치의학석사 학위 논문

3D Simulation, Postoperative Stability and Bone Healing after the Maxillary Setback Movement

상악 후퇴 이동술의 3차원 시뮬레이션, 술 후 안정성 및 골 치유에 관한 연구

2013년 8월

서울대학교 대학원
치의과학과 구강악안면외과학 전공
한 정 준

3D Simulation, Postoperative Stability and Bone Healing after the Maxillary Setback Movement

지도교수 황 순 정

이 논문을 치의학석사 학위논문으로 제출함

2013년 5월

서울대학교 대학원
치의과학과 구강악안면외과학 전공
한 정 준

한정준의 석사학위논문을 인준함
2013년 6월

위 원 장	이 신 재	(인)
부 위 원 장	황 순 정	(인)
위 원	이 원 진	(인)

-Abstract-

3D Simulation, Postoperative Stability and Bone Healing after the Maxillary Setback Movement

Jeong Joon Han, D.D.S.
Department of Oral and Maxillofacial Surgery
Graduate School
Seoul National University
(Directed by professor Soon Jung Hwang, Dr. med. Dr. med. dent)

Purpose: Maxillary setback surgery is necessary for patients with maxillary protrusion to improve the aesthetical facial harmony. However, it is technically difficult surgery with intra- and post-operative complications because of complicated anatomical structures. Adequate amounts of bone around the pterygomaxillary junction should be removed to avoid bony interferences, and descending palatine artery also should be identified and isolated carefully under narrow surgical field. Moreover, bone reduction of

pterygoid plate can lead to moderate but continuous bleeding which control is frequently difficult. Even though maxillary setback movement is frequently conducted in the orthognathic surgery, the amount of bone interference using simulation surgery and postoperative stability have not been reported The purpose of this study was to evaluate the amount of bone interference by simulation surgery, postoperative stability including bone healing at pterygomaxillary suture after maxillary setback surgery.

Patients and Methods: 41 patients who underwent maxillary setback surgery combined with BSSRO for orthognathic surgery were included in this study. For the evaluation of postoperative stability, patients were divided into two groups with maxillary setback less than 3 mm (Group I) and greater than 3 mm (Group II), and we lateral cephalograms taken before surgery, immediately, 6 weeks and more than 6 months after surgery were analysed. After simulation surgery in 15 patients using pre- and postoperative CT, the amount of bony interference between maxillary tuberosity and pterygoid plate was calculated after maxillary setback movement with and without consideration of autoroation of maxillomandibular complex. For the evaluation of bone healing at the pterygomaxillary junction, CT images taken immediately postoperatively and at 3 months after surgery were evaluated in 15 patients using image analyzing program.

Results: The mean surgical movements of the maxilla were 2.80

mm, 1.25 mm, 0.54 mm and 2.35 mm posteriorly at upper central incisor edge, point A, PNS and upper first molar. At 6 months after surgery, there are no significant horizontal relapse at point A and PNS. And there was no significant difference of the relapse between Group Ⅰ and Group Ⅱ. In 3D simulation surgery, the bony interferences were more in maxillary setback with consideration of autoroation of maxillomandibular complex than in simple maxillary setback, and it was increased when the distance between condylar rotation center and pterygomaxillary suture. And there was statistically significant bone healing at the pterygomaxillary junction three months after surgery ($p<0.001$).

Conclusions: Although maxillary setback surgery has technical difficulty with postoperative complications, it could be a selective treatment option for the balanced facial aesthetics in the patients with maxillary protrusion.

Keywords : maxillary setback, postoperative stability, simulation surgery, bony interference, bone healing

Student Number : 2011-23820

CONTENTS

3D Simulation, Postoperative Stability and Bone Healing after the Maxillary Setback Movement

Jeong Joon Han, D.D.S.
Department of Oral and Maxillofacial Surgery
Graduate School
Seoul National University
(Directed by Professor Soon-Jung Hwang, Dr. med. Dr. med. dent.)

Introduction

Maxillary protrusion is one of the prevalent facial morphology for Asian people in all types of skeletal malocclusion including facial asymmetry. Generally, Asian people have shorter anterior cranial base (sella to nasion) and brachycephaly. And the position of the maxilla is relatively prognathic[1,2]. Maxillary setback movement is necessary to produce functionally and aesthetically satisfactory outcomes in these patients. Maxilla can be transpositioned backward, however, its amount has limitation due to the complicated anatomical structure around pterygomaxillary suture area. Maxillary setback movement has been regarded technically difficult procedure with intra- and postoperative complications. Adequate amounts of bone around the pterygomaxillary junction should be removed to avoid bony interferences between maxillary tuberosity and pterygoid plate, where descending palatine artery should be identified and isolated carefully from surrounding bone under narrow surgical field. Moreover, abundant vessels are located within muscles which adhere to pterygoid plate, therefore, bone reduction of pterygoid plate can lead to moderate but continuous bleeding which control is frequently difficult. Management of the pterygoid plate and the surrounding vascular structure is very important for ideal repositioning of the maxilla and preventing the large amount of intraoperative bleeding[3]. Some authors reported the surgical procedure for resolving these bony interferences[4,5]. Schouman et al. reported the posterior reposition of the maxilla with resection of lower ending of pterygoid plate[4]. Judy et al. showed the successful outcome in patients who were underwent the maxillary setback surgery with resection of maxillary tuberosity including upper third molar[5]. Although surgeons predict the bony interferences using paper surgery in the diagnosis procedures for managing this region, which is only a simple backward repositioning of maxilla based on plain X-ray images, they usually encounter difficulties during the operation for removing bony interferences. Therefore, a virtual simulation surgery in three dimension with consideration of autorotation of maxillomandibular complex will be helpful to find out the location and real amount of bone interference.

Although many studies about the postoperative stability after Le

Fort Ⅰ osteotomy have been reported, there are few reports about the postoperative stability of maxillary setback surgery. Baek et al. suggested that rotational maxillary setback procedure in the patients with skeletal classⅢ malocclusion with labioversioned upper incisors and/or protrusive maxilla could be considered as a stable procedure[6]. However, this study included relatively small sample size (n=20). Studies with large sample size and with comparison of stability between small and great setback movement are necessary.

Factors that can influence on the stability after Le Fort Ⅰ osteotomy include the preoperative orthodontic treatment, inadequate mobilization, inappropriate or lack of grafting for bone gap, increased masticatory forces, inadequate methods of fixation, direction and amount of maxillary movement, soft tissue tension, and presence of clefts[7-14]. Several studies on the bone healing after Le Fort Ⅰ osteotomy were published. Compton et al. reported histologic evaluation of the punch biopsy from the osteotomy sites of five patients after Le Fort Ⅰ osteotomy[15]. This study indicated that the area between the segments healed with mature compact bone. However, the surgical movement, the site of the biopsy and the region where the bone healed were not described in detail. Ueki et al. suggested that bony healing could occur at the pterygomaxillary junction after Le Fort Ⅰ osteotomy, where the bone healing was not always complete within one year after surgery[16]. Considering that bone around pterygomaxillary suture is removed inevitably more than it needs for the planed maxillary setback movement because of narrow visible scope for bone reduction sites, bone contact at this area must be reduced with dead space, which can lead to decrease in postoperative stability.

Even though maxillary setback movement is frequently conducted in the orthognathic surgery, the amount of bone interference using simulation surgery and postoperative stability including postoperative osseous healing with large sample size have not been reported. The purpose of this study was (1) to evaluate the postoperative stability after total maxillary setback surgery, (2) to assess the bony interference between the pterygoid region and the posterior maxilla by using 3D simulation surgery, and (3) to examine bone healing of the pterygomaxillary region.

Patients and Methods

Patients

The subjects consisted of 41 patients (male:female = 22:19; mean age, 23.6 years; age range 17-36 years). All patients with maxillary protrusion underwent Le Fort I osteotomy without any multi-segmental osteotomies for the correction of skeletal malocclusion. Patients with severe asymmetry, cleft of the lip or palate, craniofacial syndromes or history of trauma were excluded. All patients had presurgical and postsurgical orthodontic treatment.

To evaluate the effect of amount of maxillary setback movement on the postoperative stability, patients were divided into two groups according to the amount of maxillary setback movement: Group I had less than 3 mm of setback movement (n = 21; male:female = 11:10; mean age, 23.1 years; age range 18-31 years), Group II had more than 3 mm of setback movement (n = 20; male:female = 11:9; mean age = 24.2 years, age range 17 - 36 years).

Surgical procedures

The lateral wall of the maxillary sinus was cut using reciprocating saw, and the nasal septum and the lateral nasal wall were cut with chisel. Pterygomaxillary separation was carried out using curved osteotome. After the pulling down the maxillary segment, the posterior maxillary sinus wall, the maxillary tuberosity and the pterygoid region were exposed. The bony interferences were identified and removed for repositioning of the maxilla. Two L-shaped miniplates at the site of the pyriform, two L-shaped miniplates at the site of the zygomatic buttress and screws were used for fixation of maxillary segment. For the mandibular surgery, BSSRO with a short lingual osteotomy was performed[17]. Then, one 4-hole miniplate and screws were used for the fixation of each side. In cases of no bone contact at the retromolar area between the distal segment and the proximal segment, one or two positioning screws were used. Rigid maxillomandibular fixation was not used postoperatively, only light traction by elastics was used for 3-4 weeks after surgery.

Cephalometric analysis

For the measurement of surgical change and the evaluation of postoperative stability, lateral cephalograms were obtained preoperatively (T0), immediately after surgery (T1), six weeks after surgery (T2) and more than six months after surgery (T3) in centric occlusion. Lateral cephalograms were traced on acetate paper by one examiner and cephalometric analysis was performed according to the superimposition technique. Landmarks such as sella (S), nasion (N), posterior nasal spine (PNS), point A (A), upper central incisor edge (Is), mesial cusp of upper first molar (M6), inferior incisor edge (Ii), point B (B), pogonion (Pog) and menton (Me) were selected on the lateral cephalogram at T0 and transferred to lateral cephalograms T1, T2 and T3. For the measurement, an x-y coordinate system was constructed on the lateral cephalogram. The x-axis (SN7) was defined by the line that passed through the nasion, and rotated 7° clockwise from the sella-nasion line (SN)[18,19]. The y-axis was constructed perpendicular to the x-axis and passed through the sella. The cephalometric landmarks defined and the reference lines used are illustrated in **Fig. 1**. Sixteen linear parameters and four angular parameters were measured. The angular parameters were SNA, SNB, ANB and maxillary occlusal plane angle (MxOP). The horizontal and vertical changes of PNS, point A, upper central incisor edge, mesial cusp of upper first molar, inferior incisor edge, point B, pogonion and menton were determined by the distance changes of those landmarks perpendicular to the x- and y-axes between T0 and T1, T1 and T2, and T1 and T3.

3D simulation surgery

3D facial CT images were obtained by an MDCT (Siemens SOMATOM Sensation 10, Munich, Germany) under 120kVp and 80 mAs. For simulation surgery, 3D skull model was reconstructed with preoperative CT data using the Mimics program (Materialise, Belgium). Conventional Le Fort I osteotomy was conducted on the 3D model and the separation of pterygomaxillary junction was also performed. Maxillary segment was repositioned to the target position. Simulation surgery includes (1) only maxillary setback movements(1mm, 3mm and 5mm), (2) maxillary setback movements (0mm, 1mm and 3mm) combined with posterior impaction (1mm and 3mm), (3) maxillary setback movements (0mm, 1mm and 3mm) combined with midline correction by parallel shift (1mm and 3mm) and (4) maxillary setback movements (0mm, 1mm and 3mm) combined with midline correction by yawing movement (1mm and

3mm) (**Table 1.**). Then, the overlapped osseous volume (volume of bone interference) between the maxillary tuberosity and the pterygoid plate was obtained. The volume of bone interference was measured (1) with and (2) without consideration of autorotational movement of maxillomandibular complex, where condylon was defined as the rotation center (**Fig. 2**). This volume was converted to a percentage of the volume of the pterygoid plates.

Assessment of bone healing

For assessment of bone healing at the pterygomaxillary junction, CT images obtained immediately after surgery and 3 months after surgery were compared using Image J program (http://rsbweb.nih.gov/ij/). The images on same axial level in the each CT datas (15 patients, 30 sides) were chosen by the one examiner(J-J H). The Region of interest (ROI) was set 50x50 pixels at both pterygomaxillary region. Images of ROI were converted to 8-bit images, and threshold was adjusted to the bone level on each image for the measurement of bony area. The bone healing was evaluated by comparing the bone ratio (BR) in ROI. (**Fig. 3, Fig. 4**).

$$\textit{Bone Ratio}\ (\%) = \frac{\textit{Bone area in ROI}}{\textit{Total area of ROI}} \times 100$$

Statistical analysis

Statistical analysis was performed using PASW statistics 21 software for Windows (SPSS Inc., Chicago, IL, USA). For assessment of the postoperative stability in all subjects, paired t-test was performed between T1 and T2 and between T1 and T3. To evaluate the effect of the amount of maxillary setback movement on the postoperative stability, the linear measurements of the Group Ⅰ (amount of the maxillary setback < 3mm) and the Group Ⅱ (amount of the maxillary setback ≥ 3mm) were analyzed and compared with the independent t-test. The wilcoxon signed ranks test was used for assessment of bone healing at the pterygomaxillary junction between immediately after surgery and 3 months after surgery.

Results

The mean surgical movements of the maxilla were 2.80±1.53 mm posteriorly and 0.30±2.92 mm superiorly at upper central incisor edge, 1.25±1.90 mm posteriorly and 0.77±2.51 mm superiorly at point A, 0.54±2.49 mm posteriorly and 3.69±2.64 mm superiorly at PNS and 2.35±1.36 mm posteriorly and 2.11±1.75 mm superiorly at upper first molar. The mean surgical movements of the mandible were 7.30±5.60 mm posteriorly and 2.16±3.42 mm superiorly at inferior incisor edge, 6.81±6.86 mm posteriorly and 1.79±2.85 mm superiorly at point B, 6.61±7.84 mm posteriorly and 1.86±2.82mm superiorly at pogonion and 6.58±7.84 mm posteriorly and 1.76±2.50 mm superiorly at menton (**Table 2.**)

Effect of the amount of maxillary set-back movement on the relapse

The amounts of the postoperative relapse at six weeks after surgery were 0.21±0.54 mm anteriorly and 0.42±0.55 mm superiorly at point A and 0.11±0.46 mm anteriorly and 0.08±0.51 mm superiorly at PNS. The amounts of the relapse at more than six months after surgery were 0.05±0.60 mm anteriorly and 0.28±0.69 mm superiorly at point A, and 0.09±0.57 mm posteriorly and 0.06±0.48 mm inferiorly at PNS. There are no significant horizontal relapse at point A and PNS more than six months after surgery.

In Group Ⅰ (maxillary setback < 3 mm), upper central incisor edge, point A, PNS and upper first molar moved 1.54 mm, 0.97 mm, 0.63 mm and 1.45 mm posteriorly, respectively. In Group Ⅱ (maxillary setback ≥ 3 mm), upper central incisor edge, point A, PNS and upper first molar moved 4.12 mm, 1.54 mm, 0.44 mm and 3.30 mm posteriorly, respectively. The differences in the amount of maxillary setback were statistically significant between the two groups at upper cenetral incisor edge and upper first molar (p<0.001)(**Table 3.**).

At six weeks after surgery, upper central incisor edge, point A, PNS and upper first molar exhibited horizontal relapse of 0.50 mm, 0.21 mm, 0.12 mm and 0.30 mm, respectively, in Group Ⅰ. In Group Ⅱ, the horizontal relapses on upper central incisor edge, point A, PNS and upper first molar were 0.67 mm, 0.21 mm, 0.11 mm and 0.33 mm, respectively. There was no significant difference between Group Ⅰ and Group Ⅱ.

At six months after surgery, upper central incisor edge, point A, PNS and upper first molar exhibited a horizontal relapse of 0.48 mm, −0.07 mm, −0.21 mm and 0.21 mm respectively, in Group Ⅰ. In Group Ⅱ, the horizontal relapses of upper central incisor edge, point A, PNS and upper first molar were 0.92 mm, 0.18 mm, 0.03 mm and 0.34 mm, respectively. There was no significant difference between Group Ⅰ and Group Ⅱ.

Bony interference at the region of pterygoid plate in 3D simulation surgery

The volume of bony interference increased as the amount of maxillary setback movement increased. Considering the autorotation of the maxillomandibular complex, this volume increased approximately 5.82 times, 3.01 times and 2.56 times in the case of 1mm-, 3mm-, 5mm setback movement (**Fig. 5**). When the movement of the maxilla includes both setback and posterior impaction, the area of bony interference is seen in **Fig. 6**, and the volume of bony interference also increased as the amounts of setback and posterior impaction increased, but in cases of increase of posterior impaction, it did not increase (**Fig. 7**). Considering the autorotation of the maxillomandibular complex, the volume also increased, and the ratio in each case was different. When the movement of the maillxa contained midline-shift to the left side, there increased the distance between pterygoid plate and maxillary tuberosity on left side and there increased bony interference on right side (**Fig. 8**). When the maxillomandibular complex autorotated, the area of bony interferences moved right side and the volume of bony interference on right side was greater than on left sides. On left side, the height of the bony interference was also lower than on right side (**Fig. 9**). Overall, the volume of bony interference at the region of the maxillary tuberosity and pterygoid plate decreased as the amount of midline-shift increased (**Fig. 10**). When the movement of the maxilla included the counterclockwise yawing correction at the top view, there increased bony interference on left side and there increased the distance between maxillary tuberosity and pterygoid plate on right side (**Fig. 11**). On right side, the height of bony interference was also lower than on left side. Overall, although the volume of interference increased as the amount of setback increased, the volume of interference did not show a specific tendency as the amount of yawing increased (**Fig. 12**).

Assessment of bone healing

The wilcoxon signed ranks test was performed to evaluate the bone healing between pterygoid plate and the region of the posterior maxilla at three months after surgery. The evaluated pterygomaxillary regions were 30 sides in 15 subjects. Mean bone ratio is 21.0 % immediately after surgery and 24.2 % at three months after surgery. There was statistically significant bone healing in the ROI after three months after surgery ($p<0.001$)(**Fig. 13**). In 26 of 30 sides (86.7%), increased bony areas between pterygoid plate and the region of the posterior maxilla were observed. However, in 4 of 30 sides (13.3%), there could not be seen bone healing at the pterygoid region.

Discussion

Anterior segmental osteotomy or total maxillary setback surgery could lead to aesthetically and functionally successful outcomes in patients with bimaxillary protrusion or maxillary protrusion. Maxillary anterior segmental osteotomy is indicated for the anterior dentoalveolar protrusions. This surgical technique requires sacrifice of two or more premolars. Its complication rate is higher than one-piece Le Fort I osteotomy[20]. It can damage the neighbouring teeth near the osteotomy, and can also give the risk of necrosis or incomplete healing of bone.[5] Schouman et al. reported that the total maxillary setback could achieve satisfactory occlusal, functional and esthetic outcomes in patients with marked upper-jaw prognathism and especially an acute nasolabial angle[4]. In their study, the mean amount of maxillary setback was 1.3 mm at the central maxillary incisor and 3.1 mm at nasopalatine duct point, and no relapse was encountered to date. In our study, the mean amounts of surgical change of the maxilla were 2.80 mm posteriorly and 0.30 mm superiorly at the upper central incisor edge. At more than six months after surgery, the mean amounts of the relapse were 0.09 mm posteriorly at PNS and 0.05 mm anteriorly at point A, and there was no statistically significant postoperative relapse. Vertically, point A moved 0.28 mm superiorly and PNS moved 0.06 mm inferiorly. Point A showed a statistically significant postoperative vertical change more than 6 months after surgery, although no significant change occurred at PNS. But, these amounts of the relapse might be insignificant clinically, because they were less than 0.1 mm. In cases of setback movement more than 5mm, no bone contact can occur in thin maxillary bone. There have been few report which studied the total maxillary setback surgery using the one piece LeFort Ⅰ osteotomy. This could be related with the technical difficulties of surgical procedures due to the anatomical structures at pterygomaxillary suture area. Generally, the region of pterygoid plate and maxillary tuberosity is the most common area which usually disturbs the posterior repositioning of the maxilla. The removal of pterygomaxillary region could result in the major bleeding due to the damage of descending palatine artery and small branches of internal maxillary vessels. Choi et al. reported that intraoperative blood loss and operation time increased significantly in patients who underwent bimaxillary surgery including maxillary setback rather than in patients who underwent bimaxillary surgery without maxillary setback[3].

During total maxillary setback surgery, bony interferences should be removed, which is usually difficult to identify due to narrow surgical field. Different surgical techniques have been reported for adequate repositioning in maxillary setback surgery. Schouman et al. performed the maxillary setback with resection of the lower ends of pterygoid processes[4]. The resection level of the pterygoid process was determined with regard to the need for correction of the posterior height of the maxilla. In another previous studies, vertical osteotomy was performed at the region of the third molar, and bone posterior to second molar including maxillary tuberosity was removed[5,21]. With this method, the maxilla could move posteriorly without bony interference, and the patients could have satisfactory aesthetic result and stable occlusion while preserving the pterygoid plates and the greater palatine neurovascular bundles and minimizing the disturbance to the eustachian tube.

In the present study, the regions of bony interferences were identified and their volume were also calculated using the simulation surgery depending on different maxillary movements, such as only maxillary setback movements, setback movements combined with posterior impaction, setback movements combined with midline correction by parallel shift and setback movements combined with midline correction by yawing movement. For proper repositioning of the maxilla, the removal of pterygoid plate and/or maxillary tuberosity is required. Considering the autorotation of the maxillomandibular complex during the adaptation of osteotomized maxilla for the repositioning to new position of maxilla, the greater bony interferences was occurred, and the demand of bony removal also increased. Where maxillomandibular complex autorotated on the condyle, which would be the center of rotation. When the distance between condylar head and the most upper posterior border of osteotomized maxilla was greater than the distance between the condylar head and the most lower posterior border of pterygomaxillary suture, this complex could be repositioned without any interferences. However, usually, the point which had maximum distance from the center of condyle is on the lower ending of pterygoid plate, therefore, there was always more bony interference during the autorotation of maxillomandibular complex than in simulation surgery with simple maxillary setback. There could be two ways to resolve the bony interferences. One is the removal of maxillary tuberosity area, and the other is the reduction of lower ending of pterygoid plate. Usually, the combination of these two methods is required to prevent the damage of descending palatine artery or internal maxillary vessel and the fracture of hamulus area (**Fig. 14, Fig. 15**). When the surgical movement of the maxilla is great, the removal of only maxillary tuberosity would not be enough for the adequate repositioning and it can increase the risk of bleeding by the damage of descending palatine arteries. The damage of descending palatine arteries during Le Fort Ⅰ osteotomy can reduce blood supply to maxilla. Lanigan et al. reported the 36 cases of the avascular necrosis of the maxillary segment, and recommended that descending palatine arteries should be preserved for the increase of the safety in Le Fort Ⅰ osteotomy[22]. When the removal of the pterygoid plate is performed alone, the damage to the internal maxillary vessel and pterygoid plexus will be increased, which may result in excessive bleeding. The damages of the pterygoid process and hamulus could influence the tension of the tensor veli palate muscle, and the functional change of this muscle could have effect on the ventilator capability of the Eustachian tube[23].

There are few reports which evaluated the bone healing at the pterygomaxillary region after maxillary setback surgery. Ueki et al reported the bone healing of pterygomaxillary junction after LeFort Ⅰ osteotomy[16]. They evaluated completion of bone healing by cortical bone continuity between pterygoid plate and posterior region of maxilla. They did not use an osteotome for pterygomaxillary separation, but use green stick fractures, and the amount of the surgical movement (advancement or impaction) was also comparatively small. In their study, bone healing was found in all the cases without artificial fractures, and in 14 of 22 sides with artificial fractures. In the present study, mean surgical setback movement of the maxilla was approximately 2.80 mm at upper central incisor edge. For the separation of pterygomaxillary junction, a pterygomaxillary osteotomy was performed. There was significant bone healing at the pterygomaxillary junction area. In comparison to CT taken immediately after surgery, there were significant bone healing between the pterygoid plate and the posterior maxilla at three months after surgery. In 26 of 30 sides (86.7%), bone healing was found at the pterygomaxillary junction, but in 4 of 30 sides (13.3%), there could not be seen the bone healing. At three months after surgery, the increase of bone area was 15.6 %, compared with that immediately after surgery. The recovery of cortical continuity was not seen in this study, but the formation of the marrow bone which represented low intensity in CT was seen. It might be that follow-up periods of three months was not enough to represent the cortical lining of the bone in the CT.

Conclusion

This study showed that postoperative relapse was not considerable after the total maxillary setback surgery. Although the amount of maxillary setback was greater, the postoperative relapse did not increase significantly. In 3D simulation surgery, bony interferences between pterygoid region and posterior region of the maxilla tend to increase with an increasing amount of total maxillary setback movement. 3D simulation also showed that the autorotation of maxillomandibular complex during operation had effect on the bony interference at the pterygomaxillary region. The bony interferences at the pterygomaxillary junction increased as maxillomandibular complex autorotated. For the adequate posterior repositioning of the maxilla, it is necessary to know the difference of the maximum distance between center of rotation and pterygoid plate from the minimum distance between condylar head and pterygomaxillary suture. The present study also showed that significantly bone healing could occur at the pterygomaxillary area. Due to short-term evaluation of bone healing area, further studies with long-term follow-up are necessary for long-term three dimensional assessment of bone healing.

References

1. Miyajima K, McNamara JA, Jr., Kimura T, Murata S, Iizuka T. Craniofacial structure of Japanese and European-American adults with normal occlusions and well-balanced faces. Am J Orthod Dentofacial Orthop 110(4): 431-438, 1996

2. Ngan P, Hagg U, Yiu C, Merwin D, Wei SH. Cephalometric comparisons of Chinese and Caucasian surgical Class III patients. Int J Adult Orthodon Orthognath Surg 12(3): 177-188, 1997

3. Choi BK, Yang EJ, Oh KS, Lo LJ. Assessment of blood loss and need for transfusion during bimaxillary surgery with or without maxillary setback. J Oral Maxillofac Surg 71(2): 358-365, 2013

4. Schouman T, Baralle MM, Ferri J. Facial morphology changes after total maxillary setback osteotomy. J Oral Maxillofac Surg 68(7): 1504-1511, 2010

5. Ward JL, Garri JI, Wolfe SA. Posterior movements of the maxilla. J Craniofac Surg 18(4): 882-886, 2007

6. Baek SH, Kim K, Choi JY. Evaluation of treatment modality for skeletal Class III malocclusion with labioversed upper incisors and/or protrusive maxilla: surgical movement and stability of rotational maxillary setback procedure. J Craniofac Surg 20(6): 2049-2054, 2009

7. Bothur S, Blomqvist JE, Isaksson S. Stability of Le Fort I osteotomy with advancement: a comparison of single maxillary surgery and a two-jaw

procedure. J Oral Maxillofac Surg 56(9): 1029-1033; discussion 1033-1024, 1998

8. Egbert M, Hepworth B, Myall R, West R. Stability of Le Fort I osteotomy with maxillary advancement: a comparison of combined wire fixation and rigid fixation. J Oral Maxillofac Surg 53(3): 243-248; discussion 248-249, 1995

9. Eskenazi LB, Schendel SA. An analysis of Le Fort I maxillary advancement in cleft lip and palate patients. Plast Reconstr Surg 90(5): 779-786, 1992

10. Louis PJ, Waite PD, Austin RB. Long-term skeletal stability after rigid fixation of Le Fort I osteotomies with advancements. Int J Oral Maxillofac Surg 22(2): 82-86, 1993

11. Mehra P, Wolford LM, Hopkin JK, Castro V, Frietas R. Stability of maxillary advancement using rigid fixation and porous-block hydroxyapatite grafting: cleft palate versus non-cleft patients. Int J Adult Orthodon Orthognath Surg 16(3): 193-199, 2001

12. Perez MM, Sameshima GT, Sinclair PM. The long-term stability of LeFort I maxillary downgrafts with rigid fixation to correct vertical maxillary deficiency. Am J Orthod Dentofacial Orthop 112(1): 104-108, 1997

13. Posnick JC, Taylor M. Skeletal stability and relapse patterns after Le Fort I osteotomy using miniplate fixation in patients with isolated cleft palate. Plast Reconstr Surg 94(1): 51-58; discussion 59-60, 1994

14. Wardrop RW, Wolford LM. Maxillary stability following downgraft and/or advancement procedures with stabilization using rigid fixation and porous block hydroxyapatite implants. J Oral Maxillofac Surg 47(4): 336-342, 1989

15. Compton JE, Jacobs JD, Dunsworth AR. Healing of the bone incision following Le Fort I osteotomy. J Oral Maxillofac Surg 42(10): 665-667, 1984

16. Ueki K, Miyazaki M, Okabe K, Mukozawa A, Marukawa K, Moroi A, Nakagawa K, Yamamoto E. Assessment of bone healing after Le Fort I osteotomy with 3-dimensional computed tomography. J Craniomaxillofac Surg 39(4): 237-243, 2011

17. Dal Pont G. Retromolar osteotomy for the correction of prognathism. J Oral Surg 19:42-47, 1961

18. Eggensperger N, Smolka K, Luder J, Iizuka T. Short- and long-term skeletal relapse after mandibular advancement surgery. Int J Oral Maxillofac

Surg 35(1): 36-42, 2006

19. Eggensperger N, Smolka W, Rahal A, Iizuka T. Skeletal relapse after mandibular advancement and setback in single-jaw surgery. J Oral Maxillofac Surg 62(12): 1486-1496, 2004

20. Park JU, Hwang YS. Evaluation of the soft and hard tissue changes after anterior segmental osteotomy on the maxilla and mandible. J Oral Maxillofac Surg 66(1): 98-103, 2008

21. Hai HK, Egyedi P. Preserving the pterygoid plates in posterior repositioning of the LeFort I osteotomy. J Craniomaxillofac Surg 17(5): 219-221, 1989

22. Lanigan DT, Hey JH, West RA. Aseptic necrosis following maxillary osteotomies: report of 36 cases. J Oral Maxillofac Surg 48(2): 142-156, 1990

23. Gotzfried HF, Thumfart WF. Pre- and postoperative middle ear function and muscle activity of the soft palate after total maxillary osteotomy in cleft patients. J Craniomaxillofac Surg 16(2): 64-68, 1988

Table 1. The movements of maxilla after LeFort I osteotomy in 3D simulation surgery

Setback(SB)	Setback(SB) + Posterior impaction(PI)	Setback(SB) + Midline shift(MS)	Setback(SB) + Yawing(Y)
A mount of SB	A mount of SB	A mount of SB	A mount of SB
	0mm	0mm	0mm
1mm	1mm	1mm	1mm
3mm	3mm	3mm	3mm
5mm	A mount of P.I	A mount of MS	A mount of Y
	1mm	1mm	1mm
	3mm	3mm	3mm

Table 2. Surgical movement and relapse at 6 weeks and 6 months after surgery.

	Surgical movement		Relapse at T2 (6 weeks after surgery)		Relapse at T3 (6 months after surgery)	
	(T1-T0)		*(T2-T1)*		*(T3-T1)*	
	Mean	SD	Mean	SD	Mean	SD
Linear measurements (mm)						
Horizontal movement						
PNS	−0.54	2.49	0.11	0.46	−0.09	0.57
point A	−1.25	1.90	0.21	0.54	0.05	0.60
Is	−2.80	1.53	0.58	0.84	0.69	1.18
U6	−2.35	1.36	0.32	0.78	0.27	1.05
Vertical movement						
PNS	3.69	2.64	0.08	0.51	−0.06	0.48
point A	0.77	2.51	0.42	0.55	0.28	0.69
Is	0.30	2.92	0.63	0.70	0.93	1.09
U6	2.11	1.75	0.33	0.63	0.34	0.82
Angular measurements						
SNA	−1.29	3.54	0.11	0.51	−0.02	0.60
MxOP	2.19	4.64	−0.38	1.94	−1.45	2.27

(+), the movement anteriorly or superiorly; (−), the movement posteriorly or inferiorly

Table 3. Surgical movement and relapse of the maxilla depending on the amount of maxillary setback (Group Ⅰ: less than 3mm; Group Ⅱ: more than 3mm)

	Group Ⅰ			Group Ⅱ			Comparison between Group Ⅰ & Group Ⅱ	
	Surgical change	Relapse at T2	Relapse at T3	Surgical change	Relapse at T2	Relapse at T3	Relapse at T2	Relapse T3
	Mean ±SD (mm)	Mean ±SD (mm)	Mean ±SD (mm)	Mean ±SD (mm)	Mean ±SD (mm)	Mean ±SD (mm)	*p* value	
PNS −x axis	−0.63 ±2.57	0.12 ±0.39	−0.21 ±0.64	−0.44 ±2.47	0.11 ±0.53	0.03 ±0.46	0.910	0.186
PNS −y axis	3.09 ±3.03	0.15 ±0.60	0.01 ±0.53	4.32 ±2.06	0.01 ±0.41	−0.12 ±0.43	0.387	0.460
point A −x axis	−0.97 ±1.90	0.21 ±0.39	−0.07 ±0.59	−1.54 ±1.89	0.21 ±0.67	0.18 ±0.59	0.991	0.197
point A −y axis	2.02 ±1.92	0.38 ±0.64	0.22 ±0.76	−0.54 ±2.42	0.47 ±0.44	0.34 ±0.62	0.615	0.576
Is −x axis	−1.54 ±0.83	0.50 ±0.81	0.48 ±1.14	−4.12 ±0.78	0.67 ±0.87	0.92 ±1.21	0.511	0.239
Is −y axis	1.80 ±2.30	0.53 ±0.80	0.57 ±0.94	−1.28 ±2.71	0.75 ±0.58	1.31 ±1.12	0.319	0.026
U6 −x axis	−1.45 ±0.82	0.30 ±0.62	0.21 ±1.13	−3.30 ±1.15	0.33 ±0.93	0.34 ±0.98	0.908	0.699
U6 −y axis	2.49 ±1.75	0.32 ±0.76	0.15 ±0.94	1.72 ±1.71	0.35 ±0.47	0.54 ±0.63	0.896	0.129
SNA	−1.40 ±2.74	0.11 ±0.46	−0.10 ±0.62	−1.17 ±1.47	0.11 ±0.57	0.05 ±0.59	0.974	0.449
MxOP	1.45 ±4.65	−0.35 ±2.25	−1.32 ±2.34	5.74 ±3.54	−0.43 ±1.61	−1.59 ±2.25	0.897	0.710

(+): the movement anteriorly or superiorly; (-) : the movement posteriorly or inferiorly

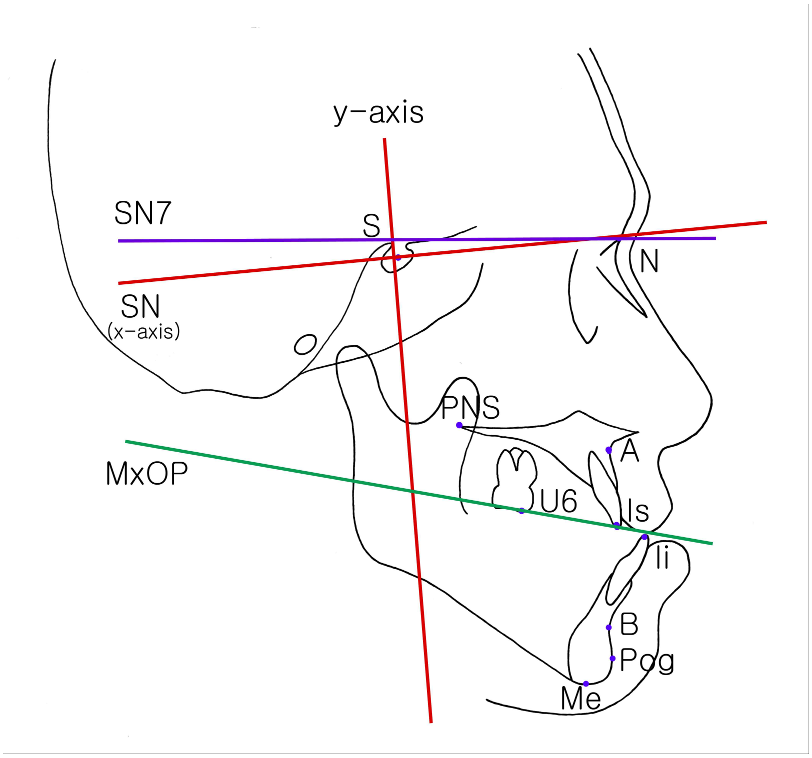

Fig. 1. Landmarks and reference lines used in the cephalometric analysis. S, sella; N, nasion; PNS, posterior nasal spine; A, point A; Is, upper central incisor edge; U6, upper first molar; Ii, lower central incisor edge; B, point B; Pog, pogonion; Me, menton; x-axis, a line drawn 7° clockwise rotated to the sella-nasion line; y-axis, a line perpendicular to the x-axis through the sella; MxOP (maxillary occlusal plane angle), an angle between the sella-nasion and Is-U6.

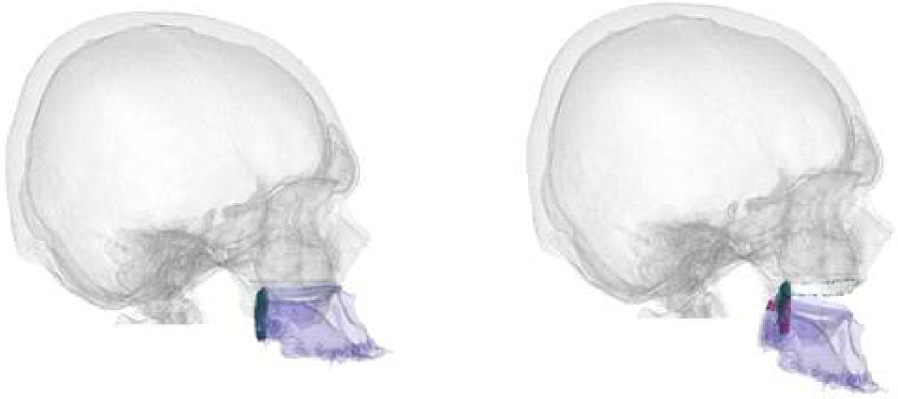

Fig. 2. The bony interference at the pterygomaxillary junction during maxillary setback movement in 3D simulation surgery. (Left), The bony interferences without consideration of the autorotation of maxillomandibular complex; (Right), The bony interferences with consideration of the autorotation of maxillomandibular complex (mandible was removed in order to show bone interference at pterygomaxillary area)

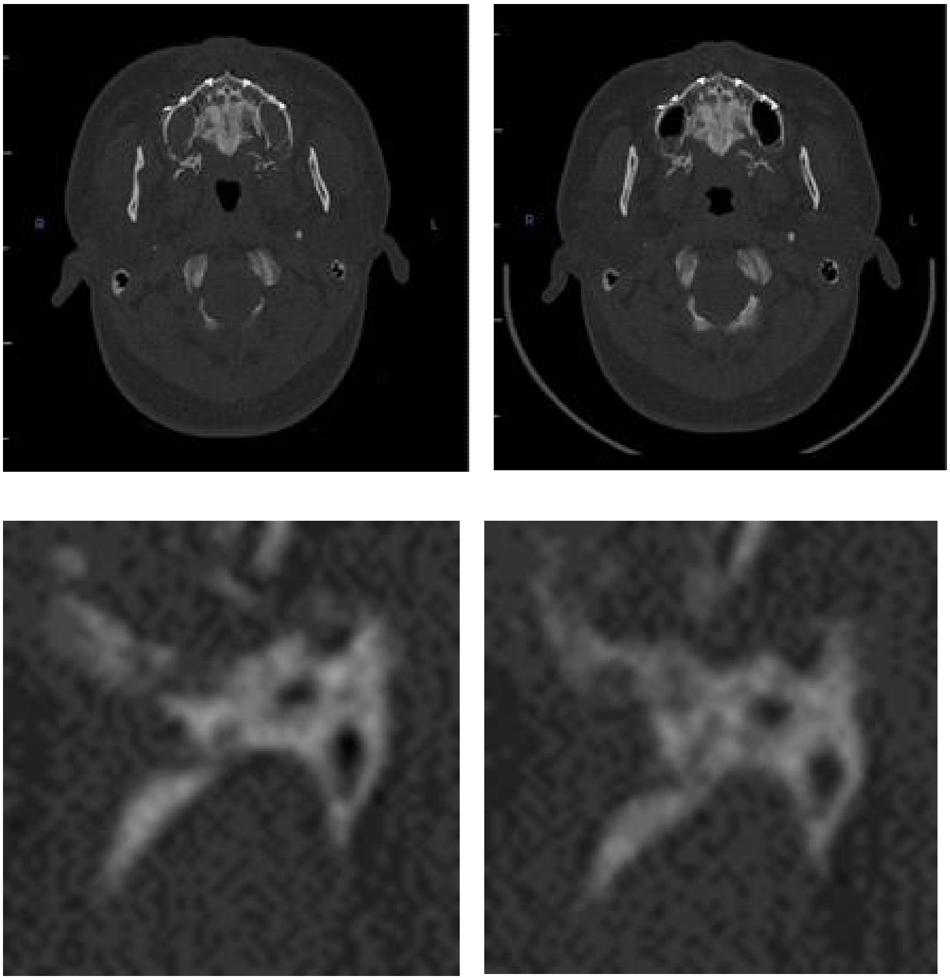

Fig. 3. The assessment of bone healing at the pterygomaxillary junction. (upper left) axial CT view immediately after surgery; (upper right) axial CT view at 3 months after surgery; (lower left) the ROI on right side immediately after surgery; (lower right) the ROI on right side at 3 months after surgery.

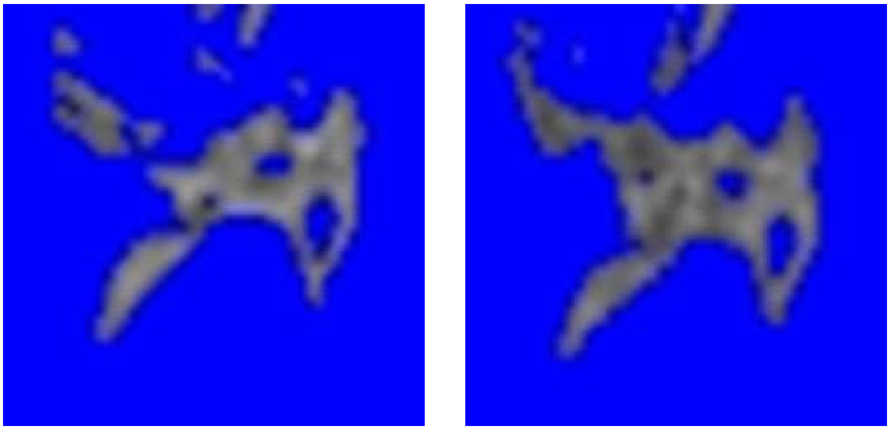

Fig. 4. The measurements of bone area in ROI at right pterygomaxillary junction. (left) the ROI immediately after surgery; (right) the ROI at 3 months after surgery

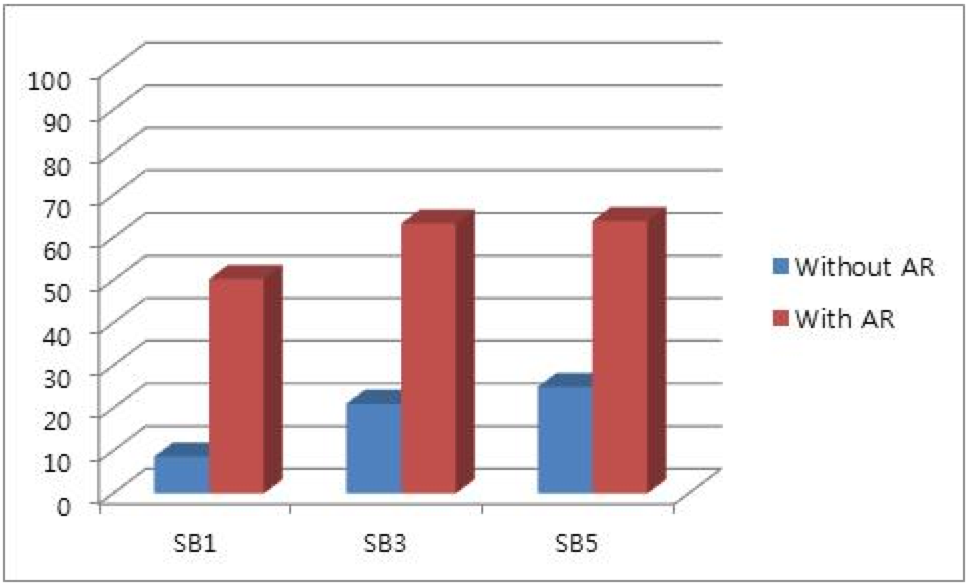

Fig. 5. Effect of the maxillary setback movement on the bony interference at the pterygomaxillary junction depending on the amount of setback movement (1, 3, 5 mm). The volume of bony interference increased as the amount of maxillary setback movement increased. Considering the autorotation of the maxillomandibular complex, this volume increased approximately 5.82 times, 3.01 times and 2.56 times in the cases of 1mm-, 2mm- and 3mm setback movement (SB, setback; AR, autorotation; y-axis: [%]).

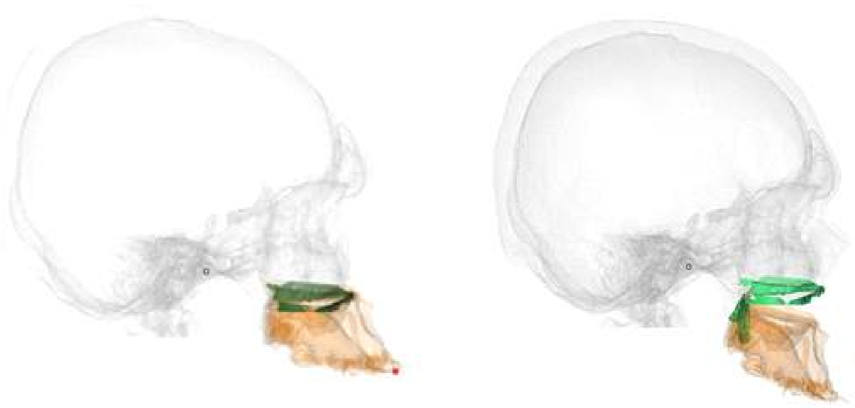

Fig. 6. The bony interference at the pterygomaxillary junction during posterior impaction of the maxilla in 3D simulation surgery. (Left) The bony interferences without consideration of the autorotation of maxillomandibular complex, (Right) The bony interferences with consideration of the autorotation of maxillomandibular complex (This figure contains the bony intereference at the sinus wall, and mandible was removed in order to show bone interference at pterygomaxillary area).

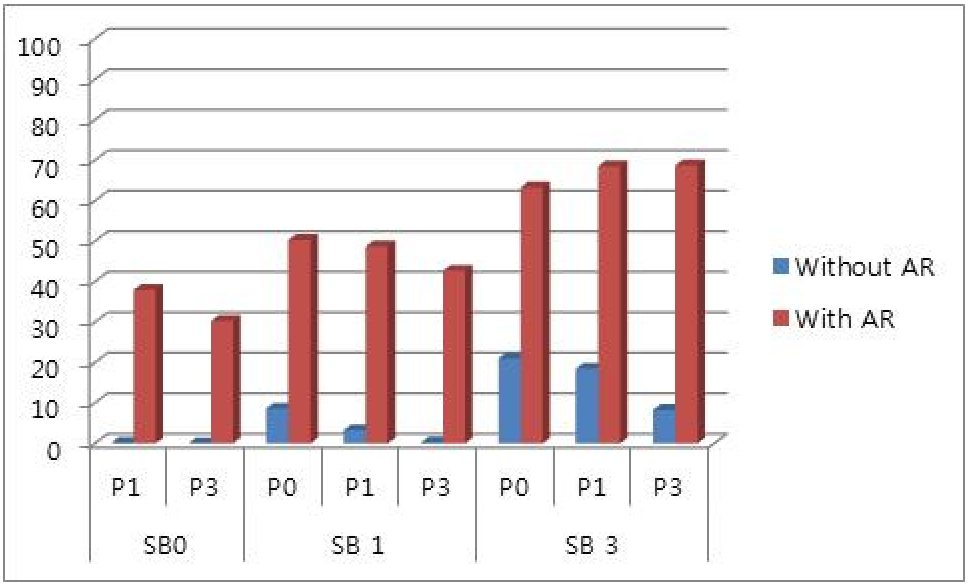

Fig. 7. Effect of the maxillary setback movement (0, 1 and 3 mm) and posterior impaction (0, 1 and 3 mm) on the bony interference at the pterygomaxillary junction. The volume of bony interference increased as the amounts of setback increased, but in cases of increase of posterior impaction, it did not increase. Considering the autorotation of the maxillomandibular complex, the volume also increased, and the ratios in each case was different (SB, setback; PI, posterior impaction; AR, autorotation; y-axis, [%])

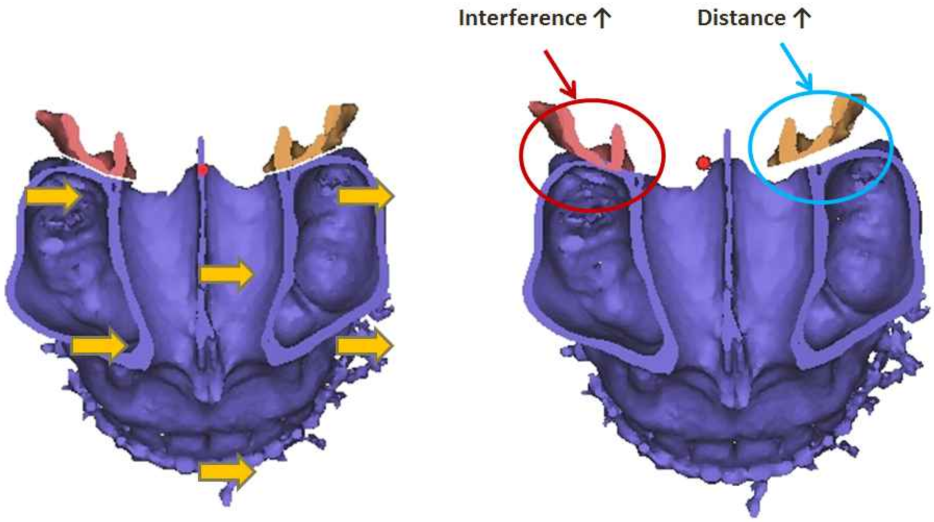

Fig. 8. The bony interference at the pterygomaxillary junction during midline-shift of the maxilla for the correction of maxillary midline deviation in 3D simulation surgery. As the maxilla moved to the left side, the distance between pterygoid plate and maxillary tuberosity on left side increased, and the bony interference on right side increased.

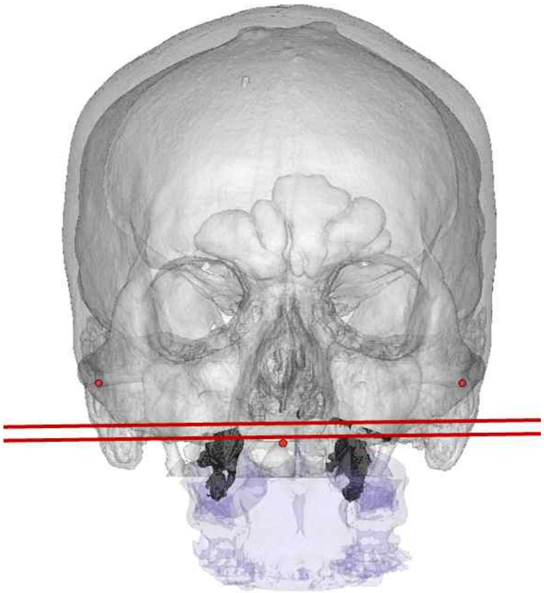

Fig. 9. The bony interference at the pterygomaxillary junction during midline-shift of the maxilla for the correction of maxillary midline deviation in 3D simulation surgery. As the maxilla moved to the left side, the height of the bony interference on left side was lower than that it on right side.

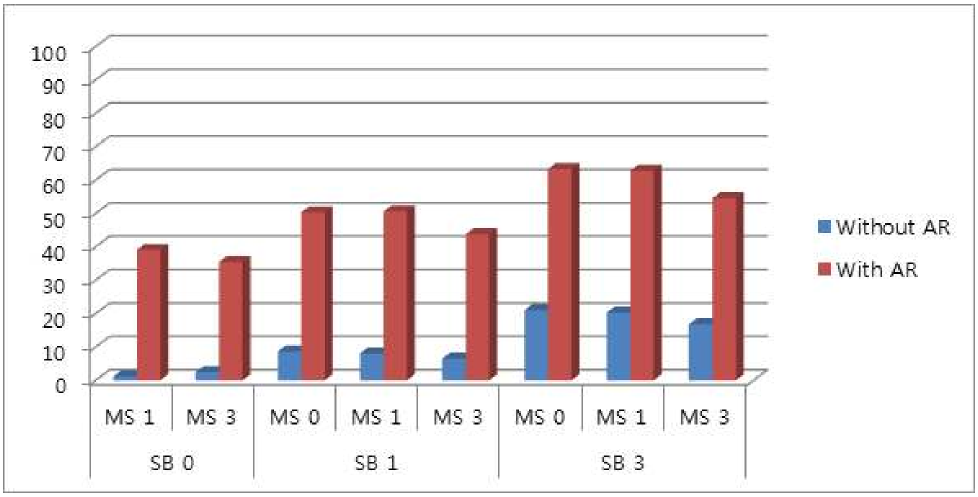

Fig. 10. Effect of the maxillary setback movement (0, 1 and 3 mm) and midline shift (0, 1 and 3 mm) on the bony interference at the pterygomaxillary junction. As the amount of maxillary setback increased, the amount of bony interference also increased. In contrast, as the amount of midline shift of the maxilla increased, the amount of bony interference decreased. (SB, setback; MS, midline-shift; AR, autorotation; y-axis, [%])

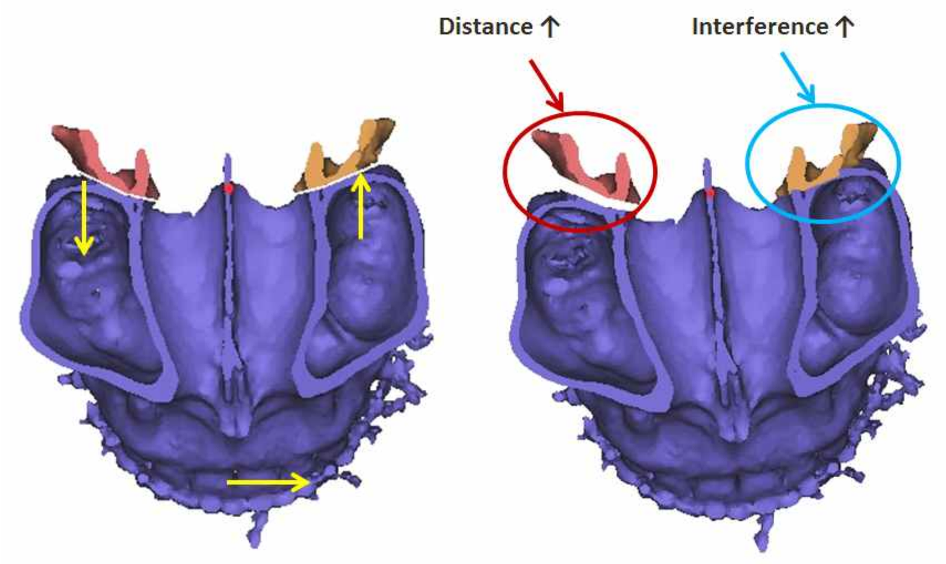

Fig. 11. The bony interference at the pterygomaxillary junction during yawing correction of the maxilla for the correction of midline deviation in 3D simulation surgery. As the maxilla rotated counterclockwise at the top view, the distance between pterygoid plate and maxillary tuberosity on right side increased, and the bony interference on left side increased. And then, the height of bony interference on right side was lower than that on left side.

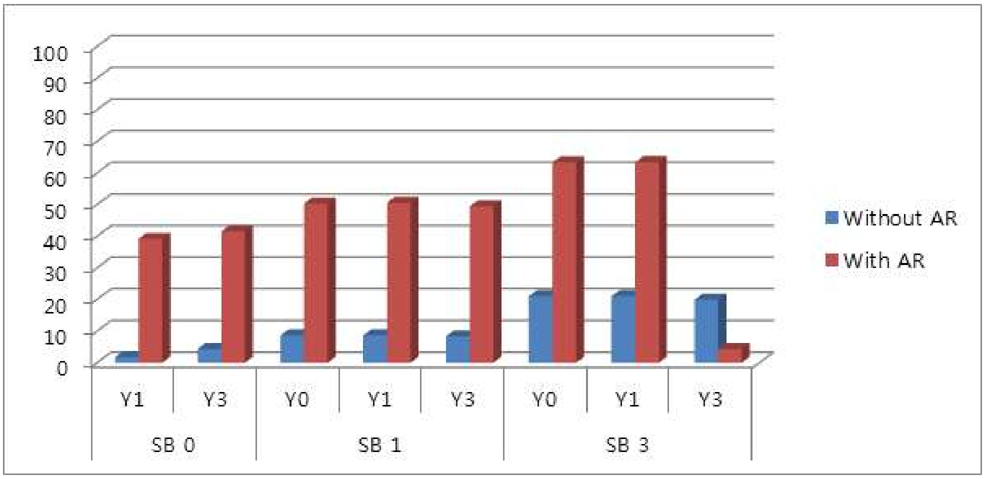

Fig. 12. Effect of the maxillary setback movement (0, 1 and 3 mm) and yawing correction (0, 1 and 3 mm) on the bony interference at the pterygomaxillary junction. Overall, although the volume of interference increased as the amount of setback increased, the volume of interference did not show a specific tendency as the amount of yawing increased (SB, setback; Y, yawing correction; AR, autorotation; y-axis, [%])

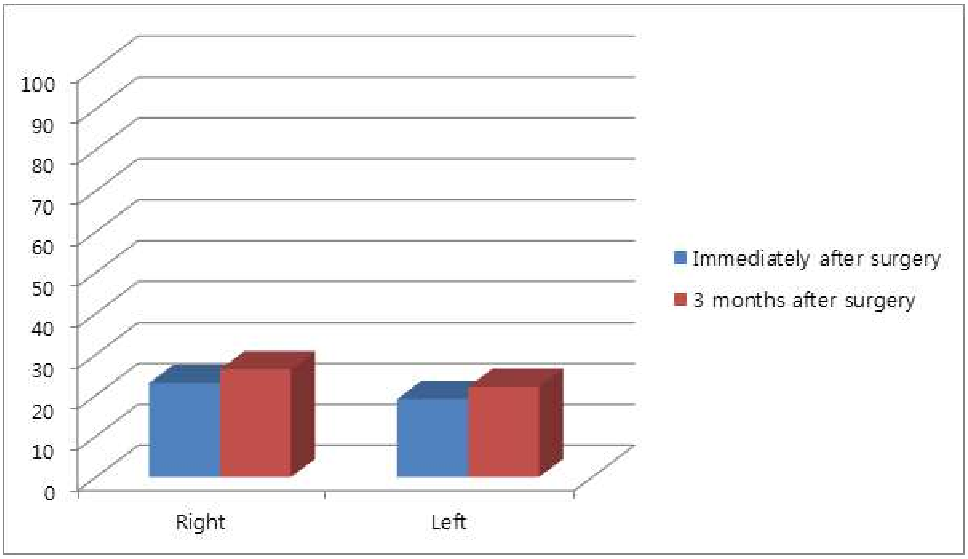

Fig. 13. Bone healing at the pterygomaxillary junction after maxillary setback surgery at 3 months after surgery. There was statistically significant bone healing after three months after surgery ($p<0.001$, Wilcoxon signed ranks test; y-axis, [%])

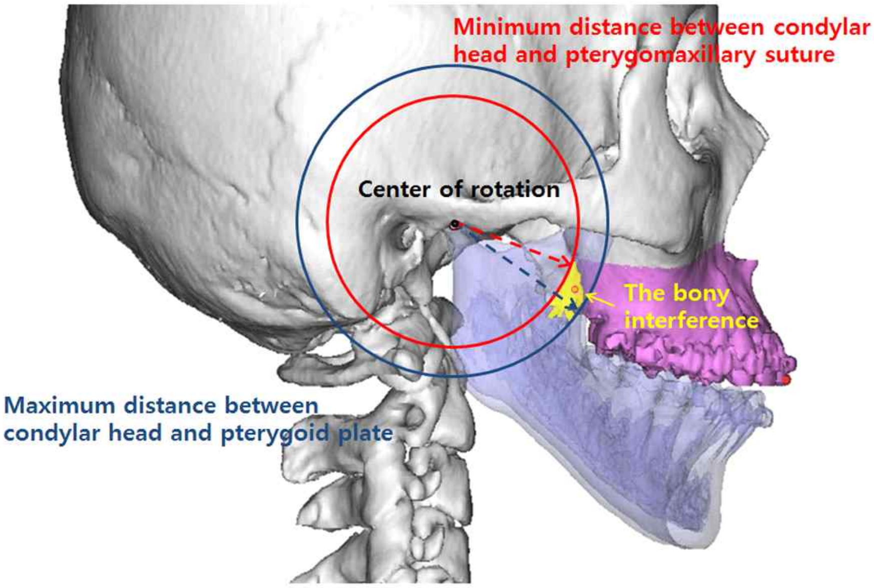

Fig. 14. Illustration of the bony interference during the autorotation of maxillomandibular complex. In order to avoid the bony interference, the minimum distance between condylar head and pterygomaxillary suture should be greater than the maximum distance between condylar head and pterygoid plate.

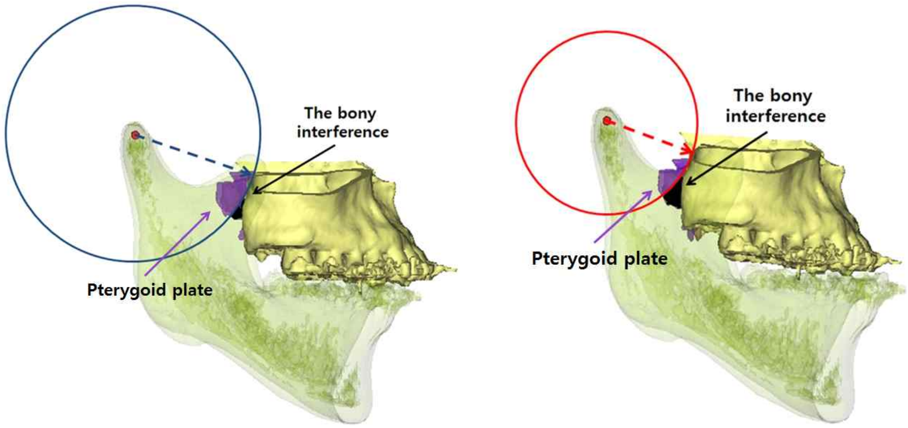

Fig. 15. Illustration of the different bony interference (black area) between long distance (left) and short distance (right) between pterygomaxillary suture and center of rotation in condyle. The small rotation arc (short distance between center of rotation and pterygomaxillary suture) of the maxillomandibular complex causes greater bony interference than the greater rotation arc (long distance between center of rotation and pterygomaxillary suture) of maxillomandibular complex.

국문초록

상악 후퇴 이동술의 3차원 시뮬레이션, 술 후 안정성 및 골 치유에 관한 연구

한 정 준

서울대학교 대학원 치의과학과 구강악안면외과학 전공

(지도교수 황 순 정)

목적

상악 전돌증을 갖는 환자에서 상악 후퇴 이동술은 환자의 안모 조화를 개선하기 위해 필요하다. 이러한 상악 후퇴 이동술은 상악골 주위의 해부학적인 복잡성으로 인해 술식의 어려움을 가져온다. 좁은 수술 시야 속에

서 골 간섭을 해소하기 위해 익돌상악부 주위의 적절한 골 삭제가 이루어져야 하며, 하행구개동맥 또한 주의 깊게 인지되고 분리되어야 한다. 또한, 익돌판의 골 삭제는 조절하기 힘든, 중등도의 지속적인 출혈을 유발한다. 상악 후퇴 이동술이 악교정 수술에서 자주 이루어짐에도, 가상 수술을 이용한 골 간섭 부위의 측정 및 수술 후 안정성에 대한 보고는 거의 이루어지지 않았다. 본 연구에서는 상악 후퇴 이동술 후 익돌상악부의 골 치유를 포함하여 상악 후퇴 이동술의 술 후 안정성을 평가하고, 3차원 시뮬레이션 수술을 통하여 골 간섭 부위를 확인하고자 한다.

연구 방법

본 연구를 위해 양측성 하악지 시상 분할 골절단술을 동반한 상악 후퇴 이동술을 시행한 환자 41명을 대상으로 수술 전, 수술 직후, 수술 6주후, 그리고 수술 6개월 후의 측면두부방사선사진 분석을 통해 술 후 재발 정도를 분석하였다. 상악 후퇴 이동술의 골 간섭 부위를 알아보기 위하여 시뮬레이션 수술을 시행하였고, 이를 통해 상악 후퇴 이동술 시 골 삭제가 요구되는 부위에 대하여 분석하였다. 또한 상악 후퇴 이동술의 술 후 골 치유 정도를 평가하기 위하여 수술 직후와 수술 3개월 후 전산화 단층 촬영을 시행한 환자 15명을 대상으로 상악골 융기 및 익돌판 부위의 골 생성 정도를 비교하였다.

결과

본 연구에서 상악 후퇴 이동량은 상악절치단, A점, PNS, 상악 제1대구치를 기준으로 각각 2.80 mm, 1.25 mm, 0.54 mm, 2.35 mm 로 나타났다. 상악 후퇴 이동술 시행 6개월 후 PNS와 A-point에서 유의한 재발은 발생하지 않았으며, 상악 후퇴 이동량이 3 mm 미만인 군 (그룹 Ⅰ)과가 상악 후퇴 이동량이 3 mm 초과인 군 (그룹 Ⅱ)의 술 후 재발 정도를 비교할 때 유의할 만한 차이는 나타나지 않았다. 상악 후퇴 이동술의 가상 수술 결과, 수술 시 발생하는 상하악 복합체의 하악과두를 중심으로한 회전은 단순 후퇴 이동보다 많은 양의 골 삭제를 요구하였으며, 상악골융기 및 익돌판 하방 부위에서의 많은 골 간섭을 발생하였다. 또한 상악 후퇴 이동량의 증가는 골 간섭 부위의 증가를 가져왔다. 전산화 단층 촬영을 이용한 상악 후퇴 이동술 후 익돌상악부의 골 치유 정도 평가시, 수술 직후와 비교하여 수술 3개월 후 유의할만한 골 생성이 관찰되었다(p<0.001).

결론

본 연구에서 상악 후퇴 이동술 후, 유의할 만한 재발은 나타나지 않았으며, 상악 후퇴 이동량이 증가하여도 술 후 안정성에는 유의할 만한 차이는 나타나지 않았다. 3차원 시뮬레이션 수술을 통해, 익돌부와 상악골 후방부에서 발생하는 골 간섭은 상악 후퇴 이동량이 증가함에 따라 증가하는 경향 보였다. 또한 수술 중 상하악복합체의 회전은 익돌상악부의 골 간섭에 영향을 주었다. 익돌상악 경계부의 골 간섭은 상하악복합체가 회전함에 따라 증가하였다. 상악골의 적절한 후퇴 이동을 이루기 위해서는 상하악복합체 회전 중심에서부터 익돌판까지의 최대 거리와 같은 회전 중심에서부터 익돌상악봉합부까지의 최소 거리의 차이를 고려하는 것이 요구된다. 본 연

구는 또한 익돌상악부에서 유의할만한 골 치유가 발생함을 보였다. 그러나 본 연구는 골 치유에 관한 단기간 평가를 하였기에, 향후 장기간의 추적 관찰을 통한 후속 연구가 필요하다.

주요어 : 상악 후퇴 이동술, 술 후 안정성, 술 후 재발, 골 간섭, 골 치유

학 번 : 2011-23820