Evaluation of Dynamic Morphologic Changes in the Masseter Muscle in Patients Undergoing Mandibular Angle Sagittal Split Osteotomy

A Report of 130 Cases

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Objective: To evaluate the dynamic morphologic changes in the masseter muscle after mandibular angle sagittal split osteotomy (MASO).

Methods: Computed tomographic (CT) examinations were performed on 130 patients treated with MASO before surgery and at 3, 6, 12, and 18 months after surgery. These CT images were stored and a 3-dimensional reconstruction was made for calculating the volume of masseter muscle using Mimics 10.01 software. The cross-sectional area of masseter muscle was evaluated preoperatively and postoperatively using 3-dimensional CT images observed from 3 selected slice levels, which paralleled the Frankfurt horizontal plane.

Results: Following treatment, the reduction of the volume and cross-sectional area of masseter muscle were calculated. The volume of the masseter muscle was reduced by 28.18%, 39.58%, 33.37%, and 31.18% at 3, 6, 12, and 18 months postoperatively, respectively. The cross-sectional area of 3 slices were reduced, but the sectional area of the lower slice had the sharpest decline, with reductions of 79.27%, 84.39%, 84.02%, and 83.57% at 3, 6, 12, and 18 months postoperatively, respectively.

Conclusions: The results showed that the masseter muscle undergoes significant atrophy after mandibular osteotomy, and these changes could be considered as a guide for the design and simulation of MASO before surgery.


SQUARE-FACE APPEARANCE IS considered an unpleasant feature, especially because of its strong and masculine impression, and its management is a common aesthetic procedure in Asians. Besides the correction of benign masseter hypertrophy, mandibular angle sagittal split osteotomy (MASO) aiming to change a square-face appearance into a slender one in women has become one of the most frequently performed aesthetic surgical procedures for the correction of a prominent mandibular angle in Asians.

The aesthetic contour lines of the lower face are formed by the combinations of maxillofacial bones and soft tissues. The masseter muscle takes an important role in facial harmony and balance. It was reported that the resection of the mandibular angle resulted in a varied amount of muscle reduction. Hence, the masseter muscle goes through a series of changes after MASO, and these changes have close connections with surgical design and prediction. However, these data (ie, changes in masseter muscle) should rest largely on clinical outcomes. To reveal the dynamic changes in masseter muscle after osteotomy and provide a surgical guide for MASO, we evaluated the preoperative and postoperative masseter muscles in patients undergoing MASO using a 3-dimensional (3D) computed tomographic (CT) imaging technique.

METHODS

A total of 130 patients (aged 18-32 years) with a prominent mandibular angle underwent MASO. A 3D CT scan measurement was performed preoperatively and postoperatively, which was used to measure the dynamic changes of masseter muscle. The patients sought an aesthetic approach for a slim and feminine-looking lower facial contour, with normal dental occlusion without any complaint of other diseases.

All patients underwent MASO, and the osteotomy was performed on the both side of the face. These operations were performed by 1 surgical team, and all patients received routine preoperative and postoperative treatment.
The intraoral incision was made over the anterior edge of the ascending ramus, extending to the level of the second molar along the oblique line of the mandible and deepening to the periosteum. Subperiosteal dissection was performed to expose the lateral cortex of the ramus, the angle, and the posterior body region. On the side undergoing ostectomy, the mandibular angle and part of lateral cortex were resected using an oscillating saw after masseter muscle detachment. All patients received 1 600 000 U of penicillin G potassium daily for 7 days after surgical procedure. The intraoral sutures were removed 7 days postoperatively. The patients were supplied with soft food during the first week after surgery and then resumed a normal diet.

3D CT Examinations

All the patients received 3D CT scanning before operation and at 3, 6, 12, and 18 months after surgery. To evaluate the structural geometry and soft-tissue structure of the craniofacial complex, a multislice helical Light Speed (GE; New York, New York) scanner was used, generating images at 120-kV tube voltage, 180-mA tube current, 8-second scan time, and 0.625-mm slice thickness. Data were stored in DICOM (digital imaging and communication in medicine) format and transferred to 1 hard disk.

The converted DICOM reconstructions and measurements were carried out with Mimics 10.01 software (Materialise, Leuven, Belgium), which enables both the craniofacial skeleton and the patient’s soft tissue to be reconstructed.

Reference Planes

To distinguish the masseter muscle from bone and other soft tissue, we can regulate the threshold until the masseter muscle was filtered. By selecting the masseter muscle in each fault image, we can get the masseter muscle’s 3D image after calculation for further measurement. The figure station can export the volume automatically. Nevertheless the masseter muscle might be confused with medial and lateral pterygoid exceeding the sigmoid notch, so we chose the region of masseter muscle beneath the sigmoid notch of the mandible as our measurement area (Figure 1).

To standardize the orientation of the 3D image, reliable, localized landmarks were established in accordance with our objectives and using recent scientific evidence. These landmarks were the right and left bilateral points located on the superolateral border of the external auditory meatus (SLEAM) and the points located in the center of left foramen infraorbitale (LFI). We took a plane in the 3D model linking the bilateral SLEAM and LFI (Frankfurt plane) as the horizontal reference plane. After rescaling the 3D skull according to the

Surgical Methods

After rescaling the 3D skull according to the

Statistical Analysis

Univariate analysis of variance for repeated measures was performed, and the data were statistically analyzed using the paired t test and given as mean (SD).

Results

Changes in Volume

Three months postoperatively, the volume of the masseter muscle was reduced by 28.18%. After 6 months, the volume was reduced markedly (by 39.58%) compared with before surgery. After 12 months, the masseter muscle recovered some of its volume, and approximately 70% of the original volume remained until 18 months. There was a statistically significant difference compared with the original volume (Table 1).

Changes in the Cross-Sectional Area

The changes in the cross-sectional area in the 3 slices were different. The percentage of reduction in the cross-sectional area in slice A was 14.19%, 21.14%, 18.44%, and 19.27% at 3, 6, 12, and 18 months postoperatively, but there was no

Table 1

<table>
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<tr>
<th>Time (Months)</th>
<th>Percentage Reduction in Cross-Sectional Area</th>
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<tbody>
<tr>
<td>3</td>
<td>14.19%</td>
</tr>
<tr>
<td>6</td>
<td>21.14%</td>
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<tr>
<td>12</td>
<td>18.44%</td>
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<tr>
<td>18</td>
<td>19.27%</td>
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Figure 1. Sketch map of a 3-dimensional reconstruction of masseter muscle. With the red region of A and B, the masseter muscle was chosen automatically; and with the blue region of C and D, the masseter muscle was chosen manually, beneath the sigmoid notch of the mandible as the measurement region.

Figure 2. Sketch map of A, B, and C planes paralleling with the Frankfurt plane. Plane A, the upper plane; plane B, the middle plane (in the middle of the mediolateral distance of the ramus); and plane C, the lower plane; the distance between them was 1 cm.
significant difference after surgery \( (P > .05) \). The percentage of reduction in slice B was 19.80%, 26.05%, 23.03%, and 21.65% at 3, 6, 12, and 18 postoperatively, respectively. It had the same tendency as the volume: a significant reduction was shown at 6 months after surgery and restoration of some of its normal dimension was seen from 6 to 12 months. The sharpest decline was seen for slice C, with reductions of 79.27%, 84.39%, 84.02%, and 83.57% at 3, 6, 12, and 18 months postoperatively, respectively, and the tendency to restore its normal dimension was not observed, with no distinctive difference between these values \( \text{Table 2 and Figure 3} \).

### Patients with a prominent mandible angle always have a hypertrophic masseter muscle complaint. Mandible reduction procedures are currently the most common operation used to improve lower facial contour in the Asian population. However, a few reports of dynamic morphologic changes in masseter muscle with MASO were found in the literature. The present study aimed to evaluate masseter muscle changes after surgery.

How to evaluate changes in masseter muscle is very important. Among the parameters evaluated, masseter muscle volume is considered the best index to evaluate muscle size, but these volumetric measurements are difficult to obtain.\(^6,7\) In addition, the cross-sectional area of the muscle is the popular alternative index to evaluate muscle size because it is reported to have a close correlation with the volume.\(^8,9\) Then the precise quantitative measurement is critical to the evaluation of morphologic characteristics of masseter muscle. Morphologic studies of human masseter muscle using CT and ultrasonography have been reported. Du et al\(^10\) proved that the average thickness of masseter muscle was diminished sharply postoperatively compared with before surgery. They measured masseter muscle by using the bidimensional method, type-b ultrasonography; however, 2-dimensional methods have inherent limitations, such as elongation or distortion of the image, which may lead to a wrong evaluation. Grummons and Kappayne van de Copello\(^11\) used frontal analyses to study asymmetry and found that the cephalometric measurements were subject to distortion as a result of the projection technique and could not be used for either quantitative or comparative purposes, especially for estimating the effect of the craniofacial surgery. Therefore, the use of 2-dimensional methods should clearly not be regarded as valid. Developments in CT and information technology give us easy access to 3D images of the craniofacial complex; CT images enable us to visualize both the soft tissues and the skeletal structure in 3 dimensions.\(^12\) The accuracy of 3D CT reconstructions is sufficiently high for the linear measurements.\(^13,14\) Cavalcanti et al\(^14\) investigated the accuracy of these by comparing the results of linear measurements on 3D CT images with physical measurements taken on corpses. They concluded that the difference between the 2 measurements was minimal and that the 3D images were of high precision. Besides, the 3D images obtained from CT enable us to observe any one of the craniofacial bones from different angles, and 3D CT reconstructive imaging is now widely used in the preoperative design and prediction for plastic surgery.\(^15\) Building these advantages, we choose a 3D CT image system for assessing the morphologic changes of masseter muscle.

The choice of a correct reference plane poses a real problem for analyzing the 3D images and also for assessing morphologic changes, since it is essential for the basic structures not to be affected by the osteotomy. The Frankfurt plane was used to standardize the plane orientation for the 3D images. The external auditory meatus has been proposed as a stable landmark for analyzing craniofacial asymmetry because its shape remains stable.\(^16\) In addition, high reproducibility has been demonstrated when these points are localized in 3D images.\(^1\) Using plane standardization also eliminates the effect of head positioning when the image is made.

The slice level used to measure the cross-sectional area is also an important parameter. Xu et al\(^17\) reported that the maximum cross-sectional area of the masseter oc-
curred at 8 mm above the mandibular foramen. We defined our measurement parameter at a level approximately in the middle of the mediolateral distance of the ramus according to the research of Kubota et al. The optimum slice level as reported by Xu et al is anatomically very close to the slice level parameters as defined by us.

In the present study, we found that masseter muscle volume decreased continuously over 6 months and had a tendency to restore its normal dimension between 6 months and 12 months, with the percentage value plateauing at approximately 70% of the original volume at 18 months postoperatively. Both the volume and cross-sectional area of masseter muscle were decreased after surgery. This indicated that both items of cross-sectional area and volume were sensitive to the alterations occurring in the mandibular angle. This muscle atrophy appears to be related to partial loss of sensitivity to the alterations occurring in the mandibular angle ostectomy, which may be helpful for predicting aesthetic lower facial contouring.

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REFERENCES