An Anatomical Study on the Position of the Summit of the Zygoma: Theoretical Bases for Reduction Malarplasty

Tomohisa Nagasao, M.D., Ph.D.
Yuji Nakanishi, M.D., Ph.D.
Yusuke Shimizu, M.D.
Asako Hatano, M.D.
Junpei Miyamoto, M.D., Ph.D.
Keizo Fukuta, M.D., Ph.D.
Kazuo Kishi, M.D., Ph.D.

Tokyo, Japan

Background: To achieve optimal outcomes in reduction malarplasty, the area of zygoma from which volume should be reduced must be accurately identified. This anatomical study aims to evaluate the location of the zygoma region that contributes most to the protrusion of the cheek.
Methods: The morphology of the zygoma was studied on 121 Japanese adults (73 men and 48 women). The midpoint of the inferior orbital rim, zygomaticomaxillary junction, the junction between the frontal process and the zygomatic arch, and the lateral orbital rim were marked to be used as anatomical reference points. Then, a vertical plane intersecting the anterior and posterior edges of the zygoma was marked. The point of the zygoma most distant from the plane was defined as the summit of the zygoma. Three-dimensional measurement using graphic software was performed, and the positional relationships between the summit and the four reference points were evaluated.
Results: In terms of horizontal position, the summit is located lateral to the lateral orbital rim and medial to the junction between the frontal process and the zygomatic arch. Regarding vertical position, the summit exists at higher positions in men than in women.
Conclusions: The summit of the zygoma is located medial to the junction of the frontal process and zygomatic arch. Therefore, bone incision lines should be placed medial to the posterior edge of the frontal process in reduction malarplasty; effective correction of the protrusion cannot be achieved solely by detachment of the zygomatic arch. The summit is located higher for men than for women. Therefore, bone incision lines should be placed higher for men than for women. (*Plast. Reconstr. Surg.* 128: 1127, 2011.)

Impressions of human faces are affected by subtle factors. Thus, cosmetic operations should be performed at accuracy levels of millimeters. This principle universally holds with various cosmetic procedures, including reduction malarplasty—one of the most common cosmetic operations in Asian countries. To achieve satisfactory outcomes in reduction malarplasty, it is necessary to identify the region of the zygoma contributing to the protruding appearance (throughout this article, we call it the "protruding region"), and reduce the volume of this region.

The identification of the protruding region might seem to be easy, because the protruding region is presumed to exist beneath the skin where the cheek appears to protrude most. Theoretically, the protrusion can be corrected by reducing the volume of this region.

However, in actual operations, identification of the protruding region is often difficult for three reasons. First, the positional correspondence of the zygoma and overlying soft tissues is lost because of dissection between them. The positional correspondence is even more blurred when the overlying soft tissue develops edema during surgical maneuvers. Second, mor-

From the Department of Plastic Surgery, Keio University Hospital, and the Verite Clinic.
Received for publication August 6, 2010; accepted November 29, 2010.

DOI: 10.1097/PRS.0b013e31821eb58e

Disclosure: *The authors have no financial interest to declare in relation to the content of this article.*

phologic features of the zygoma present individual differences; the geometric features of the zygoma surface differ for each patient. The position of the protruding regions differs accordingly. Third, observation of the surface of the zygoma is often difficult, because it is located deep in the operative field with an intraoral approach. It is difficult to perform three-dimensional evaluation of the zygoma surface, because surgeons cannot completely expose it.

We believe that if we could find a law by which we can identify the protruding region, the law would be useful for performing reduction malarplasty. The present study aims to elucidate whether or not such a law exists. Furthermore, the effectiveness of existing operative methods for reduction malarplasty is discussed with reference to obtained findings.

PATIENTS AND METHODS

Study Sample

Among patients who had computed tomographic examination of the skull from April of 2004 to August of 2007, 121 adult patients (73 men and 48 women) without any congenital anomaly were randomly selected. These patients received the examination on suspicion of facial bone fractures. Cone-Beam (Hitachi Ltd., Tokyo, Japan) computed tomography was used for the examination. Only patients who had minor fractures on one side of the face and those with no fracture were included in the study; patients who had major fractures or fractures involving both sides of the face were excluded from the study. For patients having minor fractures on one side, the intact side was included. The mean ± SD age of the patients was 32.1 ± 11.1 years for male patients and 35.4 ± 11.0 years for female patients. Age was not statistically significantly different between sexes ($p = 0.095$).

Definition of Measurement Points

Summit of the Zygoma

The most anterior point of the zygoma is the junction on the inferior orbital rim at which the zygoma and maxilla are connected. The most posterior point of the zygoma is the point on the zygomatic arch at which the zygoma and temporal bone are connected. A vertical plane intersecting these two points is marked to be used for evaluation of zygoma protrusion (Fig. 1). On the outer surface of the zygoma, the most distant point from this standardization plane is marked and defined as the summit of the zygoma. The summit of the zygoma is the inflection point of the three-dimensional curvature on the surface of the zygoma. At the summit of the zygoma, the zygoma appears to protrude most.

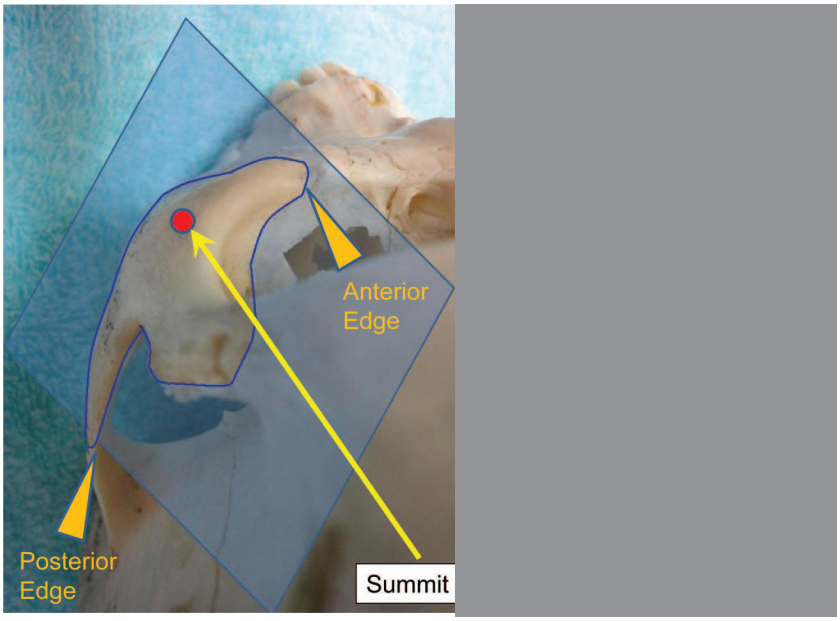

Fig. 1. Definition of the summit of the zygoma. (*Left*) A vertical plane intersecting the anterior and posterior edges of the zygoma is marked. The point of the zygoma most distant from the plane is defined as the summit of the zygoma. (*Right*) At the summit of the zygoma, the cheek appears to be protruding most.

Marking Points

The following four marking points are defined: inferior orbital rim, lateral orbital rim, zygomaticomaxillary junction, and process-arch junction. The locations of these marking points are demonstrated schematically in Figure 2. Perpendicular lines intersecting the lateral orbital rim and the process-arch junction, and horizontal lines intersecting the inferior orbital rim and the zygomaticomaxillary junction are marked. The rectangular area formed by these four lines is referred to in evaluating the position of the summit of the zygoma.

Measurement

Measurement Device

After transferring patients' computed tomographic data to a workstation (FMV Deskpower; Fujitsu Co., Tokyo, Japan), morphologic analysis of the zygoma is performed using CB Works (Hitachi). CB Works (medical software specially developed for morphologic analysis of human bodies) provides a three-dimensional coordinate system and enables measurement of lengths of body parts.

Marking of Measurement Points

On each patient's computed tomographic data, the four marking points (i.e., inferior orbital rim, lateral orbital rim, zygomaticomaxillary junction, and process-arch junction) are identified (Fig. 3). Then, the zygoma is isolated from the skull by the evaluation plane defined above in "Summit of the Zygoma" (Fig. 4). Referring to this plane, the summit of the zygoma is marked on the surface of the zygoma.

Coordinate System

A three-dimensional coordinate system is defined for measurement. The origin of the coordinate system is placed at the anterior nasal spine of the skull; *x*, *y*, and *z* axes of the system are set so that they match the mediolateral, inferosuperior, and posteroanterior directions, respectively. To standardize the view, each skull image is placed so that the line connecting the uppermost points of bilateral external auditory canals comes parallel to the *x* axis, and the Frankfurt plane becomes parallel to the *x*-*z* plane of the three-dimensional coordinate system.

Measurement

The positions of the four marking points and the summit of the zygoma are measured referring to the coordinate system. The measured values are defined by the combination of the coordinate axis and the name of the measured point. For instance, UxLOR and UyLOR indicate the distance from

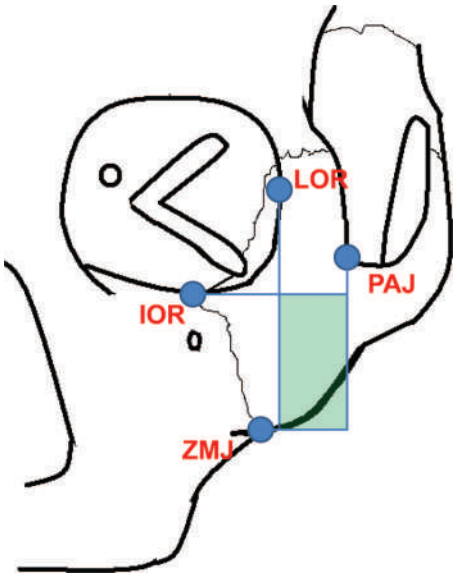

Fig. 2. Schema of the four marking points. A rectangular area is formed with two vertical lines intersecting the lateral orbital rim (*LOR*) and the process arch junction (*PAJ*), and two horizontal lines intersecting the inferior orbital rim (*IOR*) and the zygomaticomaxillary junction (*ZMJ*). The position of the summit of the zygoma is evaluated in reference to this rectangle.

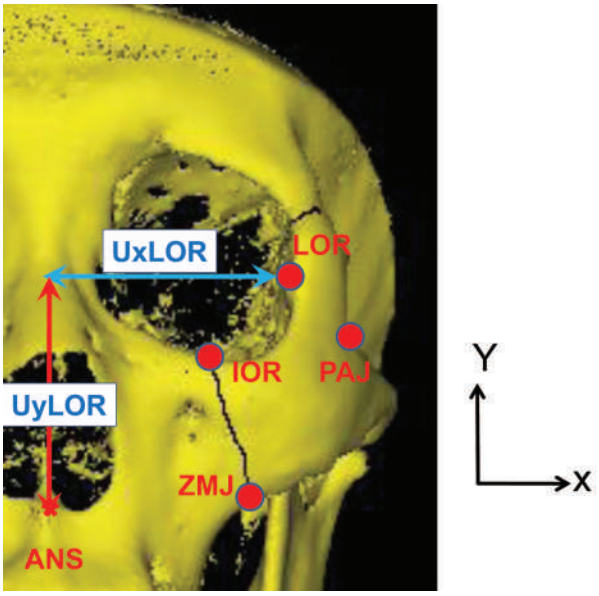

Fig. 3. Marking points are identified on the computed tomographic data, and their coordinates are measured. *LOR*, lateral orbital rim; *IOR*, infraorbital rim; *PAJ*, process-arch junction; *ZMJ*, zygomaticomaxillary junction; *ANS*, anterior nasal spine; *UxLOR*, distance from the origin to the lateral orbital rim along the *x* axis; *UyLOR*, distance from the origin to the lateral orbital rim along the *y* axis.

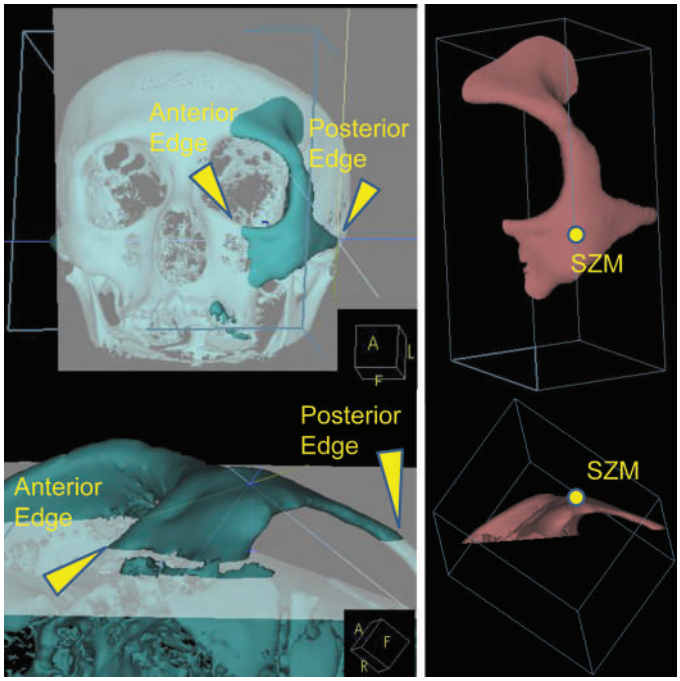

Fig. 4. Identification of the summit of the zygoma (*SZM*) on the computed tomographic data.

the origin to the lateral orbital rim along the *x* and *y* axes, respectively (Fig. 3).

Definition of Parameters

For the purpose of evaluating the position of the summit of the zygoma in reference to the rectangular area defined by the four marking points (Fig. 2), the following two parameters are defined.

$$\text{RxSZM} = (\text{UxSZM} - \text{UxLOR})/(\text{UxPAJ} - \text{UxLOR})$$
$$\text{RySZM} = (\text{UySZM} - \text{UyZMJ})/(\text{UyIOR} - \text{UyZMJ})$$

The denominators for RxSZM and RySZM indicate the horizontal and vertical lengths, respectively, of the reference rectangle (*A* and *B* in Fig. 5). The numerators for RxSZM and RySZM indicate the horizontal and vertical distances, respectively, of the summit of the zygoma from the inferomedial edge of the rectangular area (*a* and *b* in Fig. 5). Thus, RxSZM and RySZM are indicators of horizontal and vertical position of the summit of the zygoma in reference to the rectangular area ("R" of RxSZM and RySZM means "relative"). For instance, when the summit of the zygoma happens to coincide with the central point of the rectangular area (point *M* in Fig. 5, *right*), RxSZM and RySZM are both 0.5. When the summit of the zygoma exists inside of the rectangular area, RxSZM and RySZM take values greater than 0 and less than 1. When the summit of the zygoma exists outside of the rectangular area, one or both of these parameters take values less than 0 or greater than 1. For instance, when the summit of the zygoma is located at P1 in Figure 5, *right*, RxSZM = −0.5 and RySZM = 0.5; when the summit of the zygoma is located at P2, RxSZM = 0.5 and RySZM = 1.5.

Evaluation

The range, average, and standard deviations of RxSZM and RySZM are calculated for each of the male and female groups. Thereafter, statistical differences in these values between the two groups are examined using SPSS Version 10 for Windows (SPSS, Inc., Chicago, Ill.). Values of $p < 0.05$ are considered to be statistically significant. The *t* test was used for the evaluation, because RxSZM and RySZM presented normal distribution. Values of $p < 0.05$ are considered to be statistically significant.

RESULTS

The ranges, averages, and standard deviations for RxSZM and RySZM are shown in Tables 1 and 2, respectively; the distributions of RxSZM and RySZM are shown in Figure 6.

The essence of the findings and their translation are as follows:

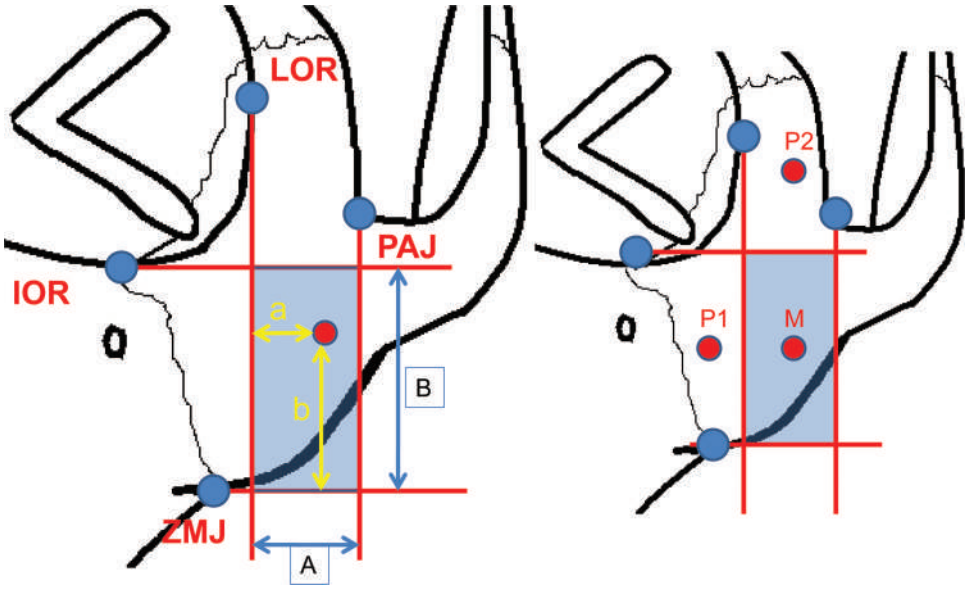

Fig. 5. (*Left*) Position of the summit of the zygoma is evaluated referring to the rectangular area defined by the four marking points. *LOR*, lateral orbital rim; *IOR*, infraorbital rim; *PAJ*, process-arch junction; *ZMJ*, zygomaticomaxillary junction. (*Right*) When the summit of the zygoma is located at P1, RxSZM and RySZM take values of –0.5 and 0.5, respectively; when the summit of the zygoma is located at P2, RxSZM and RySZM take values of 0.5 and 1.5, respectively.

Table 1. RxSZM: Indicator for Horizontal Location of the Summit of the Zygoma

RxSZM	Male Patients (n = 73)	Female Patients (n = 48)	p
Range	0.09 – 0.95	0.05 – 0.82	0.11
Average ± SD	0.47 ± 0.18	0.42 ± 0.17	

Table 2. RySZM: Indicator for the Vertical Location of the Summit of the Zygoma

RySZM	Male Patients (n = 73)	Female Patients (n = 48)	p
Range	0.30 – 1.02	0.29 – 1.03	0.001
Average ± SD	0.74 ± 0.12	0.63 ± 0.15	

1. RxSZM and RySZM generally take values between 0 and 1. This finding indicates that the summit of the zygoma exists inside of the rectangular area defined by the four marking points (i.e., lateral orbital rim, process-arch junction, inferior orbital rim, and zygomaticomaxillary junction).
2. Although RxSZM does not present statistically significant differences between the male and female groups, RySZM takes greater values for male patients than for female patients. These findings indicate that although the summit of the zygoma does not present differences between male patients and female patients in terms of mediolateral positions, the summit of the zygoma presents differences in terms of inferosuperior positions. The summit of the zygoma is located at higher positions for men than for women.

DISCUSSION

Aesthetics between Asian and Western cultures presents great differences. In Western cultures, protrusion of the malar region is recognized to symbolize youth. In contrast, malar protrusion is viewed as unsightly in Asian cultures.[1–3] Generally, facial features of Asians are smaller than those of Caucasians. In the same way that foods served in large dishes appear small, the smallness of the facial features is exaggerated when the contours of the face appear large because of the protrusion of the cheek. Therefore, protruded cheeks are not favored in Asian countries, making reduction malarplasty one of the most common cosmetic operations in East Asian countries.

In performing reduction malarplasty, accurate planning regarding the region on which volume reduction should be performed is essential. Because zygomas have individual differences in size, providing certain laws for identifying the most protruding region is more useful than providing directly measured data for making operative plans for reduction malarplasty. Thus, we defined a rect-

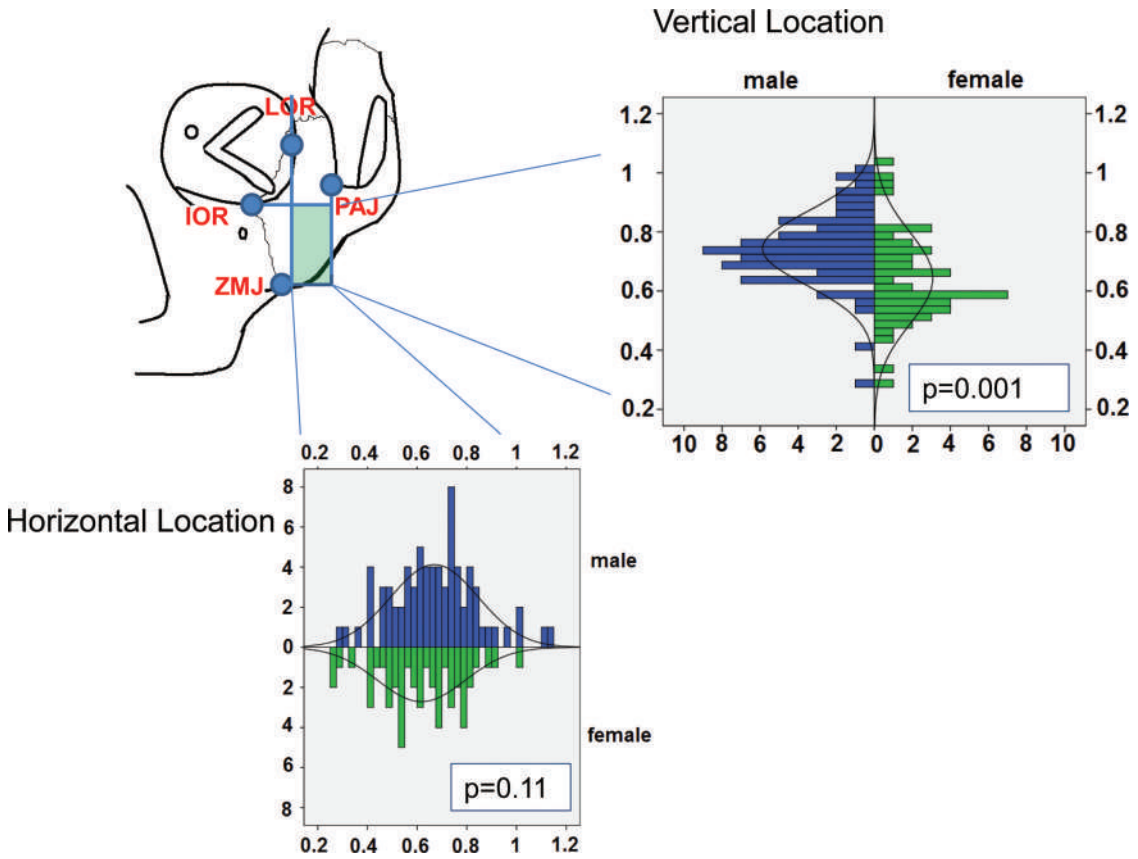

Fig. 6. Distribution patterns of the summit of the zygoma with horizontal and vertical positions. Although the distribution of the summit of the zygoma presents no difference between sexes in terms of horizontal positions, a difference is observed with vertical positions. The summit of the zygoma is located higher for male patients than for female patients. *LOR*, lateral orbital rim; *IOR*, infraorbital rim; *PAJ*, process-arch junction; *ZMJ*, zygomaticomaxillary junction.

angular region identified by four marking points (i.e., inferior orbital rim, lateral orbital rim, process-arch junction, and zygomaticomaxillary junction) and evaluated the location of the summit of the zygoma by referring to this region. We chose these marking points because they are easily detectable by external touch or observation, even if the positional correspondence between the soft tissues and the zygoma surface is lost because of dissection and soft-tissue swelling. The inferior orbital rim, process-arch junction, and lateral orbital rim are identifiable by feeling with fingers; the zygomaticomaxillary junction can be placed under direct observation during an intraoral approach. By referring to these marking points and identifying the protruding region accurately, operators can effectively perform reduction malarplasty.

The findings of the present study can be summarized with two items. First, the summit of the zygoma is located inside of the rectangular area defined by the four marking points. Second, the summit of the zygoma is located higher for male patients than for female patients. Although substantial numbers of existing reports refer to sex-related morphologic differences of human faces,[4–6] the present study is the first to have performed minute evaluation of the three-dimensional morphology of the zygoma and to have demonstrated a statistical difference between sexes in the shape of the zygoma.

Why is the vertical location of the summit of the zygoma higher for male patients than for female patients? It would be inappropriate to attribute this difference to a single cause, because growth of facial bones is affected by complicated factors. However, we consider the difference in masseter muscle function to be one of the main factors making the difference. The growth of facial bones is affected by mechanical forces working on the bones.[7] Masticatory forces are greater for male patients than for female patients.[8–10] Constant oc-

currence of strong mastication induces thickening of the zygoma. This is probably the reason why the zygoma grows more in male patients than in female patients, causing differences in the vertical height of the summit of the zygoma.

Existing operative methods for reduction malarplasty are discussed referring to the present study's findings. We classify surgical methods of reduction malarplasty into three types according to where the zygomatic separation is conducted (Fig. 7). In type 1 methods, the separation is conducted at the junction between the zygoma body and the zygomatic arch.[11–16] In type 2 methods, the zygoma is separated at the frontal process, zygomaticomaxillary buttress, and zygomatic arch, isolating and mobilizing the zygoma in a so-called tripod shape.[17,18] In type 3 methods, the frontal process is left untouched, and a unit consisting of the zygoma body and zygomatic arch is separated.[19,20] The methodologic rationality of the operative methods for these three types is reviewed.

With type 1 methods, the zygoma is separated at the junction between the zygomatic arch and the zygoma body. However—as demonstrated in the present study—the summit of the zygoma is located medial to the process-arch junction (the junction between the frontal process and the zygomatic arch). Thus, when the zygomatic arch is separated at the process-arch junction from the zygoma body, the summit of the zygoma remains protruding. Therefore, it is concluded that the protrusion of the malar region cannot be corrected solely by the separation and inward shifting of the zygomatic arch. To correct the protrusion of the cheek with a type 1 method, shaving of the zygoma is needed in addition to operation on the zygomatic arch—as Lee and Park and Onizuka et al. reported.[15,16]

However, it is our opinion that even if abrasion of the zygoma is also performed, smoothness of the cheek contour is hard to achieve with type 1 methods. This is explained by referring to Figure 8. When the zygomatic arch is separated at the position shown in Figure 8, *above*, *left*, and shifted in the medial direction, the zygoma presents a structure shown in Figure 8, *above*, *right*. With this situation, the part of the zygoma demonstrated in Figure 8, *below*, *left*—including the summit of the zygoma—is still protruding. To eliminate the protruding appearance of the zygoma, this part needs to be removed. However, this part includes the junction of the zygomatic body and zygomatic arch. Thus, the removal of the marked part makes the junction between the zygomatic arch and the zygoma body fragile. The fragility leads to disintegration of the two structures, forming a step and impairing natural contour of the cheek.[21]

The above-stated problem does not occur with type 2 and type 3 methods, because the summit of the zygoma is mobilized and repositioned. However, with type 2 methods—where the frontal process is part of the mobilized bone—coronal incision is needed to approach the frontal process. Leaving scars on the scalp blurs the meaning of reduction malarplasty as a cosmetic procedure. Thus, we value type 3 methods more highly than type 2 methods. In type 3 methods, two pairs of bone incision lines are placed on the anterior surface of the zygoma, and a unit consisting of the

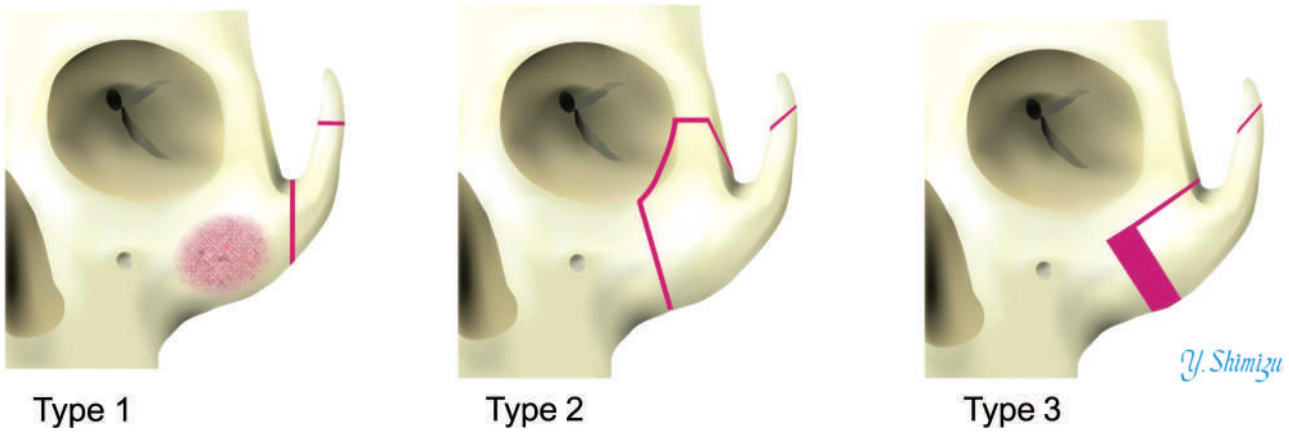

Fig. 7. Classification of operation methods of reduction malarplasty. (*Left*) With type 1 methods, the zygomatic arch is separated and shifted medially. For the region marked red, volume reduction is also conducted. (*Center*) With type 2 methods, the zygoma is isolated in a tripod shape and shifted in the medial direction. (*Right*) With type 3 methods, a bone unit consisting of the zygoma body and zygomatic arch is isolated.

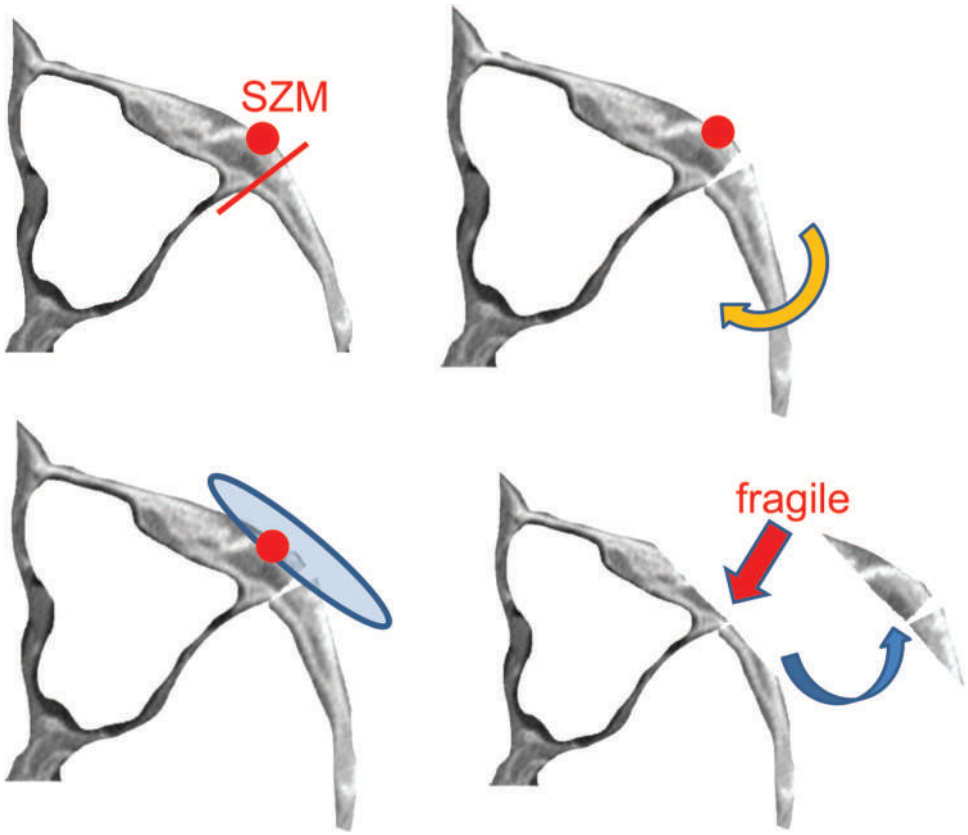

Fig. 8. Graphic demonstration of the problems in reduction malarplasty with zygomatic arch isolation (type 1 methods). Even after the zygomatic arch is isolated and shifted medially (*above*), the summit of the zygoma (*SZM*) remains untouched. Thus, the remaining protrusion needs to be corrected by shaving the area marked (*below*, *left*). However, this impairs the stability of the junction between the zygomatic body and zygomatic arch (*below*, *right*).

zygoma body and the zygomatic arch is mobilized and repositioned (Fig. 9, *above*). Because the junction of these structures is left intact, the smoothness of the zygoma contour is preserved (Fig. 9, *below*).

To achieve satisfactory outcomes with type 3 methods, the position of bone incision matters. The second finding of the present study—that the summit of the zygoma is placed higher for men than for women—is useful in designing the bone incision. As shown in Table 1, the average values of RySZM are 0.74 for men and 0.63 for women. The denominator for RySZM—the distance along the *y* axis between the zygomaticomaxillary junction and inferior orbital rim—was approximately 20 mm (21.6 ± 2.9 mm for men and 21.0 ± 2.8 mm for women). These values are not provided in the tables. Thus, the vertical positions of the summit of the zygoma differ between male patients and female patients by 2 to 3 mm.

In performing type 3 reduction malarplasty, we design osteotomy lines taking the sex-related morphologic differences of zygoma into account. Because the summit of the zygoma exists at higher positions in men than in women, bone incision lines should be placed at higher positions by 2 to 3 mm for male patients than for female patients (Fig. 10). Paying attention to this anatomical difference leads to optimal outcomes. To evaluate patients' satisfaction, we conducted a survey on 89 patients (10 men and 79 women) who underwent type 3 reduction malarplasty between April of 2000 and November of 2009 at our institutes. In the survey, the patients were asked to rate the operative outcomes by means of a four-grade scale (i.e., poor, fair, good, and excellent). Seventy-four patients (83.1 percent) rated the result excellent, proving the effectiveness of the operative method. The numbers of patients who rated the result as good, fair, and poor were 13 (14.6 percent), two

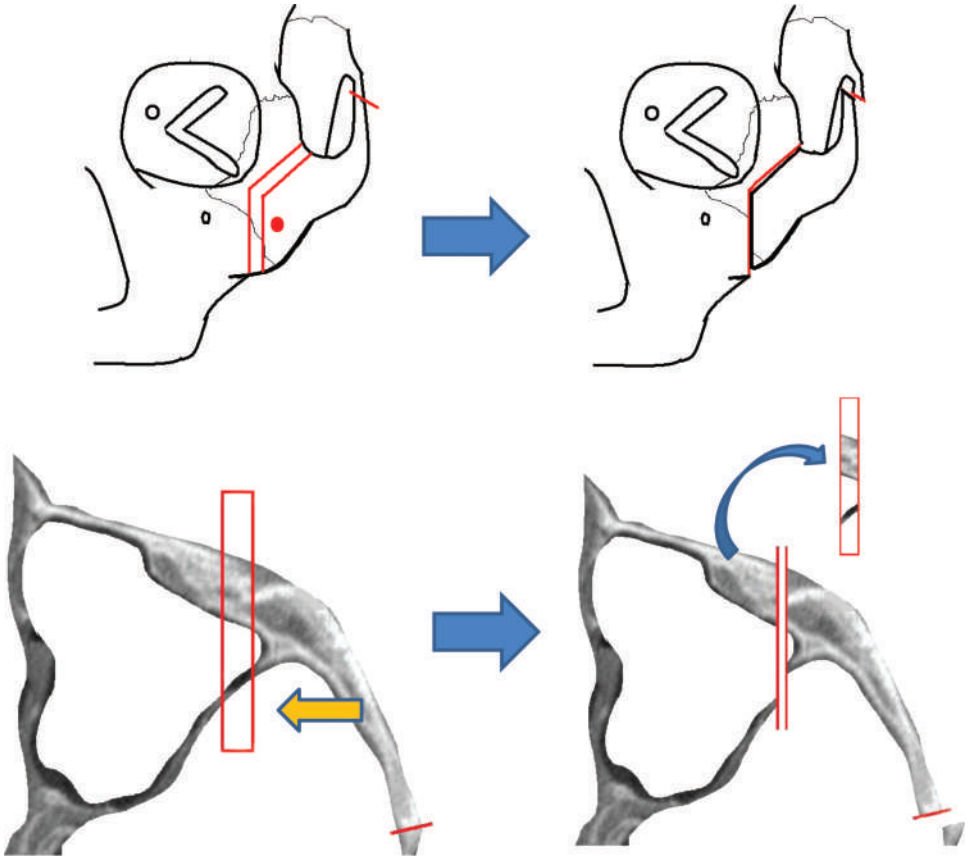

Fig. 9. With type 3 methods, a segmental part of the zygoma is removed by sagittal slicing, and the union consisting of the zygoma body and zygomatic arch is transferred medially. Thereby, the natural curvature of the cheek is preserved.

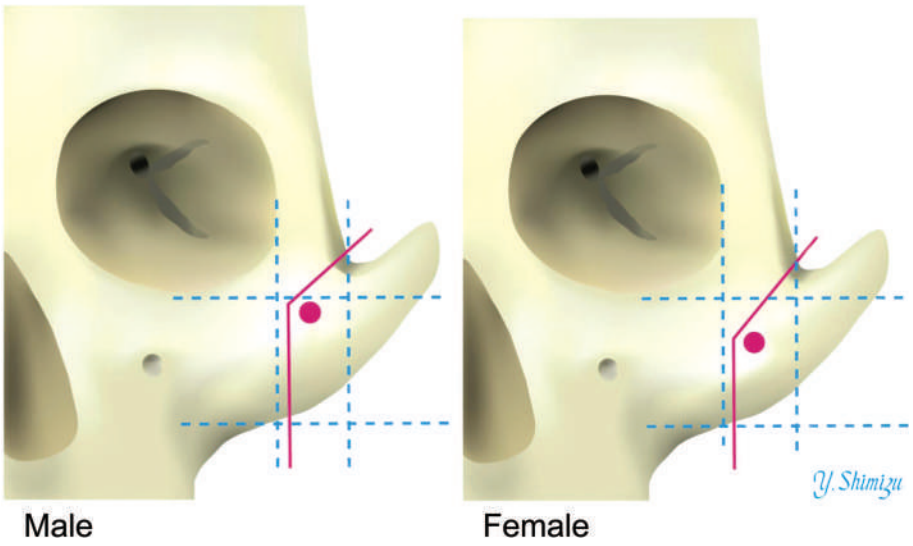

Fig. 10. In performing type 3 methods, the lines of the osteotomy should be placed higher for males than for females.

(2.2 percent), and zero (0 percent), respectively. Representative cases are demonstrated in Figures 11 and 12. For the male patient in Figure 11, bone incision lines were placed at higher positions than for the female patient in Figure 12.

The present study was conducted on Japanese patients. Because morphology of the face is affected by ethnicity, the findings might not be universally applicable to other races. However, we believe clinical importance of the present study is not impaired by the potential specificity of its findings to Japanese, because reduction malarplasty is rarely conducted for races other than Asians; for Caucasians, augmentation malarplasty is more common. We believe the present study is clinically meaningful. By taking the findings obtained in the present study into consideration, cosmetic surgeons can improve the outcomes of reduction malarplasty.

CONCLUSIONS

In the quest for basic knowledge for conducting reduction malarplasty, anatomical evaluation

Fig. 11. A case of reduction malarplasty for a male patient. Preoperative (*left*) and postoperative (*right*) views.

Fig. 12. A case of reduction malarplasty for a female patient. Preoperative (*left*) and postoperative (*right*) views.

of the protrusion of the zygoma was conducted on 121 Japanese patients. The most protruding part of the zygoma was defined as the summit of the zygoma, and the positions of the summit of the zygoma were evaluated referring to computed tomographic data of the patients. In terms of mediolateral position, the summit of the zygoma is located between the lateral orbital rim and the junction of the frontal process and zygomatic arch. Thus, separation of the zygoma should be performed medial to the junction of the frontal process and zygomatic arch. In terms of inferosuperior position, the summit of the zygoma is located at higher positions for male patients than for female patients. Therefore, bone incision lines should be placed higher for male patients than for female patients.

Tomohisa Nagasao, M.D., Ph.D.
Department of Plastic and Reconstructive Surgery
Keio University Hospital
Shinjuku-Ward
Shinanomachi 35, Tokyo, Japan
nagasao@sc.itc.keio.ac.jp

PATIENT CONSENT

Patients provided written consent for the use of their images.

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