Summary

Background: To evaluate maxillary stability following Le Fort I osteotomy using postero-superior movement after pterygoid plate fracture. Additionally the authors sought to analyze the postoperative changes at the intentional pterygoid plate fracture site.

Materials and methods: Thirty-six patients with class III deformities treated with total maxillary setback at the Lefort I level were enrolled in a retrospective cohort study. Relative changes in measurement points were identified on cone-beam computed tomographic scans (CBCT) as well as lateral cephalograms. The outcome variables were determined as changes at measurement points obtained preoperatively, immediately postoperatively, and 6 months after surgery.

Results: The average posterior repositioning of ANS in the 36 patients was 1.78 mm and the mean superior repositioning at PNS was 2.78 mm. The maximal recurrence rate was less than 10% at the 6 months postoperative time point. The intentional fracture site of the pterygoid plates healed with a linear pattern. There were no major complications such as airway edema, hemorrhage and nerve damage reported over the 6-month follow-up period.

Conclusions: Intentional fracture of the pterygoid plates has a role in the retropositioning of the maxilla with good healing at the fracture site, little relapse and satisfactory postoperative stability.
Keywords

Maxillary total posterior repositioning

Ptetygoid plate

intentional fracture
Introduction

Le Fort I osteotomy has been used extensively to manage various dentofacial deformities (Cortese, 2012). It is safe with few rare life-threatening sequelae (Acebal-Bianco et al., 2000; Bell, 1975). In addition, rotational repositioning of the maxilla may result in a useful rotation of the maxillomandibular complex, which can improve skeletal class III malocclusion, anterior open bite, and facial asymmetry (Park et al., 2001). Asian patients may often have skeletal class III malocclusion where rotation of the maxillomandibular complex may also result in alteration of the occlusal plane, midfacial depression, and change in the angle of the upper and lower anterior teeth (Baek et al., 2009).

Forward movement of the anterior nasal spine (ANS) due to the rotation of the maxilla may result in some undesirable changes, such as alterations in the shape of the nasal cartilage tissue or a protrusion of the upper labial region. Total maxillary setback (TMS) can be useful in resolving such problems (Chouet-Girard et al., 2003).

However, the anatomic position of the pterygoid plates which are posterior to the maxilla as well as the location of the airway behind the maxilla, limits the amount of posterior maxillary repositioning possible. A variety of approaches have been described to facilitate total maxillary setback while respecting the anatomic constraints. Initially, maxillary tuberosity removal was introduced for TMS (Bell, 1975; Hai et al., 1989; Ueki et al., 2004; Ueki et al., 2009). If the maxillary setback amount exceeded the thickness of the tuberosity, then the pterygoid plates could be sectioned and fractured or removed (Lee et al., 2015). Previous methods, which included the removal of impacted maxillary third molars and the partial removal of the maxillary
tuberosity or pterygoid plates, are insufficient to achieve a clinically meaningful TMS.

Our surgical team has used a method of TMS by separating the distal bone fragment using an intentional fracture of the pterygoid plates (IFPP) and then moving the maxilla passively backward. This allows a total setback at a useful level for resolving non-aesthetic concerns that may arise from the ANS or protrusion of the upper labial area. However, IFPP may cause potential problems, such as cavernous sinus bleeding, dislocation of the pterygoid plate bone fragments due to the lateral pterygoid muscle pull, and failure of the total setback due to the incomplete fracture of the pterygoid plate bone fragment. Therefore, this study aimed to determine the safety and postoperative stability of the maxilla following Le Fort I level TMS using IFPP. The authors also aimed to examine the healing pattern of the bony fragments at the fracture site of the pterygoid plates in order to better understand the TMS procedure when combined with IFPP.

**Materials and Methods**

(1) Study Design and Patients

This study was approved by the Institutional Review Board of Pusan National University Dental Hospital (K-2016-19220442). A total of 246 patients were treated with Le Fort I osteotomy at the Department of Oral and Maxillofacial Surgery of Pusan National University Dental Hospital during the period of January 2012 to June 2014. Using a retrospective analysis 36 consecutive patients with skeletal class III malocclusion treated with rotational repositioning of the maxillomandibular complex using a TMS at the Le Fort I level were enrolled in the study. There were 17 males and 19 females. The mean age was 22 years for both sexes. The 36
patients underwent TMS rotational ANS superior and posterior repositioning. Only those patients with ANS posterior repositioning of greater than or at least 1 mm were included in this study. In addition, only those cases in who had IPPF for rotational and posterior repositioning were included. Exclusion criteria included patients with a history of cleft lip and or cleft palate.

(2) Management of the Pterygoid Plates

Following Le Fort I osteotomy, the pterygoid plates were exposed via maxillary downfracture. The IPPF was performed at the end of the osteotomy line (Figure 1). After the bone around the descending palatine artery was removed, a straight chisel was placed on the leading edge of the lateral pterygoid plate, and then medial and lateral osteotomies were performed. The fractured pterygoid plates were completely separated from the pterygoid process above (Figure 2). Hemostasis was achieved through the topical application of hemostatic agents, such as Surgicel (ETHICON, Scotland), to the posterior part of the fracture site.

(3) Lateral Cephalogram and Cone-Beam Computed Tomographic Imaging

Lateral cephalogram and cone-beam computed tomographic (CBCT) images were obtained immediately after the surgery (T0) and 6 months after the surgery (T1). For the CBCT images, the intentional fracture site of the pterygoid plates was observed in the sagittal, coronal, and axial views. An example of a CBCT image is presented in Figure 3 in order to illustrate the imaging of an intentional pterygoid plate fracture site.
(4) Landmarks and Measurement Variables

The landmarks used on the lateral cephalogram to determine relapse are listed in Table 1. The locations of the landmarks are shown in Figure 4. The postoperative relapse rate of the maxilla was determined through a comparison between immediately after surgery (T0) and 6 months following surgery (T1).

The maxillary depth and McNamara’s nasion perpendicular were used as variables for identifying the postoperative anteroposterior stability of the maxilla. The increase in the maxillary depth and the decrease in the McNamara’s nasion perpendicular would show that the maxilla has relapsed into an anterior position. The distances from the FH plane to Point A and posterior nasal spine (PNS) were used as variables to confirm the postoperative supero-inferior stability of the maxilla. The distance from FH to Point A and PNS would be expected to decrease with clockwise rotational repositioning of the maxilla. However, if there would be an increase in the comparison between immediately after the surgery (T0) and 6 months after the surgery (T1), then the maxilla would have relapsed into an inferior position. In order to check the stability of rotational repositioning, SNA and the palatal plane were used as variables. The increase in SNA and the decrease in the palatal plane indicate that the maxilla has relapsed counterclockwise.

(5) Data Analysis

The lateral cephalograms were digitized using the V-ceph 3.5 software (Cybermed Co, Seoul, Korea). The values of each variable for the time points immediately after the surgery (T0) and 6 months after the surgery (T1) were derived by using the analysis mechanism of the same
software. The postoperative relapse rate of the maxilla ($\triangle T1-T0$) was analyzed by comparing the variables at T0 and T1, and the paired samples t-test was performed in order to quantify the relapse tendency. For the statistical analysis, SPSS 21.0 (SPSS Inc., Chicago, IL) was used, and a p-value of 0.05 or less was considered as statistically significant.

**Results**

During the 6-month follow-up, there were no major postoperative complications, including airway related complaints, acute or delayed hemorrhage, discomfort due to limitation in mouth opening, and occlusal changes, and neuropathy of cranial nerves, such as the optic nerve. All these patients had a period of physical therapy with elastic occlusal guidance for up to 3 months postoperatively. The mean ANS posterior repositioning amount of the patients was 1.78 mm, and their mean PNS superior repositioning amount was 2.78 mm. The changes in the variables, which are measured in order to analyze the relapse rate of the maxilla according to the postoperative recovery period, are summarized in Table 2. The relapse rate shown in each variable was converted to the percentage for 6 months after the surgery. The relapse rate was less than 10% of all the variables, excluding the palatal plane. The variables with the lowest relapse rate were Maxillary Depth (0.2085%) and SNA (0.2274%). On the other hand, the relapse rate of the palatal plane was observed to be high with 25.0059%. In the paired samples t-test results, the differences in McNamara’s nasion perpendicular, FH-Point A, and FH-PNS were statistically significant with regard to the postoperative stability of the maxilla.

An example of the healing pattern of the intentional fractured pterygoid plate visualized on CBCT imaging is shown on Figure 5. This was similar in the 36 patients. In addition, the healing pattern showed a linear pattern regardless of the effect of the peripheral muscle tissue.
Position changes of the pterygoid plates or bone loss due to resorption, dysraphia, or malunion were not observed at the intentional pterygoid fracture sites.
Discussion

The indication for TMS with rotation is illustrated by the pre-operative and six month postoperative photographs and lateral cephalograms shown in Figure 5. This patient was dissatisfied with her long face and protrusive mandible. The patient underwent TMS with rotation. The position of her maxillary incisors was altered so that the problem of a concurrent acute nasolabial angle and lip protrusion were corrected. Posterior repositioning of the maxilla using TMS with rotation allowed the necessary mandibular posterior movement. The indication for TMS with rotation is a patient with combinations of a long face, mandibular prognathism, an acute nasolabial angle, a protrusive upper lip and a class III malocclusion.

W. R. Proffit described the hierarchy or order of postoperative stability of maxillary and mandible orthognathic surgery according to the direction of movement. According to his suggestion, maxillary superior movement is known to be the most stable procedure. If the amount of superior repositioning of the maxilla is 2 mm or more and if rigid fixation is performed, then the postoperative relapse rate is known to be close to zero (Proffit et al., 2004). LT. J. Bailey expressed stability by converting the postoperative relapse rate into a percentage. He explained that if the postoperative relapse rate is less than 10%, the procedure is “highly stable”. The stability hierarchy proposed by LT. J. Bailey is summarized in Table 3 (Bailey et al., 2004).

The postoperative relapse rate of TMS using the intentional fracture of the pterygoid plates examined in this study was less than 10% (Table 4). According to the suggestion of LT. J. Bailey, the rotational total maxillary setback using the intentional fracture of the pterygoid plates is a procedure with a very high degree of stability. Han and Hwang have confirmed the
healing of the pterygomaxillary junction after TMS (Han et al., 2014). The results of this study reveal that the affected area of IFPP has healed smoothly without any postoperative complications or anteroposterior and supero-inferior relapse (Bailey et al., 2004).

However, no other studies have been performed to check the healing pattern of the osteotomized pterygoid plates. The pterygoid plate is an anatomical structure which can easily cause edema due to hemorrhage or hematoma if damaged.

Therefore, there is a risk of airway obstruction. Since the cranial base is located in the superior direction, there is also the possibility of damage to cranial nerves, such as the optic nerve. In addition, the pterygoid plates provide the insertions for the lateral pterygoid muscles, and there is a risk of limitation in mouth opening or trismus. However, none of the patients in this study showed the aforementioned postoperative complications.

The pterygoid plate is a structure that is not easy to access in general situations due to its positional characteristics. The descending palatine artery, which is located at the front, is one of the structures that can cause difficulty when manipulating the pterygoid plates. In order to handle the pterygoid plates without massive bleeding, the blood vessel that is wrapped around the bone must be properly detached and managed. The pterygoid plexus is located behind the pterygoid plates. There is a high risk of massive bleeding if the plate fracture is handled inappropriately. For this reason, osteotomy in the correct direction and proper separation of the pterygoid plates are necessary. It is most important to check for bleeding and treat the hemorrhage by applying a hemostatic agent, such as Surgicel (ETHION, Scotland), to the plate separation site.

A problem of limitation in the amount of posterior movement of the maxilla occurs if the
pterygoid plates are fractured but incompletely separated. However, this is avoidable by confirming the mobility of the fractured fragment. The IFPP procedure is easy to apply and it does not require a long time, as compared with the other methods such as removal of the leading edge of the pterygoid plate, partially removing the trailing edge of the maxillary tuberosity, and removing the fractured pterygoid plate after tooth extractions. The surgical instruments are chisels which are easy to handle. They can be applied safely according to the intention of the surgeon. A satisfactory TMS can be achieved in a relatively simple manner, and bleeding can also be easily controlled as the field is secured and visualized during maxillary downfracture.

The pterygoid plate is a structure formed by a thin bone fragment, which is C-shaped. The lateral pterygoid muscle is attached to the posterior surface of the pterygoid plates. The healing of the intentionally fractured plate could have various problems due to these anatomical characteristics. Displacement or gradual movement of a fractured piece of pterygoid plate may occur due to the action of the lateral pterygoid muscle. In addition, there is the possibility that a bone fragment that was separated from the base of the skull may be partially resorbed or may even entirely disappear. Even if the bone fragment does not disappear, it may not fuse with the base of the skull. There may be interference of hemostatic agent applied between the bony fragments, for example Surgicel, resulting in a malunion. However, in the CBCT images, the fracture pieces of the pterygoid plate were not malpositioned or resorbed, and their shape was not changed despite the 3-month postoperative physical therapy period. The healing of the fracture site was also observed with the fragment healing to the base of the skull without malunion or nonunion.
The results of this study of 36 patients showed that the IFPP is a safe procedure that was applied without the occurrence of major complications such as hemorrhage, nerve injury, or dyspnea due to edema. In addition, the postoperative stability was good and the fracture site healed appropriately. Buhara et al. showed the movements at the pterygoid plate site to be quite predictable using finite element method studies (Buhara et al., 2017). Therefore, a rotational total maxillary setback using the intentional fracture of the pterygoid plate can be considered as an adjunct to orthognathic surgery with a high level of stability.

**Conclusions**

An intentional fracture of the pterygoid plates can be used together with Le Fort I level total maxillary setback without major complications such as hemorrhage, nerve damage, and dyspnea due to edema. In addition, postoperative stability is good and healing of the pterygoid fracture site has been documented. There was no quantitative analysis regarding the healing of the pterygoid plate in this study. Therefore, quantitative analysis of healing at the pterygoid fracture site using pixels of CBCT images will be the subject of future study.
Funding Disclosure

This research did not receive any specific grants from any funding agencies in the public, commercial, not-for-profit sectors. None of the authors this manuscript have any commercial interests in any products mentioned in this study.
Table 1. Landmarks and Measurement Variables Used in this Study

<table>
<thead>
<tr>
<th>Landmarks</th>
<th>Measurement Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nasion</td>
<td>The angle formed by the Frankfort horizontal plane and the line from the nasion to point A</td>
</tr>
<tr>
<td>Sella</td>
<td>Maxillary Depth</td>
</tr>
<tr>
<td>Porion</td>
<td>McNamara’s Nasion Perpendicular</td>
</tr>
<tr>
<td>Orbitale</td>
<td>The distance from point A to a line from the nasion constructed perpendicular to the Frankfort horizontal (FH) plane</td>
</tr>
<tr>
<td>ANS</td>
<td>FH Plane – Point A</td>
</tr>
<tr>
<td>PNS</td>
<td>FH Plane - PNS</td>
</tr>
<tr>
<td>Point A</td>
<td>The distance from PNS to FH plane</td>
</tr>
</tbody>
</table>

Angular Stability

| SNA               | The angle formed by the sella-nasion (SN) and NA lines      |
| Palatal Plane     | The angle formed by the FH plane and ANS-PNS line           |
Table 2. Changes of Measurement Variables

<table>
<thead>
<tr>
<th></th>
<th>Mean T0</th>
<th>Mean T1</th>
<th>ΔT1-T0</th>
<th>SE</th>
<th>P-Value (*p &lt; 0.05)</th>
<th>Change Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mx. Depth</td>
<td>92.9425</td>
<td>92.8217</td>
<td>-0.1208</td>
<td>0.6870</td>
<td>0.1493</td>
<td>0.2085</td>
</tr>
<tr>
<td>McNamara’s Perpend.</td>
<td>3.5358</td>
<td>3.4544</td>
<td>-0.0814</td>
<td>0.2214</td>
<td>0.0170*</td>
<td>8.4145</td>
</tr>
<tr>
<td>FH-A</td>
<td>26.6467</td>
<td>26.3875</td>
<td>-0.2592</td>
<td>0.8534</td>
<td>0.0385*</td>
<td>2.6579</td>
</tr>
<tr>
<td>FH-PNS</td>
<td>21.4967</td>
<td>21.2522</td>
<td>-0.2444</td>
<td>0.6561</td>
<td>0.0159*</td>
<td>2.6960</td>
</tr>
<tr>
<td>SNA</td>
<td>81.9941</td>
<td>81.8947</td>
<td>-0.0994</td>
<td>0.6792</td>
<td>0.1928</td>
<td>0.2274</td>
</tr>
<tr>
<td>Pal.</td>
<td>-1.3206</td>
<td>-1.2692</td>
<td>0.0514</td>
<td>0.5125</td>
<td>0.2756</td>
<td>25.0059</td>
</tr>
</tbody>
</table>

Table 3. Stability of Orthognathic Surgery by L’Tanya J. Bailey

“**Highly stable**” Less than a 10% chance of significant posttreatment change

“**Stable**” Less than a 20% change of significant posttreatment change and almost no chance of major posttreatment change

“**Stable if modified in a specific way**” e.g., rigid fixation

“**Problematic**” A considerable probability of major posttreatment change

Table 4. Postoperative Relapse Rate of Each Variable (Percentage)

<table>
<thead>
<tr>
<th></th>
<th>Change Rate (%)</th>
<th>L’Tanya J. Bailey’s Stability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mx. Depth</td>
<td>0.2085</td>
<td></td>
</tr>
<tr>
<td>SNA</td>
<td>0.2274</td>
<td></td>
</tr>
<tr>
<td>FH-A</td>
<td>2.6579</td>
<td>Less than 10%</td>
</tr>
<tr>
<td>FH-PNS</td>
<td>2.6960</td>
<td>“Highly stable”</td>
</tr>
<tr>
<td>McNamara’s Perpend.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pal.</td>
<td>25.0059</td>
<td></td>
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</tbody>
</table>
Figure 5 Clinical photographs and lateral cephalograms of a patient who underwent total maxillary set back with rotation. A) Preoperative lateral photograph. B) Postoperative lateral view taken at 6 months following surgery. C) Preoperative anterior view. D) Anterior view at postoperative 6 months post operative time point. E) Preoperative lateral cephalogram. F) Post operative lateral cephalogram taken at 1 year.
Figure 1. Pterygoid plate management: A) Exposed leading edge of the pterygoid plates; B) Placement of a straight chisel on the leading edge of the pterygoid plates with the yellow arrows indicating the direction of the osteotomy; C) Separation of the fractured plates from the superstructure; and D) Appearance of the maxilla and the pterygoid plates when moved passively backward.

Figure 2. CBCT image to observe the intentional fracture site of the pterygoid plates with the yellow arrows indicating the fracture sites: A) Coronal view of the intentional fracture site; B) Sagittal view; and C) Axial view.
Figure 3. Healing pattern of the intentional fracture site of the pterygoid plates (patient 6) immediately after the surgery: A) Coronal view; B) Sagittal view; and C) Axial view. Pterygoid plates 6 months after the surgery: D) Coronal view; E) Sagittal view; and F) Axial view.

Figure 4. Landmarks used for the analysis. Porion and orbitale are marked for the FH plane. PNS and ANS were marked to observe the superoinferior, anteroposterior movement of the maxilla. Sella,
Nasion, Point A were used to check the angular movement of maxilla.