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Evaluation of facial soft tissue asymmetric changes in Class III patients after orthognathic surgery using three-dimensional stereophotogrammetry

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Abstract. The aim of this study was to investigate changes in facial soft tissue asymmetry over time after orthognathic surgery in Class III patients using three-dimensional stereophotogrammetry. The study included 101 patients with a skeletal Class III malocclusion (72 female, 29 male; age range 19–53 years, mean age 28.6 years) who underwent orthognathic surgery. The minimum follow-up was 12 months. Three-dimensional photographs were acquired using the 3dMDtrio stereophotogrammetry system, and 21 anthropometric landmark positions were evaluated at three time points: before surgery (T0), 6 months (T1) and 12 months (T2) after surgery. Facial asymmetry was assessed and classified as follows: 0–2 mm, mild; 2–5 mm, moderate; > 5 mm, severe. The average distance for whole face asymmetry differed between T0 (median 0.76 mm) and T1 (median 0.70 mm); however, there was no statistically significant difference at any time point. The chin volume asymmetry score differed significantly between T0 (median 1.11 mm) and T1 and T2 (median 1.08 mm for both; $P < 0.001$ and $P = 0.001$, respectively), but not between T1 and T2 ($P = 0.061$). The study findings indicate that the asymmetry of the facial soft tissues has the potential to return after 6 months, without reaching the baseline.

Keywords: Stereophotogrammetry; Facial asymmetry; Orthognathic surgery; Angle Class III; Orthodontics; Malocclusion.

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The appearance of the face, an important factor for humans, affects self-esteem and psychological and social wellbeing.[1] Nowadays, even slight asymmetry may lead to patient dissatisfaction due to increasing concerns regarding facial appearance.[2,3] Perfect symmetry of the craniofacial tissues does not exist and there is biological variation.[1,4] Asymmetry can be caused by many factors,[5] and often the aetiology remains unknown.[6] The

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prevalence of facial asymmetry varies from 21% to 85%.[7] Chin deviation is the most significant feature and is more frequent with lateral guidance of the occlusion.[6] Notably, the lower third of the face is more asymmetric because the mandible has a longer period of growth than the maxilla,[5] and any type of malocclusion increases the possibility of an asymmetric face.[8] Indeed, 28% of Class II patients and 40% of Class III patients have facial asymmetry.[8]

Accurate correction of facial asymmetry remains challenging[6]. Orthognathic surgery can improve jaw discrepancies, facial symmetry, and aesthetics.[8–10] Nowadays, surgeons give more attention to the external soft tissue profile and improvements in the diagnostics of facial symmetry.[10,11] There is a need to quantify and evaluate the asymmetry of the face before, during, and after surgical treatment and during the follow-up period.[8,10,12]

There are individual variations in the soft tissue response after surgery, affecting the symmetry.[13] This variation is complex[5] and may depend on factors such as differences in morphology and elasticity, and variations in soft tissue thickness, muscular tone,[13] skeletal movement size, and surgical technique.[14] Immediately after orthognathic surgery, the response of the facial soft tissue is set by the capacity of the inflammatory response. During the first 6 months post-surgery, there is huge individual variation in soft tissue swelling.[14,15] The morphology of the face recovers by 83–90% after 3 months.[11,16,17]

Anthropometry is a science that developed in the 19th century18. Three-dimensional (3D) imaging device technology has improved measurement accuracy.[8,19] Presently, the gold standard method for measurement is 3D stereophotogrammetry,[11] which can be used for documentation, treatment planning, and the analysis of 3D changes in the craniofacial complex throughout the long-term treatment process.[2,18,20,21] However, there are limited reports on precise soft tissue changes and long-term follow-up after orthognathic surgery in Class III patients,[14,22] and the results of these studies are inconsistent due to different methodologies and materials. Moreover, these studies mainly focused on immediate and short-term (< 6 months) changes. Therefore, the aim of this study was to investigate the changes in facial soft tissue asymmetry at least 12 months after orthognathic surgery in Class III patients using 3D stereophotogrammetry.

Materials and methods

Study design and sample

This prospective, longitudinal cohort study recruited healthy White European patients with a skeletal Class III malocclusion. All patients underwent orthodontic treatment together with orthognathic surgery between 2011 and 2018 in the Department of Orthodontics, Institute of Stomatology, Rīga Stradiņš University (Riga, Latvia). The minimum follow-up for these patients was 12 months.

All orthognathic surgeries were performed by three experienced oral and maxillofacial surgeons. The type of orthognathic surgery was determined by clinical findings and was either bimaxillary surgery (i.e. Le Fort I osteotomy (LFI) in combination with a bilateral sagittal split osteotomy (BSSO) or vertical ramus osteotomy) or single jaw surgery (i.e. LFI or BSSO).

Facial asymmetry was evaluated using mirror-to-original shell images at three time points: before surgery (T0), 6 months after surgery (T1), and 12 months after surgery (T2). Changes between these three time points were investigated according to sex, type of surgery, facial region (whole face, as well as upper, middle, and lower facial regions), and deviation of the pogonion point (Pogo). Asymmetric changes in the facial soft tissue were not compared with the amount of skeletal movement.

Ethical considerations and study registration

This study was performed in accordance with the guidelines of the Ethics Committee of Rīga Stradiņš University (RSU 26.04.2012). The guidelines and criteria of the Declaration of Helsinki and Current Controlled Trials were followed (ISRCTN registry, ISRCTN26961096). Participation was voluntary, data confidentiality was ensured, and every patient provided informed consent.

Inclusion and exclusion criteria

This study included patients with a skeletal Class III malocclusion; no history of trauma, maxillofacial surgery, or recognized craniofacial syndromes as aetiological factors; preoperative and postoperative orthodontic treatment; and 3D facial images obtained at all three time points.

Exclusion criteria were as follows: patients with a cleft or other craniofacial anomalies or syndromes; patients who did not have a 3D image at one or more time points; patients with beards and/or moustaches at any time point; patients with one distorted 3D image.

Stereophotogrammetry system and image acquisition

Images for all of the involved patients were acquired using the 3dMDtrio stereophotogrammetry system (3dMD LLC, Atlanta, GA, USA) to assess facial soft tissue dimensions. 3D photographs were recorded at T0, T1, and T2.

Patients were seated on an adjustable chair and asked to adopt a neutral facial expression, with teeth in loose contact. They were recommended to keep their head in a natural position, as described previously.[21] The 3dMD system recorded the head and neck areas. If the participant moved during shooting, the procedure was repeated. Two experienced and trained photographers took all images.

After the acquisition process, all of the scanned images were saved on a computer using 3dMDvultus version 2.5.0.1 (3dMD LLC) and were processed in 3dMD Patient version 4.1 (3dMD LLC). In this program, the 3D image contour was manually refined by removing the peripheral areas. The confounding regions, such as the hairline, ears, neck, and shoulders, were removed because they are vulnerable to errors and can affect asymmetry quantification.

Quantification of asymmetry

The acquired images were loaded into 3dMDvultus version 2.5.0.1. (3dMD, LLC) and analysed from all angles using the facial shell on the computer screen. The program ensures the evaluation of linear and angular distances and measures surface distances, surface areas, and volumes.[19]

The 21 anthropometric landmarks were digitally marked on each 3D facial surface at three time points by one operator (Fig. 1). Each landmark position was determined in three coordinates (x, y, and z). These landmarks were selected as described previously.[2,23,24] A detailed landmark list and definitions are provided in Supplementary Material Table S1.

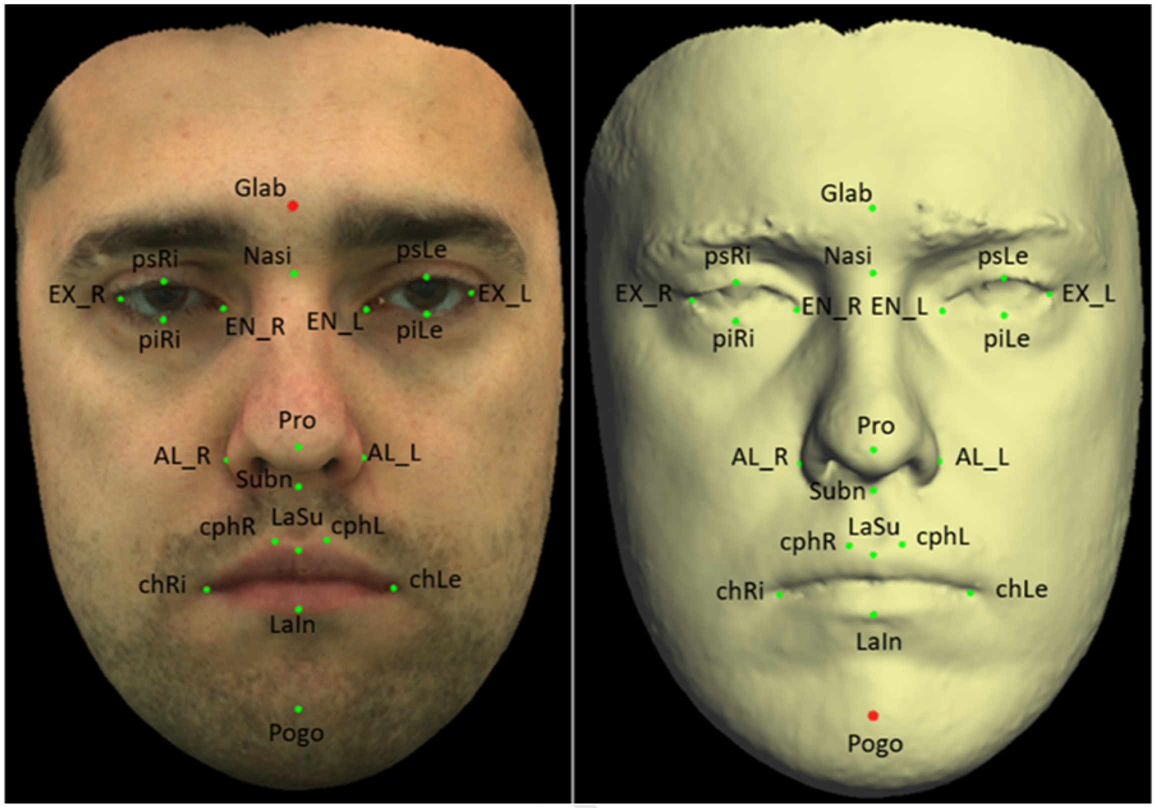

Fig. 1. Anthropometric landmarks on three-dimensional frontal images (colour and monochrome images; $n = 21$): Glab, glabella; Nasi, soft tissue nasion; En_R, right endocanthion; En_L, left endocanthion; Ex_R, right exocanthion; Ex_L, left exocanthion; psLe, left palpebrale superius; psRi, right palpebrale superius; piRi, right palpebrale inferius; piLi, left palpebrale inferius; Pro, pronasale; Subn, subnasale; AL_R, right nasal ala; AL_L, left nasal ala; LaSu, labrale superius; LaIn, labrale inferius; chRi, right cheilion; chLe, left cheilion; cphR, crista philtri right; cphL, crista philtri left; Pogo, soft tissue pogonion.

After calibration, all landmarks (seven paired and seven single points) were marked throughout the whole patient group. Facial asymmetry was determined quantitatively using 3D data for each patient with a mirroring approach.[2] Analyses were performed using Rapidform 2006 (Geomagic, Rock Hill, SC, USA). The face position was standardized as described previously.[25] For each patient, a mirror facial shell was generated and superimposed on the original surface (best-fit registration). Average and maximum distances were measured between the original and mirrored surfaces.[2,9,12,21,26,27] Each facial shell was divided into five regions (Fig. 2).

The chin volume asymmetry score (CVAS) was used to measure chin asymmetry from the 3D facial model28. The chin area was divided into two solid shapes and their volumes were calculated (Fig. 3). Asymmetry was quantified by the ratio of these volumes (CVAS), as described previously.[1] First, the chin region was separated from the face using two planes, so that the planes were close to the region. One plane was parallel to the coronal plane (XY plane) and passed through the posterior exocanthion point, and the other passed through the labrale inferius and was parallel to the transverse plane (XZ plane). The resulting closed 3D object was then divided into two parts by the sagittal plane, and the volume of these parts was calculated. The CVAS was defined as the larger volume divided by the smaller one.[28]

Linear parameters were used to analyse the horizontal facial symmetry. Patients were divided into three groups according to deviation of the pogonion point from the midsagittal plane at each of the three time points: 0–2 mm, mild asymmetry; 2–5 mm, moderate asymmetry; > 5 mm, severe asymmetry. Positive and negative distance values were to the left side and right side of the midsagittal plane, respectively.

Error of method analysis

The first stage of the study was to investigate the intra-operator repeatability of facial anthropometric landmark identification on the 3D images. A single operator performed the landmark identification and all measurements. The operator randomly selected a training sample of 30 facial surfaces and digitally marked the 21 landmarks. They were then re-measured under the same conditions after a 2-week interval following the initial measurement session. Landmark coordinates were collected from the software and saved in a table in Microsoft Excel. After data evaluation, they were statistically verified.[29]

Statistical analysis

All data were statistically analysed using R version 3.6.1 (R Foundation for Statistical Computing, Vienna, Austria).

Landmark coordinates were analysed using different statistical tests. The intra-class correlation coefficient (ICC) and 95% confidence interval (CI) were used to calculate the intra-operator reliability. Microsoft Excel was used to estimate the mean, median,

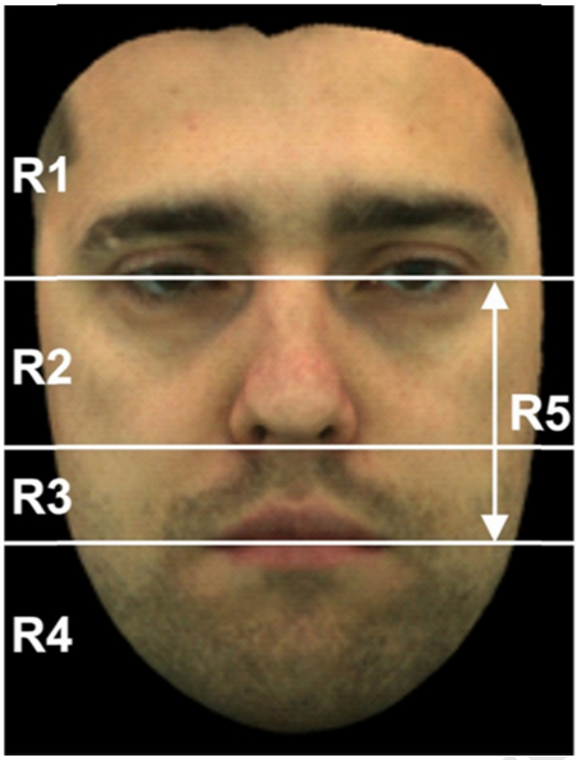

Fig. 2. The facial shell was divided into five regions: region 1 (R1), the part of the face above the mid-eye line; region 2 (R2), between subnasale (sn) and the mid-eye line; region 3 (R3), between the mid-lip line (chLe–chRi) and subnasale; region 4 (R4), the part of the face below the mid-lip line (chin zone); region 5 (R5), between the mid-lip line (chLe–chRi) and mid-eye line.

minimum, and maximum of landmark coordinates.

A descriptive analysis was used to evaluate differences between the groups, and the median, standard deviation, and interquartile difference were calculated. The Wilcoxon signed-rank test was used as a non-parametric statistical test. A P-value of < 0.05 was considered significant.

Every group was tested with the Lilliefors test to determine whether data were normally distributed (normality test) based on the Kolmogorov–Smirnov test. The normality test was theoretically acceptable but was not consistent with a normal distribution between the time periods (e.g., T0, but not T1 and/or T2).

Results

A total of 158 patients with a skeletal Class III malocclusion who underwent orthodontic and orthognathic surgery at the Institute of Stomatology, Rīga Stradiņš University between 2011 and 2018 agreed to participate in this study; 57 (36.3%) of these patients were excluded (Fig. 4). The remaining 101 patients (72 (71.3%) female, 29 (28.7%) male; age range 19–53 years, mean age 28.6 years) fulfilled the predefined criteria and were included in further 3D image analysis (Table 1). Regarding the type of orthognathic surgery performed, 79 (78.2%) patients underwent bimaxillary surgery, 21 (20.8%) underwent LFI alone, and one (1.0%) patient underwent BSSO.

Landmark accuracy

The mean difference in landmark error was 0.33 mm (range 0.14–0.59 mm). The statistical intra-operator repeatability of facial anthropometric landmarks ranged from 0.859 to 0.998. Landmarks with ICC values between 0.8 and 0.89 ('good' reliability) were found on the *x*-axis (four of 21 landmarks): LaSuX (0.878), PogoX (0.859), SubnX (0.862), and LalnX (0.898); all other landmarks were indicative of excellent reliability (≥0.90). The 95% CI ranged from 0.704 to 0.997, indicating no significant difference in the accuracy of landmark positions between the operator's measurements obtained with a 2-week interval.

Primary outcome

Analysis of the whole face asymmetry showed a difference in the average distance between T0 (median 0.76 mm) and T1 (median 0.70 mm) (Fig. 5). However, no statistically significant difference was found at any time point. The maximum distance for the whole face showed a statistically significant difference between T0 (median 3.26 mm) and both T1 (median 2.82 mm; $P = 0.001$) and T2 (median 2.91 mm; $P = 0.018$) (Table 2).

Subgroups

Statistically significant facial asymmetries were found in all regions of the face. The regions with the largest differences were regions 3, 4, and 5 (Table 2). Region 4 showed a statistically significant difference in average distance between T0 (median 1.35 mm) and T1 (median 0.99 mm) ($P = 0.006$), and between T0 and T2 (median 1.06 mm) ($P = 0.023$) (Fig. 6).. A higher asymmetry appeared particularly in the lower and middle regions (region 4: maximum distance 3.24 mm, interquartile range (IQR) 2.08–4.69 mm; region 3: maximum distance 2.48 mm, IQR 1.95–3.17 mm).

No statistically significant differences in asymmetry were found between the sexes at any time point and in any region of the face. The results for asymmetry showed a similar correlation in both groups (Table 3). Male faces had a higher soft tissue asymmetry than female faces before surgery, although this was not statistically significant (average distance T0: 0.95 mm in male patients vs 0.70 mm in female patients; $P = 0.253$).

The patients were divided into two groups according to the type of surgery performed to analyse the correlation between facial asymmetry and surgery type. No statistically significant differences in average distance or maximum distance were detected between the groups at any time point. The tendency for asymmetry was higher in the bimaxillary surgery group than in the single jaw surgery group, although the difference was not statistically significant. The maximum distance between these facial shells before surgery was 3.53 mm (IQR 2.60–4.85 mm) in the bimaxillary surgery group but only 2.53 mm (IQR 2.18–3.69 mm) in the single jaw surgery group (Table 4).

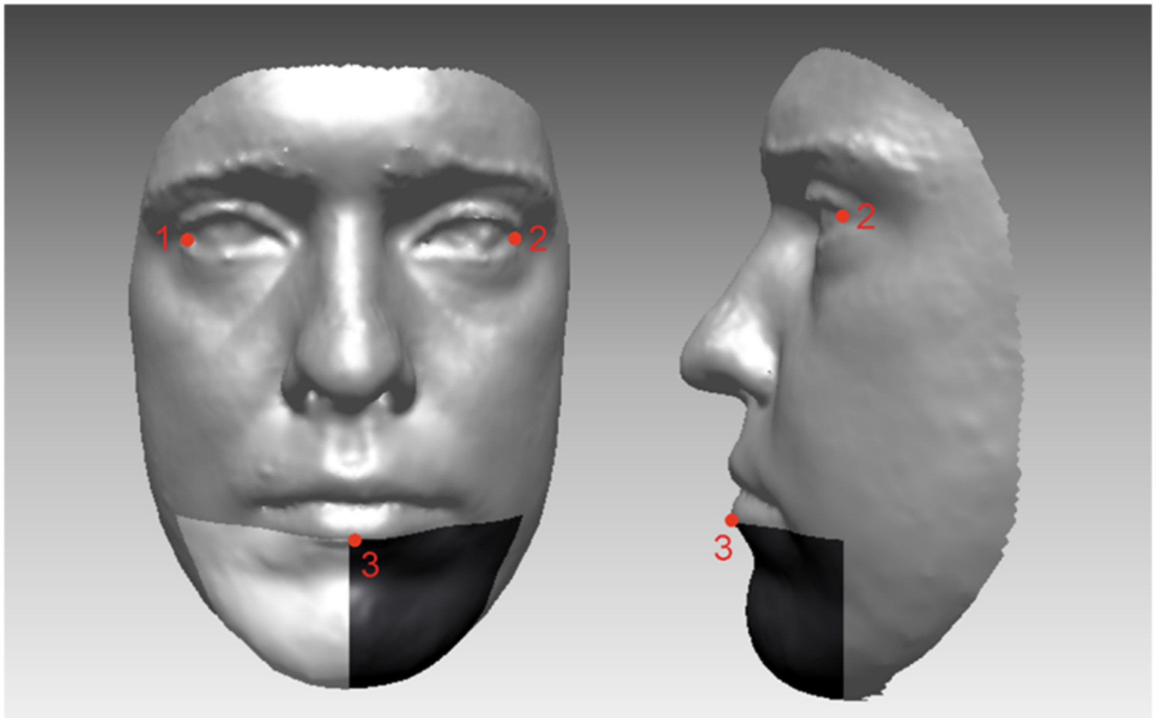

Fig. 3. Chin volume asymmetry score (CVAS). The chin region was separated from the face using two planes, with the planes close to the region: one plane parallel to the coronal plane (XY plane) and passing through the posterior exocanthion point, and the other plane passing through labrale inferius and parallel to the transverse plane (XZ plane). This closed 3D object was then divided into two parts by the sagittal plane, and the volume of these parts was calculated. The CVAS was defined as the larger volume divided by the smaller volume. 1: Ex_R, right exocanthion; 2. Ex_L, left exocanthion; 3. LaIn, labrale inferius.

Deviation of the pogonion point

The distribution of asymmetry groups varied between the time points. Fig. 7 shows the changes in patient numbers in each group across the three time points. There was an increase in the number of patients in the mild asymmetry group after surgery, suggesting that soft tissue asymmetry in the larger number of patients ranges from 0 to 2 mm. A statistically significant difference in average distance between T0 and T1 was observed in the moderate (2–5 mm) asymmetry group ($P = 0.03$) (Table 5). It was not possible to perform an analysis for the severe asymmetry group because of the small sample size.

Chin volume asymmetry score

The CVAS differed significantly between the three time points ($P < 0.001$) (Fig. 8). No significant difference in CVAS between the time points was found for male patients or patients

Table 1. Selected data and distribution of patients ($N = 101$).

Age (years)	
Range	19–53
Mean	28.6
Sex, *n* (%)	
Female	72 (71.3%)
Male	29 (28.7%)
Surgery type	
Bimaxillary	79 (78.2%)
Le Fort I	21 (20.8%)
BSSO	1 (1.0%)

BSSO, bilateral sagittal split osteotomy.

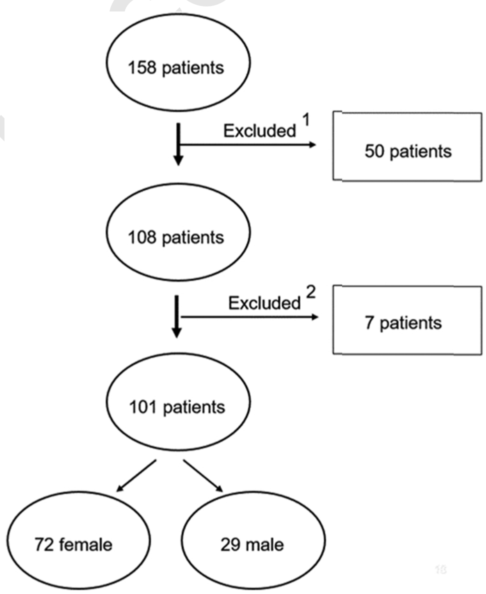

Fig. 4. Flowchart of patient enrolment and dropout. [1]Lack of images at any time point or images with defects. [2]One of three patient images could not be used due to image distortion by facial hair, which could lead to inaccurate data.

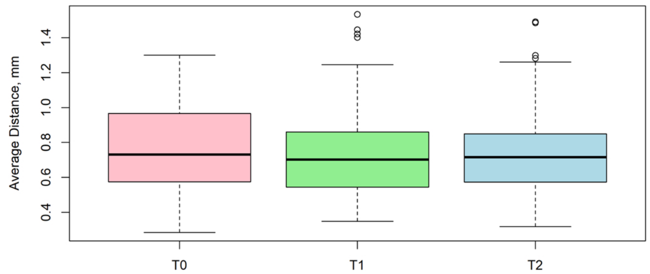

Fig. 5. Box plot of the average distance for the whole face at the three time points: before surgery (T0), 6 months after surgery (T1), and 12 months after surgery (T2). Data points that are outside the interval are represented as points on the graph and considered potential outliers. There are four potential outliers at T1 and the same at T2.

undergoing LFI (Table 6). However, female patients and patients undergoing bimaxillary surgery showed statistically significant differences in CVAS between T0 and T1 (female: $P = 0.022$; bimaxillary surgery group: $P = 0.004$) and between T0 and T2 (female: $P = 0.008$; bimaxillary surgery group: $P < 0.001$), but not between T1 and T2.

Discussion

The main purpose of orthognathic surgery in patients with skeletal Class III malocclusion is to correct the dentofacial morphology and achieve a normal facial shape.[10] To be objective and avoid subjective criteria for facial surfaces, doctors have to evaluate patient faces and collect 3D data using non-invasive and easy techniques.[2] The 3D stereophotogrammetry method is a modern non-invasive and non-contact surface scanning method that reconstructs 3D shape structures from plain photographs.[22] In the present study, the surface-based method was used for facial asymmetry analysis.[2,9,12,21,26]

Precision is very important in craniofacial analysis.[19,30] Plooij et al.[18] emphasized that the intra-observer coefficient of reliability should be above 0.8 for most points to represent excellent reliability.[31–33] In the present study, this coefficient was 0.92. The lowest precision was obtained for four landmarks on the x-axis, but the landmark error was < 1 mm; thus, it was clinically acceptable and reliable.[19,24,27,32–34] Toma et al.[24] mentioned that there were relatively lower degrees of reproducibility for landmarks placed on slightly curved slopes, and reproducibility might differ more between the landmark axes. However, because the 3D image can be enlarged, rotated, and viewed from all angles, it provides better opportunities to accurately place the landmarks on the 3D facial images.[7,12,19,35]

The results highlight an important trend in facial soft tissues after surgery. There was a statistically significant normalization of soft tissue symmetry at 6 months after surgery compared with that before the surgery. However, the extent of asymmetry increased between 6 and 12 months after surgery. The soft tissue asymmetry may not reach the same level as that before the surgery, but it has the potential to change, even after 6 months. This finding suggests that time plays an important role in the postoperative period due to soft tissue swelling, relocation, and remodeling.[14,36] According to the study by Gill et al.[14] (2017), at 6–12 months after surgery there can still be 10–15% of facial swelling. Therefore, it is not recommended to evaluate the final response of the soft tissues earlier than 6 months after surgery,[14,17] and the baseline response at 12 months shows a more stable volume of the facial soft tissues.[11]

To date, there is no agreement on which facial part is the most asymmetric. The present study results are consistent with those of a previous study, which showed that the lower facial portion was more asymmetric[21]. Differences in results could be due to the variety of methodological approaches and selection. This study focused on the soft tissues of five facial regions, and the most statistically significant changes and normalization in symmetry were found in region 4 (the

Table 2. Descriptive statistics and comparisons of average and maximum distances of whole facial asymmetry and facial region asymmetry, between the three time points: before surgery (T0), 6 months after surgery (T1), and 12 months after surgery (T2).

Region[a]	T0 Median (mm)	T1 Median (mm)	T2 Median (mm)	*P*-value T0 vs T1	T0 vs T2	T1 vs T2
Whole face						
Average distance	0.76	0.70	0.71	0.082	0.287	0.062
Maximum distance	3.26	2.82	2.91	0.001*	0.018*	0.145
Region 2						
Average distance	0.51	0.51	0.52	0.321	0.730	0.005*
Maximum distance	2.16	2.07	2.09	0.154	0.699	0.638
Region 3						
Average distance	0.73	0.76	0.78	0.321	0.091	0.036*
Maximum distance	2.48	2.35	2.39	0.082	0.192	0.193
Region 4						
Average distance	1.35	0.99	1.06	0.006*	0.023*	0.056
Maximum distance	3.24	2.85	2.83	0.018*	0.117	0.188
Region 5						
Average distance	0.58	0.61	0.62	0.657	0.220	0.024*
Maximum distance	2.49	2.41	2.51	0.052	0.146	0.458

*Statistically significant; $P < 0.05$.

[a]Region 2 (R2): part of the face between subnasale (sn) and mid-eye line. Region 3 (R3): part of the face between the mid-lip line (chL–chR) and subnasale. Region 4 (R4): part of the face below the mid-lip line (chin zone). Region 5 (R5): part of the face between the mid-lip line (chL–chR) and mid-eye line.

part of the face below the mid-lip line; chin zone). Fig. 7 shows the increase in number of patients in the mild asymmetry group after the surgery. Table 5 illustrates that in region 4, the moderate (2–5 mm) asymmetry group showed statistically significant normalization between T0 and T1. In addition, it was found that the asymmetry of the patient faces was predominant on the left facial side. Consistent with this, Ko et al.[7] reported that 66.7% of patients with a Class III malocclusion had a greater extent of left-side dominance, probably because the growth potential dominates on one side of the face5. In this study, the predominant side of the face was the left side before the surgery but changed to the right side after the surgery, probably due to overcorrection during surgery.

The shapes of female and male faces differ systematically, but there is no clinically significant difference in asymmetry between the sexes.[2,12] This study confirmed no statistically significant differences in maximum distance between the sexes, linear parameters, or facial regions. However, female faces showed lower average distances of the face than male faces, although the maximum distance was almost the same in both groups. This could be explained by the unequal sizes of the sex groups and relatively small

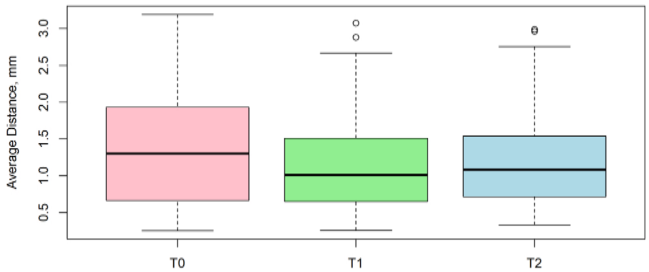

Fig. 6. Box plot of the average distance for facial region 4 at the three time points: before surgery (T0), 6 months after surgery (T1), and 12 months after surgery (T2). Region 4 is the part of the face below the mid-lip line (chin zone). Data points that are outside the interval are represented as points on the graph and considered potential outliers. There are two potential outliers at T1 and the same at T2.

Table 3. Descriptive statistics and comparisons of average and maximum distances of facial asymmetry in the two sex groups, between the three time points: before surgery (T0), 6 months after surgery (T1), and 12 months after surgery (T2).

Sex	T0 Median (mm)	T1 Median (mm)	T2 Median (mm)	*P*-value		
				T0 vs T1	T0 vs T2	T1 vs T2
Female						
Average distance	0.70	0.72	0.66	0.489	0.339	0.648
Maximum distance	3.38	2.80	2.65	0.018*	0.023*	0.777
Male						
Average distance	0.95	0.70	0.70	0.094	0.244	0.635
Maximum distance	3.60	2.88	2.82	0.168	0.110	0.787

*Statistically significant; $P < 0.05$.

Table 4. Descriptive statistics and comparison of average and maximum distances of facial asymmetry in the two surgery type groups, between the different time points: before surgery (T0), 6 months after surgery (T1), and 12 months after surgery (T2).

Surgery type	T0 Median (mm)	T1 Median (mm)	T2 Median (mm)	*P*-value		
				T0 vs T1	T0 vs T2	T1 vs T2
LFI						
Average distance	0.59	0.66	0.70	0.734	0.734	0.734
Maximum distance	2.53	2.23	2.48	0.359	0.734	0.426
LFI+BSSO						
Average distance	0.82	0.73	0.68	0.160	0.078	0.572
Maximum distance	3.53	2.92	2.73	0.008*	0.007*	0.486

LFI, Le Fort I osteotomy; LFI + BSSO, Le Fort I osteotomy and bilateral sagittal split osteotomy.
*Statistically significant; $P < 0.05$.

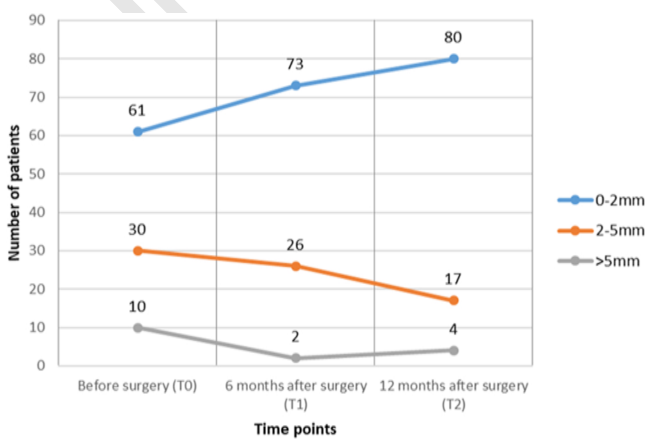

Fig. 7. Changes in the numbers of patients in each asymmetry group across the three time points: before surgery, 6 months after surgery, and 12 months after surgery. The patients were divided into three groups according to the deviation of pogonion point at all three time points: 0–2 mm, mild asymmetry; 2–5 mm, moderate asymmetry; > 5 mm, severe asymmetry.

Table 5. Descriptive statistics and comparisons of the average and maximum distances of facial asymmetry in region 4 according to the asymmetry groups[a], and of the chin volume asymmetry score (CVAS), between the three time points: before surgery (T0), 6 months after surgery (T1), and 12 months after surgery (T2).

	T0 Median (mm)	T1 Median (mm)	T2 Median (mm)	*P*-value T0 vs T1	T0 vs T2	T1 vs T2
Region 4						
Mild (0–2 mm)						
Average distance	0.70	0.86	0.88	0.57	0.27	0.43
Maximum distance	2.34	2.42	2.64	0.68	0.17	0.24
Moderate (2–5 mm)						
Average distance	1.53	1.25	1.14	0.03*	0.01*	0.93
Maximum distance	4.18	3.15	2.76	0.14	0.01*	0.56
Severe (> 5 mm)						
Average distance	2.74	–	2.94			
Maximum distance	4.98	–	4.98			
Mild (0–2 mm)						
CVAS	1.05	1.06	1.07	0.95	0.72	0.62
Pogonion point	0.08	0.26	0.11	0.46	0.51	1.00
Moderate (2–5 mm)						
CVAS	1.16	1.07	1.10	0.01*	0.02*	0.59
Pogonion point	2.23	2.30	2.06	0.88	0.99	0.93
Severe (> 5 mm)						
CVAS	1.69	–	1.55			
Pogonion point	− 8.43	–	− 6.38			

*Statistically significant; $P < 0.05$.
[a]Deviation of the pogonion point from the midsagittal plane.

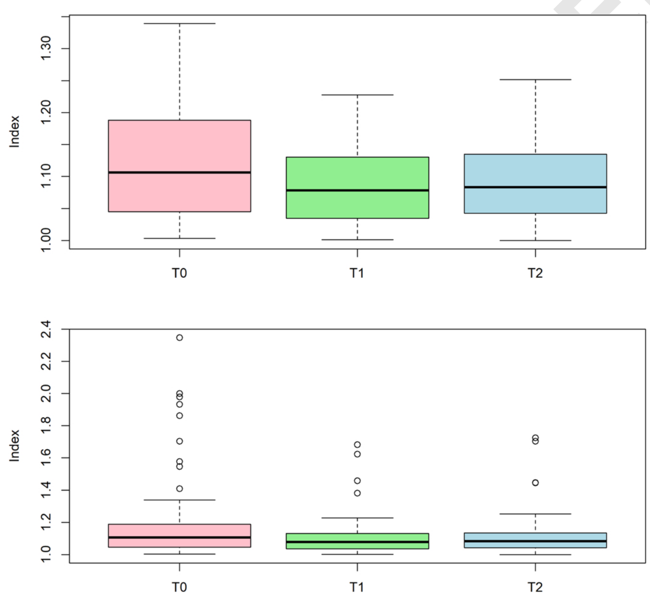

Fig. 8. Box plot of the chin volume asymmetry score (CVAS) at the three time points: before surgery (T0), 6 months after surgery (T1), and 12 months after surgery (T2). Data points that are outside the interval are represented as points on the bottom graph and considered potential outliers. There are nine potential outliers at T0, four at T1, and three at T2. The score has a minimum value of 1. The more asymmetrical the face, the larger the value.

number of male participants. In addition, there is controversy about the correlation between facial asymmetry and skeletal Class II and III deformities. Accumulating evidence indicates that skeletal Class III patients frequently have facial asymmetry.[5,7,37] Consistent with this, the present study also demonstrated that almost 40% of patients had a deviation of pogonion point of more than 2 mm, and the surgery type was bimaxillary surgery in the majority (78.3%); only 21.8% of patients were treated with single jaw surgery.

In Class III cases, before the surgical approach is chosen, the appearance of the facial soft tissue and the possible change after the surgery should be considered[36]. In this study, based on facial symmetry before and after surgery, a correlation between facial asymmetry and the surgery type was not found. Several studies have demonstrated that orthognathic surgery can improve facial symmetry, although differences between groups were not statistically significant.[6,10,13] A previous study using cone beam computed tomography (CBCT) reported that the soft tissue movement followed the hard tissue movement, with a correlation of 0.9 (range 0.85–0.98), suggesting that the soft tissue landmarks are affected similarly by the skeletal movements[22]. However, the soft tissue changes after orthognathic surgery and asymmetry changes can only be partially predicted due to individual biological differences.[38]

There are several limitations in this study. First, due to the wide age range, it was impossible to determine the correlation between asymmetry and different ages. Second, the sex groups were unequal in size, and the number of male participants was relatively small. Third, the image quality of different facial surfaces could have affected the evaluation of facial asymmetry. Fourth, the soft tissue changes were not compared with the actual skeletal movement measured on CBCT. Furthermore, the surgery type groups were not equal; the majority of the

Table 6. The chin volume asymmetry score (CVAS) (a) at all three time points (before surgery (T0), 6 months after surgery (T1), and 12 months after surgery (T2)); (b) by sex group, and (c) by surgery type group.

CVAS[a]	T0 Median	T1 Median	T2 Median	*P*-value T0 vs T1	T0 vs T2	T1 vs T2
Time	1.11	1.08	1.08	< 0.001*	0.001*	0.061
Sex						
Female	1.12	1.09	1.08	0.022*	0.008*	0.938
Male	1.14	1.08	1.09	0.110	0.146	0.635
Surgery type						
LFI+BSSO	1.14	1.09	1.08	0.004*	< 0.001*	0.846
LFI	1.05	1.08	1.09	0.652	0.910	0.301

LFI, Le Fort I osteotomy; LFI + BSSO, Le Fort I osteotomy and bilateral sagittal split osteotomy.
*Statistically significant; $P < 0.05$.
[a]The score has a minimum value of 1. The more asymmetrical the face, the larger the value.

surgical procedures were bimaxillary surgery. Fifth, other factors, such as lip thickness, tonicity, and volume, were not analysed. These factors could help adequately describe the facial soft tissue response after surgery.[39] Other authors have found that the soft tissue response to skeletal movements is less if the soft tissues are thicker. In addition, if muscular tone is greater, there may be a closer link between the tissue movements. This will also depend on the magnitude of the skeletal movement and surgical technique.[14] Despite these limitations, this study is novel in evaluating asymmetry of the facial soft tissues in a large group of skeletal Class III patients who had 3D images obtained at three time points, using a 3D stereophotogrammetry technique. A longitudinal study applying the 3D stereophotogrammetry technique is needed to further determine long-term changes in asymmetry of the facial soft tissues after surgery.

In conclusion, the asymmetry of the facial soft tissues was found to decrease significantly after orthognathic surgery in Class III patients. The study findings suggest that the asymmetry of the soft tissues has the potential to return after 6 months, without reaching baseline. It is recommended that the final response of the soft tissues is not evaluated earlier than 6 months after surgery because it is not stable, and the follow-up period should be at least 12 months. Further studies are needed to investigate long-term changes in asymmetry (at > 12 months) of the facial soft tissues after orthognathic surgery in Class III patients using the 3D stereophotogrammetry technique and to compare this with skeletal movements on CBCT.

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Competing interests

None.

Ethical approval

This study was performed in accordance with the guidelines of the Ethics Committee of Rīga Stradiņš University (RSU 26.04.2012).

Patient consent

Participation was voluntary, data confidentiality was ensured, and every patient provided informed consent.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ijom.2022.06.022.

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