3D evaluation of the lingual fracture line after a bilateral sagittal split osteotomy of the mandible


Abstract. The purpose of this prospective observational study was to evaluate whether cone beam CT (CBCT) is a useful tool for analyzing the fracture line in a bilateral sagittal split osteotomy (BSSO). The patient group consisted of 40 consecutive patients (9 males and 31 females) with a mandibular hypoplasia who underwent a BSSO advancement (Hunsuck modification; n = 80 splits) between September 2006 and July 2008. The mean age at the time of surgery was 34 years (range 17–61 years). A newly developed lingual split scale was used to categorize the path of the fracture line on the lingual side of the ramus based on one-day postoperative data sets reconstructed from CBCT data. Although all splits (n = 80) were performed according to the standardized protocol, only 51% of the fracture lines run according to the Hunsuck’s description, whereas 33% ran through the mandibular canal and 16% split otherwise. The split pattern was influenced by the length of the medial osteotomy (p = 0.01). In conclusion, 3D imaging is a useful tool for analyzing the surgical outcome of a BSSO and has the potential to provide substantial data on the position of the proximal segments as a result of the lingual fracture line.

Keywords: maxillofacial surgery; computer-assisted three-dimensional imaging; cone-beam CT; dysgnathia; bilateral sagittal split osteotomy; hunsuck modification; reliability.

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Bilateral sagittal split osteotomy (BSSO) is the most used orthognathic surgical procedure for the correction of mandibular dysgnathic deformities. The Obwegeser-Dal Pont osteotomy and the Hunsuck modification are frequently used to advance or set back the mandible. When performing a BSSO, there is no visual control of the lingual split pattern that occurs during the split procedure. Postoperative nerve damage in a BSSO might be a result of the fact that the exact split pattern is unknown during the surgery.

The surgical result of a BSSO is mainly evaluated using conventional X-rays, such as an orthopantomogram. This method does not allow a precise analysis of the split pattern. Recently, software platforms have been introduced to reconstruct a 3D model from (cone-beam) CT data to analyze 3D data in a virtual operating room (VOR). With these 3D models, a clear view of the lingual surface of the mandible can be achieved, enabling observation of the previously hidden lingual aspect of the fracture line. Until now, no studies have been performed to study the lingual surface of the mandible in three-dimensions.

The purpose of this prospective observational study was to evaluate whether CBCT is a useful tool for analyzing the lingual split in a BSSO and to evaluate the lingual split.
Materials and methods

Subjects

40 Caucasian patients with a symmetrical mandibular hypoplasia without a maxillary hypo/hyperplasia or an anterior open bite, (9 males and 31 females) were prospectively enrolled in this study and underwent a BSSO advancement between September 2006 and July 2008. All patients were older than 15 years with a mean age at the time of surgery of 34 years (range 17–61 years). Inclusion criteria were a non-syndromic mandibular hypoplasia (skeletal Class II deformity) and a signed informed consent. The exclusion criteria were a history of orthognathic surgery or simultaneously performed other orthognathic procedures, such as a Le Fort osteotomy or a chin osteotomy.

The study protocol (181/2005) was approved by the Medical Ethical Commission of the Radboud University Nijmegen Medical Centre, Nijmegen, The Netherlands.

Osteotomy technique

All surgical procedures were performed under general anaesthesia with nasal intubation. A BSSO with a Hunsuck modification was designed to advance the mandible was performed in all patients. If third molars were present, they were removed during the procedure. Two senior surgeons performed the split at one side, while they supervised a resident performing the other side. In some cases, both sides were operated on by a resident. The horizontal bone cut on the lingual surface (medial bone cut) was made just above the mandibular foramen and extended just dorsally of the foramen. The vertical bone cut on the buccal surface (buccal bone cut) was made behind the first molar. The bone cuts were then connected and the osteotomy was completed with a chisel. If third molars were present, they were removed simultaneously with the osteotomy. The distal segment of the mandible was advanced, and kept in position using an acrylic wafer and temporary intermediary fixation (IMF). The proximal segment was gently pushed upward and backward to seat the condyle correctly in the fossa. For fixation of the fragments, titanium miniplates with four screws were used (KLS Martin, Tuttinglen, Germany). The IMF was removed and the occlusion checked.

To categorize the different split patterns a lingual split scale (LSS) was developed (Table 2, Fig. 2). The LSS consisted of four categories based on the path of the fracture line on the lingual side of the ramus. In all cases, the split began at the distal end of the medial bone cut and followed one of the following paths: split type 1 (LSS1) fractured through or behind the mandibular foramen towards the inferior border of the mandible as described by Hunsuck; in split type 2 (LSS2) the medial bone cut extended towards the posterior border before bending to the inferior border of the ramus; split type 3 (LSS3) fractured through the mandibular foramen and the mandibular canal towards the inferior border; split type 4 (LSS4) included all other unfavourable fracture patterns, i.e. a buccal plate fracture or a bad split.

To evaluate the influence of the position of the end of the medial bone cut on the path of the lingual fracture line, the medial bone cuts were graded using the anterior border of the mandibular foramen as a cut-off. In other words, grade A were medial bone cuts that ended in front and grade B were medial bone cuts that ended behind the anterior border of the mandibular foramen.

To define the error of method of the LSS and the length of the medial bone cut, an intra- and interobserver reliability test was performed. Two OMF residents (MN and JP) independently categorized 40 splits according to the LSS and 40 medial bone cuts on the 3D objects in the VOR of 20 patients, which was repeated by one observer (JP) after 1 month to prevent memory bias. One observer (JP) analyzed 80 splits and medial bone cuts on the 3D objects in the VOR.

Table 1. i-CAT™ 3D imaging system specifications.

<table>
<thead>
<tr>
<th>X-ray source</th>
<th>High frequency, constant potential, fixed anode 120 kVp, 3-8 mA (pulse mode)</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-ray beam</td>
<td>Cone-beam</td>
</tr>
<tr>
<td>Focal spot</td>
<td>0.5 mm</td>
</tr>
<tr>
<td>Field of view</td>
<td>16 cm (diameter) * 22 cm (height)</td>
</tr>
<tr>
<td>Image detector</td>
<td>Amorphous silicon flat panel 20 cm * 25 cm</td>
</tr>
<tr>
<td>Voxel size</td>
<td>0.4 mm</td>
</tr>
<tr>
<td>Gray scale</td>
<td>14 bit</td>
</tr>
<tr>
<td>Scan time</td>
<td>40 s (extended height)</td>
</tr>
<tr>
<td>Radiation dose</td>
<td>136 μSv</td>
</tr>
</tbody>
</table>
All statistical data analyses were carried out with the SPSS software program, version 16.0 for Windows (SPSS Inc, Chicago, USA). The kappa-coefficient was used to calculate the intra- and interobserver reliability of the LSS. The influence of the presence of a third molar, the position of the end of the medial bone cut, gender and the surgeon’s experience on the observed split pattern were calculated using crosstabs and the Fisher Exact test. These were also used to determine the influence of patient gender and surgeon’s experience on the position of the end of the medial bone cut and the matching of left and right split patterns. Student’s $t$-test was used to analyse the influence of age on the position of the end of the medial bone cut. An ANOVA was performed to analyse the influence of age on the split pattern.

## Results

### Subjects

The mean age at the time of surgery was 34 years (range 17–61 years). The 31 female patients had a mean age of 33.7 (range 17.1–60.9) years and the 9 male patients had a mean age of 36.2 (range 16.8–55.8) years. 80 splits were performed according to the standardized protocol. 27 splits were performed by a senior surgeon, 51 by a resident supervised by a senior surgeon and 2 were unknown. 24 mandibular third molars were removed simultaneously with the osteotomy (Table 3).

### 3D evaluation

The 3D objects and the display of the 3D objects in the VOR were of very good quality. All rotational movements were possible, which visualized the lingual aspect of the mandible just as clearly as the buccal aspect during the surgical procedure. This enabled objective analysis of the lingual fracture line in three dimensions. The kappa-coefficient of the intra- and interobserver reliability was 0.95 ($p = 0.000$) and 0.69 ($p = 0.000$), respectively, for the LSS and 0.90 ($p = 0.000$) and 0.78 ($p = 0.000$), respectively, for the grading of the medial bone cuts.

In more than half of the splits ($n = 41$; 51.3%) the fracture line was categorized as LSS1, whereas LSS2, LSS3 and LSS4 were seen in respectively $n = 11$ (13.8%), $n = 26$ (32.5%) and $n = 2$ (2.5%) splits (Table 3). Examples of the lingual split pattern are shown in Fig. 3. In 23 patients (58%) the left and right split showed the same pattern; in the remaining 17 patients the left and right split showed the same pattern; in the remaining 17 patients

### Table 2. Characteristics of the fracture line on the lingual side of the ramus.

<table>
<thead>
<tr>
<th>Split pattern of the lingual fracture line</th>
<th>LSS1</th>
<th>LSS2</th>
<th>LSS3</th>
<th>LSS4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical pattern of fracture line to inferior border of the mandible (‘true’ Hunsuck)</td>
<td>11</td>
<td>0</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Horizontal pattern of fracture line to posterior border of the ramus</td>
<td>0</td>
<td>11</td>
<td>19</td>
<td>0</td>
</tr>
<tr>
<td>Fracture line through the mandibular canal to inferior border of the mandible</td>
<td>24</td>
<td>5</td>
<td>23</td>
<td>2</td>
</tr>
<tr>
<td>Other patterns, i.e. a buccal plate fracture or a bad split</td>
<td>30</td>
<td>6.25</td>
<td>28.75</td>
<td>1.25</td>
</tr>
</tbody>
</table>

## Table 3. Distribution of 80 splits on the lingual split scale (LSS), categorized both to gender, the length of the medial bone cut and the presence of third molars.

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Female</th>
<th>Grade A</th>
<th>Grade B</th>
<th>3rd molars</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>#</td>
<td>%</td>
<td>#</td>
<td>%</td>
<td>#</td>
<td>%</td>
</tr>
<tr>
<td>LSS1</td>
<td>11</td>
<td>13.75</td>
<td>30</td>
<td>37.5</td>
<td>24</td>
<td>30.0</td>
</tr>
<tr>
<td>LSS2</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>6.25</td>
<td>6</td>
<td>7.5</td>
</tr>
<tr>
<td>LSS3</td>
<td>7</td>
<td>8.75</td>
<td>19</td>
<td>23.75</td>
<td>23</td>
<td>28.75</td>
</tr>
<tr>
<td>LSS4</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2.5</td>
<td>1</td>
<td>1.25</td>
</tr>
<tr>
<td># of splits</td>
<td>18</td>
<td>22.5</td>
<td>62</td>
<td>77.5</td>
<td>53</td>
<td>66.3</td>
</tr>
</tbody>
</table>

In grade A the medial bone cut ended ‘in front’ of the anterior border of the mandibular foramen. In grade B the medial bone cut ended ‘behind’ the anterior border of the mandibular foramen. The crosstabs and the Fisher exact test showed a statistically significant difference between the end of the position of the medial bone cut and the lingual split pattern ($p = 0.01$), but not with the presence of third molars ($p = 0.55$). LSS = Lingual Split Scale, pattern 1 to 4.
(42.5%) the left and right split pattern were different.

Table 3 shows the grading of the medial bone cut in relation to the type of split. In 53/80 (66%) splits, the medial bone cut ended in front of the anterior border of the mandibular foramen (grade A). Almost half of these splits ran as LSS1 (45%) or LSS3 (43%). The remaining 27 (34%) medial bone cuts ended behind the anterior border of the mandibular foramen. In this group, 17 splits ran according to LSS1 (63%) and only 3 according to LSS3 (11%).

**Statistical analysis**

The split pattern was statistically significantly related (p = 0.01) to the position of the end of the medial bone cut. The presence of a third molar, gender and age had no influence on the observed split pattern (p = 0.55, p = 0.20 and p = 0.14, respectively). The surgeon’s experience was not related to the split pattern (p = 0.55).

The position of the end of the medial bone cut was not gender or age dependent, p = 0.40 and p = 0.14, respectively. The surgeon’s experience was not related to the position of the end of the medial bone cut (p = 0.14).

The matching of left and right split pattern was not gender dependent (p = 0.36).

**Discussion**

Several methods have been described to split the mandible while performing orthognathic surgery. A conventional lateral headplate and an orthopantomogram have been used to evaluate the split pattern, which inherently introduced analysis bias either caused by overprojection or by the panoramic (2D) representation, respectively. In addition to these restrictions, the true characteristics of the fracture line on the lingual side of the ramus can not be objectified using these radiographic tools. Since the patient is a three-dimensional (3D) subject, quantitative assessment of facial hard and soft tissue should be a 3D instead of a 2D procedure. A 3D model can be obtained by rendering the DICOM files of the CBCT scan into the hard tissue surface representation. With the latter technique, the use of the digital 3D reconstruction of a mandible has many advantages over a 2D view of the lateral headplate, including the postoperative assessment of the surgical osteotomies.

Software platforms for 3D surgical planning have been introduced to prepare and evaluate surgical procedures in a VOR based on (cone-beam) CT data. For example, preoperatively, one can study the anatomy of the mandible, to avoid an ‘unfavourable split’. When reviewing...
the postoperative 3D images of the BSSO, and especially the medial bone cut and the split pattern shortly after the surgical procedure, one can use it not only as an objective evaluation of the surgical result, but as a teaching instrument for (inexperienced) residents as well.

Patients were well informed concerning the limited hazards of these images. For medical and legal reasons, it was mandatory to confirm the correct position of the condyles postoperatively, which was previously done with an orthopantomogram. Since postoperative imaging was necessary, it was decided to use a form of imaging that would be helpful for the present study as well as further studies concerning postoperative swelling and esthetic evaluation. Compared with an orthopantomogram, the radiation dose was higher, but compared with a CT scan it was significantly lower. With the ALARA principle and the currently available imaging techniques in mind, it was determined, that the patients were not exposed to any unnecessary radiation to obtain these study results.

The split pattern has been described, but it has not been assessed with 3D imaging. In this study, the data were evaluated in a VOR, which enabled the observers to rotate the 3D object in any direction during the evaluation and to assess the complete ramus interactively including the lingual side, which is hardly visible during the surgical procedure and therefore the path of the lingual fracture line is under little surgical control. In the VOR, the lingual aspect of the mandible was just as clearly visualized as the buccal aspect during the surgical procedure.

Both surgeons and residents intended to perform a BSSO with a Hunsuck modification in all cases, but only half of the splits (51%) ran as described by Hunsuck. Macintosh, has found that there is an uncertainty of 7% concerning the predictability of the surgical outcome of a BSSO. He might have found a higher percentage, if 3D imaging had been used. In the present study, in the remaining splits the lingual fracture line extended the medial bone cut straight to the posterior border of the ramus in 14% (n = 11) or it stopped at the mandibular foramen and proceeded through the mandibular canal in 33% (n = 26). As a result, the latter group might be more at risk of nerve damage. In this study, 2 sides (2.5%) showed an unfavourable split pattern, which was comparable with other reported percentages.

It is important to note that in contrast to the fracture line, the length and position of the medial bone cut can be visually controlled and verified during the surgical procedure. In this study group no relation was found between the surgeon’s experience and the position of the end of the medial bone cut. When the medial bone cut ended behind the anterior border of the mandibular foramen, the chance of splitting the ramus according to Hunsuck’s description increased from 44% to 63% and the chance of splitting through the mandibular canal was statistically significantly reduced from 43% to 11%, which might reduce the risk of postoperative hypoesthesia or anaesthesia. The current study cannot reveal the clinical relevance of these findings concerning hypoesthesia or anaesthesia and the impact on facial balance, progressive condylar resorption or stability of the surgical procedure. Further research is ongoing to study the correlation between the above mentioned variables and the variances of the different split patterns. It is interesting to evaluate whether the characteristics of the fracture line are influenced, or can be controlled, by adaptation of the length or direction of the medial (behind the mandibular foramen) and buccal bone cuts, or whether the fracture line simply seeks the path of least resistance.

In this study, in 17 patients the same surgical technique, performed or supervised by the same surgeon, resulted in a different split pattern at the left and right side. The split areas of the four different split patterns varied considerably in size. This might cause a difference in the amount of initial bone contact in the postoperative situation between the left and the right side. As a consequence, the displacement of the proximal segments might be influenced by this difference. This can be studied in a VOR which matches the pre- and postoperative data. With 3D cephalometric analysis, it is also possible to measure the positional changes of the distal and the proximal segments in 3D as well as changes of the overlying soft tissues. Specific rotations along the anteroposterior, transverse and vertical axes, such as pitch, roll and yaw can be visualized.

In conclusion, CBCT based evaluation of the BSSO combined with the lingual split scale enabled objective evaluation of the surgical result, thereby adding a new dimension to the discussion of BSSO techniques. Further research is ongoing to determine the relationship between the localization of the buccal bone cut, the length of the medial bone cut, the characteristics of the fracture line on the lingual side and the amount of displacement of the proximal segment and postoperative hypoesthesia or anaesthesia. The long term effects of these movements on the overlying facial soft tissue are being studied to enhance the surgical outcome.

Competing interests
None declared.

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Ethical approval
The study protocol was approved by the Medical Ethical Commission of the Radboud University Nijmegen Medical Centre, Nijmegen, The Netherlands (181/2005).

References


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