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Density of the mandibular ramus (cancellous:cortical bone volume ratio) as a predictor of the lingual fracture pattern in bilateral sagittal split osteotomy

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Abstract

The aim of this retrospective cohort study was to evaluate the relative amount of cancellous bone in the mandibular ramus as a predictor of lingual fracture patterns after bilateral sagittal split osteotomy (BSSO). The study including 78 consecutive patients (156 osteotomy sites). In preoperative cone-beam computed tomographic (CT) scans, the volumes of cancellous and cortical bone in the BSSO surgical field were estimated. Patients were divided into two groups based on the cancellous:cortical bone ratio. We studied postoperative cone-beam CT scans for lingual fracture lines and subcategorised them according to the lingual split scale (LSS). Generalised linear mixed models (GLMM) were estimated to evaluate the association between the cancellous:cortical bone ratio and the lingual fracture pattern. There was a significant association between the cancellous:cortical bone ratio of the mandibular angle and the lingual fracture pattern after BSSO. Mandibular angles with a relatively small amount of cancellous bone showed significantly more LSS3 fracture lines (OR = 1.990, 95%CI 1.043 to 3.796, p = 0.043). These mandibular angles also showed more unfavourable fractures (LSS4), although this was not significant (OR = 2.352, 95%CI 0.748 to 7.392, p = 0.143). The relative amount of cancellous bone in the mandibular angle is significantly associated with the lingual fracture line after BSSO.

Keywords: Orthognathic; Sagittal split; Cone beam; Fracture; Volumetric

Introduction

Bilateral sagittal split osteotomy (BSSO) is a widely used procedure in orthognathic surgery to correct mandibular deformity that is trusted by many surgeons because of its reliability. Nevertheless, not all steps in the surgical process are under the surgeon's direct control.[1] For example, the course of the lingual fracture line is still not fully predictable. In some cases it might be unfavourable, or even result in a "bad split" that complicates the operation. Various patterns of lingual fracture lines can be acceptable in a BSSO, and

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not all unfavourable fractures can be classified as bad splits. Surgeons should strive to control the lingual fracture as far as possible, to make the BSSO procedure as predictable as possible. Several authors have analysed postoperative conventional and cone-beam computed tomographic (CT) scans after BSSO to classify lingual fracture patterns,[2–7] and they found that the lingual fracture line is highly variable and unfavourable fractures occur in 0 to 15% of splits.[2–7]

The combination of factors that influences the lingual fracture pattern is still not clear. Radiological examination of the ascending ramus of the mandible could help to identify factors that are important in BSSO. In the present study we hypothesised that mandibles with a relatively small amount of cancellous bone might produce different lingual fracture patterns and possibly more unfavourable splits. If this "cancellous:cortical bone volume ratio" is a predictor of the lingual fracture pattern, it could help surgeons to predict and control the sagittal split.

The aim of this retrospective study, therefore, was to calculate the preoperative cancellous:cortical bone ratio in the mandibular angle to find out if there is a possible association with lingual fracture line patterns after BSSO.

Material and methods

Study sample

The clinical records and radiographs of consecutive patients who had BSSO in the Zuyderland Hospital, Heerlen, The Netherlands, between June 2009 and August 2017 were analysed retrospectively. Inclusion criteria were: the presence of a complete and symmetrical mandibular dental arch and no previous mandibular surgery. Patients who did not give their consent for use of their data for research purposes were excluded.

Surgical protocol

All procedures were carried out by experienced oral and maxillofacial surgeons who followed a standard surgical protocol. All patients had had their lower third molars removed at least six months preoperatively. A preoperative cone-beam CT scan (i-CAT Next Generation, Imaging Sciences International) was taken several weeks before the BSSO as part of the standardised clinical protocol. This scan was used by the operating surgeon to evaluate the morphology of the mandible and the course of the inferior alveolar nerve.

All operations were done under general anaesthesia with nasal intubation, with BSSO according to a conventional Obwegeser-Dal Pont osteotomy design with Hunsuck modification. The horizontal bone cut was positioned just above the mandibular foramen, and the vertical bone cut at the distal border of the second molar. The mandible was split with splitting forceps and separators (Smith Ramus Separator and Smith Sagittal Split Separators, Walter Lorentz Surgical), with minimal use of chisels.[8] Bones were stabilised with miniplates (Synthes 2.0 system, DePuy Synthes). Intermaxillary fixation with elastics was applied for two weeks postoperatively. The protocol also included a postoperative cone-beam CT scan as radiographic examination of the outcome after BSSO. This scan was taken relatively late after BSSO (eight weeks) and was used by the operating surgeon to evaluate fixation, morphology, and position of the temporomandibular joint; position of the proximal segment; and initial bone healing.

Data collection

The patients' medical records were screened for sex, type of malocclusion, age at operation, and simultaneous orthognathic procedures (Le Fort I osteotomy or genioplasty). Preoperative and postoperative cone-beam CT scans were investigated using Horos v.2.1.1 software. In the preoperative cone-beam CT scan, the part of the mandible that contained the BSSO was digitally separated at the planes in which the horizontal and vertical bone cuts at BSSO are made.

The plane in which the horizontal (lingual) bone cut is made was defined as the horizontal plane parallel to the occlusal plane and directly above the lingula. The plane in which the vertical (buccal) bone cut is made was defined as the vertical plane perpendicular to the inferior border of

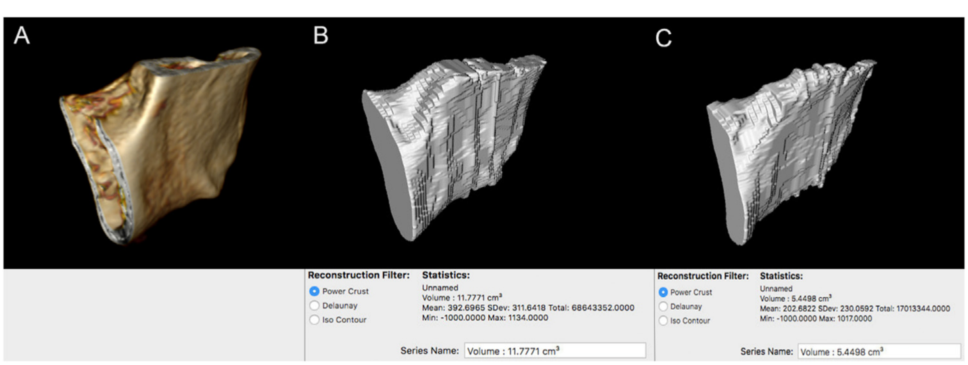

Fig. 1. Digital separation of the BSSO operation field (A); volumetric measurement of the whole BSSO operation field (B) and volumetric measurement of the cancellous part of the operation field (C).

Table 1
Type of malocclusion.

Type of malocclusion	No. of patients
Class II division 1	53
Class II division 2	6
Class III	19

the mandible, directly posterior to the second molar and perpendicular to the buccal surface of the mandible. This part of the mandibular ramus (as defined by these two planes) was digitally separated, and volumetric measurements were made using the Horos volumetric Region Of Interest tool. The volume of the segment as a whole and the volume of its cancellous part were measured by the Horos software using semi-automatic segmentation, and the volume of the cortical bone was calculated (Fig. 1).

The ratio of the cancellous bone volume to cortical bone volume was calculated to indicate the amount of cancellous bone (marrow) relative to the amount of cortical bone (cortex). Subsequently, in the postoperative cone-beam CT scans, the lingual fracture lines were assessed using Horos v.2.1.1 in 3-dimensional Volume Rendering Mode combined with studying the 2-dimensional slices in the horizontal plane. The fracture lines were categorised according to the lingual split scale (LSS).[2] The LSS consists of four categories based on the path of the fracture line on the lingual side of the ramus. LSS1 indicates a vertical pattern of the fracture line to the inferior border of the mandible (a 'true' Hunsuck[9]), LSS2 a horizontal pattern of the fracture line to the posterior border of the ramus, LSS3 a fracture line through the mandibular canal to the inferior border of the mandible, and LSS4 all other fracture line patterns.

Statistical analyses

For statistical analyses we used IBM SPSS for Windows software (version 20.0, IBM Corp). Descriptive statistics were used to analyse the primary outcome variable (LSS), primary predictor variable (cancellous:cortical bone volume ratio), and secondary variables (sex, age, type of malocclusion, and simultaneous orthognathic procedures). To investigate the association between outcomes and possible risk factors, generalised linear mixed models (GLMM) were estimated.[10] These models are used to take into account the repeated measurement design: left and right measurement for each patient. Adjusted odds ratios (OR) and 95% CI were reported and probabilities of less than 0.05 were accepted as significant.

Results

A total of 78 patients (46 women and 32 men, mean (SD) age 28 (9) range 17-52 years) were included. Fifty-nine patients had a Class II, and 19 a Class III, malocclusion (Table 1). Sixty-one patients also had other orthognathic procedures simultaneously (Table 2).

Table 2
Surgical procedures.

Procedure	No. of patients
BSSO	17
BSSO with genioplasty	5
BSSO with Le Fort I	35
BSSO with Le Fort I and genioplasty	21

BSSO = bilateral sagittal split osteotomy.

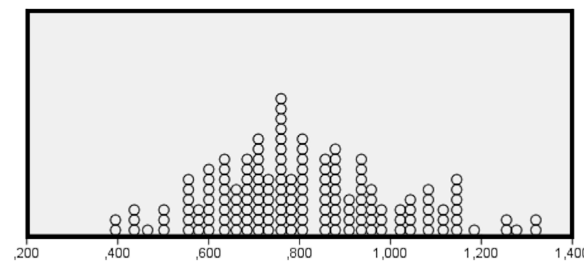

Fig. 2. Diagram indicating the distribution of the cancellous:cortical bone ratio.
Horizontal = cancellous:cortical bone ratio. Vertical = number of mandibular angles.

Table 3
Distribution of fracture line patterns for mandibular angles with a low or high cortico:cancellous bone volume ratio.

	No.	LSS 1	LSS 3	LSS 4
Group 1 (ratio<0.775)	78	36	30	12
Group 2 (ratio>0.775)	78	49	24	5
Total	156	85	54	17

LSS = lingual split scale.

In the preoperative cone-beam CT scans, the amount of cancellous bone and the amount of cortical bone within the BSSO surgical field were estimated in all 156 mandibular angles. The cancellous:cortical bone volume ratio was calculated for each mandibular angle, and is shown in Fig. 2. The mean ratio was 0.775. The mandibular angles were divided into two groups based on the mean cancellous:cortical bone volume ratio: Group 1 (ratio <0.775) and Group 2 (ratio >0.775). In the postoperative cone-beam CT scans of these 156 splits, we analysed the postoperative fracture patterns and found a LSS1 pattern in 85, a LSS3 pattern in 54, and a LSS4 pattern in 17 (Fig. 3).

No LSS2 fracture lines were found. All LSS4 fracture patterns were unfavourable, but none could be classified as a bad split that complicated the intraoperative or postoperative procedure. The two groups showed different fracture patterns after BSSO (Table 3).

Group 1 (ratio <0.775) was associated with a tendency to relatively more LSS3 fracture lines, and Group 2 (ratio >0.775) had a higher incidence of LSS1 fracture lines. The cancellous:cortical bone volume ratio was significantly associated with the different lingual fracture line patterns (OR = 1.990, 95% CI 1.043 to 3.796, p = 0.043). There was no significant association between the cancellous:cortical bone

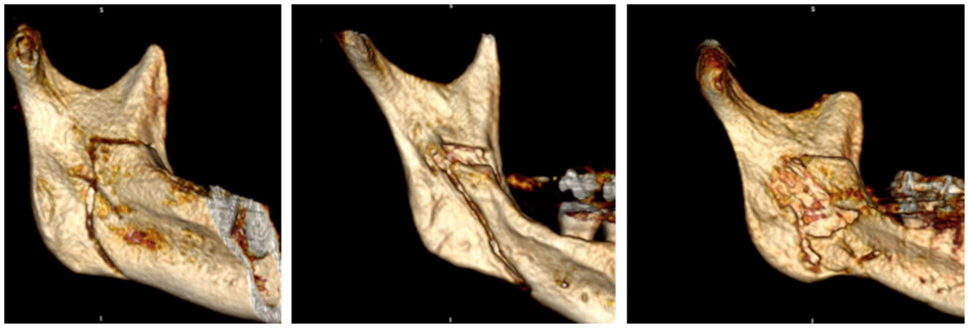

Fig. 3. Three-dimensional view of different lingual fracture line patterns. LSS1 (A), LSS3 (B), and LSS4 (C).

Table 4
Odds ratio (OR) along with 95% confidence interval estimated with a GLMM for lingual fracture line pattern.

	OR (95% CI)	p value
CCR*	1.990 (1.043-3.796)	0.037
Side	0.933 (0.500-1.741)	0.827
Gender	1.203 (0.641-2.260)	0.565
Type of malocclusion	0.835 (0.404-1.726)	0.627

* cancellous-cortical ratio.

Table 5
Odds ratio (OR) along with 95% confidence interval estimated with a GLMM for unfavourable split.

	OR (95% CI)	p value
CCR*	2.352 (0.748-7.392)	0.143
Side	1.296 (0.452-3.719)	0.629
Gender	2.141 (0.756-6.065)	0.152
Type of malocclusion	0.871 (0.272-2.792)	0.817

* cancellous-cortical ratio.

volume ratio and the occurrence of a LSS4 fracture line (OR = 2.352, 95%CI 0.748 to 7.392, $p = 0.143$).

The results from the GLMM analyses are shown in Tables 4 and 5.

Discussion

In this study we aimed to evaluate the association between the cancellous:cortical bone ratio in the mandibular angle and the lingual fracture patterns after BSSO. We found that mandibles with a relatively small amount of cancellous bone were significantly associated with more LSS3 fracture patterns. These mandibles also showed more "unfavourable" LSS4 fracture patterns, although this was not significant.

Optimising control over the lingual fracture line when splitting the mandible is important, and insights into the factors that influence lingual fracture patterns are required. These insights could help surgeons achieve more predictable splits and to create the lingual fracture they desire. Preoperative cone-beam CT scan examination of the mandible could play an important part in predicting lingual fracture lines during BSSO.[5]

Several studies have investigated the shape of the mandible as a possible predictor.[5,11–13] Some authors found a higher risk of bad splits in thinner mandibles and in mandibles with a ramus of a smaller vertical dimension.[11–13] Others stated that a layer of cancellous bone is needed to provide a cleavage plane when splitting the mandible during BSSO.[14–18] To our knowledge, no previous studies have been published that have investigated characteristics of mandibular bone volume as predictors of lingual fracture patterns after BSSO. In a previous preclinical study, we hypothesised that the mandibular canal, or mylohyoid groove, or both, created a "path of least resistance" for the lingual fracture, but we could not confirm this.[19]

One might hypothesise that the lingual fracture pattern is unimportant, as long as 'bad splits' do not occur. However, we think that the surgeon should strive not only to avoid bad or unfavourable splits, but also to try to achieve the most favourable split for each patient. The preoperative cone-beam CT scan informs the surgeon about the mandibular anatomy of a specific patient and could therefore lead to individual adjustments in the osteotomy design. In their review, Chrcanovic and Freire-Maia emphasised this need for an osteotomy designed for each individual patient.[20] Adjustments that can be made to the design include an angled osteotomy, a modified inferior border cut, or even an inferior border osteotomy.[8,21]

Which lingual fracture pattern is "the best" is still part of the debate. Many surgeons do the BSSO according to the Hunsuck modification.[9] With this, the surgeon generally attempts to establish a LSS1 fracture line.[2] This requires the presence of a substantial amount of cancellous bone behind and below the level of the mandibular canal. A LSS1 fracture pattern might be more favourable in large mandibular advancements to increase the amount of bony contact between the proximal and distal segments and avoid the risk of postoperative defects of the inferior mandibular border.[22]

A LSS3 fracture line might be more favourable in a patient with severe asymmetry, where there is a risk of interference between the proximal and distal segment after the sagittal split,[23] but the disadvantage of this is that it allows for less bony overlap between the segments.

The LSS2 pattern is generally considered to be a less predictable pattern because the fracture runs through an area that lacks cancellous bone.[24] We also think that a LSS2 fracture line, when it has to be forced towards the distal border of the mandible with a chisel, creates risks for the inferior alveolar nerve and surrounding structures. However, we did not aim to evaluate the different fracture patterns, so we are unable to state which lingual fracture pattern is "the best". This remains an interesting topic for future research.

In our study group, unfavourable fracture lines (LSS4) occurred in 11% of the sagittal splits. These were strictly defined, as all patterns that could not be categorised as LSS1, LSS2, or LSS3. This explains the difference in incidence of unfavourable fractures in this study compared with the incidence of bad splits as reported elsewhere.[1] We found no fracture patterns that could be classified as "bad splits" – that is, buccal plate fractures or fractures that complicated the clinical procedure.

We have used only a fraction of the information that is present in preoperative and postoperative cone-beam CT scans of patients undergoing BSSO. The preoperative scans were useful in assessing the amount of cancellous bone, and the postoperative scans (made eight weeks postoperatively) still had the lingual fracture lines clearly visible (particularly when we used a combination of 3-dimensional and 2-dimensional views). Using these data, we found a significant association between the relative amount of cancellous bone in the mandibular angle and the lingual fracture patterns after BSSO. As the number of patients in our study was relatively small, further research on a larger number of patients is needed.

Conflict of interest

We have no conflicts of interest.

Ethics statement/confirmation of patients' permission

Ethics approval was not required. Patients' permission for use of radiological data was obtained, and those who did not give their consent for the use of their radiological data were excluded from this study.

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