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The relationship between the changes in three-dimensional facial morphology and mandibular movement after orthognathic surgery

Dae-Seung Kim [a,b], Kyung-Hoe Huh [b,c], Sam-Sun Lee [b,c], Min-Suk Heo [b,c], Soon-Chul Choi [b,c], Soon-Jung Hwang [b,d,**], Won-Jin Yi [b,c,*]

[a] Interdisciplinary Program in Radiation Applied Life Science Major, College of Medicine, BK21, Seoul National University, Seoul, South Korea
[b] Dental Research Institute, School of Dentistry, Seoul National University, Seoul, South Korea
[c] Department of Oral and Maxillofacial Radiology, BK21, Seoul National University, Seoul, South Korea
[d] Department of Oral and Maxillofacial Surgery, BK21, Seoul National University, Seoul, South Korea

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ABSTRACT

Purpose: The purpose of this study was to investigate the relationship between changes in three-dimensional (3D) facial morphology and mandibular movement after orthognathic surgery. We hypothesized that facial morphology changes after orthognathic surgery exert effects on 3D mandibular movement.
Materials and methods: We conducted a prospective follow-up study of patients who had undergone orthognathic surgical procedures. Three-dimensional facial morphological values were measured from facial CT images before and three months after orthognathic surgery. Three-dimensional maximum mandibular opening (MMO) values of four points (bilateral condylions, infradentale, and pogonion) were also measured using a mandibular movement tracking and simulation system. The predictor variables were changes in morphological parameters divided into two groups (deviated side (DS) or contralateral side (CS) groups), and the outcome variables were changes in the MMO at four points.
Results: We evaluated 21 subjects who had undergone orthognathic surgical procedures. Alterations in the TFH (total facial height), LFH (lower facial height), CS MBL (mandibular body length), and DS RL (ramus length) were negatively correlated with changes in bilateral condylar movement. The UFH, DS MBL and CS ML (mandibular length) showed correlations with infradentale movement. The CS ML, DS ML, MBL, UFH, and SNB were correlated with pogonion movement.
Conclusion: The height of the face is most likely to affect post-operative mandibular movement, and is negatively correlated with movement changes in the condyles, infradentale and pogonion. The changes in CS morphological parameters are more correlated with mandibular movement changes than the DS. The changes in CS MBL and bilateral RL were negatively correlated with condylar movement changes, while the bilateral MBL and CS ML were positively correlated with changes in infradentale and pogonion.

1. Introduction

Orthognathic surgery is widely performed to improve facial aesthetics and masticatory function, including mandibular movement, thus enhancing quality of life (Jan and Johanne, 2012). Some studies have examined the functional or morphological changes that can occur after orthognathic surgery, assessing parameters such as mechanical advantages, bite force, soft tissue, and range of mandibular movement (Kouta et al., 2012; Popat et al., 2012; Sforza et al., 2010; Song et al., 1997; Throckmorton and Ellis, 2001; Throckmorton et al., 2000, 1980; Verze et al., 2011; Yang et al., 2005; Zarrinkelk et al., 1996, 1995). Mandibular movement generally decreases after orthognathic surgery (Aragon et al., 1985; Boyd et al., 1991; Storum and Bell, 1984; Ueki et al., 2008). On the other hand, in their long-term follow-up study, Pepersack and Chausse reported no decrease in maximum mouth opening (Pepersack and Chausse, 1978). Zimmer et al. (1992) reported differences in the patterns of changes in mandibular movement according to different orthognathic surgical procedures. Other studies

* Corresponding author. Department of Oral and Maxillofacial Radiology, BK21, Seoul National University, Seoul, South Korea. Tel.: +82 2 2072 3049; fax: +82 2 744 3919.
E-mail address: wjyi@snu.ac.kr (W.-J. Yi).
** Corresponding author. Department of Oral and Maxillofacial Surgery, BK21, Seoul National University, Seoul, South Korea.

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have explored the relationship between changes in mandibular movement and morphology after surgery (Aragon et al., 1985; Ueki et al., 2005). A positive correlation was found between changes in the condylar long axis angle and in the incisal path and lateral movement range (Ueki et al., 2005). The amount of surgically created mandibular setback was also correlated with the maximal interincisal opening (Aragon et al., 1985). No study has assessed the relationship between changes in three-dimensional (3D) facial morphology and 3D mandibular movement after orthognathic surgery.

Some studies have investigated the relationship between mandibular movement and facial morphology (Farella et al., 2005; Fukui et al., 2002; Ingervall, 1971). A correlation between the mandibular movement range and the facial morphology of the ramus inclination and mandibular length was reported (Ingervall, 1971). Fukui et al. (2002) reported positive correlations between maximum mouth opening and various facial morphology parameters, including ramus inclination, gonial angle, and maxillary length. In addition to these findings, patients with facial asymmetry exhibited an asymmetrical condylar path angle (Mimura and Deguchi, 1994), and condylar path asymmetry was associated with facial asymmetry parameters (Pirttiniemi et al., 1990). In a previous study, we analyzed the relationship between the range of mandibular movement and facial morphology, as measured in 3D (Kim et al., 2010a). The mandibular movement was correlated with facial morphology features such as SNA, ramus length, mandibular length, and mandibular body length. The 3D morphology value could predict the variation in mandibular movement to a certain extent (Kim et al., 2010a). The asymmetry in movement between the condyles increased as the mandibular deviation increased (Kim et al., 2010a). Therefore, the 3D facial morphology changes that are introduced by orthognathic surgery can affect 3D mandibular movement, and a relationship may exist between the extent of changes in facial morphology and mandibular movement, as measured in 3D.

The purpose of this study was to investigate the relationship between 3D mandibular morphological and movement changes after orthognathic surgery. We hypothesized that the facial morphology changes that follow orthognathic surgery exert effects on the 3D mandibular movement. Three-dimensional mandibular movement and facial morphology changes were acquired pre- and post-operatively from patients who had undergone orthognathic surgeries. We then analyzed the relationship between the changes in 3D facial morphology and mandibular movement.

2. Materials and methods

We conducted a prospective follow-up study of patients who had undergone orthognathic surgical procedures. The surgery performed consisted of Le Fort I and sagittal split ramus osteotomy (SSRO). Three-dimensional facial CT and mandibular movement data were acquired before and three months after surgery. To be included in the study sample, patients were planned for orthognathic surgery and agreed to perform mandibular movement tracking. Patients were excluded as study subjects if they had preoperative TMD symptoms, a malformed condyle or mouth openings smaller than 35 mm. To acquire 3D images, facial CT scan was performed at 120 kVp and 80 mAs with a slice thickness of 0.75 mm using a CT scanner (Siemens SOMATOM Sensation 10, Munich, Germany), both pre- and post-operatively. Three-dimensional mandibular movements were also recorded using a mandibular movement tracking system immediately after CT scanning (Kim et al., 2010a, Kim et al., 2010b). The experimental protocol was approved by the Institutional Review Board of our university. The object and method of this study was explained, and informed consent was obtained from all subjects. We have read the Helsinki Declaration and have followed the guidelines in this investigation.

For the measurement of facial morphology, eleven landmarks (Table 1) were defined on the surface models that were reconstructed from the CT images while carefully verifying the position of the points on the multiplanar slice images using Amira 5.0 software (TGS Inc., San Diego, CA, USA). Three-dimensional facial morphological parameters were measured based on the landmarks from pre- and postoperative images (Table 2). The mandibular deviation of each subject was determined according to the midline, passing the nasion and parallel to the z-axis. From the coronal view, the side containing the menton was defined as the deviated side (DS), while the other side was referred to as the contralateral side (CS). Bilaterally existing morphological parameters were divided into two groups (DS or CS groups) according to the mandibular deviation from the pre-operative images. The degree of asymmetry of the bilateral parameters was calculated as an absolute difference between the DS and CS measurements. To evaluate the overall facial asymmetry, the Nas–Me angle, which is the angle between the nasion–menton line and the line parallel with the FH plane, was measured in the coronal view. All subjects were considered to have

Table 1
Landmarks used for facial morphology analysis.

Landmark	Abbreviation	Definition
Nasion	Nas	Craniometric point at the bridge of the nose where the frontal and nasal bone of the skull meet
Orbitale	Or	Lowest point on the lower edge of the cranial orbit
Subspinale	A	Deepest point in the bony concavity in the midline below the anterior nasal spine
Supramentale	B	Most posterior midline point, above the chin, on the mandible between the infradentale and pogonion
Menton	Me	Lowest point of the mandibular symphysis
Gonion	Go	Midpoint of the mandibular angle between the ramus and corpus mandibulae
Condylion	Con	Highest point on the superior outline of the mandibular condyle
Anterior nasal spine	ANS	Nasal spine at the front extremity of the intermaxillary suture
Sella	S	Saddle-shaped, hollowed extension of the sphenoid bone
Infradentale	Id	Crest of the alveolus between the mandibular incisors
Pogonion	Pog	Most anterior point on the chin

Table 2
Morphological parameters used for analysis.

Landmark	Abbreviation	Definition
3D length		
Ramus length	RL	Distance between Con and Go
Mandibular body length	MBL	Distance between Go and Me
Mandibular length	ML	Distance between Con and Me
Total facial height	TFH	Distance between Nas and Me
Upper facial height	UFH	Distance between Nas and ANS
Lower facial height	LFH	Distance between ANS and Me
Projected lateral angle		
SNA	SNA	Angle formed by sella-nasion-point A
SNB	SNB	Angle formed by sella-nasion-point B
ANB	ANB	Angle formed by point A-nasion-point B
3D angle		
Gonion angle	GA	Angle formed by joining Con, Go, and Me