Sex-Specific Facial-Soft-Tissue Morphology in Mandibular Prognathism

Shibusawa, Nobuhide
Department of Maxillofacial Diagnostic and Surgical Sciences, Division of Oral and Maxillofacial Surgery, Graduate School of Dental Science, Kyushu University

Yamada, Tomohiro
Department of Oral and Maxillofacial Surgery, Graduate School of Biomedical Sciences, Nagasaki University

Yasuda, Kousuke
Department of Oral and Maxillofacial Surgery, Graduate School of Biomedical Sciences, Nagasaki University

Tajiri, Shiho
Department of Dentistry and Oral Surgery, Iizuka Hospital

他

https://hdl.handle.net/2324/7402146

出版情報：Journal of Craniofacial Surgery. 36 (7), pp.2494-2498, 2025-10. Ovid Technologies (Wolters Kluwer Health)
バージョン：

OPEN

Sex-Specific Facial-Soft-Tissue Morphology in Mandibular Prognathism: A Homologous-Model Analysis

Nobuhide Shibusawa, DDS,† Tomohiro Yamada, DDS, PhD,† Kousuke Yasuda, DDS, PhD,† Shiho Tajiri, DDS, PhD,‡ Goro Sugiyama, DDS, PhD,* Ichiro Takahashi, DDS, PhD,§ and Masafumi Moriyama, DDS, PhD**

Abstract: This study aimed to evaluate sex differences in facial soft tissue morphology in patients with mandibular prognathism and to assess treatment outcomes while considering these differences. It included 30 patients (15 males and 15 females) with skeletal mandibular prognathism who underwent bilateral sagittal split ramus osteotomy (SSRO), along with a control group of 30 healthy volunteers (15 males and 15 females). Three-dimensional facial data were collected, and homologous modeling was used to analyze facial morphology. Qualitative and quantitative analyses were performed using principal component analysis (PCA), analysis of variance (ANOVA), and Tukey's test. The results showed that males had greater facial height and a longer chin, whereas females had a smaller chin and a more rounded zygomatic-cheek area. In male patients, postoperative facial morphology approached that of healthy males. However, female patients retained masculine facial features such as midface flatness and increased facial height, even after surgery. These findings suggest that surgical intervention in the midface and chin regions may be necessary for female patients to improve facial esthetics and satisfaction, even when occlusion is properly corrected. This study highlights the importance of considering sex differences in facial soft tissue morphology when planning orthognathic surgery for patients with mandibular prognathism.

Key Words: Homologous modeling, mandibular prognathism, sex difference, SSRO

(*J Craniofac Surg* 2025;36: 2494–2498)

The goals of treatment for jaw deformities include improving occlusion and functions such as feeding and speech, as well as enhancing facial appearance. Typically, when creating a surgical plan for jaw deformities, factors such as occlusal stability, facial symmetry, and chin position are considered. However, these plans are often based on hard tissue assessments using cephalometric or CT imaging. Consequently, surgical planning tends to focus on hard tissues, with limited awareness of sex differences in soft tissues. Although numerous studies have examined differences in facial morphology between men and women, most have focused on hard tissues,[1–4] and relatively few have addressed soft facial tissues. Generally, male faces are characterized by broader dimensions, a more prominent and angular mandible, while female faces tend to be more rounded with a smaller masticatory area.[5,6] To date, most analyses of facial morphology have relied on one-dimensional measurements, such as distances and angles, or on subjective photographic evaluations.[7,8] Recently, however, it has become possible to easily obtain 3D shape data, and homologous modeling technology—capable of statistically analyzing 3D shapes—has been developed and applied practically.[9–11] Nonetheless, its application in the medical field remains limited. In this study, we clarified sex differences in facial soft tissues among normal individuals and evaluated whether treatment outcomes in patients with jaw deformities are appropriate when these sex differences are taken into account.

MATERIALS AND METHODS

The subjects consisted of 30 patients (15 males and 15 females) diagnosed with skeletal mandibular prognathism who underwent bilateral sagittal split ramus osteotomy (SSRO) between 2013 and 2022 at Kyushu University Hospital. Asymmetric cases and those with congenital anomalies such as cleft lip and palate were excluded (Supplemental Data; Table 1, Supplemental Digital Content 1, http://links.lww.com/SCS/I202). A control group of 30 healthy volunteers (15 males and 15 females) was also included.

From the *Department of Maxillofacial Diagnostic and Surgical Sciences, Division of Oral and Maxillofacial Surgery, Graduate School of Dental Science, Kyushu University, Fukuoka, Japan; †Department of Oral and Maxillofacial Surgery, Graduate School of Biomedical Sciences, Nagasaki University, Nagasaki, Japan; ‡Department of Dentistry and Oral Surgery, Iizuka Hospital, Fukuoka, Japan; and §Department of Dental Science, Division of Oral Health, Growth and Development, Graduate School of Dental Science, Kyushu University, Fukuoka, Japan.
Received June 16, 2025.
Accepted for publication July 8, 2025.
Address correspondence and reprint requests to Tomohiro Yamada, DDS, PhD, Department of Oral and Maxillofacial Surgery, Graduate School of Biomedical Sciences, Nagasaki University, 1-7-1, Sakamoto, Nagasaki-City, Nagasaki, Japan; E-mail: t-yamada@nagasaki-u.ac.jp
This work was supported by JST SPRING, Grant Number JPMJSP2136.
The authors report no conflicts of interest.
Supplemental Digital Content is available for this article. Direct URL citations are provided in the HTML and PDF versions of this article on the journal's website, www.jcraniofacialsurgery.com.

ISSN: 1536-3732
DOI: 10.1097/SCS.0000000000011746

STL of Facial Soft Tissue Surface Data

Three-dimensional facial data were collected from healthy subjects using a 3D image capture and analysis system (VECTRA® H2/CANFIELD, USA). Images were taken in a sitting position with the mouth closed. The collected data were used for 3D reconstruction and converted into STL files.

In the patient group, DICOM data from CT images were converted into STL files using Mimics software (Materialise, Leuven, Belgium). CT imaging was performed using an Aquilion scanner (Canon Medical Systems, Ohtawara, Japan) installed in the radiography room at Kyushu University Hospital. Imaging was conducted with the patient in the supine position, with the mouth closed. Parameters included a tube voltage of 120 kV, tube current of 140 mA, slice thickness of 1 mm, and table movement speed of 13 mm/s. The imaging range extended from just above the supraorbital ridge to the hyoid bone.

In each dataset, the line connecting the left and right external canthi was set as the x-axis. The line perpendicular to the x-axis and passing through the nasal apex was defined as the y-axis, and the intersection of these 2 axes was defined as the origin. The x-axis was aligned parallel to the Frankfort horizontal (FH) plane, and the z-axis was set perpendicular to the x-axis, passing through the nasal root point.

The template data used consisted of facial profile data from an adult male, comprising 4580 points. Seventeen anatomic landmarks were manually marked on each face and matched with the corresponding points from both the template and CT data (Fig. 1). Using the homologous modeling support software HBM-Rugle® (Medic Engineering, Kyoto, Japan), the template data were fitted to the landmark points on each facial profile. All facial profile datasets were then converted into homologous model data consisting of 4580 corresponding points (Fig. 2).

Gender Difference Analysis

For qualitative evaluation, HBM-Rugle® was used to generate an average facial model for each sex. Quantitative evaluation was performed using principal component analysis (PCA). Faces were analyzed by redefining them as principal components, ordered by their respective amplitudes within each group. The degree of variance (eigenvalue) of each principal component was calculated for comparisons across groups. PCA was followed by multiple regression analysis. Analysis of variance (ANOVA) and Tukey test were used to compare groups within the PCA results. All descriptive and statistical analyses were performed using R 4.2.3 (SAS Institute Inc., Cary, NC).

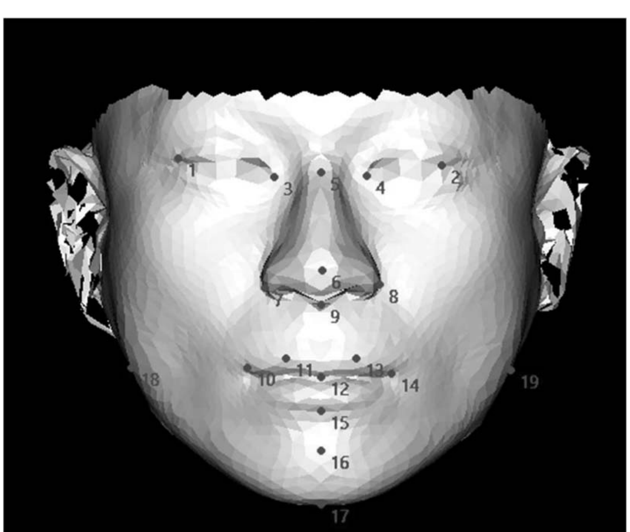

FIGURE 1. Anatomic landmarks plotted on a 3D model surface.

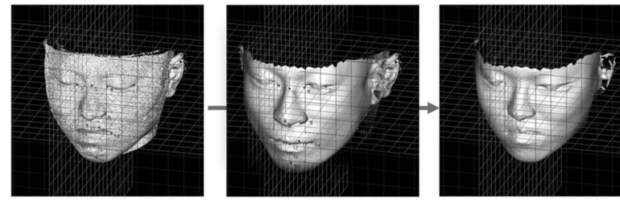

FIGURE 2. Homologous modeling process for facial data. From left to right: original facial data, template data fitted to the face, and the resulting homologous model.

Ethical Approval

The study protocol was reviewed and approved by the Institutional Review Board of Kyushu University Hospital (approval no. 23491)

RESULTS

Analysis of Male-Female Differences in Normal Faces

Qualitative analysis of the average face showed that, in the frontal view, males tended to have greater overall facial height and a longer chin, while females tended to have a smaller chin. In the lateral view, the midface was straighter in males, whereas the zygomatic-to-cheek area appeared more rounded in females, and the chin was slightly smaller (Fig. 3).

In the principal component analysis, up to the 14th principal component was extracted (cumulative contribution rate: 94.038%). The cumulative contribution rate from the 1st to the 6th principal components was 80.083% (Supplemental Data: Table 2, Supplemental Digital Content 1, http://links.lww.com/SCS/I202). The ROC curve for the first 6 principal components

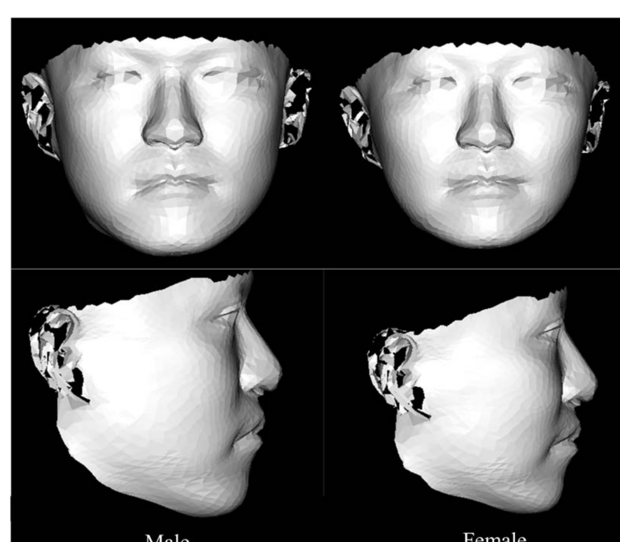

FIGURE 3. Average face of healthy females and males. In the front view, males tended to have a taller face and a longer chin overall, while females tended to have a smaller chin. In the profile view, males tended to have a straighter midface, while females showed a rounder cheekbone area and a slightly smaller chin.

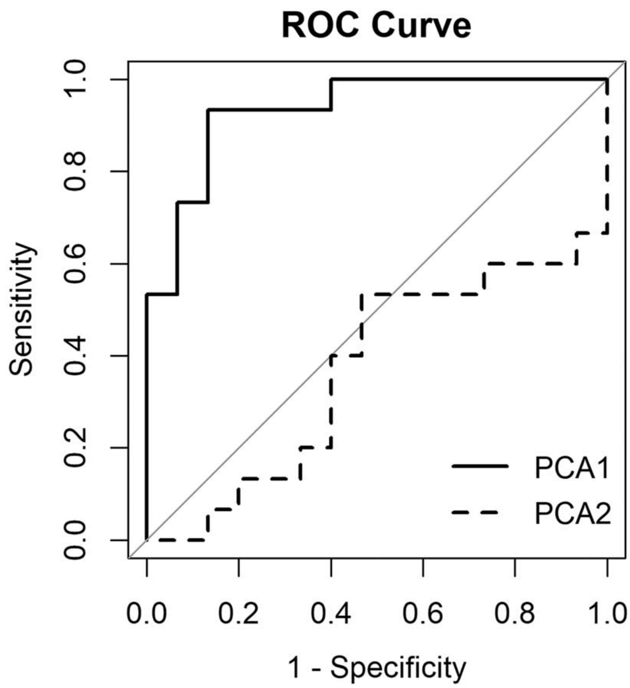

FIGURE 4. ROC curve of PC1 and PC2 in healthy females and males. The ROC curve comparing healthy females and males showed an AUC of 93.33% for the first principal component (red line). This indicates that the first principal component distinguishes between male and female facial morphology with high accuracy, reflecting key morphologic differences.

showed a marked difference, with the first principal component having an AUC of 93.33% (Fig. 4: ROC curve, Fig. 5: Morphing in PC1). The AUC for the second principal component was 36.89%.

Pre- and Postoperative Morphometric Analysis of Patients With Mandibular Prognathism (Male)

Qualitative analysis of the average face showed that the preoperative features—such as shortening of the upper lip, chin protrusion, and excessive chin length—were improved after surgery, and the postoperative facial shape approached that of the average healthy male (Fig. 6).

Principal component analysis extracted up to the 14th principal component (cumulative contribution rate: 91.932%). The cumulative contribution from the 1st to the 6th principal components was 78.136% (Supplemental Data: Table 3, Supplemental Digital Content 1, http://links.lww.com/SCS/I202). Analysis of variance (ANOVA) indicated differences in the first,

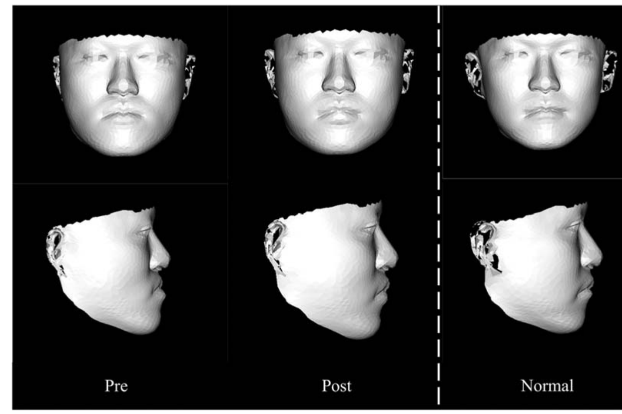

FIGURE 6. Average face (male). Preoperative facial morphology showed a prominent protruding chin. Postoperatively, the average facial morphology of male patients more closely resembled that of healthy male subjects than of healthy females.

third, and fourth principal components. Tukey test revealed significant differences between patients and healthy subjects in the first and fourth components, and between healthy subjects and preoperative patients in the third component only (Fig. 7: box-and-whisker diagram, Fig. 8: scatter plot). Morphed images corresponding to the fourth principal component are shown in Figure 9.

In the healthy group, the face appeared shorter, and the lower lip thinner. In contrast, the preoperative patient group exhibited a longer face, a thicker lower lip, and differences in mandibular angle morphology.

Pre- and Postoperative Morphologic Analysis of Patients With Mandibular Prognathism (Female)

In the preoperative average face, a flat midface and chin protrusion were observed. Postoperatively, although the chin was retracted in the lateral view, the molars still appeared long. The roundness of the cheek area remained largely unchanged before and after surgery and still differed from that of normal subjects (Fig. 10).

Principal component analysis extracted up to the 15th principal component (cumulative contribution rate: 91.835%), and the cumulative contribution from the 1st to the 8th principal components was 79.641% (Supplemental Data: Table 4, Supplemental Digital Content 1, http://links.lww.com/SCS/I202). ANOVA showed significant differences in the first and third principal components. Tukey's test indicated significant differences between the patient group and healthy subjects for the first

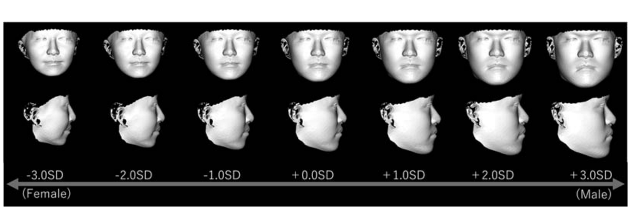

FIGURE 5. Virtual shape created from the 1st principal component. Female faces are smaller overall, with a characteristically rounded shape from the cheekbones to the cheeks. In addition, the lower jaw is shorter and the protruding chin is less prominent compared with males. In contrast, male midfaces are straighter, the lower jaw is longer, and the chin protrusion is more noticeable.

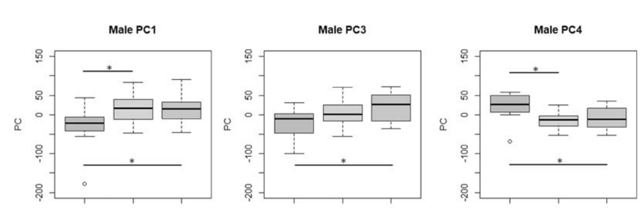

FIGURE 7. Box plots for statistically significant principal components (male). In males, significant differences were observed in the first, third, and fourth principal components. The first and fourth components showed significant differences between the patient and healthy control groups, while the third component showed a significant difference between the preoperative patient group and the healthy control group. *: $P < 0.05$

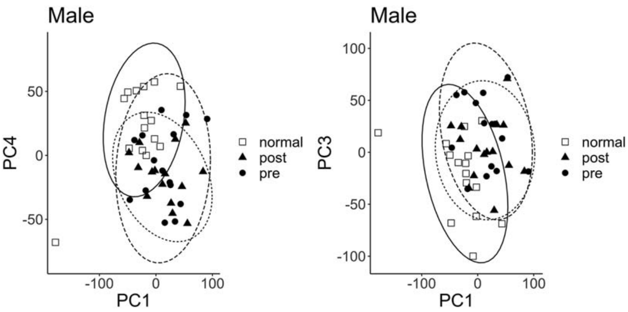

FIGURE 8. Scatter plot of patient facial appearance before and after surgery compared with healthy subjects (male). The principal components that showed significant differences in males were the first, third, and fourth. Scatter plots were generated with the first principal component on the x-axis and the third or fourth on the y-axis. The first and fourth principal components highlighted characteristics that did not overlap between the groups' probability ellipses.

principal component, and between healthy subjects and postoperative patients for the third component only (Fig. 11: box-and-whisker diagram, Fig. 12: scatter plot). Morphed images based on the third principal component are shown in Fig. 13.

Significant differences were observed between the healthy and postoperative patient groups, including differences in aspect ratio in the lateral view, chin protrusion, midface roundness, and lower lip thickness.

DISCUSSION

Although the primary goal of treating jaw deformities is to improve oral and maxillofacial function, esthetic enhancement also plays a significant role. Many patients with jaw deformities experience feelings of inferiority and depression, and treatment plans should consider esthetic outcomes as well.[12]

While sex differences in facial morphology have long been studied, it remains important to consider these characteristics when setting esthetic treatment goals for jaw deformities.[1,4,6,12,13] In particular, regarding soft tissues, it has traditionally been noted that males have a greater overall facial height, while females tend to have a relatively larger central facial area and a smaller masticatory region.[15] In addition, males are reported to exhibit greater facial irregularity than females. Some studies have also suggested that Oriental populations, particularly Japanese women, tend to have wider central facial structures compared with men.[16]

However, evaluation methods for facial soft tissue morphology are not yet well established. Even when 3-dimensional facial surface data are collected, analyses often rely on superimposition within the same individual or comparisons

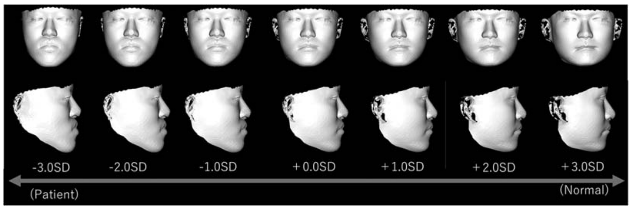

FIGURE 9. Virtual shape created from the 4th principal component (patient and healthy/male). The fourth principal component showed significant differences between the healthy control and patient groups. The healthy group had a shorter facial length and thinner lower lip, whereas the patient group had a longer face and thicker lips.

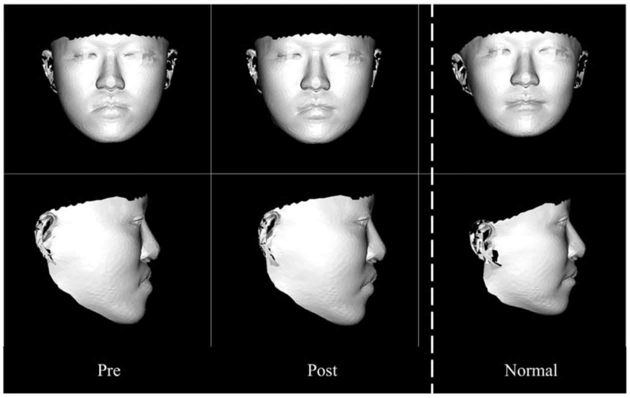

FIGURE 10. Average face (female). The preoperative average face in female patients showed noticeable chin protrusion, a flat midface, and features resembling a masculine facial appearance. Postoperative results showed improvement in chin protrusion, but midface flatness and increased facial height remained more prominent compared with healthy females.

based on distances and angles between feature points.[8] No standard method has been developed to assess the 3-dimensional curvature of facial shapes.

In recent years, homologous modeling has enabled statistical processing of 3D shape data.[17,18] Homologous modeling is a technique that applies a common template—with a defined number of polygons—onto each 3D dataset by matching anatomic landmarks. This process creates models with consistent polygon counts across samples.[19] The original method was introduced by Mochimaru and colleagues in their work, Analysis of 3D human foot forms using the free-form deformation method and its application in grading shoes lasts. This technique enables both quantitative comparisons and multivariate analysis. In this study, we used homologous modeling to evaluate 3-dimensional facial features and applied it to assess surgical outcomes in patients with jaw deformities.

First, we examined whether facial shape differences between males and females could be identified in a healthy population, and if so, what those differences were. As a result, conventional observations—such as females having a rounder zygomatic-to-cheek area and a slightly smaller chin—were confirmed with statistical clarity. This supports the need to address soft tissue morphologic and dimensional differences between sexes in treatment planning.

Given the confirmed sex differences in the soft tissues of normal subjects, we deemed it necessary to analyze the facial

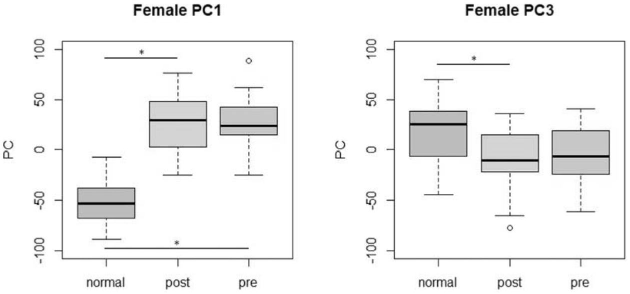

FIGURE 11. Box plots for statistically significant principal components (female). Analysis of variance identified principal components with significant differences among healthy subjects, preoperative patients, and postoperative patients. Tukey test revealed that in females, significant differences were found in the first and third principal components. The first component differed between the patient and healthy groups, while the third component differed between postoperative patients and healthy controls. *: $P < 0.05$

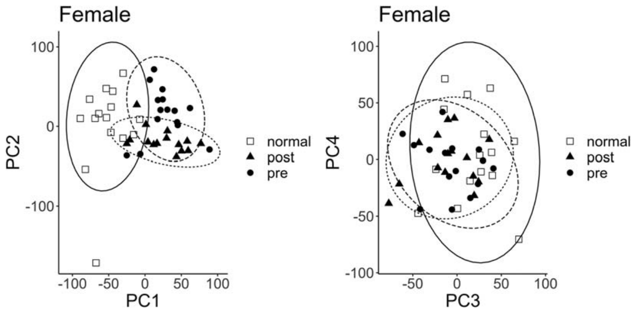

FIGURE 12. Scatter plot of patient facial appearance before and after surgery compared with healthy subjects (female). A scatter plot was created using the first and third principal components, which showed significant differences in females. The first component likely represents overall morphologic differences between patient and healthy groups. The third component showed a significant difference between postoperative patients and healthy controls. The patient group appeared to be enclosed within the healthy group's probability ellipse. Plots and ellipses were generated using R (version 4.2.3).

morphology of jaw deformity patients separately by sex. We therefore reviewed outcomes of single-jaw mandibular setback surgery in patients with mandibular prognathism and no asymmetry, stratified by sex. Results showed that male patients were more likely to achieve postoperative facial profiles similar to healthy controls with mandibular surgery alone. However, female patients continued to exhibit masculine features such as midface flatness and increased facial height, even after surgery. This suggests that, even when occlusion is corrected to class I, a single mandibular procedure may not yield ideal facial soft tissue outcomes in female patients with mandibular prognathism.

Therefore, in female patients, surgical intervention may need to extend to the midface (cheek area) and molar region to improve overall facial appearance. Conversely, male patients with skeletal class II malocclusion may also experience limited improvement with mandibular surgery alone.

One limitation of this study was the small sample size. Further case accumulation and multicenter validation are needed to establish more robust evidence for treatment strategies. However, within this study, the results appear relatively reliable, as the analysis was limited to a consistent deformity pattern—mandibular prognathism without asymmetry.

Even in procedures focused on hard tissue, considering soft tissue morphology—and especially sex differences—may contribute significantly to improved patient satisfaction.

CONCLUSION

In this preliminary study, we analyzed the soft tissue morphology of the face in patients with mandibular prognathism who underwent orthognathic mandibular surgery alone. The findings suggest that female patients may retain masculine facial features postoperatively, even when occlusion is corrected to class I. Therefore, surgical modification of the midface (cheeks) and chin should be considered for female patients to enhance facial appearance. Even in hard tissue surgeries, attention to sex-related soft tissue differences may help improve overall patient satisfaction.

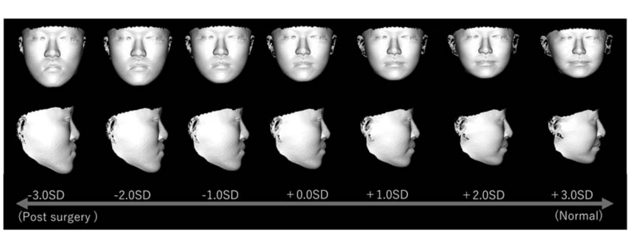

FIGURE 13. Virtual shape created from the 3rd principal component (postoperative patient and healthy/female). The third principal component showed a significant difference between the postoperative patient group and the healthy control group. It reflects differences in overall facial size (postoperative faces were longer and deeper) and in chin protrusion.

ACKNOWLEDGMENTS

We would like to thank Tanijiri Toyohisa for technical assistance with the experiments.

REFERENCES

1. Hirata K, Nagaoka T. Sex assessment on the basis of fragmentary crania of the medieval Japanese. *Anthropol Sci (Japanese Series)* 2005;113:17–26
2. Okazaki K. Sex assessment of subadult skeletons based on tooth crown measurements: an examination on the interpopulational variation of sex differences and an application to excavated skeletons. *Anthropological Sci (Japanese Series)* 2005;113:139–159
3. Tanaka T, Hanihara K, Koizumi K. Sex determination of the modern Japanese skull by means of discriminant function. *Sapporo Med J* 1979;48:582–593
4. Nagaoka T, Hirata K. Sex determination of medieval japanese skeletons based on head and neck circumferences of long bones. *Anthropol Sci (Japanese Series)* 2009;117:23–30
5. Pekka S, Bernard KCBE. *KNIGHT's Forensic Pathology. 4th ed.* CRC Press; 2016.
6. Wilton MK. *The Human Skeleton In Forensic Medicine Second Printing*. Charles C Thomas; 1962.
7. Bulut O, Freudenstein N, Hekimoglu B. Dilemma of gonial angle in sex determination. *Am J Forensic Med Pathol* 2019;40:361–365
8. Senem TO, Deniz S, Ilker E, et al. Photographic facial soft tissue analysis of healthy turkishyoung adults: anthropometric measurements. *Aesthetic Plast Surg* 2009;33:175–184
9. Nakano H, Mizobuchi S, Suzuki K, et al. Evaluation of the utility of homologous modeling and principal component analysis for sex determination of the mandible. *J Hard Tissue Biol* 2021;30:69–72
10. Fukuta M, Kato C, Biwasaka H, et al. Sex estimation of the pelvis by deep learning of two-dimensional depth images generated from homologous models of three-dimensional computed tomography images. *Forensic Sci Int Rep* 2020;2:1–5
11. Yamamoto S, Tanikawa C, Yamashiro T. Morphologic variations in the craniofacial structures in Japanese adults and their relationship with sex differences. *Am J Orthod Dentofacial Orthop* 2023;163:93–105
12. Saito I, Kurabe K, Kobayashi T, et al. Process of psychosocial changes by surgical-orthodontic treatment in patients with jaw deformities : a qualitative study based on a grounded theory approach. *Jpn J Oral Maxillofac Surg* 2020;66:178–187
13. Diana HT, Silviya YN, Nevena F, et al. Size and shape of human mandible: sex differences and influence of age on sex estimation accuracy. *Leg Med* 2023;65:102322
14. Jordan JB, Hailey J, Jose DA, et al. Sex differences in adult facial three-dimensional morphology: application to gender-affirming facial surgery. *Fac Plast Surg Aesthet Med* 2022;24:24–30
15. Kurauchi Y. A study of sexual dimorphism in the Japanese face using moire topography. *Showa Univ Dent Soc* 1998;18:376–387
16. Kodama J, Inoue K, Nagashima M, et al. Sex differences in the shapes of several parts of the young Japanese face. *Appl Hum Sci* 1995;14:191
17. Al BS, Nakano H, Yasuda K, et al. Three-dimensional geometric morphometry of facial soft tissue changes after bilateral sagittal split ramus osteotomy. *J Craniofac Surg* 2022;33:92–97
18. Yasuda K, Nakano H, Yamada T, et al. Identifying differences between a straight face and a posed smile using the homologous modeling technique and the principal component analysis. *J Craniofac Surg* 2019;30:2378–2380
19. Toda H, Sato N, Tokita R, et al. Morphologic variations of modern Japanese scapula described using 3D homologous modeling method. *J Phys Ther Fundam* 2022;25:10–17

