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Original Article

Changes in smile parameters after surgical-orthodontic treatment for skeletal Class III malocclusion

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Abstract *Background/purpose:* Many patients pursue attractive smiles, and surgical-orthodontic treatment is a common method. We aimed to analyze the changes in smile parameters after surgical-orthodontic treatment in patients with skeletal Class III pattern and identify factors influencing postoperative outcomes.
Materials and methods: This retrospective study comprised 34 patients with skeletal Class III malocclusion and pure mandible prognathism who received surgical-orthodontic treatment. Hard and soft tissue parameters were assessed through lateral cephalometry, and smile esthetics were evaluated through extraoral photography. Postoperative changes in smile parameters and between-parameter correlations were analyzed. Random forest and decision tree deep learning models were used to identify factors influencing postoperative changes.
Results: Substantial postoperative changes were observed in the buccal corridor, upper lip height, and smile index. Significant between-sex differences were noted in the upper midline and right chelion. Strong, positive correlations were found between upper lip height and upper lip ratio and between lower lip height and lower lip ratio. By contrast, strong negative correlations were observed between lower teeth exposure and smile index and between interlabial gap and smile index. The highest degrees of postoperative changes were noted in asymmetry-associated smile parameters: lower lip area, interlabial gap, smile index, buccal corridor, and arc ratio.
Conclusion: Considerable changes were noted in skeletal, dental, and soft tissue parameters after surgical-orthodontic treatment. However, the changes in smile esthetics were less prominent

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from the frontal view. As for chin asymmetry, the most to least prominent changes were in the lower lip area, interlabial gap, smile index, buccal corridor, and arc ratio, respectively.

Introduction

Because of its esthetic value, a person's smile is important to them and their orthodontist. Many individuals seek orthodontic treatment to achieve a more attractive smile.[1,2] Smile seems to be the first priority regarding soft tissue esthetics for laypersons. Therefore, it becomes more and more important to focus on smile in contemporary orthodontics.

Surgical-orthodontic treatment is the most common therapeutic strategy for severe skeletal Class III malocclusion. Many studies have highlighted skeletal and soft tissue changes after orthognathic surgery for this condition.[3–6] However, few studies have explored postoperative changes in smile esthetics, especially for skeletal Class III patients.[7–10]

In this study, we analyzed the changes in smile parameters after surgical-orthodontic treatment for skeletal Class III malocclusion with mandible prognathism. In addition, we investigated the effects of sex and chin asymmetry on smile parameters before and after this treatment. Two null hypotheses were formulated: no postoperative change would occur in any smile parameter, and sex would not influence smile esthetics.

Materials and methods

Patient selection

This retrospective study was approved by the Institutional Review Board of Taipei Medical University (approval number: N201803029). We identified patients who were treated at the Orthodontic Department of Taipei Medical University Hospital between 2013 and 2017.

The inclusion criteria were as follows: being aged $\geq$18 years at the time of treatment initiation; having completed orthodontic treatment and achieved favorable orthodontic finishing; having received a diagnosis of skeletal Class III malocclusion with mandibular protrusion and eventually undergoing mandibular setback orthognathic surgery; and having complete pretreatment and posttreatment data, such as lateral cephalometric and panoramic radiographs as well as extraoral and intraoral photographs. Individuals with cleft lip or palate or any congenital disease were excluded from this study. The final analysis included 34 patients (mean age: 21.58 $\pm$ 4.63 years; men: 15).

Cephalometry

All cephalometric radiographs were taken with the same cephalostat. The patients were instructed to stand with the Frankfort horizontal plane parallel to the floor. To obtain linear and angular measurements, one examiner traced all pretreatment and posttreatment lateral cephalometric radiographs by using the Viewbox software (version 4.0.1.7; 2013; dHAL, Kifissia City, Greece).

Photography

All pretreatment and posttreatment extraoral and intraoral photographs were obtained using a DSLR camera (Canon EOS 550D; Av mode with F4.5, ISO 1600, and flash; Canon, Saitama City, Japan) mounted on a tripod. The patients were instructed to sit on a chair, which was placed 150 cm away from the camera, with the Frankfort horizontal plane parallel to the floor and look straight at the camera. While the photographs were being taken, the patients were requested to say "cheese" or "seven" in a natural manner with a natural head position. To obtain linear and angular measurements, one examiner analyzed all pretreatment and posttreatment photographs by using ImageJ software (version 1.50i; 2016; National Institutes of Health, Bethesda, MD, USA).

Measurements of smile parameters

Smile parameters (n = 21) were divided into four categories: smile esthetics, lip height ratio, lip asymmetry, and lip area. The selected smile parameters are defined in Table 1.

Smile esthetics

On the basis previous smile analyses,[11–21] we selected eight smile esthetic parameters (Fig. 1; C1). Because the absolute values of these parameters are influenced by interpersonal differences, photo variations, and other factors, all parameters were evaluated in terms of ratios (a/b%), except for the upper midline and tooth number (Table 3), to minimize errors and increase reliability.

Lip height ratio

Lip width, upper lip height, lower lip height, and upper and lower lip height ratios were measured (Fig. 2; C2).

Lip asymmetry

A horizontal reference line passing through the left and right ektokanthions was regarded as the *x*-axis in frontal-view photographs, whereas a vertical reference line passing through the midpoint of both sides of the ektokanthions was regarded as the *y*-axis.[22] To evaluate lip asymmetry, we measured the distances from the right and left lip commissures to the *x*-axis; the ratio of the right distance to the left distance

Table 1 Definition of smile variables.

Smile Variables	Definitions
Esthetic variables (C1)	
Buccal corridor	Intercommisural width/Intercanine width
Arc ratio	Perpendicular distance of the incisal edge of the tooth 11 (FDI number) to a line connecting the cusp tips of the maxillary canine. The distance between a tangent line of the upper border of the lower lip and the maxillary intercanine line
Upper midline	Amount of deviation of the maxillary dental midline to the facial midline
Lower teeth exposure	Distance from the incisal edge of the tooth 41 to upper border of lower lip/mesiodistal size of tooth 11
Upper lip height	The shortest distance from the incised edge of tooth 11 to the lower border of the upper lip/ mesiodistal width of tooth 11
Tooth number	The number of the exposed teeth in the maxilla
Smile index	Intercommisural width/Interlabial gap
Interlabial gap	Interlabial gap/Intercanine width
Lip height ratio (C2)	
Lip width	Distance from the right commissure to the left commissure
Upper lip height	Distance from the upper border of the upper lip to the lower border of the upper lip
Lower lip height	Distance from the upper border of the lower lip to the lower border of the lower lip
Upper lip ratio	Upper lip height to upper lip width
Lower lip ratio	Lower lip height to lower lip width
Lip asymmetry (C3)	
Right chelion (mm)	Distance from the X axis to the right lip commissure
Left chelion (mm)	Distance from the X axis to the left lip commissure
H inclination	Angle between inter-commissure and X axis
V inclination	Angle between Y axis and the line connecting superius and inferius labrale
Chelion ratio	Right chelion distance/left chelion distance
Lip area (C4)	
A (mm^2)	Upper lip area (mm^2)
B (mm^2)	Lower lip area (mm^2)
C (mm^2)	Lip gap area (mm^2)

was defined as the chelion ratio. A perfectly symmetrical lip has a chelion ratio of 1; a chelion ratio of <1 indicates that the right side is larger than the left side and vice versa.

Horizontal inclination (indicating horizontal asymmetry) was defined as the angle between the line passing through the right chelion and left chelion and the horizontal reference line. Vertical inclination (indicating vertical asymmetry) was defined as the angle between the line passing through the labrale superius and labrale inferius and the vertical reference line (Fig. 2; C3).

Lip area

The upper lip vermilion and lower lip vermilion were identified from the patients' frontal extraoral photographs. Lip gap was defined as a gap between the lower border of the upper lip and the upper border of the lower lip. ImageJ was used to measure the areas of the upper lip (A), lower lip (B), and lip gap (C) before and after surgical-orthodontic treatment (Fig. 2; C4).

Statistical analysis

Statistical analyses were performed using SPSS (version 22.0; IBM Corporation, Armonk, NY, USA). Statistical significance was set at $P < 0.05$. A paired-samples t test was conducted to compare smile parameters before and after surgery, thereby measuring postoperative changes. An independent-samples t test was performed to determine between-sex differences in smile parameters. Between-parameter correlations were investigated using Pearson correlation analysis. A heatmap was plotted to visualize the interactions between 21 smile parameters across 4 categories. Random forest and decision tree deep learning models were constructed using the SAS Viya software. These models were used to identify the smile parameters associated with postoperative mandible asymmetry.

Results

Postoperative changes in smile parameters

The mean changes in the smile parameters are summarized in Table 2. Among the 21 smile parameters, 3 exhibited significant changes after surgery: buccal corridor, smile index, and upper lip height. Postoperatively, mean reductions of 0.07 ($P = 0.024$) and 1.00 ($P = 0.031$) were observed in the buccal corridor and smile index, respectively. By contrast, a mean increase of 0.17 ($P = 0.003$) was observed in upper lip height.

Correlation of sex with smile esthetics

The correlations between sex and the selected smile parameters are summarized in Table 3. After surgery, two

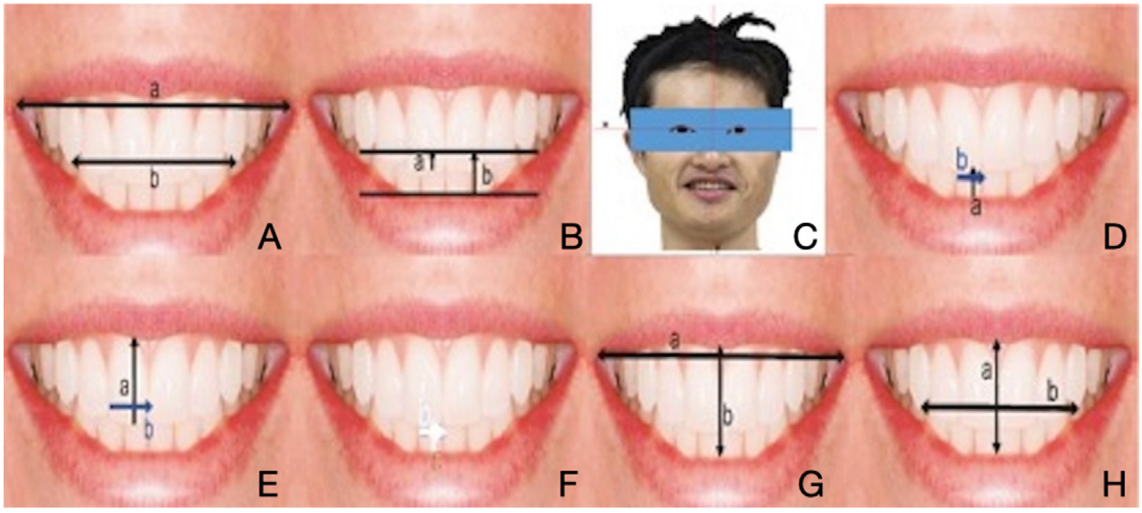

Figure 1 Smile parameters: esthetic parameters (C1). Buccal corridor (A) = a/b, arc ratio (B) = a/b, upper midline (C), lower teeth exposure (D) = a/b, upper lip height (E) = a/b, tooth number (F), smile index (G) = a/b, and interlabial gap (H) = a/b.

parameters exhibited significant between-sex differences. Postoperatively, the upper midline significantly improved in women compared with men ($P = 0.033$). The right chelion distance significantly decreased in women ($P = 0.031$) but increased in men.

Between-parameter correlations and the parameters' effects on asymmetry

The coefficients for between-parameter correlations and the corresponding *p* values are presented in Fig. 4. Strong, positive correlations were found between upper lip height and upper lip ratio ($\kappa = 0.99$) and between lower lip height and lower lip ratio ($\kappa = 0.8$). Similarly, strong, positive correlations were found between lower teeth exposure and interlabial gap ($\kappa = 0.63$) and between right chelion and left chelion ($\kappa = 0.7$). By contrast, strong negative correlations were found between lower teeth exposure and smile index ($\kappa = -0.67$) and between smile index and interlabial gap ($\kappa = -0.78$). The random forest analysis revealed the key smile parameters associated with asymmetry (Fig. 3). The most crucial parameter was the lower lip area, followed by the interlabial gap, smile index, buccal corridor, and arc ratio.

Discussion

For skeletal Class III cases, mandibular prognathism accounts for majorities of them. In order to avoid confounding factors to decrease bias, we only included mandible prognathism in this research. In this retrospective study, most of the smile parameters were calculated in terms of ratios instead of absolute values to minimize errors from photograph processing and increase reliability. Moreover, the parameters were selected after a thorough review of the literature on factors influencing smile esthetics.[11,12,19,23] We measured the lip height ratio, lip asymmetry, and lip area,[24] which strongly affect smile esthetics but are usually neglected in smile analysis. As shown in Table 2, smile analyses revealed significant postoperative changes in three smile parameters: buccal corridor, upper lip height, and smile index.

The buccal corridor significantly increased ($P = 0.024$) after orthognathic surgery. However, no significant change was noted in lip width, which indicates that the intercommissural width remains unchanged in most patients. Our patients had undergone dentoalveolar decompensation before mandibular setback surgery.[25] We constricted the maxillary dental arch and expanded the mandibular dental arch to prevent posterior crossbite after surgery; this approach resulted in a reduction in intercanine width, which explains the increase in the buccal corridor.

A significant increase was noted in upper lip height after surgery ($P = 0.003$). However, tooth width, the denominator in the aforementioned formula, barely changed. During dentoalveolar decompensation, we corrected the flared, compensated maxillary incisor to enhance the reverse overjet for mandibular setback surgery,[25] thereby increasing the upper incisal display. In our cephalometric analysis, the U1—NA angle significantly decreased from 32.29° to 28.76°; in addition, the distance of U1 to NA significantly decreased from 7.07 to 5.21. These results are consistent with those obtained in clinical practice. Flared incisors tend to reduce the incisal display, whereas upright incisors tend to increase it.[20] This finding explains the observed increase in the upper lip height of our patients.

In our study, both right and left chelions achieved almost the same height after orthognathic surgery; the chelion ratio increasing nonsignificantly from 0.99 to 1.02 (Table 2). Yashamita et al. reported that the height ratio of the deviated side to the contralateral side significantly increased from 0.92 to 0.99 and that both chelions attained almost the same height. Before surgery, the horizontal inclination and vertical inclination of the lip was 2.7° and 10.2°, respectively. After surgery, these values reduced significantly to 0.5° and 2.0°, respectively.[22] The discrepancy between the findings of the present and previous studies can be explained by the fact that the degree of mandible asymmetry in our study was smaller than that in

Table 2 Paired samples t-test results for smile variables (C1, C2, C3, C4).

	T1 Mean ± SD (n = 34)	T2 Mean ± SD (n = 34)	T2–T1 Mean ± SD (n = 34)	*P* value
Esthetic variables (C1)				
Buccal corridor	1.71 ± 1.99	1.78 ± 1.33	0.07 ± 0.17	0.024*
Arc ratio	0.76 ± 1.06	0.67 ± 0.92	−0.09 ± 1.23	0.67
Upper midline	0.40 ± 0.72	0.25 ± 0.45	−0.15 ± 0.77	0.28
Lower teeth exposure	0.61 ± 0.45	0.62 ± 0.38	0.00 ± 0.38	0.97
Upper lip height	0.73 ± 0.29	0.91 ± 0.27	0.17 ± 0.31	0.003**
Tooth number	7.44 ± 0.62	8.06 ± 1.52	0.62 ± 1.95	0.07
Smile index	6.72 ± 2.74	5.71 ± 1.89	−1.00 ± 2.59	0.031*
Interlabial gap	0.30 ± 0.11	0.33 ± 0.10	0.02 ± 0.11	0.26
Lip height ratio (C2)				
Lip width	43.16 ± 4.42	43.22 ± 4.39	0.06 ± 0.34	0.33
Upper lip height	4.96 ± 1.35	4.78 ± 1.39	−0.18 ± 1.06	0.34
Lower lip height	7.35 ± 1.39	7.76 ± 1.60	0.41 ± 1.23	0.06
Upper lip ratio	0.28 ± 0.89	0.28 ± 0.89	0.00 ± 0.02	0.45
Lower lip ratio	0.32 ± 0.88	0.32 ± 0.88	0.01 ± 0.03	0.36
Lip asymmetry (C3)				
Right chelion (mm)	43.06 ± 4.73	43.04 ± 5.05	−0.01 ± 2.31	0.97
Left chelion (mm)	42.56 ± 4.57	41.69 ± 8.29	−0.87 ± 7.17	0.49
H inclination	0.76 ± 1.48	0.76 ± 1.37	0.00 ± 1.83	1.00
V inclination	0.88 ± 3.19	0.00 ± 0.00	−0.88 ± 3.19	0.17
Chelion ratio	0.99 ± 0.03	1.02 ± 0.18	0.03 ± 0.18	0.39
Lip area (C4)				
A (mm^2)	632.89 ± 348.00	582.34 ± 334.96	−50.55 ± 152.59	0.06
B (mm^2)	946.22 ± 468.26	923.91 ± 473.07	−22.30 ± 169.76	0.45
C (mm^2)	847.20 ± 433.00	891.64 ± 417.45	44.44 ± 327.49	0.43

P value: *<0.05; **<0.01; ***<0.001.

the study of Yashamita et al.; however, in our study, even small asymmetry influenced, to some extent, the postoperative changes in smile parameters.

No significant postoperative change was noted in upper lip, lower lip, or lip gap area. Seung et al. evaluated the morphological changes in the lips after mandibular setback surgery; for their analysis, the researchers used three-dimensional cone-beam computed tomography images.[24] In frontal-view photographs, neither the upper nor the lower lip area exhibited any significant postoperative change; however, in lateral-view photographs, an increase was noted in the upper lip area, whereas a reduction was noted in the lower lip area.[24] These findings are in line with our findings indicating that in frontal-view photographs, neither the upper nor the lower lip area exhibited any significant postoperative change.

As shown in Table 3, between-sex differences were observed only in the upper midline ($P = 0.033$) and right chelion ($P = 0.031$). The upper midline was likely to deviated more in men (from 0.13 to 0.30 mm) than in women (from 0.61 to 0.21 mm). Furthermore, the distance of the right chelion increased in men (from 43.87 to 44.80 mm) but decreased in women (from 42.42 to 41.46 mm). The two aforementioned parameters differed significantly between the sexes; however, the actual postoperative changes were small (within 1 mm). Future large-scale studies should be conducted to analyze these differences between men and women.

Strong, positive correlations were noted between upper lip height and upper lip ratio and between lower lip height and lower lip width. These results were expected because the numerator in the formulas of both parameters was the same. Strong, positive correlations were also noted between lower teeth exposure and interlabial gap and between right chelion and left chelion. The strong correlation between lower teeth exposure and interlabial gap might have resulted from the extended interlabial gap, which suggests an increase in the downward motion of the lower lip; this increase enhances lower teeth exposure. The positive correlation between right chelion and left chelion is reasonable. In a patient without any apparent facial asymmetry, both chelions should be at a similar vertical distance from the interpupillary line.

Strong, negative correlations were observed between lower teeth exposure and smile index and between interlabial gap and smile index. The aforementioned explanation is applicable to the negative correlation between lower teeth exposure and smile index: a smaller degree of lower teeth exposure indicates a lower downward motion of the lower lip, which results in a lower interlabial gap and a lower denominator of the smile index.

We used random forest and deep learning models to identify the asymmetry-associated smile parameters that exhibited the highest degrees of changes after mandible orthognathic surgery. Machine learning models could provide the order of the importance of all factors. It would provide useful information for clinicians to refer to when they make treatment plans. The predominant asymmetry-associated parameter was lower lip area, followed by

Table 3 Correlation of sex and smile esthetics.

	Female			Male			*P* value
	T1 Mean ± SD (n = 19)	T2 Mean ± SD (n = 19)	T2−T1 Mean ± SD (n = 19)	T1 Mean ± SD (n = 15)	T2 Mean ± SD (n = 15)	T2−T1 Mean ± SD (n = 15)	
Esthetic variables (C1)							
Buccal corridor	1.76 ± 0.17	1.69 ± 0.13	−0.07 ± 0.17	1.80 ± 0.23	1.72 ± 0.14	−0.07 ± 0.18	0.891
Arc ratio	0.92 ± 1.12	0.86 ± 1.13	−0.06 ± 1.42	0.55 ± 0.98	0.43 ± 0.47	−0.12 ± 0.98	0.881
Upper midline	0.61 ± 0.86	0.21 ± 0.38	−0.40 ± 0.89	0.13 ± 0.35	0.30 ± 0.53	0.17 ± 0.45	0.033*
Lower teeth exposure	0.50 ± 0.37	0.52 ± 0.32	0.02 ± 0.30	0.76 ± 0.51	0.74 ± 0.41	−0.02 ± 0.46	0.762
Upper lip height	0.76 ± 0.24	0.86 ± 0.26	0.10 ± 0.28	0.70 ± 0.34	0.96 ± 0.28	0.26 ± 0.33	0.127
Tooth number	7.32 ± 1.60	7.68 ± 1.49	0.37 ± 2.19	7.60 ± 1.68	8.53 ± 1.46	0.93 ± 1.62	0.411
Smile index	6.75 ± 2.71	6.11 ± 2.02	−0.64 ± 2.69	6.68 ± 2.87	5.21 ± 1.64	−1.46 ± 2.47	0.366
Interlabial gap	0.29 ± 0.11	0.30 ± 0.08	0.01 ± 0.11	0.32 ± 0.11	0.36 ± 0.11	0.04 ± 0.11	0.416
Lip height ratio (C2)							
Lip width	42.26 ± 4.65	42.37 ± 4.62	0.11 ± 0.46	44.30 ± 3.96	44.30 ± 3.96	0.00 ± 0.00	0.382
Upper lip height	4.45 ± 1.14	4.40 ± 1.50	−0.05 ± 1.03	5.60 ± 1.35	5.27 ± 1.10	−0.33 ± 1.11	0.451
Lower lip height	7.21 ± 1.18	7.58 ± 1.64	0.37 ± 1.212	7.53 ± 1.64	8.00 ± 1.56	0.47 ± 1.30	0.822
Upper lip ratio	0.41 ± 1.19	0.41 ± 1.19	0.00 ± 0.03	0.12 ± 0.03	0.11 ± 0.02	−0.01 ± 0.02	0.263
Lower lip ratio	0.43 ± 1.17	0.44 ± 0.05	0.01 ± 0.03	0.16 ± 0.03	0.16 ± 0.05	0.00 ± 0.04	0.475
Lip asymmetry (C3)							
Right chelion (mm)	42.42 ± 5.08	41.66 ± 4.97	−0.76 ± 2.59	43.87 ± 4.27	44.80 ± 4.72	0.93 ± 1.49	0.031*
Left chelion (mm)	41.74 ± 4.74	39.13 ± 9.69	−2.61 ± 9.20	43.60 ± 4.27	44.93 ± 4.57	1.33 ± 1.76	0.113
H inclination	0.63 ± 1.34	0.89 ± 1.63	0.26 ± 1.66	0.93 ± 1.67	0.60 ± 0.99	−0.33 ± 2.02	0.352
V inclination	0.58 ± 2.52	0.00 ± 0.00	−0.58 ± 2.52	1.27 ± 3.94	0.00 ± 0.00	−1.27 ± 3.94	0.541
Chelion ratio	1.00 ± 0.03	1.04 ± 0.24	0.04 ± 0.23	0.98 ± 0.03	0.98 ± 0.03	0.03 ± 0.03	0.504
Lip area (C4)							
A (mm^2)	577.84 ± 367.14	514.21 ± 290.64	−63.63 ± 163.89	702.62 ± 320.66	668.63 ± 376.28	−34.00 ± 140.78	0.582
B (mm^2)	889.16 ± 442.36	871.47 ± 387.57	−17.68 ± 164.20	1018.49 ± 505.21	990.34 ± 570.90	−28.15 ± 182.21	0.862
C (mm^2)	791.68 ± 395.65	883.68 ± 382.82	92.00 ± 345.74	917.53 ± 480.83	901.72 ± 471.32	−15.81 ± 303.56	0.348

P value: *<0.005; **<0.01; ***<0.001.

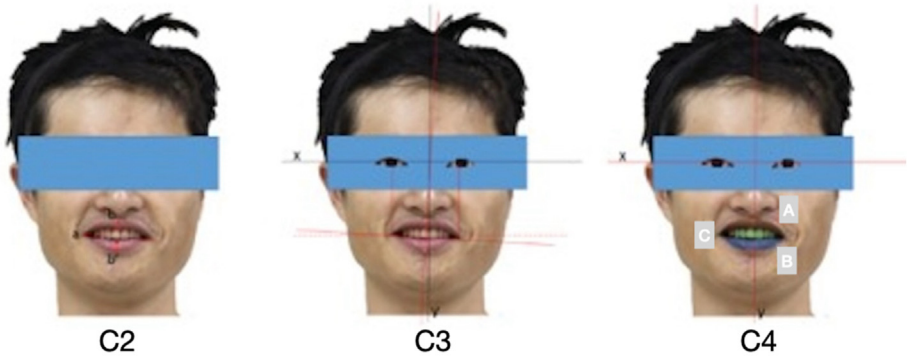

Figure 2 Smile parameters: lip height ratio (C2), lip asymmetry (C3), and lip area (C4). Lip height ratio: lip width (a), upper lip height (b), lower lip height (b′), upper lip ratio (b/a), lower lip ratio (b′/a). Lip asymmetry (• right chelion and left chelion; • labrale superius and labrale inferius): right chelion (mm), left chelion (mm), horizontal inclination (°), vertical inclination (°), and chelion ratio (%). Lip area: upper lip area (A), lower lip area (B), and lip gap area (C).

interlabial gap, smile index, buccal corridor, and arc ratio. The use of machine learning models for investigating their association with a specific object is novel. Our findings can facilitate the construction of models for predicting changes in patients' smile parameters after orthognathic surgery for mandible asymmetry.

This study has some limitations. First, only three smile parameters exhibited significant changes after surgical-orthodontic treatment, likely because skeletal Class III malocclusion is an anteroposterior direction discrepancy and smile esthetics showed less improvements in the frontal view than in the lateral view. Second, although our sample size was adequate and had sufficient statistical power, it was still small. Furthermore, we could not perform a subgroup analysis by age or sex. Postoperative changes may be difficult to interpret due to bias from differences in the number of patients before and after surgery. Women were overrepresented in our study, and our findings might thus be biased in this regard. Finally, skeletal Class III malocclusion results from maxillary deficiency, mandible prognathism, or their combination; these patterns require different surgical approaches. Because we focused on mandible prognathism, our results may not be applicable to patients with other Class III

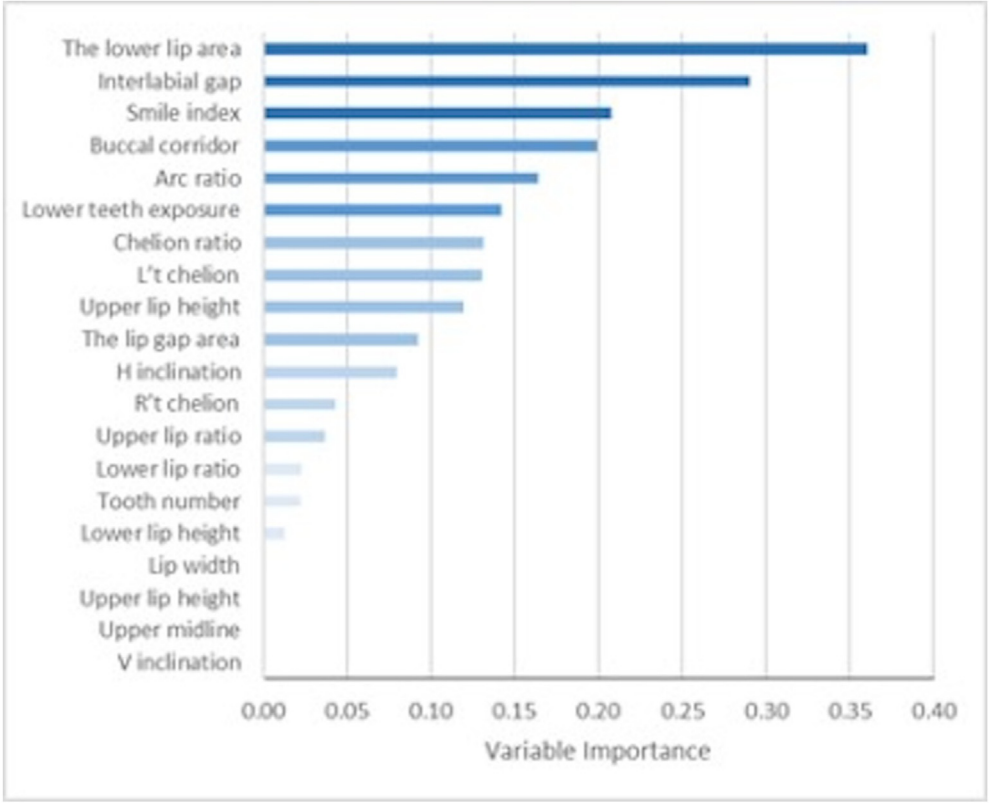

Figure 3 Random forest feature importance for asymmetry.

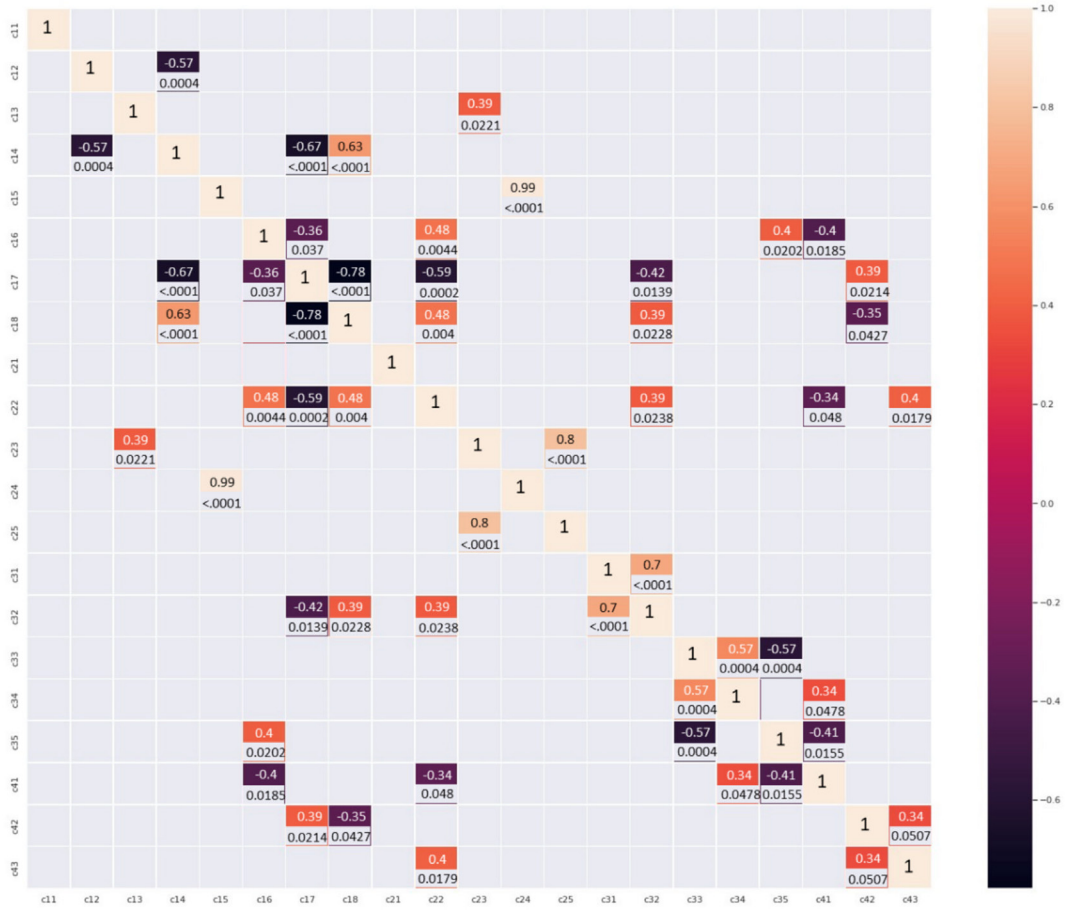

Figure 4 C11(Buccal corridor), C12(Arc ratio), C13(Upper midline), C14(Lower teeth exposure), C15(Upper lip height), C16(Tooth number), C17(Smile index), C18: (Interlabial gap), C21(Lip width), C22(Upper lip height), C23(Lower lip height), C24(Upper lip ratio), C25(Lower lip ratio), C31(Right chelion), C32(Left chelion), C33(H inclination), C34(V inclination), C35(Chelion ratio), C41(The upper lip area), C42(The low lip area), C43(The lip gap area).

malocclusion patterns. In future studies, we plan to include patients with skeletal Class III malocclusion and maxillary deficiency.

Of the 21 smile parameters evaluated in this study, only 3—the buccal corridor, upper lip height, and smile index—exhibited significant changes after mandibular setback surgery and orthodontic treatment. Only two smile parameters exhibited between-sex differences: the upper midline and right chelion distance. The most significant postoperative smile parameter that was associated with asymmetry was the lower lip area, followed by the interlabial gap, smile index, buccal corridor, and arc ratio. Future studies on smile esthetic parameters are warranted to validate our findings. Specifically, postoperative changes in smile parameters should be measured by assessing frontal-, oblique-, and lateral-view photographs. Our study may facilitate patient—clinician communication regarding smile esthetics.

Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

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