Soft Tissue Asymmetry Changes following Orthognathic Surgery using Frontal Photographs

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Department of Dentistry
Graduate School
Yonsei University
June 2025

To my beloved parents

And my brother

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Soft Tissue Asymmetry Changes following Orthognathic Surgery using Frontal Photographs

While the primary goal of orthognathic surgery is occlusal rehabilitation through osteotomies, aesthetic outcomes, especially related to facial asymmetry, have become a significant concern for both patients and surgeons. Thus, this study aimed to objectively evaluate facial asymmetry in patients before orthognathic surgery and at 1, 3, 6, and 12 months post-surgery.

Frontal digital photographs (n=170 resting and n=170 social smile) from 34 patients at Yonsei University Dental Hospital were analysed. Images included pre-surgery and post-surgery intervals at 1, 3, 6, and 12 months. Using a horizontal reference line connecting the pupils and a perpendicular vertical line passing through the mid-glabella, photographs were adjusted for consistent measurements.

Six distances from the midline to key facial landmarks were measured: medial canthi (MLMC), lateral canthi (MLLC), lateral alar margin (MLLAM), and oral commissure (MLOC). Additionally, midface widths and mandibular widths were evaluated. The asymmetry index was calculated by dividing the absolute difference between right and left values by their sum. The distance between midline and median tubercle (MLMT) and to menton (MLM), as well as the angle (A) between the oral commissure line and the horizontal reference line, was also assessed.

No statistically significant differences were observed over time for mid-face measurements (MLMC, MLLC, MLLAM, and midface width) in both rest and smile states ($p>0.05$). In contrast, significant differences ($p<0.05$) were found over time for lower-face measurements (MLOC, mandible width, MLMT, MLM, and angle of oral commissure). MLOC and MLM showed significantly higher asymmetry indices at the pre-surgery time point compared to post-surgical evaluations. MLMT exhibited significantly reduced distances at 3 and 6 months post-surgery in the rest state. The angle of oral commissure in the rest state showed significant improvements at 3, 6 and 12 months post-surgery compared to pre-surgery and 1-month post-surgery. Additionally, significant differences between rest and smile states were identified at multiple time points, particularly at pre-surgery ($p<0.05$).

Orthognathic surgery effectively reduces facial asymmetry, achieving both functional and aesthetic improvements, particularly in the lower face. The use of precise, standardized measurement methods, along with static and dynamic assessments, is critical for evaluating outcomes and ensuring patient satisfaction.

Keywords: facial asymmetry, orthognathic surgery, photographic analysis, asymmetry index

I. INTRODUCTION

The main goal of orthognathic surgery is occlusal rehabilitation using osteotomies and the placement of osteotomized segments in a position that facilitates optimal function and facial aesthetics[1]. And the standard principles of aesthetics: symmetry, facial proportions and optimal arrangement of facial components; determined this facial aesthetics[2]. However, nowadays the aesthetic results have gained more relevance and are one of the main concerns of the patients and surgeons, especially related to facial asymmetry[3].

Facial symmetry has been considered to have a positive impact on attractiveness[4]. But, a perfectly symmetrical face is not common, and a slight asymmetry of the face has been considered physiological[5]. Still, beyond a threshold level of asymmetry, facial features become dysmorphic, affecting the overall aesthetics of the face[6]. However, defining this threshold level that goes from physiological to pathological is a difficult task and has been the goal of many researchers and methods.

Nevertheless, the result of orthognathic surgery might differ from the patient's expectation and the general perception of FA may differ from the quantitative values evaluated by surgeons. According to Abbasi et al. some indices, like midline, can differ between resting and smiling states[1]. Also, as Xue et al. concluded, muscles, fat and associated skin repositioned more symmetrically after bone correction surgery[7].

Thus, this study aimed to evaluate soft tissue changes in patients with corrected skeletal facial asymmetry after orthognathic surgery. This approach allows for focused analysis of soft tissue adaptation in the absence of residual skeletal asymmetry.

1. Orthognathic surgery can improve facial asymmetry when evaluated on soft tissue.
2. There is a stabilization period reflected on soft tissue asymmetry after orthognathic surgery.
3. There is a difference of facial asymmetry indices between rest and smile state.

II. MATERIALS AND METHODS

2.1 Research sample

This single-centre retrospective study was conducted at the Department of Oral and Maxillofacial Surgery, Yonsei University Dental Hospital.

This study was approved by the Institutional Research Ethics Committee of Yonsei University College of Dentistry (IRB No. 2-2025-0020) and was conducted in accordance with the Declaration of Helsinki.

Given the retrospective nature of the study, the requirement for obtaining informed consent was waived.

This study included 34 patients (11 male, 23 female) with a diagnosis of facial asymmetry, who underwent bimaxillary orthognathic surgery between 2005 and 2024 in the Department of Oral and Maxillofacial Surgery, Yonsei University Dental Hospital.

The patient inclusion criteria were as follows: 1) Patients with correction of skeletal asymmetry (menton deviation within 2 mm postoperatively) assessed through simultaneous bimaxillary surgery with or without genioplasty (Figure 1); 2) availability of preoperative clinical data and photographs with a post operative follow-up period of at least 1 year[8,9).

The patient exclusion criteria were as follows: 1) Patients with severe anteroposterior skeletal discrepancies; 2) patients with a secondary deformity of the cleft lip/palate; 3) patients diagnosed with systemic diseases affecting skeletal growth or surgical outcomes; 4) diagnosis of a head and neck neoplasm; 5) asymmetry due to paediatric craniofacial syndromes (Crouzon, Apert, Treacher-Collins, Goldenhar); 6) previous maxillofacial trauma; 7) history of paralysis/ neuromuscular disorder; 8) lip piercing; 9) facial scar; 10) previous soft-tissue facial augmentation; 11) prior history of orthognathic surgery with incomplete records or complications unrelated to skeletal asymmetry correction; 12) previous condylectomy for functional impeachment (limited oral opening, pain); 13) treatment with surgical approaches and techniques other than bimaxillary surgery; 14) insufficient preoperative and postoperative clinical data or photographs for analysis and 15) photographs show discrepancies, such as off head position[1,7,8,10,11].

Figure 1. Pre- and post-operative skeletal image of a patient with facial asymmetry surgically corrected

Frontal digital photographs at rest (n= 170) and during social smiling (n= 170) from 34 patients of the Yonsei University Dental Hospital were selected for facial asymmetry evaluation. (Figure 2) Patients' photographs of pre-orthognathic surgery and 1, 3, 6 and 12 months after surgery were extracted from digital medical charts. To ensure robust analysis, patients with complete and high-quality photographic records at all time points were included. The photographs available for evaluation were taken under the standards described by Etorre et al.[12], with consistent lighting, distance, and head positioning and background.

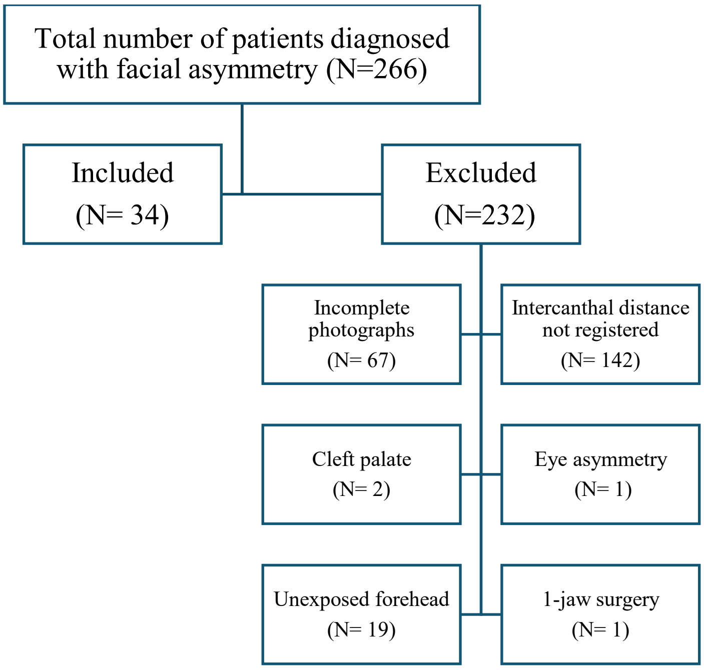

Figure 2. Flowchart for patient selection criteria.

2.2 Objective facial asymmetry evaluation

The analysis of the photographs in the rest and smile states was conducted using Adobe Photoshop 2024 (Adobe Systems Incorporated). The software's precision ruler tool and grid function were utilized for standardized measurements. First, using a horizontal reference line, the angles of all photographs were adjusted before starting the measurements. This reference line was defined by Lee et al. as an imaginary horizontal line that connects the pupils, and it is followed by a perpendicular vertical line[13]. This perpendicular vertical line is the vertical midline that passes through the mid-glabella[14]. To define mid-glabella, the middle of the intercanthal distance was used as a reference.

Then, to obtain the real distance in mm, a scale was generated in Adobe Photoshop using the intercanthal distance measured during the clinical evaluation and recorded in the digital hospital charts. Next, the researcher (SC) identified the facial landmarks[13,14] and evaluate facial asymmetry.

The nine measured points are explained in Figure 2 for rest state and Figure 3 for smile state.

Asymmetry index

Six distances from midline to each reference point were measured: midline to medical canthi (MLMC), midline to lateral canthi (MLLC), midline to lateral alar margin (MLLAM), and midline to oral commissure (MLOC). Additionally, widths of the midface at maximum distance and mandible widths from midline, including gonial angle, were measured. For each measured result, the asymmetry index was calculated by subtracting the smaller value from the larger one and dividing it by the sum of the right and left values ([Larger value - smaller value]/ [Right value + left value] x 100)[1,13].

Smile symmetry criteria

Additionally, the distances from midline to median tubercle (MLMT) and to menton (MLM) were measured[14]. Also, the angle of oral commissure (A) was measured. The angle was formed from the line that goes through the oral commissure and the horizontal reference line[13].

The intraclass correlation coefficient (ICC) was evaluated on six asymmetry indices (all ICC > 0.80), as well as on MLMT (ICC = 1.00), MLM (ICC = 0.99), and A (ICC = 0.967), measured twice on the same patients (n = 5) with a one-week interval between assessments.

To assess clinical relevance, a threshold of 5% was used for the six asymmetry indices[1,13,15], 2 mm for MLMT and MLM distances[16-18], and 2° for the angle of the oral commissure[13].

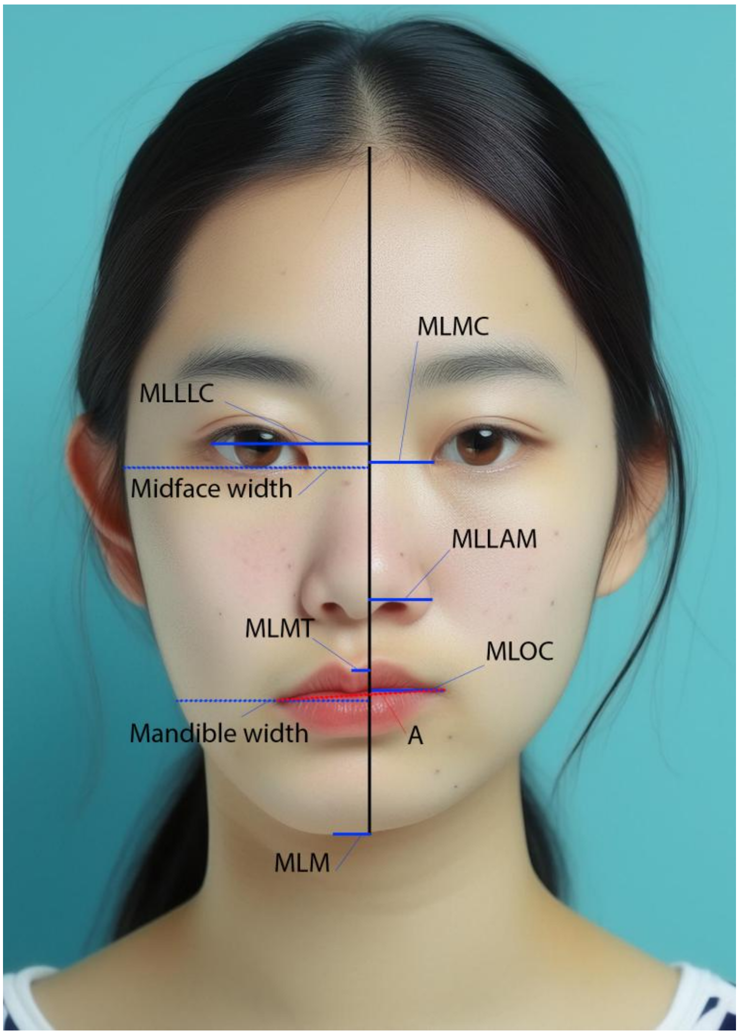

Figure 3. Method figure explaining the reference points and nine distances measured in the rest state.

MLMC: midline to medical canthi

MLLC: midline to lateral canthi

MLLAM: midline to lateral alar margin

MLOC: midline to oral commissure

Midface width: width of the midface at maximum distance from midline

Mandible width: mandible width including gonial angle from midline

MLMT: midline to median tubercle

MLM: midline to menton

A: angle of oral commissure

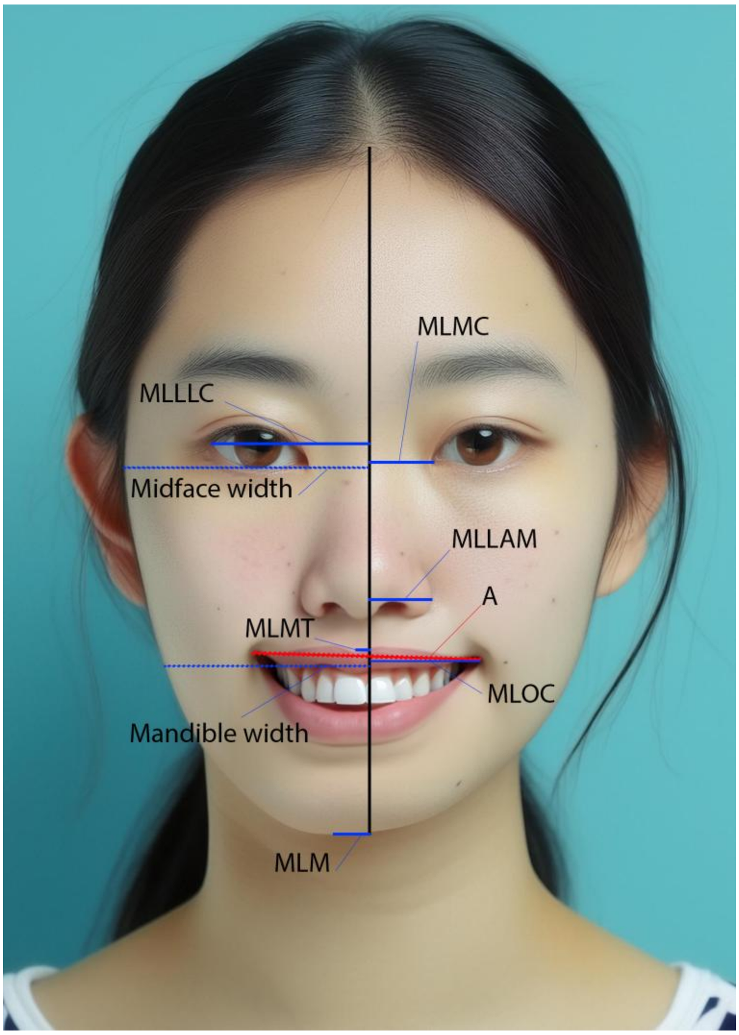

Figure 4. Method figure explaining the reference points and nine distances measured in the smile state.

MLMC: midline to medical canthi

MLLC: midline to lateral canthi

MLLAM: midline to lateral alar margin

MLOC: midline to oral commissure

Midface width: width of the midface at maximum distance from midline

Mandible width: mandible width including gonial angle from midline

MLMT: midline to median tubercle

MLM: midline to menton

A: angle of oral commissure

2.3 Statistical analysis

Mean and standard deviation (SD) were obtained for each of the nine measured points at each evaluation time in the rest and smile states.

The correlation between each measured point in rest and smile states was analysed. Normality of data distribution was assessed using the Shapiro-Wilk test. For non-normally distributed values, the Friedman test was applied for longitudinal comparisons, followed by pairwise comparisons using the Wilcoxon signed-rank test with Holm correction for multiple testing when appropriate. To compare asymmetry between rest and smile states, the paired t-test was used for normally distributed values, while the Wilcoxon signed-rank test was applied for non-normally distributed values. The statistical analyses were performed using performed using RStudio (Version 2024.04.2 Build 764, Posit Software, PBC) and R (Version 4.4.1, R Core Team, 2024).

III. RESULTS

A total of 34 patients (340 digital photographs) consisting of 11 males and 23 females were evaluated in this study (Table 1). Table 2 shows the mean and SD of the nine measured points on the frontal digital photographs in the rest state and Table 3 shows the mean and SD in the smile state.

For the mid-face measured points—MLMC, MLLC, MLLAM, and midface width—no statistically significant differences ($p>0.05$) were observed between the evaluation time points in both rest and smile states. (Tables 4, 5, 6, 7)

For the lower-face measured points—MLOC, mandible width, MLMT, MLM, and the angle of oral commissure—statistically significant differences ($p<0.05$) were observed between the evaluation time points in both rest and smile states. (Tables 8, 9, 10, 11, 12)

A statistically significant difference in MLLC was observed between the rest (0.71±0.56) and smile (1.02±0.68) states at the pre-surgery evaluation time point ($p=0.033$). (Table 5, Figure 6)

For MLOC, a statistically significant difference was observed over time in both the rest state ($p<0.001$) and smile state ($p=0.006$). For rest state, pairwise comparisons with Wilcoxon test revealed that the asymmetry index was significantly higher at the pre-surgery time point (10.69±6.62) compared to all others. The asymmetry indices at 1 (5.04±4.09), 3 (4.10±3.81), 6 (4.88±4.09), and 12 months post-surgery (5.13±3.50) formed a statistically similar group. Similarly, in the smile state, Wilcoxon test indicated that the pre-surgery asymmetry index (7.48±4.87) was significantly higher compared to all the other time points. Also, a statistically significant difference was observed between the rest and smile states at the pre-surgery evaluation time point ($p<0.001$). (Table 8, Figure 9)

For mandible width, the results indicate a statistically significant difference over time in the rest state ($p=0.004$). Wilcoxon test revealed that pre-surgery asymmetry index (4.10±3.44) was significantly different from 1- (2.50±2.15) and 12-month (2.55±1.82) post-surgery values, but not significantly different from 3- (2.52±1.82) or 6-month (2.78±2.20) post-surgery indices. Also, no significant differences were found among 1-, 3-, 6- and 12-month post-surgery time points (all p >

0.05). Additionally, when comparing the rest and smile states at the pre-surgery time point, a statistically significant difference was found ($p=0.010$). (Table 9, Figure 10)

For MLMT, in the rest state the results show a significant difference over time ($p<0.001$), with the distances at 3- (0.75±0.66) and 6-month post-surgery (0.85±0.86) being significantly lower than pre-surgery ($p<0.001$ for both comparisons). However, pre-surgery distance (1.46±1.02) was not significantly different from the 1- (1.00±0.73) and 12-month (0.97±0.76) post-surgery distances. No significant differences were observed among 1-, 3-, 6- and 12- month post-surgery time points (all $p > 0.05$). Similarly, in the smile state, a statistically significant difference was observed over time ($p=0.006$), with the pre-surgery distance (1.49±1.11) significantly higher compared to 6- (0.88±0.81) and 12-month (0.93±0.77) post-surgery values, but not from 1- (1.17±1.07) and 3-month post-surgery (0.98±0.78) indices. No significant differences were observed among 1-, 3-, 6- and 12-month post-surgery time points (all $p > 0.05$). (Table 10, Figure 11).

For MLM, the statistically significant differences were found between pre-surgery and all the other time points in the rest state (4.06±2.89) and smile state (4.03±2.89) ($p<0.001$ for both comparisons). (Table 11, Figure 12).

When evaluating the angle of oral commissure, a statistically significant difference was found over time in the rest state ($p<0.001$), with a significantly larger pre-surgery angle (2.11±1.30). Wilcoxon test revealed that the 3- (0.84±0.80), 6- (0.78±0.85) and 12-month (0.71±0.82) post-surgery time points presented the smallest angles, while the angle at 1- month post-surgery (1.03±0.93) represented an intermediate value. Likewise, a statistically significant difference was found over time in the smile state ($p=0.046$). The angle at 3 months post-surgery (0.99±0.78) was significantly smaller compared to the pre-surgery (1.73±1.11) and 1-month post-surgery (1.52±1.44) values. The 6- (1.04±0.72) and 12-month (1.22±0.91) post-surgery angles showed no significant differences compared to the angle at 3 months post-surgery, forming a statistically similar lower group. Also, when comparing rest and smile states, statistically significant differences were found at 1 month post-surgery ($p=0.041$) and 12 months post-surgery ($p=0.006$). (Table 12, Figure 13).

Table 1. Demographic and clinical data of the patients in the sample.

Characteristics	**n (%)**
Patients, *n*	34 (100%)
Male	11 (32.4%)
Female	23 (67.6%)
Age at surgery, *y*	24.47 ±6.55
Orthognathic Surgery	
Maxilla	
Lefort I osteotomy	34 (100%)
Mandible	
Bilateral IVRO	26 (76.5%)
With Genioplasty	15 (57.7%)
Without Genioplasty	11 (43.3%)
IVRO + JVRO	1 (2.9%)
With Genioplasty	0 (0%)
Without Genioplasty	1 (100%)
IVRO + YVRO	3 (8.8%)
With Genioplasty	2 (66.7%)
Without Genioplasty	1 (33.3%)
IVRO + SSRO	2(5.9%)
With Genioplasty	1 (50%)
Without Genioplasty	1 (50%)
Bilateral SSRO	2 (5.9%)
With Genioplasty	2 (100%)
Without Genioplasty	0 (0%)

Table 2. Mean (±SD) of asymmetry index, midline to median tubercle and menton, and angle of oral commissure at pre-surgery and post-surgery in the rest state.

	Measured point	Pre - surgery	1 month post-surgery	3 months post-surgery	6 months post-surgery	12 months post-surgery	p value
Mid-face	Midline to medical canthi	1.04 (±0.97)	0.95 (±0.80)	0.95 (±0.81)	0.70 (±0.69)	0.69 (±0.70)	0.199
	Midline to lateral canthi	0.71 (±0.56)	0.87 (±0.65)	0.59 (±0.55)	0.74 (±0.54)	0.69 (±0.51)	0.188
	Midline to lateral alar margin	3.48 (±2.57)	3.28 (±2.39)	3.17 (±1.87)	3.18 (±2.04)	3.60 (±2.31)	0.840
	Midface width	1.88 (±1.63)	1.55 (±1.34)	1.72 (±1.28)	2.00 (±1.39)	1.37 (±1.12)	0.466
Lower face	Midline to oral commissure	10.69 (±6.62)	5.04 (±4.09)	4.10 (±3.81)	4.88 (±4.09)	5.13 (±3.50)	< 0.001
	Mandible width	4.10 (±3.44)	2.50 (±2.15)	2.52 (±1.82)	2.78 (±2.20)	2.55 (±1.82)	0.004
	Midline to median tubercle	1.46 (±1.02)	1.00 (±0.73)	0.75 (±0.66)	0.85 (±0.86)	0.97 (±0.76)	< 0.001
	Midline to menton	4.06 (±2.89)	1.56 (±1.08)	1.42 (±1.03)	1.33 (±1.08)	1.42 (±1.11)	< 0.001
	Angle of oral commissure	2.11 (±1.30)	1.03 (±0.93)	0.84 (±0.80)	0.78 (±0.85)	0.71 (±0.82)	< 0.001

Table 3. Mean (±SD) of asymmetry index, midline to median tubercle and menton, and angle of oral commissure at pre-surgery and post- surgery in the smile state.

	Measured point	Pre - surgery	1 month post-surgery	3 months post-surgery	6 months post-surgery	12 months post-surgery	p value
Mid-face	Midline to medical canthi	0.83 (±0.59)	0.89 (±1.65)	0.93 (±0.82)	0.64 (±0.59)	0.59 (±0.86)	0.378
	Midline to lateral canthi	1.02 (±0.68)	0.90 (±0.61)	0.79 (±0.65)	0.87 (±0.62)	0.66 (±0.54)	0.141
	Midline to lateral alar margin	2.95 (±2.25)	3.64 (±2.59)	2.90 (±2.31)	3.08 (±2.03)	3.36 (±2.39)	0.424
	Midface width	1.95 (±1.66)	1.78 (±1.29)	2.07 (±1.24)	2.21 (±1.41)	1.57 (±1.28)	0.600
Lower face	Midline to oral commissure	7.48 (±4.87)	4.51 (±3.76)	4.43 (±3.28)	4.50 (±3.25)	4.73 (±3.05)	0.006
	Mandible width	3.36 (±2.87)	2.50 (±2.06)	2.46 (±1.95)	2.67 (±1.95)	2.47 (±1.92)	0.523
	Midline to median tubercle	1.49 (±1.11)	1.17 (±1.07)	0.98 (±0.78)	0.88 (±0.81)	0.93 (±0.77)	0.006
	Midline to menton	4.03 (±2.89)	1.59 (±1.04)	1.49 (±1.08)	1.38 (±1.14)	1.41 (±1.16)	< 0.001
	Angle of oral commissure	1.73 (±1.11)	1.52 (±1.44)	0.99 (±0.78)	1.04 (±0.72)	1.22 (±0.91)	0.046

Table 4. Mean (±SD) of midline to medical canthi (MLMC) of rest and smile state at pre-surgery and post- surgery.

Dynamic Analysis	Pre - surgery	1 month post-surgery	3 months post-surgery	6 months post-surgery	12 months post-surgery	p value
Rest state	1.04 (±0.97)	0.95 (±0.80)	0.95 (±0.81)	0.70 (±0.69)	0.69 (±0.70)	0.199+
Smile state	0.83 (±0.59)	0.89 (±1.65)	0.93 (±0.82)	0.64 (±0.59)	0.59 (±0.86)	0.378+
p value	0.186++	0.128++	0.681++	0.844++	0.285++	

p value was calculated with Friedman test (+) and Wilcoxon signed-rank test (++).

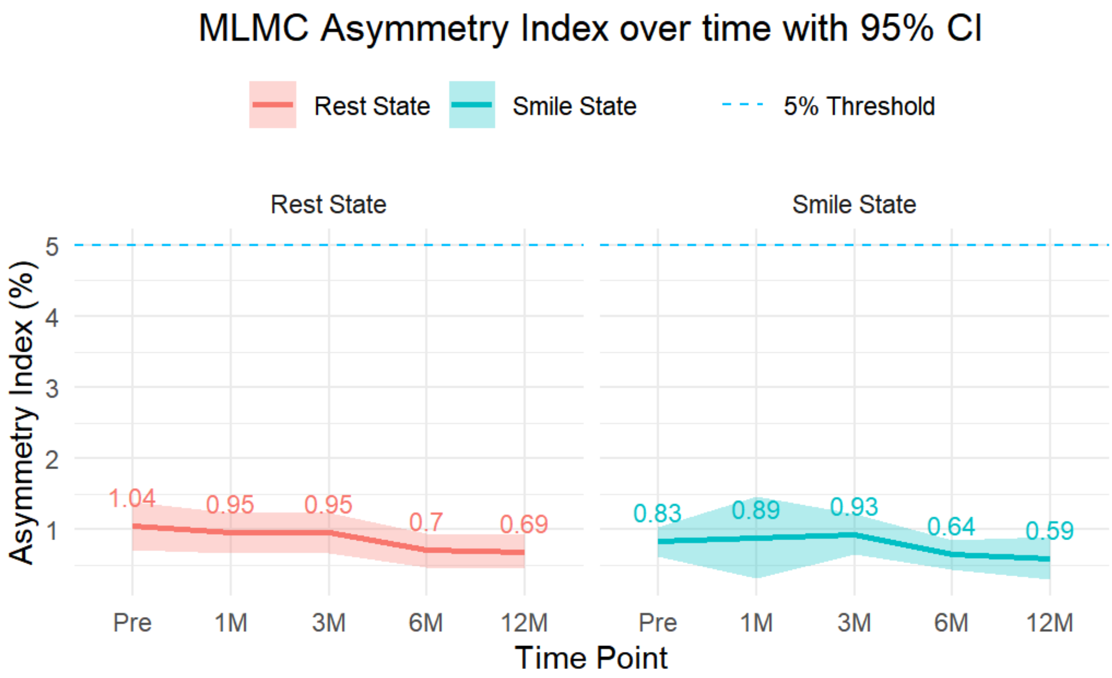

Figure 5. Asymmetry Index of midline to medical canthi (MLMC) with 95% confidence interval of rest and smile state at pre-surgery and post- surgery.

Table 5. Mean (±SD) of midline to lateral canthi (MLLC) of rest and smile state at pre-surgery and post- surgery.

Dynamic Analysis	Pre - surgery	1 month post-surgery	3 months post-surgery	6 months post-surgery	12 months post-surgery	p value
Rest state	0.71 (±0.56)	0.87 (±0.65)	0.59 (±0.55)	0.74 (±0.54)	0.69 (±0.51)	0.188+
Smile state	1.02 (±0.68)	0.90 (±0.61)	0.79 (±0.65)	0.87 (±0.62)	0.66 (±0.54)	0.141+
p value	0.033++	0.344++	0.128++	0.274++	0.698++	

p value was calculated using Friedman test (+) and Wilcoxon signed-rank test (++).

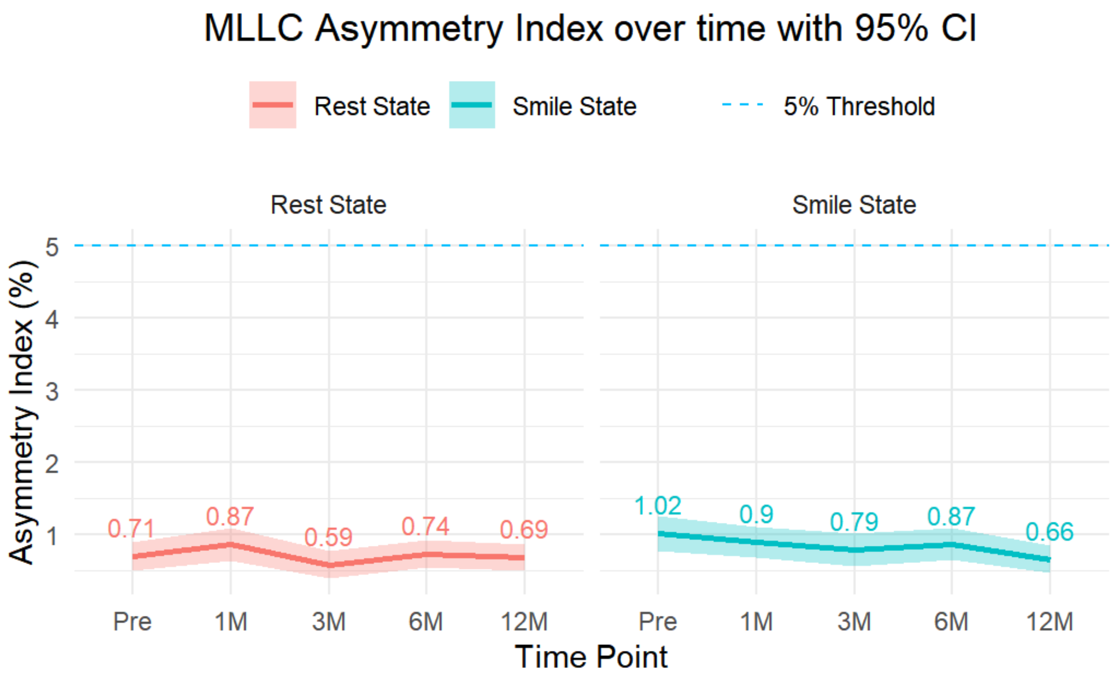

Figure 6. Asymmetry Index of midline to lateral canthi (MLLC) with 95% confidence interval of rest and smile state at pre-surgery and post- surgery.

Table 6. Mean (±SD) of midline to lateral alar margin (MLLAM) of rest and smile state at pre-surgery and post- surgery.

Dynamic Analysis	Pre - surgery	1 month post-surgery	3 months post-surgery	6 months post-surgery	12 months post-surgery	p value
Rest state	3.48 (±2.57)	3.28 (±2.39)	3.17 (±1.87)	3.18 (±2.04)	3.60 (±2.31)	0.840+
Smile state	2.95 (±2.25)	3.64 (±2.59)	2.90 (±2.31)	3.08 (±2.03)	3.36 (±2.39)	0.424+
p value	0.057++	0.253++	0.258++	0.543++	0.431+++	

p value was calculated using Friedman test (+), Wilcoxon signed-rank test (++) and Paired t-test (+++).

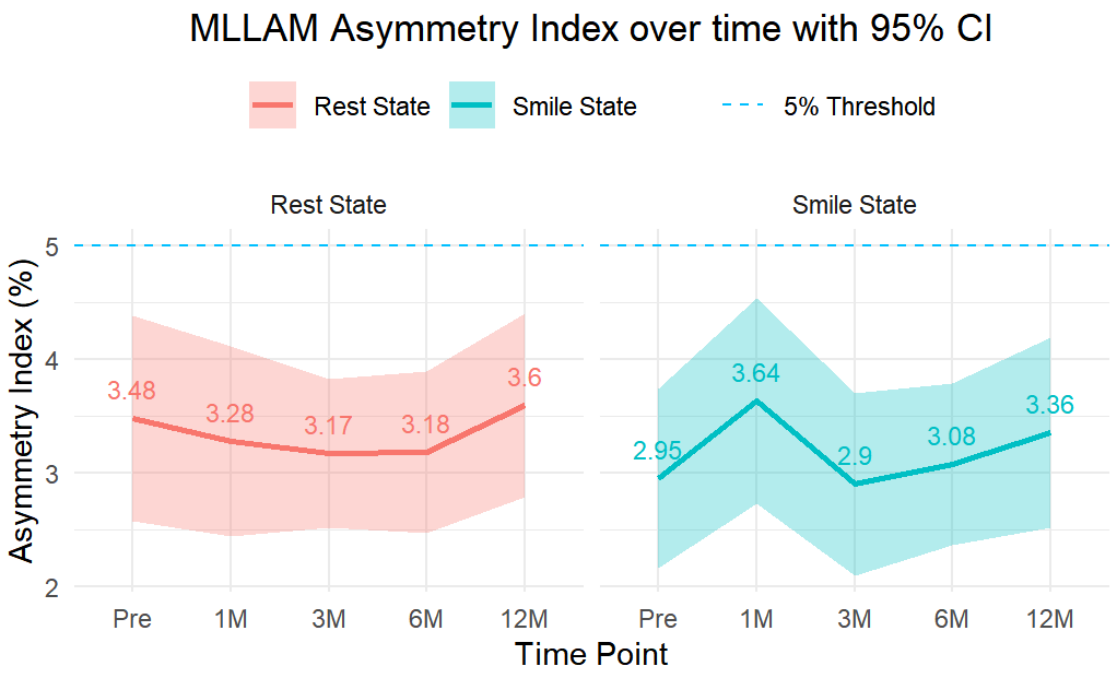

Figure 7. Asymmetry Index of midline to lateral alar margin (MLLAM) with 95% confidence interval of rest and smile state at pre-surgery and post- surgery.

Table 7. Mean (±SD) of midface width of rest and smile state at pre-surgery and post- surgery.

p value was calculated using Friedman test (+), Wilcoxon signed-rank test (++) and Paired t-test

Dynamic Analysis	Pre - surgery	1 month post-surgery	3 months post-surgery	6 months post-surgery	12 months post-surgery	p value
Rest state	1.88 (±1.63)	1.55 (±1.34)	1.72 (±1.28)	2.00 (±1.39)	1.37 (±1.12)	0.466+
Smile state	1.95 (±1.66)	1.78 (±1.29)	2.07 (±1.24)	2.21 (±1.41)	1.57 (±1.28)	0.600+
p value	0.343++	0.388++	0.138++	0.294+++	0.317++	

(+++).

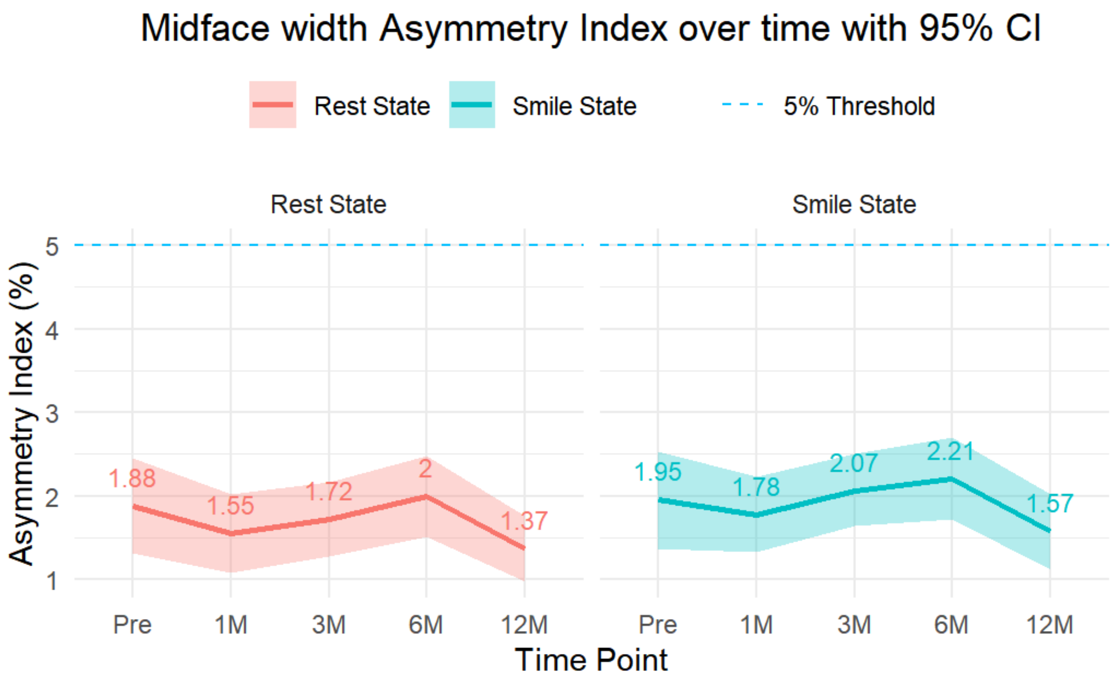

Figure 8. Asymmetry Index of midface width with 95% confidence interval of rest and smile state at pre-surgery and post- surgery.

Table 8. Mean (±SD) of midline to oral commissure (MLOC) of rest and smile state at pre-surgery and post- surgery.

Dynamic Analysis	Pre - surgery	1 month post-surgery	3 months post-surgery	6 months post-surgery	12 months post-surgery	p value
Rest state	10.69 (±6.62) a	5.04 (±4.09) b	4.10 (±3.81) b	4.88 (±4.09) b	5.13 (±3.50) b	<0.001*
Smile state	7.48 (±4.87) a	4.51 (±3.76) b	4.43 (±3.28) b	4.50 (±3.25) b	4.73 (±3.05) b	0.006*
p value	<0.001+++	0.228++	0.437++	0.499++	0.246++	

p value was calculated using Friedman test and pairwise comparisons with Wilcoxon signed-rank test with Holm correction (*), Wilcoxon signed-rank test (++) and Paired t-test (+++).

Different lowercase letters indicate statistically significant differences in the comparisons of evaluation time according to each state (row comparison).

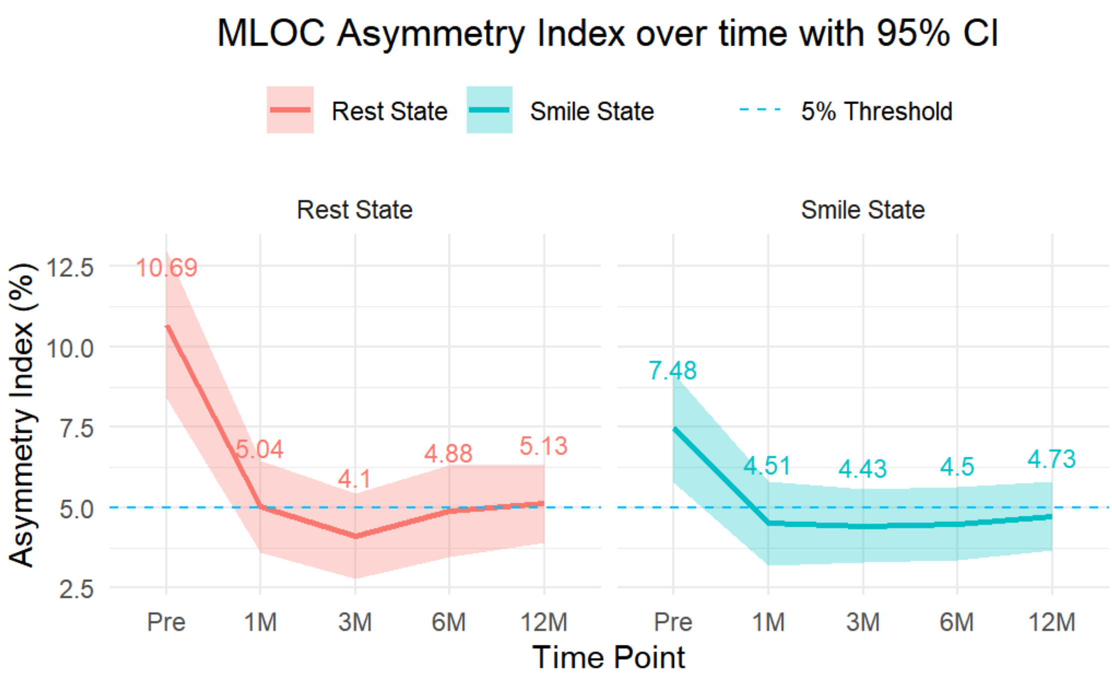

Figure 9. Asymmetry Index of midline to oral commissure (MLOC) with 95% confidence interval of rest and smile state at pre-surgery and post- surgery.

Table 9. Mean (±SD) of mandible width of rest and smile state at pre-surgery and post- surgery.

p value was calculated using Friedman test (+), Friedman test and pairwise comparisons with

Dynamic Analysis	Pre - surgery	1 moth post-surgery	3 months post-surgery	6 months post-surgery	12 months post-surgery	p value
Rest state	4.10 (±3.44) a	2.50 (±2.15) b	2.52 (±1.82) ab	2.78 (±2.20) ab	2.55 (±1.82) b	0.004*
Smile state	3.36 (±2.87)	2.50 (±2.06)	2.46 (±1.95)	2.67 (±1.95)	2.47 (±1.92)	0.523+
p value	0.010++	0.893++	0.577++	0.554++	0.388++	

Wilcoxon signed-rank test with Holm correction (*) and Wilcoxon signed-rank test (++).

Different lowercase letters indicate statistically significant differences in the comparisons of evaluation time according to each state (row comparison).

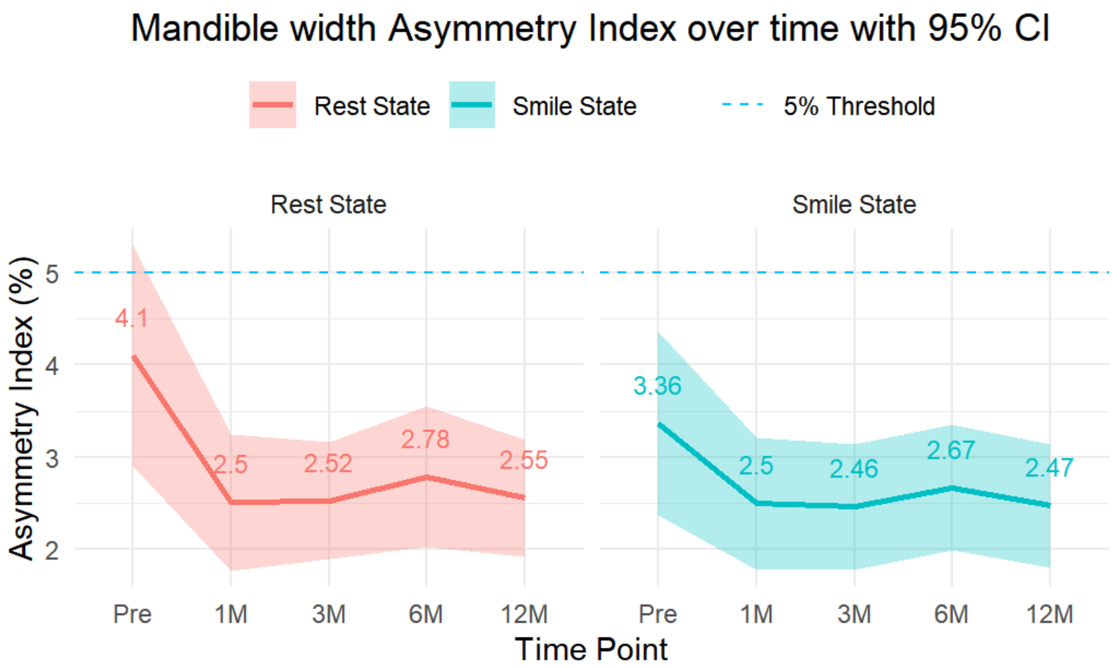

Figure 10. Asymmetry Index of mandible width with 95% confidence interval of rest and smile state at pre-surgery and post- surgery.

Table 10. Mean (±SD) of midline to median tubercle (MLMT) of rest and smile state at pre-surgery and post- surgery.

Dynamic Analysis	Pre - surgery	1 moth post-surgery	3 months post-surgery	6 months post-surgery	12 months post-surgery	p value
Rest state	1.46 (±1.02) ab	1.00 (±0.73) a	0.75 (±0.66) b	0.85 (±0.86) b	0.97 (±0.76) a	< 0.001*
Smile state	1.49 (±1.11) ab	1.17 (±1.07) a	0.98 (±0.78) a	0.88 (±0.81) b	0.93 (±0.77) b	0.006*
p value	0.915++	0.194++	0.181++	0.992++	0.688++	

p value was calculated using Friedman test and pairwise comparisons with Wilcoxon signed-rank test with Holm correction (*), Wilcoxon signed-rank test (++) and Paired t-test (+++).

Different lowercase letters indicate statistically significant differences in the comparisons of evaluation time according to each state (row comparison).

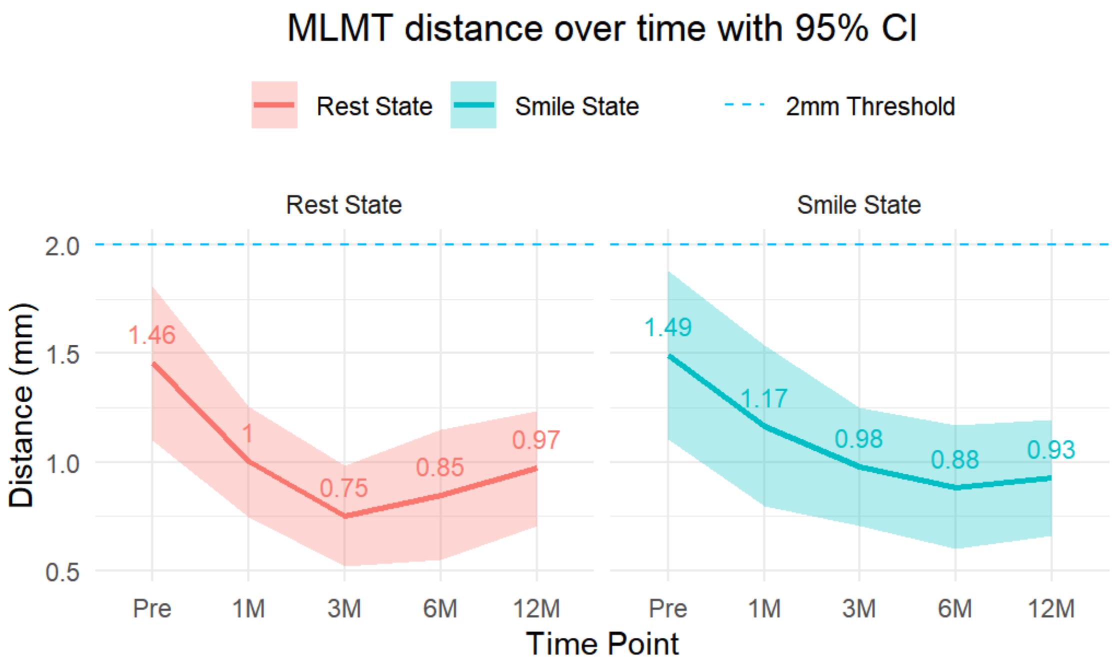

Figure 11. Mean distance of midline to median tubercle (MLMT) with 95% confidence interval of rest and smile state at pre-surgery and post- surgery.

Table 11. Mean (±SD) of midline to menton (MLM) of rest and smile state at pre-surgery and post- surgery.

Dynamic Analysis	Pre - surgery	1 moth post-surgery	3 months post-surgery	6 months post-surgery	12 months post-surgery	p value
Rest state	4.06 (±2.89) a	1.56 (±1.08) b	1.42 (±1.03) b	1.33 (±1.08) b	1.42 (±1.11) b	< 0.001*
Smile state	4.03 (±2.89) a	1.59 (±1.04) b	1.49 (±1.08) b	1.38 (±1.14) b	1.41 (±1.16) b	< 0.001*
p value	0.488++	0.853++	0.343++	0.379++	0.960++	

p value was calculated using Friedman test and pairwise comparisons with Wilcoxon signed-rank test with Holm correction (*) and Wilcoxon signed-rank test (++).

Different lowercase letters indicate statistically significant differences in the comparisons of evaluation time according to each state (row comparison).

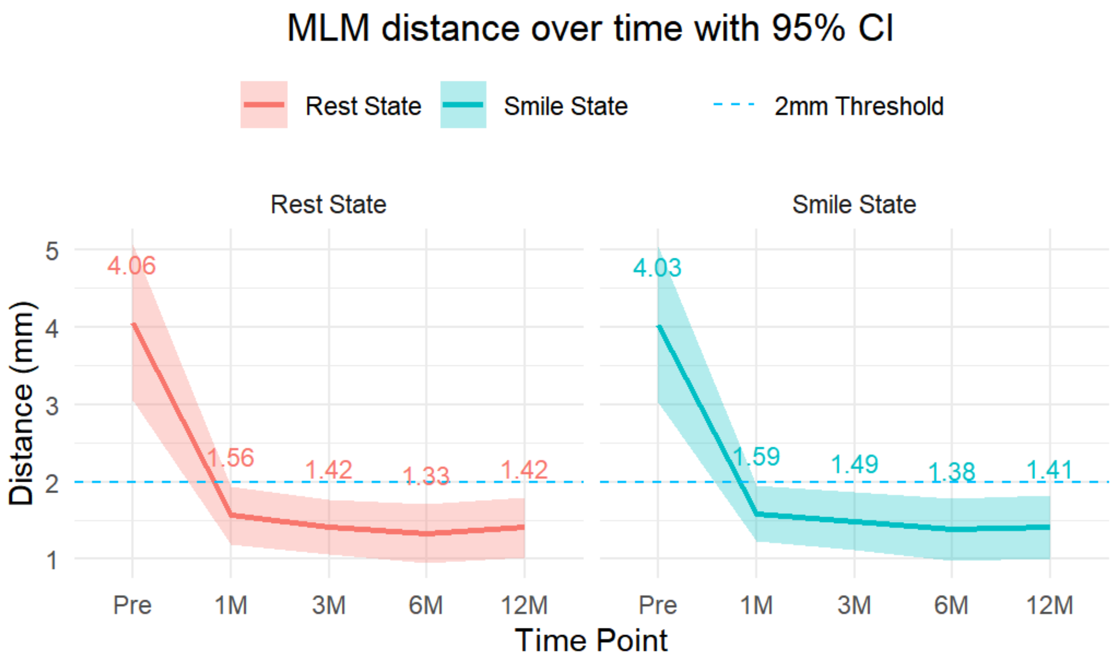

Figure 12. Mean distance of midline to menton (MLM) with 95% confidence interval of rest and smile state at pre-surgery and post- surgery.

Table 12. Mean (±SD) of angle of oral commissure of rest and smile state at pre-surgery and post- surgery.

Dynamic Analysis	Pre - surgery	1 moth post-surgery	3 months post-surgery	6 months post-surgery	12 months post-surgery	p value
Rest state	2.11 (±1.30) a	1.03 (±0.93) b	0.84 (±0.80) c	0.78 (±0.85) c	0.71 (±0.82) c	< 0.001*
Smile state	1.73 (±1.11) a	1.52 (±1.44) b	0.99 (±0.78) c	1.04 (±0.72) bc	1.22 (±0.91) bc	0.046*
p value	0.128+++	0.041++	0.912++	0.072++	0.006++	

p value was calculated using Friedman test and pairwise comparisons with Wilcoxon signed-rank test with Holm correction (*), Wilcoxon signed-rank test (++) and Paired t-test (+++).

Different lowercase letters indicate statistically significant differences in the comparisons of evaluation time according to each state (row comparison).

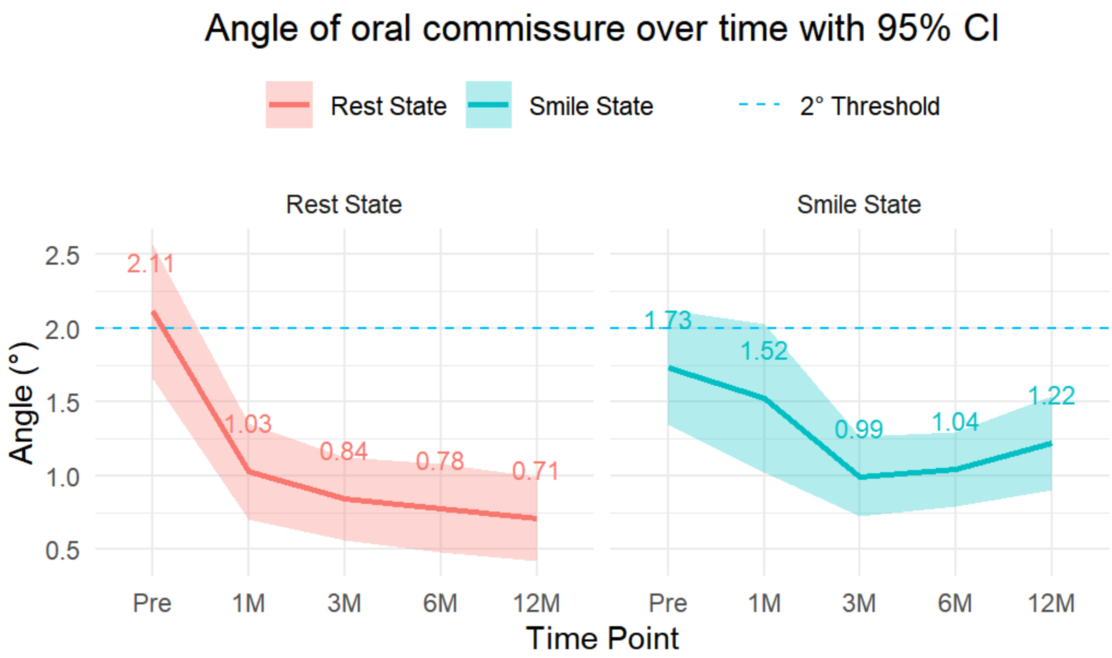

Figure 13. Mean angle of oral commissure with 95% confidence interval of rest and smile state at pre-surgery and post- surgery.

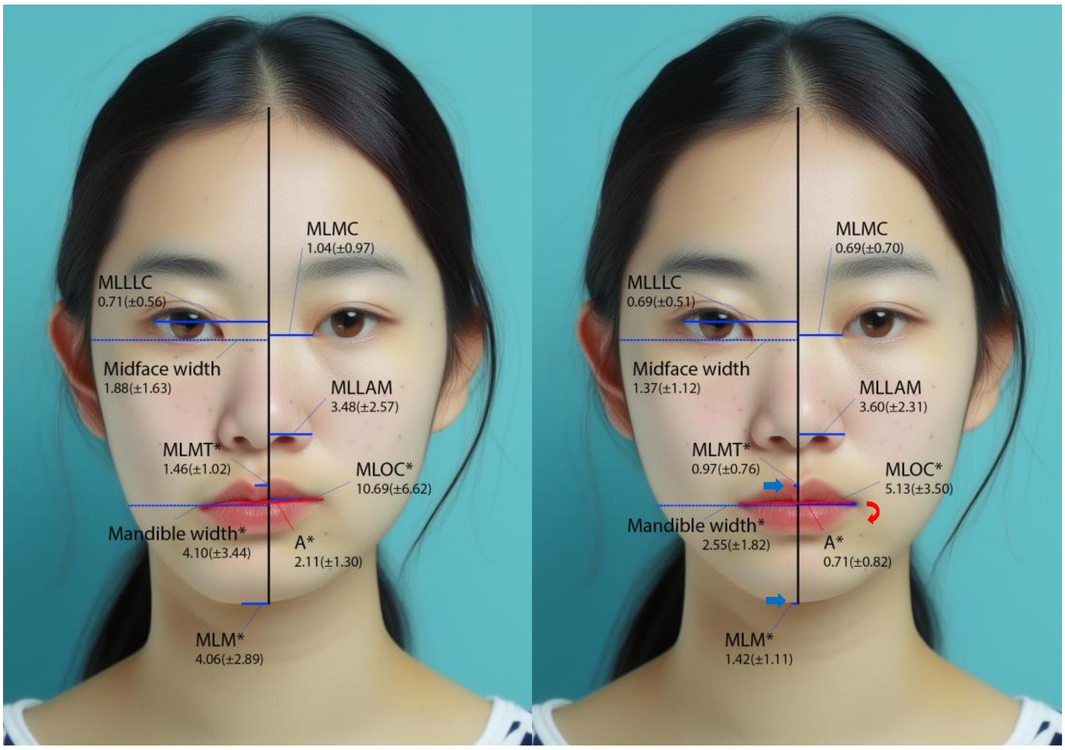

Figure 14. Conclusion figure in the rest state (pre-surgery and 12 months post-surgery)

*p<0.05

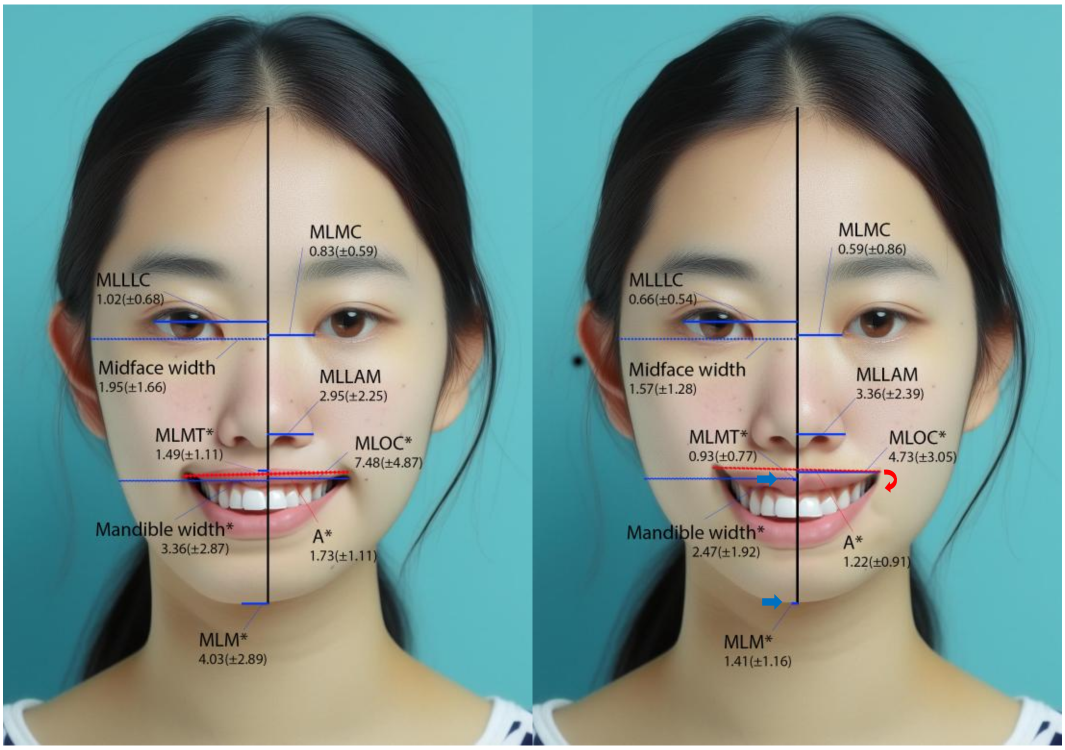

Figure 15. Conclusion figure in the smile state (pre-surgery and 12 months post-surgery)

*p<0.05

IV. DISCUSSION

The findings of this study reveal a difference between mid-face and lower-face responses to 2-jaw with/without genioplasty orthognathic surgery. While no statistically significant changes were observed over time for mid-face measurements (MLMC, MLLC, MLLAM, and midface width) in either rest ($p>0.05$) or smile states ($p>0.05$), the lower-face measurements (MLOC, mandible width, MLMT, MLM, and the angle of oral commissure) showed significant improvements across all post-surgical time points ($p<0.05$). This suggests that orthognathic surgery has a more pronounced and measurable impact on lower facial symmetry, particularly in areas directly influenced by mandibular repositioning, compared to the relatively stable mid-face region. These findings emphasize the importance of region-specific analysis when evaluating surgical outcomes in facial asymmetry correction.

These results are also consistent with what was previously described in the literature where it was reported that the main anatomical site for presence of asymmetries was lower face compared to upper and mid-face regions[19)]. Furthermore, due to the functional and aesthetic importance of the lower face, these results support the use of objective symmetry indices to guide surgical planning and post-surgery evaluations.

Additionally, when evaluating the changes over time, for both rest and smile state, pre-surgical values were significantly higher in the lower face landmarks (MLOC, mandible width, MLMT, MLM and angle of oral commissure), reflecting the baseline facial imbalance in the patients before surgical correction. The most notable improvement in facial asymmetry happened between 3 and 6 months post-surgery. This pattern was observed across some lower facial landmarks, such as MLMT and the angle of oral commissure.

However, for mandible width, despite the numerical reduction of asymmetry index in the rest state from pre-surgery to post-surgery, the non-parametric Wilcoxon test did not detect statistical significance between pre-surgery and 3 or 6 months post-surgery. This is likely due to intra-subject variability; although the pre-surgical mean was higher, large variability and the lack of consistent paired differences reduced the likelihood of detecting statistical significance. Nevertheless, these results showing a reduction in values following orthognathic surgery suggest that the surgical treatment effectively addressed skeletal and soft tissue discrepancies.

The peak improvements after 3 and 6 months post-surgery may be linked to the resolution of post-surgical swelling and soft tissue adaptation, allowing for a more stable and symmetrical appearance. By 12 months post-surgery, swelling is mostly resolved, so the values tended to stabilize, indicating that the effects of surgical treatment are maintained over time[7)]. In general, the persistence of significant improvements in both rest and smile states highlights the long-term aesthetic benefit of orthognathic surgery, not only in static but also in dynamic facial expression. So, these findings suggest that 3 to 6 months post-surgery may represent a critical period for facial remodelling and soft tissue settling.

However, when evaluating MLMT in the rest state ($p<0.001$), the 3- and 6-month post-surgery values presented significantly smaller distances compared to the other time points, whereas the pre-surgery value and those at 1- and 12-months post-surgery were statistically similar. These findings could be partially explained by the fact that, although orthognathic surgery can improve symmetry, changes in soft tissue do not always reflect the repositioning of the underlying bone[10,11,20,21)]. Besides, as concluded by Yamaguchi et al., the mouth often stays higher on the symmetrical affected side even after the surgical correction of the bones[9)]. This discrepancy may influence the position of the lips, particularly during the early healing phase post-surgery.

There was a statistical difference between rest state and smile state in the asymmetry index pre-surgery for MLLC ($p=0.033$), MLOC ($p<0.001$) and mandible width ($p=0.010$), as well as at 1 month ($p=0.041$) and 12 months post-surgery ($p=0.006$) for the angle of oral commissure. These results suggested that the mentioned measurement points are involved and highly affected by dynamic movement. The significant difference observed between rest and smile states could be due to behavioural adaptations and neuromuscular factors. Patients may hesitate or suppress their smiles due to a lack of confidence, which can be caused by self-consciousness caused by their dento-facial asymmetry[22)]. Also, smile asymmetry can develop due to imbalances in muscle tonicity on both sides of the face[1,23)]. Thus, the contrast between rest and smile states reflects asymmetry's anatomical and functional components, highlighting the importance of dynamic analysis in surgical evaluation and outcome assessment.

Although there is no standardised threshold for asymmetry indices, and values may vary depending on the type of evaluation, Bharti et al. classified values between 3% and 5% as mild asymmetry and proposed 6% as the threshold of subclinical facial asymmetry[15]. Similarly, Lee et al. reported an asymmetry index of 5.98% (±4.45) for MLLAM and 5.19% (±4.41) for MLOC[13]. On the other hand, Masuoka et al. reported that an asymmetry index of 3.96% for the midline to gonial angle, evaluated on posteroanterior cephalograms, marked the limit between patients with minimal asymmetry not requiring treatment and those with more symmetrical profiles[24]. However, Masuoka et al. found that a mean value of 2.33% for the same measurement was sufficient for orthodontists to classify patients as having marked asymmetry requiring treatment[25]. Meanwhile, Abassi et al. reported mean asymmetry indices of 3.66% for MLAM and 3.11% for MLOC based on photographic evaluation in the smile state[1]. Based on these findings, a 5% threshold was adopted in the present study as a practical upper boundary for mild or perceptible asymmetry.

In this study, a threshold of 2 mm was used to define asymmetry in the distance from MLMT, as previously reported[16,17]. Wang et al. concluded that a deviation of 2 mm or less between the labial tubercle and the facial midline was considered acceptable. In their study, a Q-sort assessment was conducted in which frontal photographs were evaluated by dentists, orthodontic patients, and first-year dental students[16]. Likewise, a 2 mm threshold was applied to MLM to assess soft tissue menton deviation, as this value has been reported to be clinically acceptable[17, 18]. In addition, a threshold of 2˚ was used for oral commissure angle value, as Lee et al. reported a mean of 1.27˚ in symmetrical individuals, indicating that values above 2˚ may be perceptible and outside the normal range[13].

The high intra-observer reliability and longitudinal design, which captured changes across multiple standardized time points over a one-year follow-up period, strengthened this study. Similarly, the use of strictly standardized clinical photographs ensured consistency between time point evaluations.

Nonetheless, a major limitation of this study is the high number of patient exclusions. Of the 266 patients initially considered, 232 were excluded due to unregistered ICD, incomplete photographic documentation, or insufficient forehead exposure in the photographs. A comparison between the excluded and included patients revealed no significant demographic or clinical differences. However, the large proportion of excluded cases may introduce a risk of selection bias, and it could limit the generalizability of our findings. Another limitation was the use of two-dimensional digital photographs, which may not fully capture the complexity of volumetric changes in facial asymmetry. Therefore, future research with more complete data collection and the use of three-dimensional imaging technologies are needed to validate these results. And, to assess the correlation between soft and hard tissue symmetry, future studies should incorporate 3D facial soft tissue scans alongside hard tissue imaging like CT scans. Additionally, integrating patient-reported outcomes could help to evaluate the correlation between facial asymmetry perception and objective evaluation of facial asymmetry.

V. CONCLUSIONS

1. This study demonstrated that orthognathic surgery has a significant effect on improving facial asymmetry, particularly in the lower face. While mid-face values remained relatively stable over time, lower-face values (MLOC, mandible width, MLMT, MLM, and the angle of the oral commissure) showed statistically significant improvements.
2. The results of this study suggested that the period between 3 and 6 months after surgery may be crucial for facial remodelling and soft tissue stabilization.
3. The differences found between static and dynamic states emphasize the influence of neuromuscular and behavioural factors, supporting the importance of dynamic assessments into pre surgical diagnosis and outcome evaluations.

The high intra-observer reliability, standardized imaging protocol, and longitudinal design strengthen the validity of the results. However, limitations include a relatively small sample size and the use of two-dimensional imaging. Future studies should consider three-dimensional imaging techniques and include patient-reported outcomes to compare objective evaluation and subjective satisfaction.

Ultimately, this study supports the effectiveness of orthognathic surgery in achieving long-term aesthetic improvements and provides a framework for evaluating surgical outcomes using objective and dynamic facial asymmetry indices.

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ABSTRACT IN KOREAN

악교정 수술 후 얼굴 비대칭의 종적 변화: 안정 및 미소 상태 전면 사진을 활용한 정량 분석

본 연구는 악교정 수술 전과 수술 후 1 개월, 3 개월, 6 개월, 12 개월 시점에서 환자의 얼굴 비대칭을 객관적으로 평가하고 비교하는 것을 목적으로 하였다. 악교정 수술의 주요 목적은 수술을 통한 교합 회복이지만, 얼굴 비대칭과 관련된 심미적 결과는 환자와 외과의 모두에게 중요한 관심사이기 때문이다.

연세대학교 치과대학병원에서 수집된 환자 34 명의 전면 디지털 사진(안정 시 n=170, 사회적 미소 시 n=170)을 분석하였다. 사진은 수술 전과 수술 후 1 개월, 3 개월, 6 개월, 12 개월의 시점에서 촬영되었다. 측정의 일관성을 위해 동공을 연결한 수평 기준선과 내안각 거리(ICC)를 기준으로 한 mid-glabella 를 통과하는 수직선을 기준으로 되어 사진을 조정하였다.

중심선으로부터 주요 안면 지표까지의 여섯 가지 거리—내안각(MLMC), 외안각(MLLC), 비익 외측 경계(MLLAM), 구각(MLOC)—를 측정하였다. 또한, 중안면 폭과 하악 폭도 평가하였다. 비대칭 지수는 좌우 값의 절대 차를 그 합으로 나누어 계산되었다. 중심선에서 중앙 결절(MLMT)과 연조직 Menton (MLM)까지의 거리, 그리고 구각선을 수평 기준선과 이루는 각도(A)도 평가하였다.

중안면부 계측치(MLMC, MLLC, MLLAM, midface width)는 이완 상태와 웃음 상태 모두에서 시간 경과에 따른 유의한 차이를 보이지 않았다($p>0.05$). 반면, 하안면부 계측치(MLOC, mandible width, MLMT, MLM, A)는 시간에 따른 유의한 차이를 나타냈다($p<0.05$). MLOC 와 MLM 은 수술 전 시점에서 수술 후 시점들에 비해 비대칭 지수가 유의하게 높게 나타났다. MLMT 는 이완 상태에서 수술 후 3 개월 및 6 개월 시점에서 유의하게 감소된 거리를 보였다. 이완 상태에서의 구각 각도는 수술 전 및 수술 후 1 개월 시점에 비해 수술 후 3 개월, 6 개월, 12 개월 시점에서 유의한 개선을 보였다. 또한, 여러, 시점에서 이완 상태와 웃음 상태 간의 유의한 차이가 관찰되었으며, 특히 수술 전 시점에서 두드러졌다($p<0.05$).

악교정 수술은 안면 비대칭을 효과적으로 개선하며, 특히 하안면에서 기능적 및 심미적 향상을 동시에 달성한다. 정확하고 표준화된 계측 방법과 정적 및 동적 평가의 병행은 수술 결과를 평가하고 환자의 만족도를 높이는 데 매우 중요하다.

핵심어: 얼굴 비대칭, 악교정 수술, 사진 분석, 비대칭 지수