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Cone beam computed tomography evaluation of tooth injury after segmental Le Fort I osteotomy

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Abstract. The purpose of this study was to explore the incidence of injuries to the teeth at the vertical osteotomy line after segmental Le Fort I osteotomy by examination of postoperative cone beam computed tomography (CBCT) images. Data for this retrospective case study were collected using CBCT images of 132 patients with an indication for Le Fort I osteotomy with three-piece segmentation of the maxilla. Twenty-two patients (17%, 95% confidence interval 10–23%) had dental injuries. No patient had more than one dental injury. Thirty-three patients (25%, 95% confidence interval 18–32%) had bone dehiscence of the teeth (defined as the osteotomy line passing through the periodontal ligament). Six patients had bone dehiscence involving two teeth and one patient had bone dehiscence involving three teeth. In the group in which dental injuries occurred, the preoperative interdental distance at the vertical osteotomy line was significantly shorter than the interdental distance in the group without dental injuries. In conclusion, this study demonstrated that a preoperative interdental distance of more than 2.5 mm significantly reduced the possibility of tooth injuries adjacent to the vertical osteotomy line during Le Fort I osteotomy with three-piece segmentation of the maxilla.

Key words: CBCT dental; complications; Le Fort I osteotomy; maxillofacial orthognathic surgeries; tooth injury.

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Segmental Le Fort I osteotomy may potentially cause injury to the teeth adjacent to the vertical osteotomy line. Le Fort I osteotomy en bloc in conjunction with orthognathic surgery is a well-recognized procedure for the correction of developmental dentofacial deformities[1,2]. According to the literature, modifying the procedure with interdental osteotomies may have several advantages[3–8]. Complications after segmentation are described as root injuries, tooth loss, periodontal injuries[9–13], changes in alveolar crest height[14,15], oronasal fistula[16], and, in very rare cases, partial jaw necrosis[17,18].

Previously, panoramic or intraoral radiographs have been used to detect dental injury after segmentation, but these images are limited by superimposition of the anatomical structures and unequal magnification in the horizontal and vertical dimensions[19]. In contrast, cone beam computed tomography (CBCT) allows navigation of the volume in the axial, sagittal, and coronal planes, which provides unobstructed views of the anatomical structures in their precise locations[20]. Therefore, the authors believe that CBCT technology provides a better diagnostic tool than panoramic or intraoral radiographs to detect dental injuries at the osteotomy line. Furthermore, the diagnostic accuracy of CBCT images allows the detection of more subtle injuries to the surface of the roots. This has been demonstrated previously in a study comparing CBCT and panoramic radiographs for the detection of root resorption[21]. Thus, there is the risk that panoramic radiographs might underestimate the amount of dental injury related to segmented maxillary osteotomies. However, very little is currently known about tooth injuries and bone dehiscence of the teeth at the osteotomy line evaluated by CBCT.

The purpose of this investigation was to explore the relationship between segmental Le Fort I osteotomy and the incidence of tooth injury evaluated by postoperative CBCT.

Materials and methods

A total of 132 consecutively treated patients with an indication for Le Fort I osteotomy with segmentation were included in this retrospective case study. None of the included patients were syndromic, had a cleft, were post-traumatic, or had previously undergone orthognathic surgery. Single-jaw surgery was performed in 38 of the patients, while the Le Fort I procedure was performed as a part of a bimaxillary procedure in the remaining 94 patients. No teeth were extracted at the osteotomy sites during the surgery.

The surgical procedures were performed between 2013 and 2016 at the Department of Oral and Maxillofacial Surgery, Aarhus University Hospital in Denmark. Five senior oral and maxillofacial surgeons performed the procedures, and parts of the surgery were performed under supervision by oral and maxillofacial residents. The sex distribution of the patients was 51 (38.6%) male and 81 (61.4%) female, and their mean ± standard deviation age at the time of surgery was 24.9 ± 6.7 years.

Description of the procedure

As part of the standard clinical protocol in the department, CBCT images were obtained for all of the patients undergoing orthognathic surgery both preoperatively (for planning) and postoperatively (for inspection of osteotomies, position of the condyles, inter-maxillary relationships, and dental root positions). The CBCT images obtained in this study formed part of a larger study evaluating the precision of virtual surgical planning. On average, images were acquired 46 days prior to surgery and 51 days postoperatively. No active orthodontic treatment was performed based on the preoperative CBCT scan until the day of surgery. The CBCT unit (NewTom, Verona, Italy) generated images with a resolution of 96 dpi, 14-bit grey-scale, field of view (FOV) 17 × 23 cm, and 0.30-mm voxel size. The CBCT unit was set at 110 kVp, 2–5 mA, with a 20-second exposure time. Experienced staff using the same standardized protocol scanned all patients.

Surgical technique

Preoperative decompensation, alignment of the teeth and dental arches, and angulation of the roots to create space for the vertical osteotomy lines were accomplished according to the department protocol and as described in the literature[22]. The surgical technique used to perform the Le Fort I osteotomy with segmentation was consistent throughout the study. The surgical procedure is well-described in the literature[23–25] and is summarized below, with special focus on the vertical osteotomy.

Nasotracheal intubation and local anaesthesia (lidocaine 10 mg/ml + adrenaline 5 μg/ml) were performed, and antibiotics (benzylpenicillin 3 g, metronidazole 1 g) and methylprednisolone (40 mg) given. A reference pin was then placed on the bridge of the patient's nose and the surgical procedure was started. A standard mucoperiosteal, vestibular incision was made with electrocautery, thereby degloving the maxilla above the tooth apices between the first molars. At the planned vertical osteotomy sites, the mucoperiosteum was reflected to the marginal bone of the alveolar ridge, exposing the complete shape of the adjacent roots. No incisions were made in the gingival papilla. The mucoperiosteum of the floor of the nasal cavity was then elevated, and subsequently a symmetric Le Fort I osteotomy was made with a burr at the lateral maxillary buttress and directed to the ipsilateral piriform rim. Using osteotomes at the pterygomaxillary junction and lateral bony part of the nasal cavity, the osteotomy was completed before separating the nasal septum from the maxilla with a U-shaped osteotome. After down-fracture of the maxilla, vertical interdental osteotomies were implemented bilaterally between the lateral incisors and canines (Fig. 1). In two patients in this study, the interdental osteotomies were made between the canines and first premolars. The osteotomy was performed with the aid of a piezoelectric saw (Piezosurgery, Mectron, Italy), either as a bicortical, complete osteotomy or as a unicortical osteotomy, finalizing the remaining osteotomy of the palatal part with a chisel. The procedure was based on the assumptions that a piezoelectric bone cut provides the least damage to bone structures and that the risk of separation of the bone from the root surface is reduced when completing the osteotomy with chisels. The piezoelectric technique was therefore applied for the entire osteotomy when space was estimated to be sufficient. In the case of potentially insufficient space between the roots, the chisel technique was used. To complete the segmentation of the maxilla, an H-shaped osteotomy of the palatal part of the maxilla was made leaving the maxilla in four segments (one palatal segment and three tooth-bearing segments) (Fig. 1). The segments were placed passively in a prefabricated splint before repositioning the maxilla in the correct planned occlusion. Internal rigid fixation was ensured with the use of titanium miniplates. When necessary, locally harvested autogenous bone graft material was placed between the segments in order to obtain bone-to-bone contact, thereby facilitating bone healing and improving skeletal stability. The occlusal splint was left for stabilization for 2 to 6 weeks postoperatively.

CBCT evaluation

Two observers (NM, NQR) evaluated the pre- and postoperative CBCT images using specific software (Romexis 3.0; Planmeca, Helsinki, Finland) that makes it possible to navigate in freely chosen planes through the volumes and to reconstruct the image sections. Initially, a number of CBCT scans were evaluated together with the senior surgeons to agree on the criteria for root injury and bone dehiscence. All positive findings were confirmed by repeated evaluations.

In a standardized manner, the interdental distance at the vertical osteotomy line was measured at three different anatomical locations: at the marginal distance, apical distance, and shortest distance. A reduction at the osteotomy line was defined as a shorter distance between the roots postoperatively

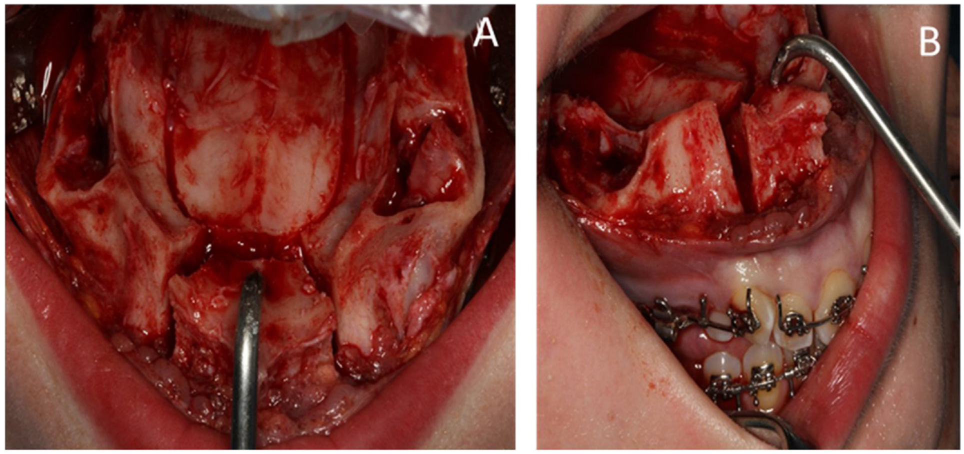

Fig. 1. Clinical pictures demonstrating the segmental osteotomy of the maxilla: (A) palatal view; (B) lateral view.

compared to the distance preoperatively. No reduction at the osteotomy line was defined as a longer or the same distance between the roots postoperatively compared to the distance preoperatively. The observers also identified dental injuries and bone dehiscence of the teeth adjacent to the osteotomy line on the postoperative CBCT scan. Dental injuries were defined as injuries to the root surface. These were registered as not present or present in the marginal third, middle third, or apical third of the root. In one case, the entire vertical length of the root was injured and this was categorized separately. Bone dehiscence was defined as no bone between the root and the osteotomy line, with the fracture line of bone running along the root and through the periodontal ligament; this was noted as present or not present.

Statistical analysis

Data management and analysis, including the calculation of descriptive statistics, were performed using Excel (Microsoft, Redmond, WA, USA) and Stata (StataCorp, College Station, TX, USA). A histogram and qq-plot demonstrated that the data had a normal distribution. A two-sample *t*-test with unequal variances was computed to test for any difference in the preoperative interdental distance between the group with dental injury present and the group with no dental injury. A χ^2 test was performed to reveal the distribution of the injury and site to a particular tooth. Additionally, a preoperative interdental cut-off distance of 2.5 mm was used to determine whether tooth injury occurred more often in the group with a preoperative interdental distance of $\leq$2.5 mm than in the group with a preoperative interdental distance of >2.5 mm (χ^2 test). The 2.5-mm distance was chosen as the cut-off from the confidence intervals of the two groups computed by the *t*-test. A statistically significant difference was considered when $P < 0.05$.

Results

A total of 132 patients were included in the study, thus the evaluation included 264 CBCT images of interdental osteotomy sites after Le Fort I osteotomy including segmentation. At the tooth level, teeth 13, 12, 22, and 23 (14, 13, 23, and 24 in two patients) were potentially at risk of tooth injury during the segmentation, giving a total of 528 teeth included in the present study. Representative cases of tooth injury and bone dehiscence diagnosed on axial and sagittal CBCT images are presented in Figs 2 and 3.

Patient level

Twenty-two of the 132 patients had tooth injuries as determined from the CBCT images obtained after the segmentation procedure (17%, 95% confidence interval (CI) 10–23%). No patient had more than one tooth injury. Thirty-three of the 132 patients had bone dehiscence according to the CBCT scan obtained after the segmentation procedure (25%, 95% CI 18–32%). Six patients had bone dehiscence involving two teeth and one patient had bone dehiscence involving three teeth.

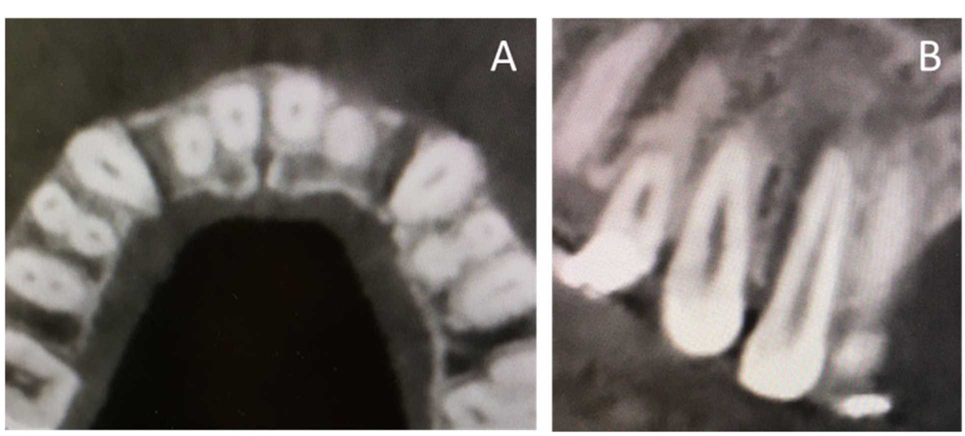

Fig. 2. Axial CBCT images demonstrating bone dehiscence of (A) tooth 13 and tooth 23, and (B) tooth 12, in two different patients.

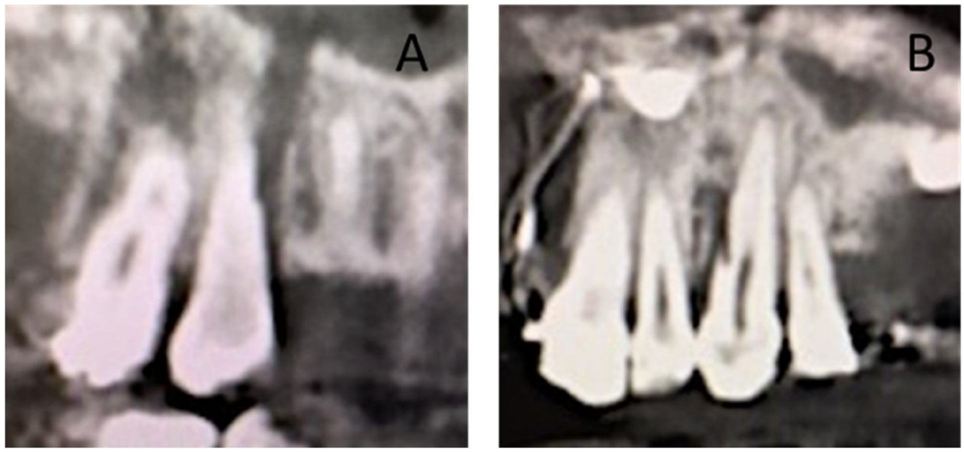

Fig. 3. Sagittal CBCT images demonstrating tooth injury to (A) tooth 13, and (B) tooth 23, in two different patients.

Osteotomy level

Of the 264 osteotomy sites evaluated, 22 involved tooth injuries in the osteotomy line (8%, 95% CI 5–12%). Six tooth injuries were registered at the right osteotomy line, while 16 were observed at the left osteotomy line. A total of 40 cases of bone dehiscence were observed at the two osteotomy lines (15%, 95% CI 11–19%); these were equally distributed with 20 cases of bone dehiscence at each site.

Tooth level

Injury occurred in 22 teeth out of the 528 teeth (4%, 95% CI 2–6%) adjacent to the osteotomy line. The teeth involved were 14, 13, 12, 22, 23, and 24. The location of the tooth injury on the tooth is shown in Table 1. Bone dehiscence occurred in 41 (8%, 95% CI 5–10%) of the teeth adjacent to the osteotomy line. The distribution of tooth injuries and bone dehiscence is presented in Fig. 4.

As shown in Table 1, the tooth injury did not have a specific location on the tooth ($P = 0.56$). In one patient, the injury to the tooth involved the entire vertical part of the root. Fig. 4 shows an almost equal distribution of the bone dehiscence primarily related to teeth 13 and 23. In contrast, tooth injury significantly more often involved the tooth distal to the osteotomy line on the left side (tooth 23 or 24) than the tooth distal to the osteotomy line on the right side (tooth 13 or 14) ($P = 0.02$).

Table 1. Location of the dental injury on the root of the involved tooth (132 patients; 528 teeth).

Site	Number
Marginal third	9
Middle third	7
Apical third	5
Entire root	1

Osteotomy site

In the group with tooth injuries indicated on the postoperative CBCT, the shortest distance between the adjacent teeth at the osteotomy site preoperatively was 2.2 mm (95% CI 1.9–2.5 mm). The same difference measured in the group without any postoperative tooth injury was 2.6 mm (95% CI 2.5–2.8 mm). This preoperative interdental difference at the osteotomy site between the two groups of 0.43 mm (95% CI 0.11–0.76) was found to be statistically significant ($P = 0.04$). In the group where the preoperative interdental distance was $\leq$2.5 mm, there was a significantly higher possibility of tooth injury compared with the group where the preoperative interdental distance was >2.5 mm. Tooth injury was not significantly dependent on the preoperative movement of the segments (reduction $n = 11$, no reduction $n = 11$) ($P > 0.05$).

Discussion

This study focused on tooth injuries as evaluated using CBCT images after segmental Le Fort I osteotomy. A total of 132 patients and 528 teeth were included in the study. The most interesting and surprising finding was that segmentation resulted in tooth injury in terms of root injury in 22 teeth and bone dehiscence in 41 teeth. This large number of root injuries to the teeth adjacent to the osteotomy line differs from the findings of the only previously published study assessing the segmental Le Fort I osteotomy using CBCT[15]. This previous study reported no root injuries in a sample of 47 patients. A possible explanation for this might be differences in the preoperative interdental distance at the osteotomy site or differences in the surgical techniques applied in the two studies. In the CBCT study by Rodrigues et al.[15], the preoperative interdental distance was

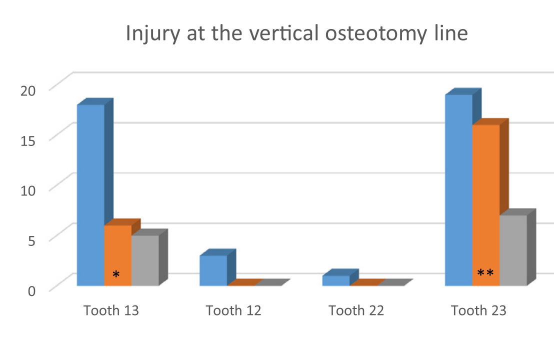

Fig. 4. Tooth at the osteotomy site involving bone dehiscence and dental injury (132 patients; 264 sites). Tooth 13: right canine; 12: right lateral incisor; 22: left lateral incisor; 23: left canine.
*One of the six dental injuries was on a first premolar, right side.
**One of the 16 dental injuries was on a first premolar, left side.

2.5 mm on average and an osteotome was used to complete the osteotomy of the palatal cortical plate. No records of bone dehiscence were registered in that study[15].

In other studies, tooth injuries were diagnosed using conventional two-dimensional radiographic examination or clinical tooth discoloration. In a retrospective study by Kahnberg et al., three dental injuries were diagnosed radiographically in 79 patients who underwent maxillary segmentation (3/79 = 4%, at the patient level)[11]. In another retrospective study by Ho et al., loss of vitality in teeth adjacent to the interdental osteotomy was reported to be 0.7% at the tooth level, and one tooth adjacent to the vertical osteotomy line was lost[16]. A study by Posnick et al. reported no surgical injuries to the teeth of 90 patients who underwent three-segment Le Fort I osteotomy[13]. None of these three studies reported the preoperative interdental distance or bone dehiscence.

In the present study, tooth injuries occurred significantly more often if the preoperative interdental distance was less than 2.5 mm. This finding is in accordance with the previously mentioned study[15], which recommended a minimum preoperative interdental distance of 2.5 mm, and with the study by Dorfman and Turvey[26]. The surgical protocol for segmental maxillary osteotomies at the present authors' institution did not previously include an exact minimum interdental distance at the vertical osteotomy line, which is why patients with a distance of less than 2.5 mm were operated on. The protocol has now been adjusted to require a minimum distance of 2.5 mm.

This study also demonstrated significantly more tooth injuries involving the tooth distal to the osteotomy line on the left side (tooth 23 or 24) than injuries involving the tooth distal to the osteotomy line on the right side (tooth 13 or 14). The reason for this is unknown and has not been described previously in the literature. It is possible that for a right-handed surgeon it is easier to perform the osteotomy at the correct angle on the right side than on the left side. By analyzing the anatomy of the teeth at the osteotomy line in the axial plane on the CBCT image before surgery, it may be possible to reduce this problem in the future.

In this study, radiological bone dehiscence occurred in 41 of the teeth adjacent to the osteotomy line. The quality of the CBCT scan did not make it possible to determine if this radiological finding was just a widening of the periodontal ligament or if it was a surgical injury to the periodontal ligament. However, this finding has not been addressed previously in the literature and it is unclear whether any conclusions can be drawn from this. Damage to the periodontal ligament of the tooth can theoretically cause loss of periodontal support and dental ankylosis[27].

Compared to conventional intraoral radiography with only two dimensions, CBCT technology makes it possible to evaluate teeth adjacent to the osteotomy line in three different planes. Details of the structures seen on CBCT should therefore be more visible than those assessed in the previously published studies. The greater accuracy and sensitivity of CBCT images compared to conventional intraoral radiographs has been demonstrated in other studies involving vertical root fractures[28,29]. However, common orthodontic appliances are known to cause artefacts reducing the diagnostic quality of CBCT Images[30].

In the past, the routine use of CBCT for postoperative control images was often considered unethical due to its known higher radiation dose than panoramic radiography. However, the technology has improved and the dose has been reduced considerably. All postoperative CBCT images were taken using the 'ultra low dose' protocol, which according to the manufacturer of the CBCT unit (Romexis 3.0; Planmeca) provides a radiation dose of 18 μSV (FOV 20 cm × 17 cm). In contrast and to provide perspective, the effective dose for a digital panoramic radiograph ranges from 2.7 μSV to 24.3 μSV[31], while the mean daily background radiation dose in Denmark is 8 μSV (Danish Health Authority).

The use of CBCT has gained increasing relevance with the introduction of three-dimensional virtual planning of orthognathic surgery. With this setup, the CBCT replaces panoramic radiographs, lateral and frontal cephalograms, and temporomandibular joint images. For presurgical evaluation as well as the follow-up of the treatment outcome, comparisons are most meaningful if the same imaging technique is used.

A striking finding in this study was the relatively high occurrence of dental injury adjacent to the vertical osteotomy line. Previously, using panoramic radiographs for postoperative control images, a diagnosis of dental injury was extremely rare. Indirectly, this suggests that a postoperative CBCT is required for adequate detection of any surgery-related damage to the teeth and supporting bone.

This study has some limitations, including its retrospective design and the lack of clinical follow-up of the radiographically diagnosed tooth injuries. However, each patient's record was thoroughly reviewed as a part of this study (2018), revealing no loss of teeth in any of the treated patients. There was no control group, but the presurgical examinations did not reveal any signs of injury before surgery. Although a certain amount of orthodontic tooth movement took place after surgery, orthodontically induced root resorption is not similar to the injuries diagnosed in this study.

In conclusion, the following recommendations are proposed: (1) a minimum preoperative distance of 2.5 mm between the roots should be respected, and (2) preoperative three-dimensional analysis of the segmentation regions is mandatory in order to select the optimal surgical technique. A natural continuation of this study would be to analyze the long-term consequences for the 22 patients with tooth injuries.

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Ethical approval. The study did not require ethical approval as it is a quality assessment study.

Patient consent. All patients consented to the treatment.

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