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A Comprehensive Assessment of Soft-tissue Sagging after Zygoma Reduction Surgery through Artificial Intelligence Analysis

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Background: Overdevelopment of zygomatic bones often results in protrusion and flaring of the midfacial region. This makes the face appear squarer than the more favorable oval shape. Therefore, zygoma reduction surgery has become a commonly performed procedure in patients seeking to obtain an ideal facial shape. Facial soft-tissue ptosis is one of the main complications of zygoma reduction surgery. Previously, the evaluation of cheek soft-tissue ptosis was subjectively based on patients and surgeons. Our study aimed to provide an objective evaluation of soft-tissue sagging in the cheek region after zygoma reduction surgery using artificial intelligence (AI).

Methods: We used AI to evaluate cheek sagging in a series of patients who underwent zygoma reduction surgery. We used four methods: tracking facial landmarks, detecting changes in the cheek curvature, and examining changes in the nasolabial fold and marionette lines. Then, the obtained numerical results were assessed for statistically significant differences using statistical validation methods.

Results: Use of AI with the four methods demonstrated no statistically significant differences between the pre- and postsurgery evaluations. AI analysis demonstrated that soft-tissue ptosis did not occur in our series of patients.

Conclusions: AI offers objective evaluation for both patients and doctors. Future research could build on this application to examine various influencing factors and develop new tools using machine learning to evaluate and predict the extent of cheek sagging in patients before surgery. *(Plast Reconstr Surg Glob Open 2024; 12:e6055; doi: 10.1097/GOX.0000000000006055; Published online 13 August 2024.)*

INTRODUCTION

Overdevelopment of the zygomatic bones often results in flaring prominence in the midfacial region.[1–3] In women, such prominence can give a masculine impression, whereas in men, it may convey an aggressive appearance.[4] Consequently, zygoma reduction surgery, aimed at reducing the size of the prominent zygomatic bones, has become a commonly performed procedure.[4,5] However, one of the main complications of this surgery is cheek sagging.[6] Thus, there is a growing concern among the patients who desire facial bone contouring regarding postoperative issues, such as midface soft-tissue ptosis.[7] For this reason, many patients hesitate to undergo the surgery.

Various attempts have been made to address this concern, including methods that involve upward fixation of the zygomatic arch.[8–11] However, the claim that soft-tissue sagging, especially in the cheeks, occurs consistently after zygoma reduction surgery, regardless of the technique, has not been scientifically validated. To date, evaluations have relied on the subjective perspectives of both patients and physicians.[12–14] This is believed to result in substantial discrepancies depending on the situation and individual perceptions. Therefore, there is a pressing need for an objective analysis.

Artificial intelligence (AI) and machine learning have advanced considerably in various fields.[15] The medical field is also undergoing the integration of AI.[16] The introduction

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Table 1. Exclusion Criteria

Exclusion Criteria
Patients who underwent facial contouring surgery other than zygoma reduction surgery
Patients who underwent aesthetic surgery in the cheek area after the surgery
Patients who underwent other aesthetic procedures (eg, filler and Botox) after the surgery
Images with noise exceeding the threshold after image preprocessing

of AI has enhanced the precision of detecting facial aging signs, such as wrinkles.[17,18] In our study, we decided to harness the power of computer science to precisely assess soft-tissue sagging in the cheek area using AI. To date, there has been a lack of objective assessments of cheek sagging after facial bone contouring surgery. Consequently, this study aimed to provide an objective evaluation of soft-tissue ptosis in the cheek region after zygoma reduction surgery using AI.

METHODS

Ethics Statements

All the participants in this study provided written informed consent for the use of their data. This study was conducted in accordance with the World Medical Association Declaration of Helsinki and approved by the institutional review board of the Korea National Institute for Bioethics Policy (approval number: P01-202312-01-007).

Patients

We evaluated 301 patients who underwent zygoma reduction surgery at our institution between January 2018 and September 2022. A minimum 1-year postsurgery follow-up was necessary to ensure accurate assessment of midface sagging, as postoperative swelling can hinder accurate results. Therefore, patients who underwent follow-up examinations at least 1 year after surgery were selected. Patients who underwent other concurrent facial contouring procedures and those who received other aesthetic procedures, for example, fillers and Botox, in the cheek area after surgery were excluded (Table 1). The final cohort was 72 patients who were included in this study.

Surgical Procedures

Surgery was performed under general anesthesia. A skin incision was made approximately 2–3 cm anterior to the tragus for the preauricular approach. Subperiosteal dissection was then performed to approach the zygomatic arch. Subsequently, osteotomy of the zygomatic arch was performed. An intraoral incision was made along the upper gingiva. Subperiosteal dissection was performed to approach the maxillary anterior wall and zygoma body. An L-shaped osteotomy was performed, avoiding the infraorbital nerve, to separate the zygoma bone. Afterward, the zygoma bone was inwardly moved according to the predesigned degree (3–4 mm set-back on average), and fixed with a four-hole plate and a two-hole plate. The preauricular region was fixed with a two-hole plate.

Takeaways

Question: If investigated using objective measurement methods, will cheek ptosis actually occur after zygoma reduction surgery?

Findings: Data obtained via artificial intelligence revealed that no cheek sagging occurred after zygoma reduction surgery in our patient population.

Meaning: Our research provides the world's first objective assessment of cheek sagging after zygoma reduction surgery, using artificial intelligence.

Study Protocol

The camera used was a Canon EOS R with an electrofocus of 17–55 mm and an image stabilizer lens set at a focal length of 35 mm. The images used in our study included frontal and diagonal views (at a 45-degree left direction). The CareMind, Inc. (Seoul, South Korea) system was used for image preprocessing and facial lesion detection.

Image Preprocessing

To ensure consistency in the facial images used and enhance the detection measurement performance, we adopted a two-step preprocessing approach.

Facial Alignment Using Face Landmarks

We used facial landmark recognition to consistently align the faces.[19] By identifying specific facial features, for example, the eyes, nose, and mouth, within the images, we centered the faces and adjusted the margins uniformly, thereby securing standardized facial positions.

Illumination Normalization Using Zero-reference Deep Curve Estimation

To standardize the illumination conditions of facial images captured under various lighting conditions, Zero-reference Deep Curve Estimation (Zero-DCE) was used.[20] This technology adjusts the illumination of images without using a reference image, thereby enhancing the consistency of visual features across diverse images.[21] Zero-DCE is a technique that improves the coherence of visual features among different images by equalizing the illumination, even in the absence of a reference image.

Assessment Using AI Methods

A comprehensive method combining facial landmark detection and shadow analysis was used to quantitatively analyze changes in cheek sagging after zygoma reduction surgery. The identified areas indicative of sagging cheeks were segregated into pre- and postprocedural regions using four distinct methods.

Method 1: Facial Sagging Evaluation with Landmarks

Developed on the basis of the Moire 3D analysis system, this method involves the extraction of specific landmarks for evaluating facial sagging.[22] Using the Mediapipe method, we detected the facial landmarks. By referencing

Fig. 1. Thirteen landmarks on the left cheek. Top row (0–4), middle row (5–8), and bottom row (9–12).

literature, facial landmarks were identified in the top, middle, and bottom rows, and cheek sagging was evaluated using this approach (Fig. 1). The extraction process involved setting the upper-left corner of the image to (0, 0). To facilitate numerical comparison, the image height was normalized between 0 and 1. Larger y-values indicated greater sagging of the cheeks.

Method 2: Curved Area Analysis

The changes in the curved area of the lower cheek were detected using a Hessian filter.[23,24] This filter used the second derivative of the image to analyze alterations in skin shading and subtle changes in the skin's structure, facilitating the measurement of areas recognized as sagging cheeks. The detected area on the lower cheek was defined using specific anatomical references. The medial margin began at the chilion, whereas the lateral margin extended to the end of the cheek. The upper margin concluded at the alar base level, and the lower margin extended down to the chin. The curved area was calculated as the ratio of the area recognized as curved within the entire lower cheek (detected area = curved area/lower cheek).

Method 3: Nasolabial Fold Depth Analysis

When cheek sagging becomes more pronounced, the nasolabial fold deepens.[25] The depth of the nasolabial fold was measured by setting the tip of the nose as the reference point ($z = 1$) and using the z-value of the three-dimensional (3D) face mesh to detect changes.[26,27] To facilitate relative comparison, the values were divided and normalized with respect to the tip of the nose. Smaller numerical values indicated elevation, representing shallow wrinkles, whereas larger values indicated erosion, signifying deeper wrinkles.

Table 2. Patient Demographics

Age (y)	29.48 ± 4.88
Sex, N (%)	72
Male	20 (27.8)
Female	52 (72.2)
Follow-up interval (mo)	19.95 ± 8.58

Numerical data are presented as mean ± SD.

Method 4: Marionette Line Depth Analysis

The z-value of the 3D face mesh was used to measure the depth and detect changes in the marionette lines extending from the corner of the mouth down along the chin.[26,27] Similar to the approach used for nasolabial fold depth detection, the values were normalized relative to the tip of the nose for comparative analysis. A smaller numerical value indicated elevation, corresponding to a shallower wrinkle depth, whereas a larger value indicated erosion, representing a deeper wrinkle depth.

Statistical Analysis

The numerical values of the facial landmarks and changes in the marionette lines were analyzed using the Wilcoxon signed-rank test because of the nonnormal distribution confirmed by both the Kolmogorov–Smirnov and Shapiro–Wilk tests. In contrast, the numerical values for the curved area analysis and changes in the nasolabial fold, which followed a normal distribution according to the Kolmogorov–Smirnov and Shapiro–Wilk tests, were analyzed using the paired *t* test. All statistical analyses were conducted using SPSS (version 18.0; SPSS, Inc., Chicago, Ill.).

RESULTS

Patient Population

A total of 82 patients were selected and evaluated with our imaging system. Ten patients were excluded because of preoperative or postoperative image noise. The final study cohort comprised 72 patients who underwent bilateral zygoma reduction surgery. There were 52 women and 20 men, with a mean of 29.48 ± 4.88 years. Patients had at least 1 year of follow-up (range, 12–36 mo) (Table 2).

Method 1

The y-values of the 13 landmarks were extracted from the ball area in the frontal view. The measurements showed no significant changes (Fig. 2; Table 3).

Method 2

The cheek area was isolated from the images captured in the diagonal view, and the measurement results revealed no significant differences before and after surgery (Fig. 3; Table 3).

Method 3

The depth of the nasolabial fold area was identified in images captured from the diagonal view. Upon comparing the values, the average exhibited an improvement, albeit with a slight variance ranging from −0.007 to 0.01,

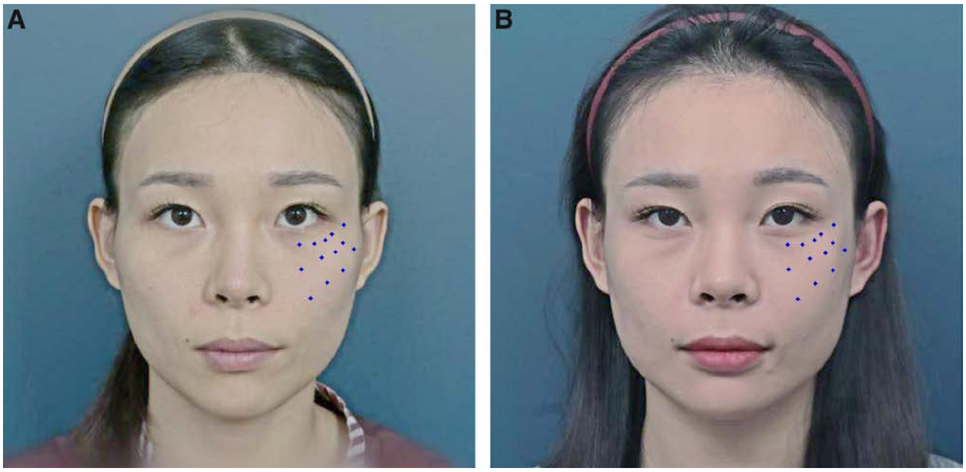

Fig. 2. Imaging detection for facial landmarks. A, Preoperative photograph. B, Postoperative photograph. No change is observed in the 13 facial landmarks before and after the surgery.

Table 3. Results of the AI Assessment

Outcome	Preoperatively	Postoperatively	*P*
Facial sagging evaluation with landmarks	0.547 ± 0.045	0.547 ± 0.045	0.426
Curved area (Hessian filter)	0.148 ± 0.029	0.143 ± 0.020	0.186
Nasolabial fold depth	0.629 ± 0.116	0.621 ± 0.105	0.704
Marionette line depth	0.228 ± 0.188	0.255 ± 0.173	0.125

Data are presented as mean ± SD.

indicating a change of less than 0.01. However, the difference was not statistically significant (Fig. 4; Table 3).

Method 4

The depth of the marionette lines was identified from the images captured at a 45-degree shooting angle. There were no statistically significant differences between the pre- and postoperative values (Fig. 4; Table 3).

DISCUSSION

With the advancement of AI in image detection, attempts have been made to evaluate wrinkles and facial aging.[17,18] We used this technology to investigate cheek sagging. Four methods were used to evaluate cheek sagging.

Moire 3D Imaging Detection for Facial Landmarks

Using Moire 3D imaging detection, we observed no statistically significant changes in the facial landmarks between before and after surgery.

Hessian Filter for Curved Area Analysis

Using a Hessian filter, we detected changes in the curvature of the cheek area. The results indicated no statistically significant change in the curvature size after surgery.

Face Mesh Technique for Nasolabial Fold Depth

Using the face mesh technique, we aimed to detect changes in the depth of the nasolabial folds. Minimal changes were observed, and there was no statistically significant difference between before and after surgery.

Face Mesh Technique for Marionette Lines

Upon observing changes in the marionette lines using the face mesh technique, we found no statistically significant deepening of the line postoperatively.

Evaluation based on facial landmarks, cheek curvature, nasolabial fold depth, and marionette line depth indicated no cheek sagging. The AI evaluation suggested that cheek sagging did not occur in our patients after zygoma reduction surgery.

This study had some limitations, including a small sample size of 72 patients. This study also did not account for factors, such as age or sex. Ezure et al[28] reported that sex does not significantly affect cheek sagging. Skin elasticity of patients affects cheek sagging.[29] However, in our study, we were unable to incorporate skin elasticity as a variable in our model. Moreover, the amount of resected bone, medial movement of the resected fragments, and weight gain and loss, which may significantly impact postsurgery sagging, were not included in our study model. Furthermore, our study was conducted on young East Asians; therefore, we cannot generalize our findings to other ethnic populations or older age groups. Further research is required to incorporate more variables into our model and determine how they influence AI-driven data processing. Although our research revealed that soft-tissue ptosis did not occur after zygoma reduction surgery, our study was conducted at a single center. The amount of soft tissue and retaining ligaments released from the bone to perform zygoma osteotomy differs by surgeon. Detachment of soft tissue from the bone plays a critical role in the occurrence of soft-tissue ptosis. Therefore, a multicenter study that broadens the scope of practice may reveal a different result of soft-tissue ptosis complications and provide unbiased feedback on surgeons' techniques.

CONCLUSIONS

Data obtained via AI revealed that no cheek sagging occurred after zygoma reduction surgery in our patient

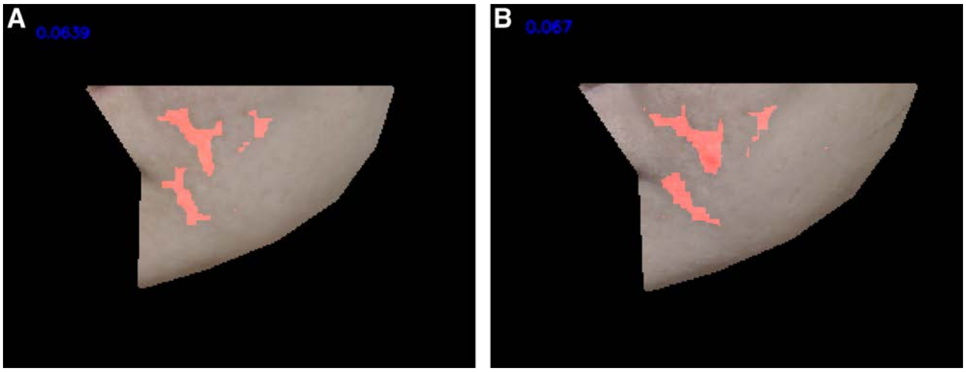

Fig. 3. Hessian filter for curved area analysis. A, Preoperative image. B, Postoperative image. The detected area of the lower cheek is defined with specific anatomical references. The medial margin begins at the chilion, whereas the lateral margin extends to the end of the cheek. The upper margin concludes at the alar base level, and the lower margin extends down to the chin. The region highlighted in red shading represents the area where the Hessian filter detected curvature. The measurement results reveal no statistically significant difference between before and after surgery.

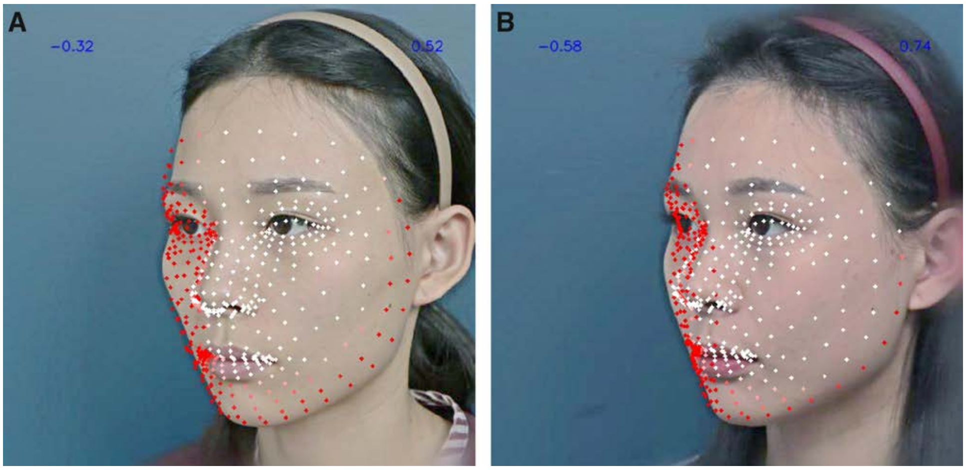

Fig. 4. Face mesh technique for nasolabial fold depth and marionette lines. A, Preoperative image. B, Postoperative image. A higher z-value is represented by more red, indicating increased depth. In the case of the nasolabial fold, there is a decrease in the numerical value, suggesting improvement; however, this change is not statistically significant. For the marionette lines, the numerical value is increased, but there is no statistically significant difference.

population. To date, there have been no objective evaluations of postoperative cheek sagging. Despite its limitations, our research provides the world's first objective assessment of cheek sagging after zygoma reduction surgery. Further exploration considering individual variations and the potential integration of machine learning for predictive analysis holds promise for future research in this field.

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DISCLOSURE

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

PATIENT CONSENT

The patient provided written consent for the use of her image.

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