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Three-dimensional analysis of maxillary stability after Le Fort I osteotomy using hydroxyapatite/poly-L-lactide plate

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ABSTRACT

Purpose: To evaluate three-dimensional change in maxillary position using biodegradable plates.
Material and methods: A total of 53 patients who underwent orthognathic surgery using biodegradable plates were analyzed retrospectively. The position of maxilla was measured three-dimensionally using cone beam computed tomography data at preoperative (T0), 1-month postoperative (T1), and 1-year postoperative (T2) time points. Changes in the maxilla 1 year after the operation (T2–T1) were analyzed to demonstrate postoperative stability. The correlation between postoperative relapse (T2–T1) and surgical movement (T1–T0) of the maxilla was investigated.
Results: At 1-year postoperatively, no significant changes in maxillary position were noted in the antero-posterior and transverse dimensions. The anterior maxillary position in the vertical dimension also showed no significant changes, but the posterior maxillary position (posterior nasal spine, greater palatine foramen) showed a 0- to 2.98-mm relapse at 1-year postoperatively. The posterior maxilla tended to relapse inferiorly when the amount of surgical upward movement was greater than 3–3.5 mm and to relapse superiorly when the amount of surgical upward movement was less than 3–3.5 mm. For all patients, no postoperative complications in the osteofixated maxilla were observed during the follow-up period.
Conclusion: Maxilla fixed with biodegradable plates was stable in the antero-posterior and transverse and the vertical (anterior maxilla) dimensions. Posterior maxillary vertical relapse was clinically acceptable, but relapse patterns that relate to the amount of surgical upward movement should be considered for surgical treatment planning.

1. Introduction

Titanium osteosynthesis has been used as a standard osteofixation method during orthognathic surgery. However, about 10% of patients require removal of hardware after the completion of bony union (Schmidt et al., 1998). The various reasons for the removal of titanium plates are radiation artifacts, thermal sensitivity, pain, and sinusitis. Additional surgical cost and postoperative pain from the secondary procedure of hardware removal is a disadvantage of titanium plates. Biodegradable plates maintain mechanical strength until bony union is completed and then undergo a resorption process to be replaced with bone. Thus, patients prefer biodegradable plates over titanium plates when options are given, and the numbers of published articles on biodegradable plates have increased (Landes et al., 2014).

Most studies evaluating postoperative stability of orthognathic surgeries using biodegradable plates have used two-dimensional (2D) cephalometric analysis. The drawbacks of 2D cephalometric analysis are difficulties in structural landmark discernment due to superimposition, right and left magnification discrepancy due to uneven distances between the x-ray detector, objects, and films, and distortion due to incorrect head position. Therefore, determining the reference points and measuring the length or size of the structures is not reliable. In particular, when orthognathic surgery involves surgical movements within millimeters, the analysis of stability could be inaccurate if the reference points are unreliable.

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Improvement on image accuracy of computed tomography (CT) and three-dimensional (3D) analysis software lead to 3D CT image analysis as a better alternative to overcome the limitations of 2D radiographs. Use of 3D CT allows an accurate hard tissue image without distortion. The reference points and planes can be determined in a precise manner to represent three-dimensional position and 3-dimensional changes in structures over time. Several studies have reported mandibular positional changes (Cevidanes et al., 2007; Lee et al., 2014) or pharyngeal airway changes (Hatab et al., 2015) after orthognathic surgery using 3D CT for the above-mentioned advantages; however studies on postoperative stability of the maxilla after Le Fort I using 3D CT have not been published.

This study aimed to evaluate the positional stability of the maxilla after Le Fort I osteotomy using biodegradable plates with 3D CT imaging, as well as the relapse patterns associated with the surgical movement.

2. Material and method

2.1. Patients and surgical procedures

This study followed the Declaration of Helsinki regarding medical protocol and ethics, and was approved by the regional Ethical Review Board of Yonsei Dental Hospital Institutional Review Board (IRB No. 2-2015-0003).

The study sample was composed of patients who underwent bimaxillary orthognathic surgery between 2012 and 2014. Patients with craniofacial anomalies such as cleft lip and palate were excluded. All patients were treated by one surgeon (Y.-S. Jung) using same orthognathic surgical protocol at the Department of Oral and Maxillofacial Surgery, Yonsei University Dental Hospital. Le Fort I osteotomy was followed by osteofixation using biodegradable system (hydroxyapatite/poly-L-lactide; Osteotrans MX®, Takiron, Osaka, Japan). Four L-shaped plates and monocortical 2.0-mm-diameter screws were placed on bilateral pyriform aperture and zygomatic buttress. In addition to Le Fort I osteotomy, patients underwent bilateral sagittal split ramus osteotomy for mandibular advancement and bilateral vertical ramus osteotomy for mandibular setback. The patients were examined with cone beam computed tomography (CBCT) (Alphard3030, Asahi Roentgen Inc., Kyoto, Japan) preoperatively (T0), 1 month postoperatively (T1), and 1 year postoperatively (T2) for the analysis of hard tissue changes over time. Medical records were reviewed for postoperative complications in the maxilla osteofixated using biodegradable plates such as foreign body reaction, infection, palpability of plates, plate exposure, wound dehiscence, or fistula.

2.2. Three-dimensional analysis

Simplant® software (Materialise, Leuven, Belgium) was used to reconstruct 3D images from CBCT data (threshold 500–3071). Reference points and planes were determined by one examiner using both CT sectional images and reconstructed 3D images.

Reference points were determined on stable structures not being changed during orthognathic surgery, as follows:

a. Nasion (Na): A midpoint of the frontonasal suture.
b. Nasal tip (NT): Most prominent point of the nasal bone.
c. Frontozygomatic suture (FZS): The junction of frontozygomatic suture and orbital wall. R-FZS: right FZS, L-FZS: left FZS.
d. Optic canal (Oc): Most inferior point of the optic canal. R-Oc: right Oc, L-Oc: left Oc, mid-Oc: the midpoint of R-Oc and L-Oc.
e. Foramen magnum (FM): Most posterior point of the foramen magnum.

Reference planes, below, were determined using the above reference points (Fig. 1).

a. Horizontal plane (HP): A plane crossing Mid-Oc, R-FZS, and L-FZS for the measurement of maxillary points in vertical distance (VER).
b. Midsagittal plane: Perpendicular to HP and crosses Na and FM.
c. Sagittal plane (SP): Parallel and 100 mm right of MSP for the measurement of maxillary points in transverse distance (TRANS).
d. Coronal plane (CP): Perpendicular to HP and MSP and crosses NT for the measurement of maxillary points in antero-posterior distance (AP).

The maxillary points were determined as followed.

a. A point: The point of the greatest concavity on the anterior border of the maxilla.
b. Nasopalatine canal (NP): Most anteroinferior point of nasopalatine canal.
c. Greater palatine foramen (GP): Most anteroinferior point of greater palatine foramen. R-GP: right GP, L-GPL: left GP.
d. Posterior nasal spine (PNS): Most posterior point of posterior nasal spine.

The distances between maxillary points and three reference planes were measured (Fig. 2). Each maxillary point was displayed in 3D fashion (AP, TRANS, VER). The amount and direction of changes in each time interval were calculated as follows:

a. Surgical movement: T1 (AP, TRANS, VER) − T0 (AP, TRANS, VER).
b. Postoperative relapse: T2 (AP, TRANS, VER) − T1 (AP, TRANS, VER).

2.3. Statistical analysis

The Kolmogorov–Smirnov test and Shapiro–Wilk test were performed to confirm the normality of distributions on measured data. A paired t-test on the postoperative relapse (T2–T1) of maxillary points was performed to evaluate the positional stability of the maxilla at 1 year after the operation. The maxillary points that showed significant changes on the paired t-test were identified and analyzed for any correlation between surgical movement (T1–T0) and postoperative relapse (T2–T1) using Pearson's correlation test and simple linear regression analysis. Statistics were considered significant at $P < 0.05$. All statistic analyses were performed with the SPSS version 18.0 software (SPSS Inc., Chicago, IL, USA).

3. Results

A total of 53 patients comprising 19 males and 34 female with mean age of 22 years (range 17–38) were included. For mandibular surgery, 5 patients underwent bilateral sagittal split ramus osteotomy, and the remaining 48 patients underwent bilateral vertical ramus osteotomy. Mobility of Le Fort I segments after osteofixation using a biodegradable system was not observed at clinical examination during the postoperative follow-up period. Also, there was no foreign body reaction, infection, palpability of plates, plate exposure, wound dehiscence, or fistula in the osteofixated maxilla during the follow-up.

Table 1 illustrates the average positional changes of maxillary points from T1 to T2. Antero-posterior and transverse dimensional changes of the maxillary points were not statistically significant.