Masseter muscle changes following orthognathic surgery
A Long-term three-dimensional computed tomography follow-up

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A Long-term three-dimensional computed tomography follow-up

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감사의 글

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지금의 제가 있기까지 어릴 때부터 꿈을 키워 주시고 언제나 격려해 주신 아버지, 모든 일에 항상 헌신적인 사랑과 기도로 돌보아 주신 어머니, 부족한 저를 언제나 믿고 응원해 주시는 시어머님과 아가씨, 사랑하는 동생 은혜와 강현씨 에게도 감사 드리며, 수련기간 동안 옆에서 아낌없이 지원해 준 남편에게 깊은 감사의 마음을 전합니다. 마지막으로 하나님께 감사 드리며 이 모든 영광을 돌립니다.

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ABSTRACT

Masseter muscle changes following orthognathic surgery

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Department of Dentistry

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The aim of this study was to evaluate the long-term changes of masseter muscle morphology in skeletal Class III patients with facial asymmetry following 2-jaw orthognathic surgery (Le Fort I osteotomy + Intraoral vertical ramus osteotomy).

Using computed tomography (CT), a longitudinal study was conducted on 17 skeletal Class III patients with facial asymmetry. Measurements from the reconstructed 3D CT images were compared from T1 (before surgery), T2 (1 year after surgery), and T3 (4 years after surgery).

The maximum cross-sectional area, orientation, thickness, and width of masseter muscle were measured on both the deviated and non-deviated sides. The control group included 17 volunteers with skeletal and dental Class I relationships without dentofacial deformities.

At T1, there were no significant differences of masseter muscle measurements (cross-sectional area, thickness, or width of masseter muscle) between the deviated and non-deviated sides. Masseter muscle orientation was significantly more vertical on the non-deviated side than the deviated side at T1 ($P < .01$), no significant bilateral differences were noted at T2 and T3. At T1, masseter muscle measurements were significantly lower than controls ($P< .01$). During T1-T3, a significant increase was noted in cross-sectional area, thickness, and width ($P < .01$) of masseter muscle. At T3, no significant difference was noted between the study group and control group.

After surgery, the masseter muscle measurements of skeletal Class III asymmetry patients showed no significant differences compare to control group within the 4-year follow-up period, indicating adaptation to the new skeletal environments and increased functional demand.

Key words: 3D CT; Masseter muscle; Orthognathic surgery; Skeletal Class III; Facial asymmetry

Masseter muscle changes following orthognathic surgery A Long-term three-dimensional computed tomography follow-up

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I. INTRODUCTION

Soft tissue analysis should be considered in the diagnosis of facial asymmetry patients because soft tissue reflects the skeletal components. Evaluation of the masseter muscle (MM), which extends from the zygomatic arch to the mandibular angle and external surface of the ramus, is important in the diagnosis of facial asymmetry patients as well as in hard tissue evaluation.

It seems that skeletal asymmetry affects MM morphology, but the relationship between skeletal asymmetry and the masticatory muscle is unclear. Also, the relationship between the normal group and patients with facial asymmetry is unclear.

The size of the masticatory muscle varies with craniofacial morphology and is an important indicator of functional capacity of masticatory system (Ueki et al., 2006; Boom et al., 2008; Naser-Ud-Din et al., 2011; van Sprosen et al., 1991; Xu et al., 1994). The masseter muscle is considered as a muscle to generate force biting or chewing and is one of the structures that is most altered by orthognathic surgery. Its postoperative status may influence the patient's physical appearance as well as masticatory function (Katsumata et al., 2004).

The functional and morphological characteristics of masticatory muscle have been investigated in patients with dentofacial deformities. Patients with mandibular prognathism exhibit lower bite force, decreased occlusal contact and lower electromyographic (EMG) activity than normal subjects (Ueki et al., 2006; Katsumata et al., 2004; Ariji et al., 2000; Ueki et al., 2009; Trawitzki et al., 2010).

The asymmetrical EMG activity was reported in patients with developmental mandibular asymmetry (Dong et al., 2008). Different level of bilateral activity of the masticatory muscles was reported in children with unilateral cross-bite or lateral forced bite, possibly a functional adaptation of the masticatory system to avoid cuspal interferences (Alarcon et al., 2009).

In patients with mandibular prognathism, the masseter muscle is thinner and smaller in comparison with normal subjects and its long axis is closer to a right angle to the FH plane (Katsumata et al., 2004; Ariji et al., 2000; Ueki et al., 2009; Trawitzki et al., 2010). In patients with facial asymmetry, Goto et al reported bilateral size differences of the masseter muscle with smaller muscle size on the deviated side compared to the non-deviated side, while other studies reported no significant bilateral differences of the masseter muscle (Goto et al., 2006; Kwon et al., 2007). Kiliaridis et al reported the masseter muscle in children with untreated unilateral cross-bite was thinner on the cross-bite side and the bilateral differences eliminated after treatment of malocclusion (Kiliaridis et al., 2007).

Orthognathic surgery, in combination with orthodontic treatment, corrects the dentofacial deformity and improves occlusal contacts, masticatory efficiency, bite force, and EMG activity. A number of studies reported the increased bite force and occlusal contact area after orthognathic surgery (Katsumata et al., 2004; Ueki et al., 2009; Iwase et al., 1998; Ellis et al., 1996; Harada et al., 2003).

However, most of them had insufficient follow-up term to evaluate the long-term postoperative improvements and treatment effect on the soft tissue and muscle changes. Therefore, the aim of the present study was to investigate long-term changes of masseter muscle after orthognathic surgery.

Using 3D CT images, we evaluated morphological changes of the masseter muscle on the deviated and non-deviated sides. We also compared this data to measurements from the control group. We hypothesized that the masseter muscle measurements of skeletal Class III patients with facial asymmetry might approach normal values at the long-term postoperative follow-up.

II. MATERIAL AND METHODS

1. Subjects

This study was carried out in a group of patients who diagnosed with mandibular prognathism and facial asymmetry and underwent orthognathic surgery at Yonsei University Dental Hospital, Seoul, South Korea from 2004 to 2007. These subjects were diagnosed as skeletal Class III malocclusion using lateral cephalometric analysis. The diagnostic criteria were unilateral or bilateral Angle Class III molar key, overjet of 0mm or less, and ANB difference of 0° or less (average, -2.2°). And they had mandibular menton deviation of more than 3.5 mm from the facial midline (average, 5.5 mm), using posterioranterior cephalometric analysis. The facial midline was defined as a line perpendicular to the line connecting Lo and Lo' through Nc (Figure 1) (Haraguchi et al., 2002).

The study group was composed of 17 patients who underwent preoperative and postoperative orthodontic treatment and 2-jaw surgery (Le Fort I osteotomy + bilateral IVRO) by one surgical team and who agreed on additional CT examinations at 4 years after surgery (6 male and 11 female; average age, 21.71 years). Patients with hemifacial microsomia, cleft lip and/or palate, or disease of the temporomandibular joint were excluded from the study.

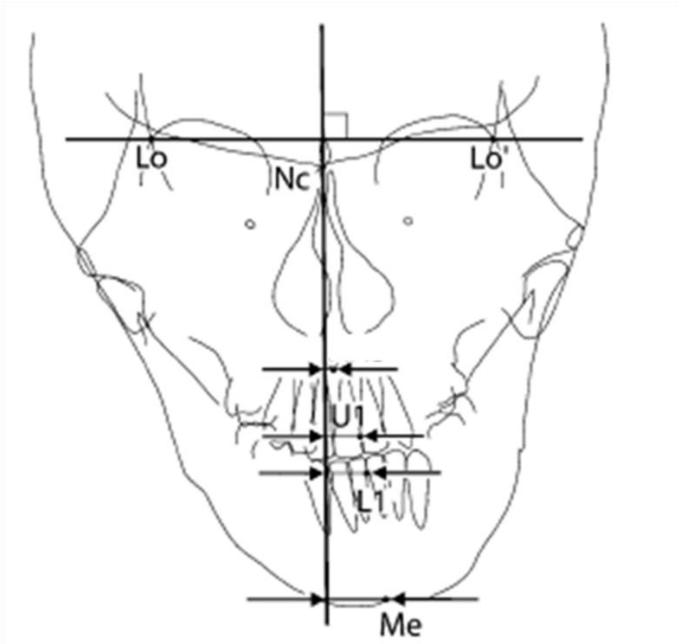

Figure1. Facial midline on P-A cephalogram.

(Lo and Lo' indicate bilateral intersection of the oblique orbital line with the lateral contour of the right and left side orbits; Nc, neck of crista galli; Me, menton)

The control group was composed of 17 volunteers with skeletal and dental Class I relationship without dentofacial deformities, significant medical history or conditions that would require orthodontic treatment. (6 male and 11 female; average age, 20.27 years). The description of the subjects is given in Table 1. Informed consent was obtained from each of the participants.

Table 1. Description of Study group and Control group

	Study group	Control group
Number of subjects	17	17
Sex	6 Male and 9 Female	6 Male and 9 Female
Race	Korean	Korean
Average age	21.71 years	20.27 years
Inclusion criteria	Skeletal/dental Class III with mandibular prognathism Chin deviation of over 3.5 mm from the facial midline	Skeletal and dental Class I No dentofacial deformities
Orthodontic treatment	Pre-and postoperative orthodontic treatment	No
Surgery	Le Fort I osteotomy + IVRO 9 of 17 patients had genioplasty	No
TMD	No signs or symptoms of TMD	No signs or symptoms of TMD

(IVRO indicates Intraoral vertical ramus osteotomy ; TMD, Temporomandibular disorder)

2. Methods

A. CT Scanning and 3D Image Reconstruction

Stereoscopic images were created for the patients based on 3D-CT images of them. The patients each underwent three-dimensional CT examinations at 1 month before surgery (T1), 1 year after surgery (T2), and at a postoperative follow-up time (T3) that occurred at an average of 4.25 years after surgery (ranged from 3.25 to 5.33 years). A spiral CT scanner (CT Hispeed Advantage/GE medical System, Milwaukee, WI) was used for CT scans under conditions of 120 kV and 200 mA. The patient's Frankfort Horizontal plane (FH plane) was adjusted parallel to the ground and their midlines were aligned with the vertical axis of the machine.

The axial images were 1mm thick and were taken at a table speed of 6mm per second. The axial images were saved as digital imaging and communication in medicine (DICOM) files and were reconstructed into 3D images using OnDemand™ software (CyberMed Inc., Seoul, Korea) (Figure 2).

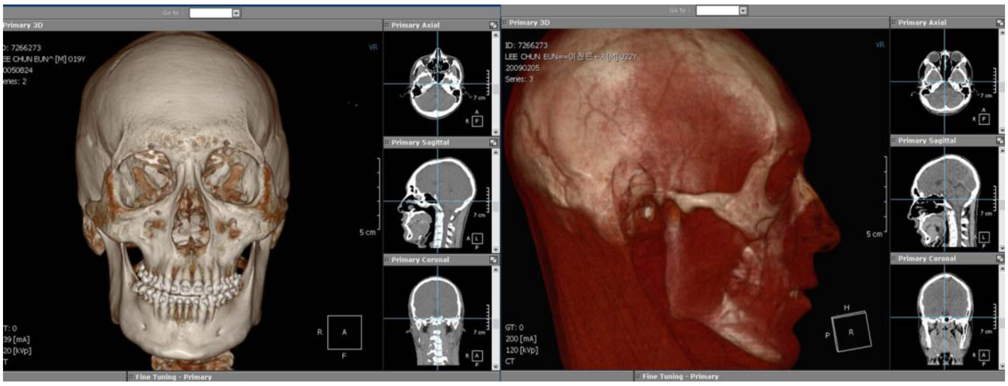

Figure 2. Reconstruction of a 3-dimensional (3D) image using OnDemand™ software (CyberMed Inc., Seoul, Korea).

The FH plane which was constructed on both sides of Porion and left of Orbitale was used as a horizontal reference plane and the midsagittal plane was drawn perpendicular to the FH plane passing through Nasion (Park et al., 2006). The shifted side of menton for the midsagittal plane was defined as deviated side and the other side was defined as non-deviated side.

B. Measurements with Reconstructed 3-D CT Images

The maximum cross-sectional area, thickness, and width of the masseter muscle were measured on both the deviated and the non-deviated side, using the reconstructed 3D CT axial images of T1, T2, and T3. To observe the clear outline of masseter muscle, the images were processed with the software by adjusting the window level, contrast, and density ranges at optimum conditions (Figure 3).

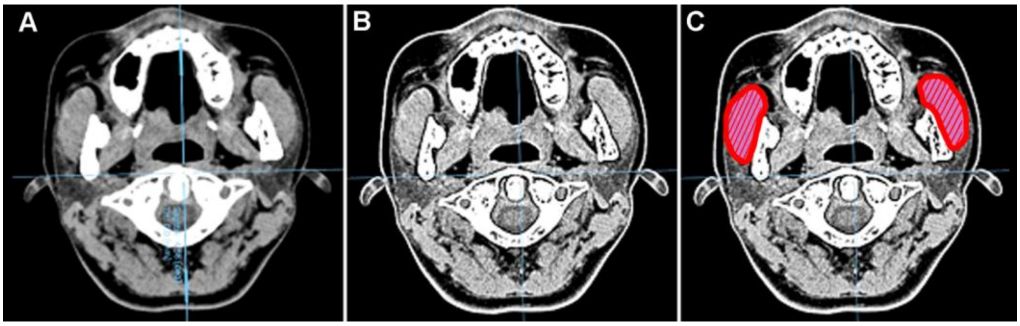

Figure 3. CT images of masseter muscle area

A: Original axial image

B: After adjusting window–level to allow visualization of masster muscle.

C: Delineation of masseter muscle area.

The maximum cross-sectional area of the masseter muscle was measured a level 10 mm above the occlusal plane of the maxillary second molar on the reconstructed CT images.

10 measurements were taken on each side of the masseter muscle, 5 mm above and below of the slice level, and the maximum cross-sectional area was determined by selecting the highest value.

To obtain the cross-sectional area of masseter muscle perpendicular to the muscle direction, the maximum area of masseter muscle (a) was calculated by multiplying the cross-sectional area measured on the axial image (a_0) by cos θ (the angle between the axial image and the section perpendicular to the muscle image) (Figure 4).

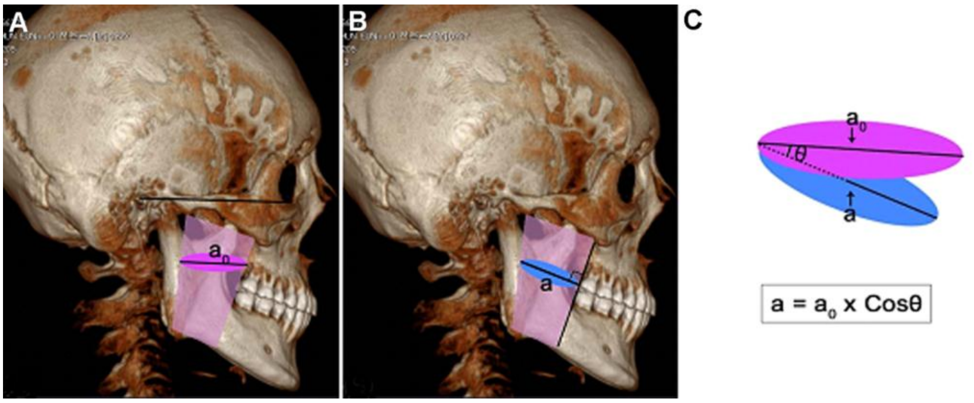

Figure 4. Measurement of cross-sectional area of the masseter muscle.

A: The cross-sectional area measured on an axial slice of the CT images.

B: The adjusted cross-sectional area perpendicular to the muscle direction.

C: Methods for calculating the area (a) from (a_0).

We calculated each cross-sectional area according to this methodology because the masseter muscle direction was different between the deviated and non-deviated sides, before surgery and after surgery, affecting the determination of actual cross-sectional area.

The masseter muscle angle was measured as the angle between the FH plane and the anterior border of masseter muscle, which was clearly defined on the lateral view of reconstructed 3D CT images (Figure 5).

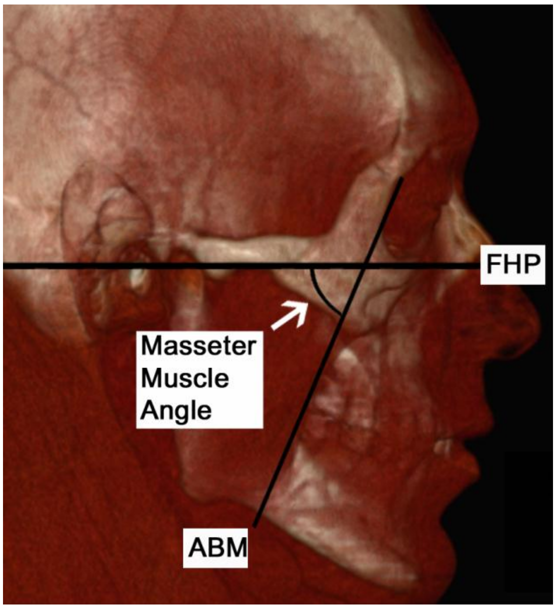

Figure 5. Masseter muscle angle was defined as the angle between FHP (FH plane) and ABM (anterior border of masseter muscle).

The thickness was measured as the thickest distance of the masseter muscle cross-sectional area and width as the distance between the most anterior and posterior points of the masseter muscle (Figure 6).

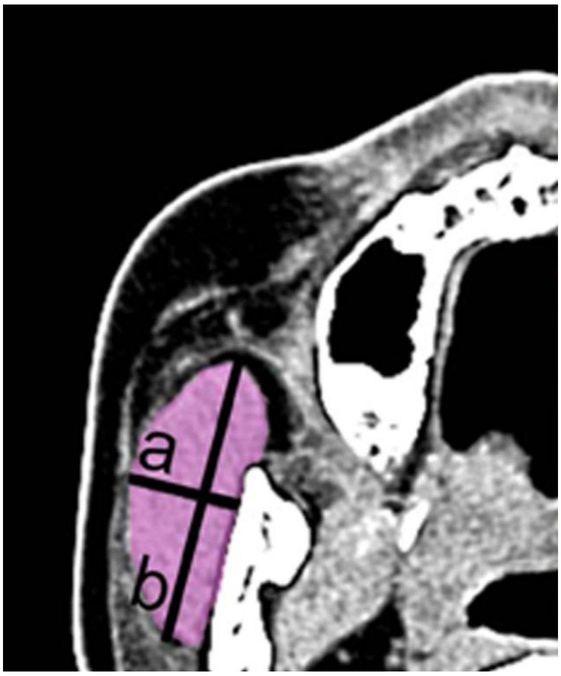

Figure 6. a: Masseter muscle thickness.
b: Masseter muscle width.

C. Statistical Analysis

All measurements were performed by one author. Measurements were repeated after 2 weeks by same author and the second measurement was used for the statistical analysis.

The intra-examiner error between two measurements was determined by means of a paired t -test and the intraclass correlation coefficient was calculated. Pearson correlation analysis was used to compare the differences between the deviated and non-deviated sides. A two-sample t-test was used to compare differences between the study group and the control group. Repeated measures analysis of variance (R-ANOVA) was used to compare the changes of masseter muscle measurements over the period from T1-T3. All statistical evaluations were performed with SAS 9.2 Ver. (SAS Inc., North Carolina).

III. RESULTS

The intra-examiner error was found to be statistically insignificant (*P*<.05) and the intraclass correlation coefficients were within acceptable value (mean of 0.92, with range of 0.90 - 0.95).

The comparison of masseter muscle measurements between deviated and non-deviated side are shown in Table 2.

Table 2. Comparisons of Masseter Muscle Measurements (Mean ± SD)

	CSA (mm²)			Thickness (mm)			Width (mm)			Angle (º)		
		Sig 1	Sig 2		Sig1	Sig2		Sig 1	Sig2		Sig 1	Sig 2
Control	419.7±73.0			14.1±1.3			39.5±2.5			63.8±3.3		
Study Group												
T1-D	333.0±52.3	***	NS	11.9±1.4	***	NS	36.5±3.6	**	NS	68.3±3.7	***	**
T1-ND	332.0±52.6	***		11.4±1.6	***		36.4±3.3	**		70.6±3.6	***	
T2-D	362.0±67.5	*	NS	13.1±1.6	*	NS	36.8±3.1	*	NS	63.6±2.8	NS	NS
T2-ND	363.6±67.6	*		12.8±1.6	*		37.3±3.0	*		64.3±2.5	NS	
T3-D	409.2±73.9	NS	NS	14.12±1.6	NS	NS	38.7±2.7	NS	NS	63.1±2.4	NS	NS
T3-ND	402.4±74.6	NS		14.1±1.7	NS		38.4±3.5	NS		63.4±2.0	NS	

Sig 1: Comparison between study group and control group

Sig 2: Comparison between deviated side and non-deviated side

CSA indicates cross-sectional area; D, Deviated side; ND, Non-deviated side; NS, Not significant; SD, Standard deviation; Sig, Significance

* $P < .05$; ** $P < .01$, *** $P < .001$.

When comparing the bilateral differences at T1, there was no significant difference of cross-sectional area, thickness and width. Only the masseter angle showed differences, which was significantly more vertical on the non-deviated side than deviated side (*P*<.01). At T2 and T3, no significant bilateral difference was found on every measurement.

The comparison of masseter muscle measurements between study group and control group are also shown in Table 2. In study group, the masseter muscle showed significant smaller cross-sectional area (*P*<.001), thickness (*P*<.001) and width (*P*<.01) compared to control group before surgery (T1) and the masseter muscle angle was significantly different from control group (*P*<.001). At T2, there was no significant difference of masseter muscle angle, but cross-sectional area (*P*<.05), thickness (*P*<.05) and width (*P*<.05) showed still significantly lower than control group. No significant differences were found between study group and control group at T3. The changes of masseter muscle during T1-T3 are shown in Figure 7.

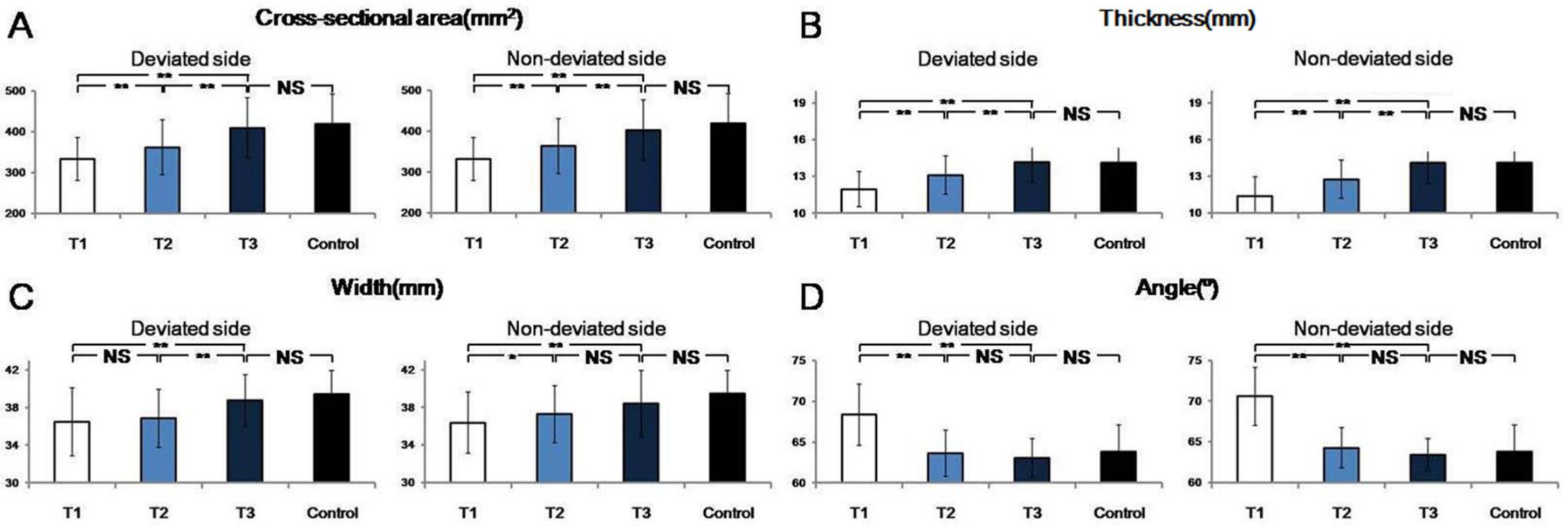

Figure 7. The changes of masseter muscle from T1 to T3.

A: Cross-sectional area (mm²) B: Thickness (mm) C: Width (mm) D: Angle (°)

T1: before surgery, T2: 1 year after surgery, T3: 4 years after surgery.

**P* < .05; ***P* < .01; ****P* < .001; NS: Not significant.

There was significant increase during T1-T2 in the cross-sectional area ($P<.01$), thickness ($P<.001$), of masseter muscle. During T2-T3, there was significant increase in the cross-sectional area ($P<.001$), thickness ($P<.001$) and width ($P<.05$) of masseter muscle measurements.

IV. DISCUSSION

The present study demonstrated that the masseter muscle measurements of skeletal Class III asymmetry patients reached the values of the control group within 4-year postoperative follow-up period.

Masticatory muscle assessments are performed using various imaging techniques, including computerized tomography (CT), magnetic resonance imaging (MRI), and ultrasound scanning (Ueki et al., 2006; Boom et al., 2008; Naser-Ud-Din et al., 2011; van Sprosen et al., 1991; Xu et al., 1994; Katsumata et al., 2004; Ariji et al., 2000; Ueki et al., 2009; Trawitzki et al., 2010; Kwon et al., 2007; Naser-ud-Din S et al., 2011; Trawitzki et al., 2011). In our study, 3D CT images were used because our patients underwent CT examinations before surgery and 1 year after surgery for surgical planning and postoperative follow-up. As this study was designed to evaluate the long-term morphologic changes of the masseter muscle, CT examinations were performed at 4 years after surgery on 17 patients who agreed on additional CT examination.

With the reconstructed 3D CT images, we could visualize not only soft tissue and muscle surfaces but also the hard tissue landmarks and reference plane to evaluate FHP-ABM angle and the cross-sectional area. We obtained the cross-sectional area of masseter muscle perpendicular to their long axis because the axial slice could be affected by the direction of each muscle (Katsumata et al., 2004). There have been many reports on the cross-sectional area on the masseter muscle using MRI or CT in subjects with normal craniofacial morphology, showing the values ranging from 363mm^2 to 500mm^2 (Boom et al., 2008; van Sprosen et al., 1991; Xu et al., 1994; Ariji et al., 2000). These contrasts might be related to variations in the samples such as craniofacial morphology, sex, race, and age. Furthermore, each of the study used different protocols for measuring cross-sectional area. The comparison of the cross-sectional area data of our study with that in the literature is shown in Table 3.

Table 3. Comparison of cross sectional area (Mean±SD) of masseter muscle reported in the literature.

Study	Method	Sample		$CSA(cm^2)$
		n	sex	
Ariji (2000)	CT	91	49 male 42 female	**3.7 ± 0.8**
Boom (2008)	MRI	31	9 male 22 female	**4.9 ± 1.2**
Sprosen (1991)	MRI	32	32 male	**4.6 ± 1.0**
Xu (1993)	CT	65	40 male 25 female	**5.0 ± 1.1**
D.H Lee (2012)	CT	17	6 male 11 female	**4.2 ± 0.7**

CSA indicates cross-sectional area; CT, computed tomography; MRI, magnetic resonance imaging; SD, Standard deviation; n, number of subjects

The slice level for the maximum cross-sectional area is also an important variable and we carried out measurements at 10 mm above occlusal plane from the maxillary second molar. The artifacts from brackets and wires were avoided on this chosen level, and the slice level used in our study was very close to the optimal slice level reported in previous studies (Xu et al., 1994; Katusumata et al., 2004; Ariji et al., 2000; Ueki et al., 2009).

At T1, no significant differences were found in cross-sectional area, thickness and width of masseter muscles between the deviated and non-deviated sides. Only the angle showed significant bilateral differences and it can be explained by the laterodeviation of the mandible and gonion. The muscle direction correlates closely with skeletal morphology, and masseter muscle orientation is influenced by position of the zygomatic arch and gonion, to which the muscle attaches. The muscle orientation became symmetrical as the skeletal components got symmetry by orthognathic surgery, and no significant bilateral angular differences were noted after surgery. As shown in the previous studies which reported postoperative reduction of FHP-ABM angle in patients with mandibular prognathism, a significant postoperative reduction of masseter angle was noted in this study (Katusumata et al., 2004; Ariji et al., 2000).

The asymmetric EMG pattern was reported in patients with developmental mandibular asymmetry or mandibular lateral shift (Dong et al., 2008). In our study, even the patients had posterior cross-bite, the study group had relatively stable interdigitation due to dental compensation and no significant bilateral difference of muscle size was noted at T1. Although we did not measure EMG patterns in this study, we could assume that the bilateral differences of EMG might not be notable. It is reported that the stability of both condyle is more important than that of the dentition to achieve the symmetrical muscle activation pattern (Alarcon et al., 2009).

The masseter muscle measurements of study group were significantly lower than control group before surgery, but they increased during T1-T3 at both sides, showing a tendency to approach control values by T3. Using ultrasonography, Trawitzki et al also reported an increase in masseter muscle thickness of Class III patients after surgical correction of dentofacial skeletal deformity; at 6-8 months after surgery, the values were still lower than controls, but reached those of controls 3 years after surgery (Trawitzki et al., 2010; Trawitzki et al., 2011). These indicate that a certain period of time is necessary for the postoperative functional improvement because a new neuromuscular mechanism is established for the formation of a more stable oral environment (Di palma et al., 2009).

The cross-sectional area of muscle reflects the physiological action of a muscle through its relation to the maximum isometric force that can be exerted by that muscle (van Sprosen et al., 1991). The correlation between masseter muscle cross-sectional area and maximum voluntary bite force was reported and this parameter might indicate the functional capacity of masticatory system (van Sprosen et al., 1991; Iwase et al., 1998).

A number of studies have reported increased bite force, occlusal contact area, EMG activity and improved masticatory efficiency after surgery (Ueki et al., 2009; Di palma et al., 2009; Iwase et al., 1998; Ellis et al., 1996; Harada et al., 2003; Throckmorton et al., 1996; Throckmorton et al., 2001), however, the reason for this improvement is unclear. It is a subject still under debate that surgery itself improves masticatory function. Previous studies reported that the postoperative improvements in muscular activity were due to better occlusal stability, and not to surgically induced biomechanical advantages (Di palma et al., 2009; Throckmorton et al., 1996; Throckmorton et al., 2001). The importance of occlusion for the neuromuscular equilibrium and dental supports was investigated in patients undergoing orthognathic surgery. Changes of muscle size, increased occlusal contact area providing greater dental supports, sensitivity of teeth, muscles and the temporomandibular joints and even the patinets' willingness to exert maximum effort have been suggested as factors in determining the occlusal force after surgery (Ellis et al., 1996).

The continuous increases of masseter muscle size in our study indicate that not only the skeletal environment was altered by surgery, but also additional adaptation to new stomatognathic environments occurred over time with improved occlusion and masticatory activity by orthodontic treatments. Also, the pattern of change varied among the individuals in the study group, suggesting that various factors may influence the morphologic changes.

Some limitations of this study should be mentioned. We did not compare the data between sexes because of limited sample sizes, and longitudinal studies with larger samples are required. Furthermore, as the muscle size is not the only factor to evaluate muscular function scientifically, future studies with analyzing bite force, occlusal contact, and muscular activity (EMG) are required to investigate the factors influencing the postoperative changes.

V. CONCLUSIONS

The aim of this study was to evaluate the long-term changes of masseter muscle morphology in skeletal Class III patients with facial asymmetry following 2-jaw orthognathic surgery (Le Fort I osteotomy + Intraoral vertical ramus osteotomy).

Using computed tomography (CT), a longitudinal study was conducted on 17 skeletal Class III patients with facial asymmetry. Measurements from the reconstructed 3D CT images were compared from T1 (before surgery), T2 (1 year after surgery), and T3 (4 years after surgery).

The maximum cross-sectional area, orientation, thickness, and width of masseter muscle were measured on both the deviated and non-deviated sides. The control group included 17 volunteers with skeletal and dental Class I relationships without dentofacial deformities. There were no significant differences between deviated and non-deviated side of masseter muscle measurements of skeletal Class III asymmetry patients except masseter muscle orientation. The masseter muscle measurements of skeletal Class III asymmetry patients were significantly lower than control group before surgery. After surgery, the masseter muscle measurements of skeletal Class III asymmetry patients reached those of the control group within 4-year follow-up period.

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국 문 요 약

악교정 수술 이후의 교근 변화: 3차원 CT 를 이용한 장기 관찰

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이 다 혜

본 연구는 안면 비대칭을 동반한 골격성 제 III 급 부정교합 환자군에서 양악수술(Le Fort I osteotomy+ Intraoral vertical ramus osteotomy) 을 시행한 이후 교근의 장기적 변화 양상을 관찰한 것이다.

실험군은 17 명으로 이루어졌으며 (남자: 6 명, 여자: 11 명, 평균 연령: 21.71 세) 수술 전 (T1), 술후 1 년 (T2), 술후 4 년 (T3) 에 촬영한 CT 를 이용하였다. 대조군은 악안면 기형을 동반하지 않은 정상교합자 17 명 (남자:6 명, 여자: 11 명, 평균연령: 20.27 세) 으로 구성하였다. 실험군과 대조군 모두에서 3 차원 CT 영상을 재구성하여, 교근의 단면적, 두께, 너비를 각각 측정하였고 수술 전에 실험군에서 편위측과 비편위측 간에 차이가 있는지 비교하였으며,

시간에 따른 실험군의 교근 측정치의 변화 양상을 알아보았고 이를 대조군과 비교하였다.

수술 전 (T1), 실험군의 교근 측정치를 비교한 결과, 교근의 주행 각도를 제외하고는 교근의 단면적, 두께, 너비는 편위측, 비편위측 간에 유의할 만한 차이를 보이지 않았다. 교근의 주행 각도는 수술 전 (T1) 에 비편위측에서 유의성 있게 더 수직적 주행 성향을 보였으나 ($p<0.01$) 악교정 수술 후 (T2, T3) 골격적 대칭성을 회복하면서 편위, 비편위측 간의 유의할 만한 차이를 나타내지 않았다. 술전, 술후 1 년의 교근 단면적, 두께, 너비는 대조군에 비해 낮은 측정치를 나타내었으며, T1-T3 동안 유의성 있게 증가하여 ($p<0.01$), 술후 4 년에는 대조군과 유의할 만한 차이를 보이지 않았다.

안면 비대칭을 동반한 골격성 제 III 급 환자군에서 양악 수술 이후 4 년간 관찰한 결과, 교근은 개선된 환경과 증가된 기능적 요구에 부합해서 크기가 증가되는 경향을 보였고, 대조군의 수치에 가까워 지는 경향을 나타내었다. 추후, 이러한 형태학적 변화가 실제로 근육의 기능 개선과 관련이 있는지 입증하기 위한 교근의 EMG, 교합력, 교합양상 관찰 등의 연구가 필요할 것이다.

핵심 되는 말: 3차원 단층 사진, 교근, 악교정 수술, 골격성 제 III급 부정교합, 안면비대칭