Assessment of the Thickness of the Roof of the Glenoid Fossa Using Cone Beam Computed Tomography in Orthognathic Surgery Patients: A Preliminary Study

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Purpose: The aim of this study was to assess the change in thickness of the roof of the glenoid fossa (RGF) in patients undergoing orthognathic surgery using cone-beam computed tomography (CBCT) images.

Methods: This retrospective study measured the thickness of the RGF in 19 patients (10 males, 9 females) who underwent orthognathic surgery at Chosun University Dental Hospital. The thickness of the RGF was measured perpendicularly between the 'glenoid fossa line' and 'middle cranial fossa line' on parasagittal and paracoronal reconstructions.

Results: The mean RGF thickness increased from 0.83 ± 0.44 mm to 0.86 ± 0.46 mm after surgery. The average change in thickness of the RGF was 0.17 ± 0.18 mm. The thickness of the RGF in the temporomandibular joint (TMJ) showed no significant difference by sex, and the change in thickness of the TMJ did not vary by surgical method.

Conclusions: We found that the thickness of the RGF increased after orthognathic surgery, as revealed by CBCT. Further studies including larger numbers of subjects and long-term follow-up are needed to confirm the results of this study.

Key Words: Cone-beam computed tomography; Orthognathic surgery; Roof of glenoid fossa; Temporomandibular joint

INTRODUCTION

The temporomandibular joint (TMJ), unlike other joints of the body, is very complicated, being composed of osseous components (condyles, glenoid fossa, and articular eminences) and soft tissues (articular discs and joint capsules) [1].

The marked thickness of the roof of the glenoid fossa (RGF) of the TMJ is important to withstand the various types of stimulation associated with facial trauma involving superior displacement of the mandibular condyle into the middle cranial fossa, as well as the effects of TMJ arthroplasty and

joint reconstruction [2].

In general, orthognathic surgery is performed in patients with skeletal class II and III dentofacial deformities, and in patients with asymmetry. Orthognathic surgery includes one-jaw surgery (mandibular advancement or mandibular setback) and two-jaw surgery (bimaxillary advancement or setback). Orthognathic surgery affects the relationships of the soft tissues, as well as the osseous components of the TMJs [3,4].

Many studies have evaluated changes in condyle position and condyle shape after orthognathic surgery [3,5-7]. Cevitanes et al. [3] studied changes of the condyle of

the TMJs after orthognathic surgery, and reported surgical displacement and adaptive responses relative to adjacent structures in the craniofacial complex [3]. Skeletal stability differs depending on the orthognathic surgical method used. Busby et al. [6] and Proffit et al. [7] found that mandibular setback alone was more stable over the long term than when combined with maxillary surgery.

We suspect that not only changes in the condyle, but also in the morphology of the glenoid fossa, could be caused by orthognathic surgery. A previous study determined that the thickness of the RGF is clinically important [8]. This study evaluated changes in the glenoid fossa following orthognathic surgery using cone beam computed tomography (CBCT). CBCT images, which can be obtained relatively economically and involve lower radiation doses, have proven remarkably useful in craniofacial investigations [3]. The aim of this study was to assess the change in thickness of the RGF in patients undergoing orthognathic surgery.

MATERIALS AND METHODS

1. Subjects

This study included patients who underwent orthognathic surgery at the Oral and Maxillofacial Surgery Department of Chosun University Dental Hospital. Patients were diagnosed with mandibular prognathism, retrognathism, or asymmetry underwent one-jaw surgery (mandibular setback or advancement) or two-jaw surgery (maxillomandibular setback or advancement). The total number of patients undergoing

orthognathic surgery from January 2015 to September 2019 was 104. However, only 19 patients (10 males, 9 females; mean age, 26.5 ± 6.7 years) were selected, due to the exclusion of those without postoperative CBCT data, a truncated TMJ on CBCT images, or temporomandibular disorder prior to surgery. This retrospective study was approved by the Institutional Review Committee of Chosun University Dental Hospital (CUDH) (IRB no. 1901/013).

2. Image Analysis

Images of the glenoid fossa of the temporal bone were edited using three-dimensional imaging software (OnDemand3D; CyberMed Co., Seoul, Korea). As in a previous study [8], the images were reconstructed based on the angle of the condylar head. Paracoronal sections were obtained parallel to the horizontal axis of the condylar head, and parasagittal sections were reconstructed parallel to the line connecting the center point of the condylar head with the coronoid process (1 mm slice thickness, 1 mm slice interval). The reconstructed data sets were exported as Digital Imaging and Communications in Medicine image stacks.

3. Measurement of the Thickness of the Roof of the Glenoid Fossa

The method used for measuring RGF thickness was the same as in previous studies [8]. Measurements were obtained on images of the central region of the glenoid fossa in parasagittal and paracoronal sections using G3 software (Infiniti Healthcare, Seoul, Korea). The images were assessed

Fig. 1. Parasagittal reconstruction of cone beam computed tomography images. (A) Roof of the glenoid fossa (RGF), thickness of the Roof of glenoid fossa. (B) Thickness of the RGF before orthognathic surgery. (C) Thickness of the RGF after orthognathic surgery. (D) A super-imposition of images before and after orthognathic surgery. Pre-operative image for yellow color, post-op image for grey color.

in a darkened room on a personal computer with a 32-inch LCD monitor. The contrast and brightness of the images were adjusted using the image processing tool of G3 to ensure optimal visualization. The thickness of the RGF was determined as the perpendicular distance between the 'glenoid fossa line' and 'middle cranial fossa line' on parasagittal (Fig. 1) and paracoronal reconstructions. RGF thickness was measured three times, by one investigator, at the thinnest part of the glenoid fossa among multiple slices, with the mean value calculated for statistical analysis. The same examiner measured the thickness of the RGF, in the same way as in a previous study [8], therefore, interexaminer agreement was not assessed in this study.

4. Statistical Analysis

Statistical analyses were performed using PASW Statistics for Windows, Version 18.0 (SPSS Inc., Chicago, IL, USA). The Shapiro-Wilk test was used to test the normality of the data distribution. A p-value <0.05 was regarded as statistically significant. All quantitative variables are described as means±standard deviations. In a previous study [8], intra- and interexaminer agreement with respect to RGF thickness

was evaluated using the intraclass correlation coefficient. Comparison of the RGF thickness of patients pre- and post-surgery, and analyses of RGF thickness according to sex and surgical method, were performed using t-tests.

RESULTS

This study involved 19 patients (10 males and 9 females) who underwent corrective surgery (Table 1). The mean age was 26.5±6.7 years (Table 1). Increases in RGF thickness were observed in all 19 patients (Table 2). The mean RGF thickness increased from 0.83±0.44 mm to 0.86±0.46 mm

Table 1. Patients demographic data

Variable	Value
Age	26.5±6.7
Sex	
Male	10
Female	9
Surgical method	
1-Jaw surgery	11
2-Jaw surgery	8

Values are presented as mean±standard deviation or number only.

Table 2. The thickness of the RGF on pre- and post-surgery (unit: mm)

Position	Sagittal (n=19)				Coronal (n=19)			
	Rt. (before/after)		Lt. (before/after)		Rt. (before/after)		Lt. (before/after)	
1	0.58	0.68	1.17	1.26	0.68	0.78	1.02	1.22
2	0.40	0.59	0.39	0.49	0.40	0.68	0.52	0.78
3	0.78	1.01	0.68	0.78	0.88	1.02	0.56	0.88
4	1.26	1.65	0.58	0.69	1.26	1.95	0.68	0.88
5	1.17	1.46	0.68	0.78	1.14	1.44	0.52	0.73
6	0.40	0.57	0.68	1.20	0.50	0.63	0.74	1.26
7	0.76	0.78	0.68	0.90	0.79	0.78	0.88	1.18
8	0.68	0.74	0.68	0.80	0.68	0.78	0.69	0.80
9	0.98	1.05	1.19	1.35	0.88	1.02	1.19	1.39
10	1.67	2.23	2.20	2.92	1.48	2.37	2.40	2.98
11	0.54	0.61	0.75	0.78	0.59	0.73	0.68	0.72
12	0.69	0.84	0.63	0.71	0.60	0.88	0.70	0.85
13	0.55	0.73	0.45	0.67	0.58	0.71	0.50	0.71
14	0.69	0.73	0.74	0.74	0.56	0.69	0.68	0.69
15	0.81	0.66	1.14	1.17	0.74	0.58	1.14	1.16
16	0.52	0.51	0.49	0.59	0.43	0.52	0.59	0.60
17	0.33	0.42	0.33	0.39	0.33	0.43	0.33	0.40
18	0.58	0.60	0.41	0.56	0.51	0.66	0.50	0.58
19	0.68	0.76	0.85	0.88	0.73	0.84	0.79	0.87
Total	0.74±0.33	0.87±0.45	0.77±0.43	0.93±0.55	0.72±0.30	0.92±0.49	0.80±0.45	0.98±0.55

RGF, roof of glenoid fossa; Rt., right ; Lt., left.

Values are presented as distance or mean±standard deviation only.

after surgery (Table 3). The average change in thickness of the RGF was 0.17 ± 0.18 mm (Table 4).

The change in thickness of the RGF on parasagittal and paracoronal images showed no significant difference by sex (Table 5).

In total, 8 of 19 patients underwent two-jaw surgery (7 patients underwent maxillary LeFort 1 surgery and mandibular setback, and 1 underwent maxillary and mandibular advancement), and 11 patients underwent one-jaw surgery (mandibular setback) (Table 1). There was no significant difference in the change in thickness of the TMJ according to surgical method (one- vs. two-jaw surgery) (Table 6).

DISCUSSION

The TMJ is affected by the surrounding environment [9]. Factors contributing to changes in the structure of the TMJ include disc derangement, degenerative arthritis and orthognathic surgery [9].

CBCT is a highly efficient and low-cost imaging modality suitable for observing bone changes [10]. In particular, since the radiation dose is lower than that of conventional CT, CBCT can be performed several times over the follow-up period [10]. In general, CBCT is used to accurately evaluate skeletal structure, devise a surgical plan before orthognathic surgery, and evaluate skeletal changes during follow-up [3,10]. We analyzed before- and after-surgery CBCT images using three-dimensional imaging software in our evaluation of the skeletal structure of the TMJ.

In this study, the thickness of the RGF was not significantly different from the value for Koreans obtained in a previous study [8]. We evaluated the change in thickness (pre- vs.

post-surgery) of the RGF on CBCT images in patients who underwent orthognathic surgery. The average thickness of the RGF increased from 0.83 ± 0.44 mm to 0.86 ± 0.46 mm (Table 3). There have been many studies of changes in the condyle and glenoid fossa of TMJs after orthognathic surgery [11-15]. Cottrell et al. [11] reported minimal long-term changes in healthy patients after orthognathic surgery. An et al. [12] noted that surgical correction of skeletal deformities requires a soft-tissue response and condylar remodeling, to adapt to the new environment. They noted condylar

Table 4. The change amount of the thickness of the RGF on pre- and post-surgery

Position	Sagittal (n=19)		Coronal (n=19)	
	Rt. (mm)	Lt. (mm)	Rt. (mm)	Lt. (mm)
1	0.10	0.09	0.10	0.20
2	0.19	0.10	0.28	0.26
3	0.23	0.10	0.14	0.32
4	0.39	0.11	0.69	0.20
5	0.29	0.10	0.30	0.21
6	0.17	0.52	0.13	0.52
7	0.02	0.22	-0.01	0.30
8	0.06	0.12	0.10	0.11
9	0.07	0.16	0.14	0.20
10	0.56	0.72	0.89	0.58
11	0.07	0.03	0.14	0.04
12	0.15	0.08	0.28	0.15
13	0.18	0.22	0.13	0.21
14	0.04	0.00	0.13	0.01
15	-0.15	0.03	-0.16	0.02
16	-0.01	0.10	0.09	0.01
17	0.09	0.06	0.10	0.07
18	0.02	0.15	0.15	0.08
19	0.08	0.03	0.11	0.08
Total	0.13 ± 0.16	0.15 ± 0.18	0.20 ± 0.23	0.18 ± 0.16

RGF, roof of glenoid fossa; Rt., right ; Lt., left.

Values are presented as distance or mean $\pm$ standard deviation only.

Table 3. The mean of the thickness of RGF on pre- and post surgery

Position	Pre-surgery (n=19)				Post-surgery (n=19)			
	Rt. (mm)		Lt. (mm)		Rt. (mm)		Lt. (mm)	
	Sagittal	Cononal	Sagittal	Cononal	Sagittal	Cononal	Sagittal	Cononal
Mean value according to position	0.74 ± 0.33	0.72 ± 0.30	0.77 ± 0.43	0.80 ± 0.45	0.87 ± 0.45	0.92 ± 0.49	0.93 ± 0.55	0.98 ± 0.55
Total mean value	0.83 ± 0.44				0.86 ± 0.46			
Mean value of change amount	0.17 ± 0.18							

RGF, roof of glenoid fossa; Rt., right ; Lt., left.

Values are presented as mean $\pm$ standard deviation.

Table 5. Differences between male and female about orthognathic surgery patients

Sex	Rt. coronal	Lt. coronal	Rt. sagittal	Lt. sagittal
Male	0.26±0.29	0.21±0.20	0.15±0.18	0.22±0.23
Female	0.13±0.13	0.16±0.11	0.11±0.13	0.09±0.06

RGF, roof of glenoid fossa; Rt., right; Lt., left.

Statistically significant difference ($p < 0.05$) (t-test).

Table 6. Differences according to surgical methods (1-jaw/2-jaw surgery)

Surgical method	1-jaw surgery (0.17±0.18)	2-jaw surgery (0.15±0.18)
1- jaw surgery (0.17±0.18)	-	-
2- jaw surgery (0.15±0.18)	0.496*	-

*Statistically significant difference ($p < 0.05$) (t-test).

surface changes, and reported that condylar inward rotation was closely related to changes in the condylar surface [12]. Kim et al. [13] reported that orthognathic surgery was able to correct dentofacial deformities and alter the neuromuscular environment. They noted that surgical correction led to a physiological adaptation process, according to changes in the position of the condyle [13]. Owatad et al. [14] reported that the glenoid fossa was remodeled according to changes in the surrounding environment, likely involving the condyle. Kai et al. [15] showed that the RGF was thicker in patients with versus without degenerative joint changes and disc displacement. They suggested that this may be attributable to remodeling, or might occur in response to mechanical stress [15].

Many studies have reported bone changes, such as flattening and rotation of the condyle, after orthognathic surgery [16,17]. We suggest that these changes in the surface and location of the condyle also affect the glenoid fossa of the TMJ. The increase in thickness of the RGF seen in this study showed that structural changes and mechanical stress after surgery affected the glenoid fossa of the TMJ [17].

There was no significant difference in the thickness of the RGF according to sex (Table 5). These results are consistent with previous studies showing that the thickness of the RGF is not affected by age or sex [2,18].

In this study, 11 of 19 patients underwent one-jaw surgery (mandibular setback), while 8 patients underwent two-jaw (maxillary) surgery (Table 6). There was no significant difference in the variation in thickness of the TMJ

according to the surgical method (Table 6). An et al. [12] reported no significant difference in the extent of remodeling of the constant bone between one- and two-jaw surgeries. However, Wolford et al. [17] reported greater bone remodeling in two- versus one-jaw surgery. In one-jaw surgery, there is a difference in the position of the condyle, and the stress applied to the glenoid fossa, according to whether mandibular setback or advancement is performed [3,5,17]. Wolford et al. [17] reported that physiological adaptation is difficult when surgical correction is performed in the counterclockwise direction.

There were several limitations to our study. First, the small sample size makes it difficult to generalize the results. Also, Koreans typically have a class III skeletal structure [19,20]. In this study, only one patient had a class II skeletal structure (Table 6). In addition, many studies have shown that bone to remodeling after surgery can take a relatively long time [21,22]; however, in our study, CT was performed only about 1 year after surgery. Therefore, long-term follow-up should be implemented in future studies to assess bone remodeling.

In conclusion, we found that the thickness of the RGF increased after orthognathic surgery, as revealed by CBCT. Further studies including larger numbers of subjects and long-term follow-up are needed to confirm the results of this study.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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