 1- 10 mm through the inferior border)*	13 (32,5%)
Group 3 *(Running more than 10 mm through the inferior border)*	14 (35%)
Group 4 *(Not starting lingual, but buccaly)*	0 (0%)

Discussion

The purpose of this study was to determine the various lingual splitting patterns in cadaveric human mandibles after a BSSO and the possible influence of the mandibular canal and the mylohyoid groove on the lingual fracture line into the mandibular foramen. The investigators hypothesized that the lingual fracture during a BSSO is running through the mylohyoid groove or the mandibular canal, as a proposed weakest point of the mandible, with the lingual split subsequently ending in the mandibular foramen. Furthermore, we wanted to estimate a predictable "natural" fracture path of the lingual fracture using sagittal splitters and separators, without forced chiseling of the inferior border and identify possible other sequelae of this technique (ie. bad splits).

The hypothesis that the mandibular canal and mylohyoid groove will function as the path of least resistance was not confirmed in our data. We observed that a minority of the splits had a relationship with the mandibular canal (35%) and/or the mylohyoid groove (30%) and that the concave contour of the lingual cortex between the mandibular foramen and the inferior border cut defined a relatively consistent fracture path. However, a trend was observed in which the occurrence of a lingual split into the mandibular foramen (LSS3) was associated with the fracture running to the mylohyoid groove. The mandibular canal or the dental status could not correlated within this limited dataset.

The inferior border fractures were classified almost equally into groups 1, 2 and 3 (0 mm, 1–10 mm, and >10 mm, respectively). No buccal fracture lines occurred in group 4. These results could explain why only 30% and 35% of the lingual fractures had a relationship with the mylohyoid groove or the mandibular canal, respectively. Instead of running more cranially, the fracture still ran through the inferior border. Furthermore, the absence of bad splits is favorable in comparison to the series of Plooij et al.[15] This previous study used chisels, and 3% of the fractures were bad splits, in keeping with the literature. In this cadaveric study no bad split occurred, which is well below the incidence (mean 4,6% per patient) mentioned in the literature.[14]

Further, in the present study, 34 (85%) mandibles had a mylohyoid groove; 4 (10%) showed bridging of the mylohyoid groove; and 2 mandibles (5%) lacked a mylohyoid groove. These findings are consistent with earlier reports, which showed a mylohyoid canal or bridging around 7% (Table 2).[3]

As shown in Table 1, the relative frequencies of the different type of splits differ between Plooij et al.[15] and the current study. The more anterior split (i.e., more splits to the mandibular foramen and less "Hunsuck" and "Obwegeser" splits) was favored in the current study. Plooij et al.[15] also previously described that the chance of splitting the ramus according to Hunsuck's description increased from 44% to 63% when the medial bone cut ended behind the anterior border of the mandibular foramen, and that the chance of splitting through the mandibular canal was significantly reduced from 43% to 11%. In the present cadaveric study, the medial bone cut was ended in the mandibular foramen, resulting in 72.5% of the lingual fractures ending in the mandibular foramen, with 6-fold higher chance when the lingual fracture ran along the mylohyoid groove. The relation with the mandibular canal could not be explored due to the limited size of this data set. Different splitting techniques and patterns have been described for BSSO. The lingual side caudally of the mandibular foramen mandible is not visible, and no intentional lingual cut is made during clinical BSSO. Hence, the path of the lingual fracture is under little control.[15] However, in an earlier pilot study with cadaveric pig mandibles[14], we concluded that prying and spreading the mandible during the SSO, with the use of splitters and separators, provides a consistent splitting pattern. Creating an intended split running through the mandibular foramen along the mandibular canal and could possibly follow the path of least resistance.

According to these previous and current reports, we believe it is not necessary to place the horizontal bur cut dorsally from the mandibular foramen and/or perform a cortical separation by chisel cranially and dorsally from the mandibular foramen in order to obtain a predictable split. Moreover, with a more anterior split, less "bony" splitting is performed in the sagittal plane, therefore resulting in less instrumentation along the IAN during the split, probably causing less trauma to the IAN and less operation time.

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In the literature, exact information on the IAN remaining in the proximal segment after the split is scarce. In the present study, 11 of the sites (27.5%) required instrumentation to release the IAN from the proximal segment, which seems to be average and in line with our previously reported clinical study (27.5% vs. 23.7%).[1] In the report of Van Merkesteyn et al.,[2] the remaining IAN in the buccal segment was slightly higher and did not seem to lead to a high incidence of hypoesthesia.

The value of studies of splitting techniques in cadaveric mandibles may be limited because of the use of formalinized mandibles and the higher frequency of edentulous mandibles when compared to a clinical setting. Also in this case-series only 2 hemi— mandibles were present containing molars, being a possible influence positioned along the bur cuts or fracture line. The increase in the gonial angle in older patients and edentate subjects is controversial, and the IAN position could vary following the degree of alveolar ridge resorption. However, according to Oth et al.[5] the use of mandibles from older individuals remains a suitable option for performing such a study. Nonetheless, extrapolating the results to a clinical setting should be done with caution, also because this model has a superior visibility of the mandibular foramen when performing the bone cuts, whereas this degree of visualization is less in a clinical case.

Conclusions

The hypothesis that the mandibular canal and/or the mylohyoid groove will function as the path of least resistance was only partially confirmed. That is, the mandibular canal and/or the mylohyoid groove did provide the point of weakest resistance, resulting in 35% and 30% of the lingual fractures, respectively. Further, 72.5% of the lingual fractures ended in the mandibular foramen, with a 6-fold greater chance of having a fracture in the mandibular foramen when it ran along the mylohyoid groove. Additionally, we showed a higher incidence of a more "anterior" split compared to Plooij et al.[15], probably because of our different splitting method. The present study showed that the use of splitters and separators does not increase the amount bad splits compared with the literature.

These results should stimulate further research into lingual fracture lines. In particular, the relation of different types of bur cuts to the various lingual fracture lines should be evaluated in a large sample size. Subsequent comparative studies could be performed in a clinical setting to evaluate the fracture lines postoperatively with cone beam CT and their possible relation to postoperative hypoesthesia. Eventually these differences could influence the post-operative hypoesthesia of the IAN, especially when not using chisels along the IAN to the inferior border of the mandible.

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