

Article

Three-Dimensional Evaluation of Soft Tissues in Orthognathic Surgery: A Pilot Study of Digital Planning Predictability

Martina Rumpianesi ¹, Carlotta Preite ¹ , Francesca Cremonini ¹ , Luisa Valente ² , Riccardo Tieghi ² and Luca Lombardo ^{1,*} 

¹ Postgraduate School of Orthodontics, University of Ferrara, Via Luigi Borsari 46, 44121 Ferrara, Italy

² Unit of Cranio-Maxillofacial Surgery, St. Anna University Hospital of Ferrara, 44124 Ferrara, Italy

* Correspondence: dott.lulombardo@gmail.com

Abstract

Three-dimensional (3D) facial scanning integrated with cone-beam computed tomography (CBCT) has improved digital planning and postoperative assessment in orthognathic surgery. This retrospective pilot study evaluated the accuracy of digital surgical planning, skeletal and soft-tissue movements, and postoperative edema evolution in 12 patients undergoing bimaxillary orthognathic surgery. Pre- and postoperative CBCT scans, facial scans, and virtual surgical plans were analyzed. Planning accuracy was assessed by comparing predicted and postoperative cephalometric measurements. Skeletal and soft-tissue displacements were evaluated using corresponding landmarks, while postoperative edema was evaluated through 3D facial scan superimposition. Before Bonferroni correction, significant differences were observed for the SNB angle ($p = 0.005$) and the Mandibular Plane Angle ($p = 0.008$); after adjustment, only the SNB angle remained statistically significant. Significant positive correlations between skeletal and soft-tissue displacements were found for Point B along the x -axis ($\rho = 0.769$, adjusted $p = 0.048$) and y -axis ($\rho = 0.797$, adjusted $p = 0.032$), and for Pogonion along the z -axis ($\rho = 0.988$, adjusted $p < 0.016$). No statistically significant differences in postoperative edema remained after Bonferroni correction. Overall, digital surgical planning showed good agreement between planned and postoperative outcomes, while 3D facial scanning proved useful for evaluating soft-tissue response.

Keywords: orthognathic surgery; three-dimensional facial scanning; virtual surgical planning

1. Introduction

Orthognathic surgery is a branch of maxillofacial surgery focused on correcting skeletal and dentoalveolar discrepancies through three-dimensional repositioning of the maxillary and mandibular bases. It is indicated when orthodontic treatment alone cannot restore proper balance between masticatory function, facial aesthetics, and skeletal harmony, often improving patients' self-perception and psychological well-being [1,2].

Its objective is to improve facial harmony and proportions, achieve symmetry, establish proper dental occlusion, and ensure both occlusal and skeletal stability, all within a context of optimal periodontal, muscular, and joint health [3]. Facial analysis is essential for diagnosis, allowing evaluation of proportions and relationships among skeletal, dental, and soft-tissue structures [4,5]. Achieving these outcomes requires close collaboration between the orthodontist and the maxillofacial surgeon. Preoperative orthodontic treatment is essential for establishing proper dental alignment and preparing the dental arches for



Academic Editor: Thomas Lindner

Received: 10 June 2026

Revised: 6 July 2026

Accepted: 8 July 2026

Published: 10 July 2026

Copyright: © 2026 by the authors.

Licensee MDPI, Basel, Switzerland.

This article is an open access article distributed under the terms and conditions of the [Creative Commons Attribution \(CC BY\)](https://creativecommons.org/licenses/by/4.0/) license.

surgery [6]. Its main objectives are the correction of crowding and tooth rotations, flattening of the Curve of Spee and Curve of Wilson, and appropriate positioning of the maxillary and mandibular incisors within their respective alveolar bone bases. In selected cases, tooth extractions may be necessary to accomplish these goals.

The accuracy and completeness of orthodontic preparation can be effectively assessed using three-dimensional (3D) printed pre-surgical models [7]. Once the final occlusion has been simulated and the absence of pre-contacts verified, the patient can be considered ready for surgery.

Today, surgical planning is commonly performed using dedicated digital software integrated with CBCT data and the patient's facial scan. Compared with conventional methods, three-dimensional virtual planning improves surgical accuracy and treatment predictability of both hard and soft-tissue outcomes and enables the creation of a virtual treatment objective (VTO) and precise digital surgical planning [7].

The postoperative phase is also crucial for treatment success. Patients are closely monitored in the first 24–48 h, and common effects such as edema, bruising, and temporary limitation of mandibular movement typically resolve over time.

Following surgery, increased capillary permeability induced by inflammatory mediators leads to leakage of plasma and proteins into the interstitial compartment [8]. This alteration of microcirculatory balance results in fluid shifts between vascular and interstitial compartments, with an increase in tissue volume, particularly evident in the perioral and perimandibular regions.

Edema generally reaches its peak within the first 48 h after surgery [9] and then gradually decreases until complete resolution [10]. Three-dimensional monitoring of edema through 3D scans allows objective quantification of volumetric changes in soft tissues over time, providing useful data for evaluating the postoperative course and the effectiveness of edema management procedures [11,12].

In recent years, facial scanners have become valuable diagnostic tools in orthodontics. They provide non-invasive, radiation-free, high-definition 3D images of the face, enabling detailed aesthetic analysis and improved treatment planning, and consequently better treatment personalization [13]. Moreover, these devices are clinically reliable for routine practice [14] and improve both patient–clinician communication and interdisciplinary collaboration through realistic three-dimensional facial visualization [15].

Facial scans can also be integrated with CBCT data for comprehensive three-dimensional analysis, particularly in orthognathic surgery planning. This integration is clinically reliable [16] and enhances the accuracy, personalization, and predictability of treatment outcomes.

Despite the increasing use of digital workflows in orthognathic surgery, the combined evaluation of digital planning accuracy, skeletal–soft-tissue relationships, and postoperative edema within a single three-dimensional workflow remains limited. Therefore, this retrospective pilot study aimed to assess the predictability of orthognathic surgery outcomes through the assessment of hard- and soft-tissue changes. Specifically, the objectives were to assess the accuracy of digital surgical planning in predicting postoperative hard- and soft-tissue outcomes, to investigate the relationship between skeletal movements and the corresponding soft-tissue response, and to evaluate the ability of three-dimensional facial scanning to monitor postoperative edema and volumetric changes over time.

2. Materials and Methods

2.1. Sample Selection

The study sample comprised 12 patients (2 males and 10 females) who underwent orthognathic surgery between 2023 and 2025 at the Department of Maxillofacial Surgery,

Sant'Anna Hospital, Ferrara. All patients had previously completed a phase of orthodontic preparation at the Department of Orthodontics, University of Ferrara.

Six patients presented with skeletal Class II malocclusion, 4 with skeletal Class III malocclusion, 1 with skeletal open bite, and 1 with severe facial asymmetry. All patients underwent digitally planned bimaxillary orthognathic surgery, consisting of a Le Fort I osteotomy of the maxilla and a bilateral sagittal split osteotomy (BSSO) of the mandible. In three patients, digitally planned genioplasty was performed in conjunction with the orthognathic procedure: one with severe facial asymmetry, one with skeletal Class II malocclusion, and one with skeletal Class III malocclusion. Inclusion criteria were age ≥ 18 years, the presence of a skeletal malocclusion requiring surgical correction, and no history of previous orthognathic surgery. All patients were followed for a minimum of 6 months postoperatively. Exclusion criteria included age < 18 years, previous orthognathic surgery, and craniofacial syndromes or congenital craniofacial anomalies. Patients with incomplete postoperative CBCT scans were not excluded from the study but were excluded from specific analyses when reliable identification of the required anatomical landmarks was not possible.

For each patient, preoperative records included intraoral and extraoral photographs, extended field-of-view (FOV) CBCT scans, intraoral scans of the dental arches, scans of dental models in surgical occlusion, and three-dimensional facial scans. Postoperative records consisted of three-dimensional facial scans acquired at 1, 3, and 6 months after surgery, together with an extended FOV CBCT scan obtained at least 6 months postoperatively. CBCT scans were acquired using a NewTom VGi evo unit (NewTom, Cefla S.C., Imola, Italy) with an extended field of view (24×19 cm), a voxel size of 0.3 mm, a tube voltage of 110 kV, a tube current of 9 mA, and an exposure time of 3.5 s. The same acquisition protocol was used for all preoperative and postoperative CBCT examinations.

Some postoperative CBCT scans presented artifacts or incomplete image acquisition involving the chin region and/or the nasal tip. As reliable landmark identification was not possible in these areas, the corresponding patients were excluded from analyses involving the affected landmarks and related cephalometric measurements. In accordance with the ALARA (As Low As Reasonably Achievable) principle, no additional radiographic examinations were performed.

In addition, two patients were unable to attend the 1- and 3-month postoperative follow-up visits for facial scan acquisition and were therefore excluded from the analysis of postoperative edema evolution.

Digital planning was performed using IPS Case Designer software, version 2.3.6.1 (KLS Martin, Tuttlingen, Germany) (Figure 1A,B). The preoperative CBCT dataset was imported into the software and oriented according to the Frankfurt horizontal plane and the facial midline. Intraoral scans were then uploaded and integrated with scans of the dental models in surgical occlusion to perform virtual surgical planning. The facial scan (OBJ format) was superimposed onto the skin surface reconstructed from the CBCT, enabling visualization of the soft tissues in relation to the underlying skeletal structures (Figure 1C). Three-dimensional facial scans were acquired using a structured-light facial scanner (EinScan H, model 70565; Shining 3D Technology GmbH, Stuttgart, Germany) featuring a manufacturer-reported accuracy of up to 0.05 mm and a working depth range of 200–700 mm. All scans were performed in a controlled environment under standardized lighting conditions. Participants were positioned according to the manufacturer's recommendations, with the scanner maintained at a working distance of approximately 50 cm. During image acquisition, patients maintained a natural head position, teeth in maximum intercuspation, relaxed lips, and closed eyes. Male participants with facial hair were asked to trim or shave their beards to minimize interference with soft-tissue acquisition. The acquired images

were processed using the dedicated EinScan H software (EXScan H v1.0.5.3; SHINING 3D, Hangzhou, China) and exported as OBJ (Wavefront 3D) files for subsequent analysis.

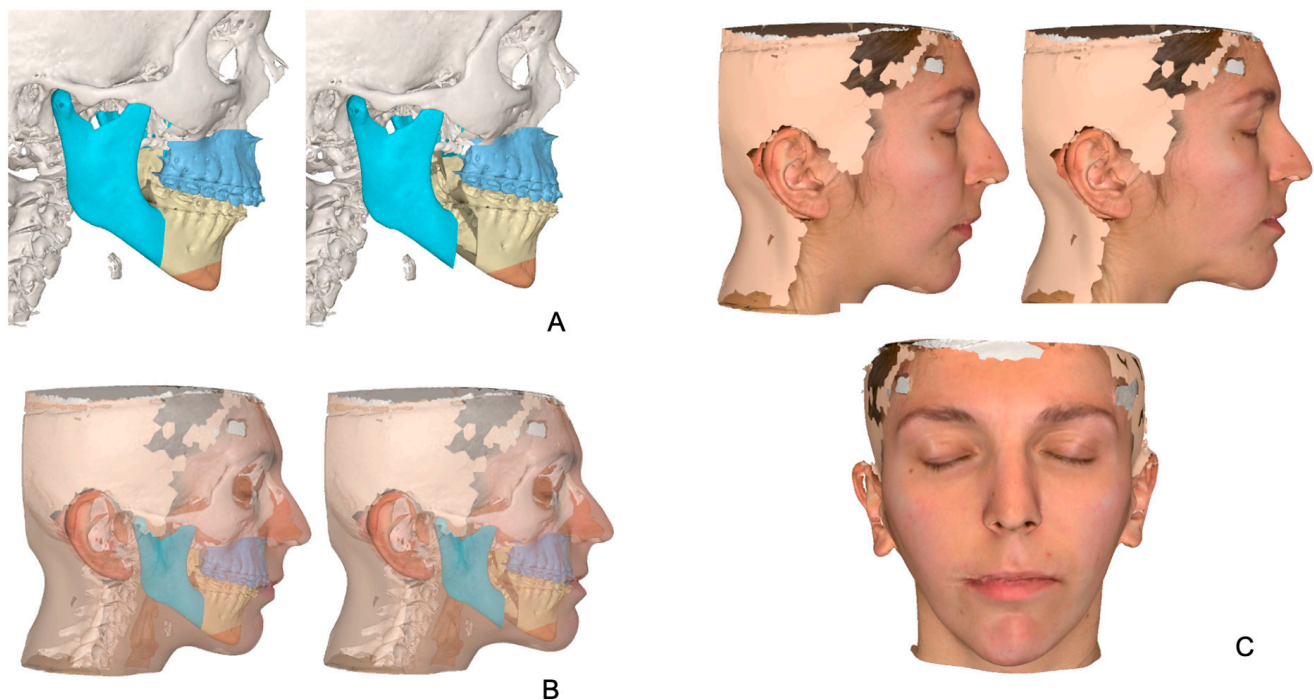


Figure 1. Surgical planning: hard tissues (A), CBCT-derived soft tissues (B), and facial scans (C).

To ensure consistent spatial orientation of the pre- and postoperative CBCT scans within the same Cartesian coordinate system, rigid image registration was performed using a dedicated software function. Anatomical landmarks located in regions unaffected by surgery, including the frontozygomatic and temporozygomatic sutures, were identified on both scans and used as reference points for superimposition.

2.2. Digital Planning Accuracy and Soft-Tissue Prediction

Using a dedicated function of the IPS Case Designer software, a three-dimensional cephalometric analysis was performed on the preoperative CBCT superimposed on the corresponding facial scan (Figure 2). The main cephalometric landmarks were identified three-dimensionally at both hard and soft-tissue levels. The software automatically calculated the predicted postoperative values for each cephalometric parameter based on the planned surgical movements. Nine cephalometric angles were evaluated (ANB, SNA, SNB, Mandibular Plane Angle, Skeletal Facial Angle, Facial Angle, Mentolabial Angle, Nasolabial Angle, Z Angle). These cephalometric angles were selected because they represent validated and commonly used skeletal and soft-tissue parameters in orthognathic diagnosis and treatment planning. Together, they provide a comprehensive three-dimensional assessment of sagittal skeletal relationships, vertical facial pattern, and facial soft-tissue profile.

The same cephalometric analysis was subsequently performed on the postoperative CBCT, obtained at least 6 months after surgery, and superimposed on the 6-month facial scan.

This procedure allowed comparison between the planned angular measurements and those clinically achieved at both hard and soft-tissue levels.

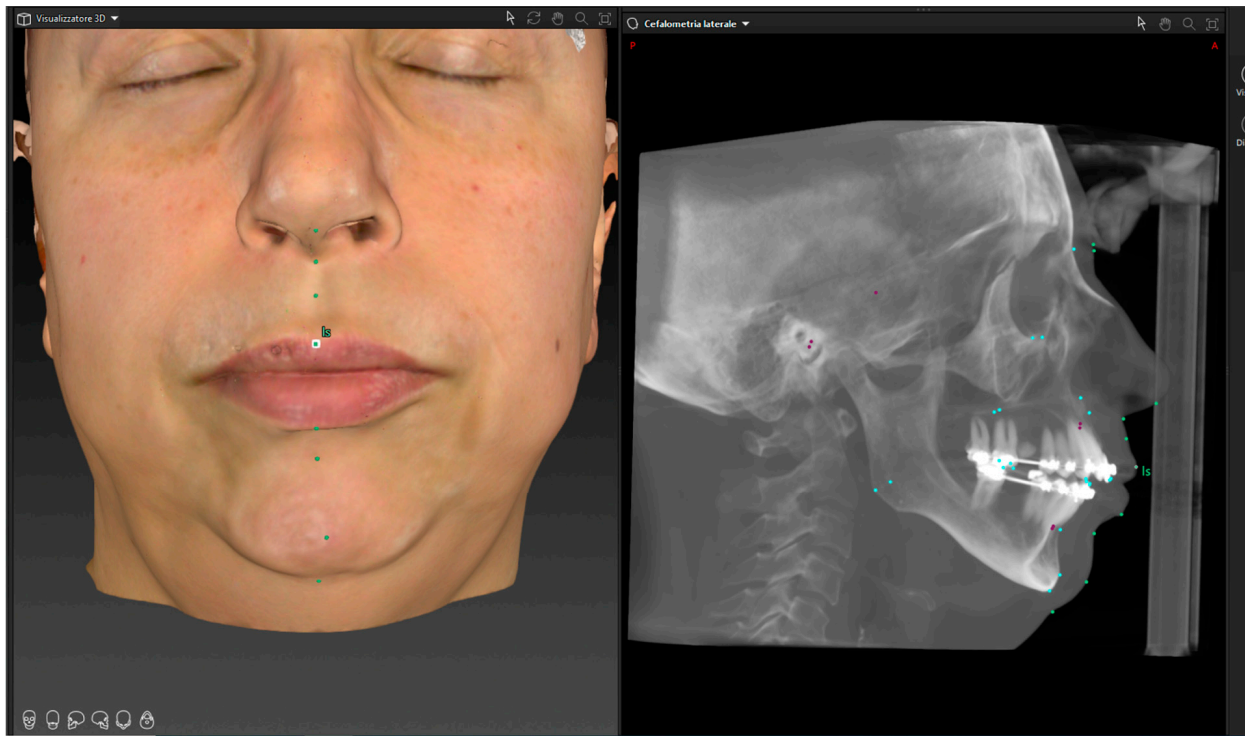


Figure 2. Identification of soft- and hard-tissue landmarks used for cephalometric analysis on the facial scan (**left**) and CBCT-derived lateral cephalogram (**right**).

2.3. Relationship Between Skeletal Movement and Soft-Tissue Response

Pre- and postoperative CBCT scans were oriented in the same manner, placed within the same Cartesian coordinate system, and superimposed on pre- and postoperative facial scans. On the registered images, the following cephalometric landmarks were manually identified: skeletal Point A, soft-tissue Point A, skeletal Point B, soft-tissue Point B, skeletal Menton, soft-tissue Menton, skeletal Pogonion, and soft-tissue Pogonion. These landmarks were selected because they feature both skeletal and soft-tissue counterparts, allowing for the evaluation of the relationship between hard and soft tissues. For each point, Cartesian coordinates (x , z , y) were recorded (Figure 3). The x -axis corresponded to mediolateral displacement in the frontal plane, the z -axis to anteroposterior displacement in the sagittal plane, and the y -axis to vertical displacement relative to the software-generated reference planes. Pre- and postoperative coordinates were compared for each landmark to quantify tissue displacement and assess the relationship between skeletal movements and the corresponding soft-tissue response.

2.4. Postoperative Edema and Volumetric Assessment

Facial scans in STL format were analyzed using Geomagic Control X software (Control X 2020.1 3D Systems Inc., Rock Hill, SC, USA) to assess the percentage of surface coincidence between scans acquired at different time points for the same patient.

The one-month postoperative scan was selected as the reference mesh, while the 3- and 6-month postoperative scans were used for comparison. Meshes were superimposed using the Best-Fit alignment algorithm to achieve optimal registration accuracy.

The software's 3D comparison function was then used to generate a quantitative report and a color-coded surface deviation map between the superimposed models.

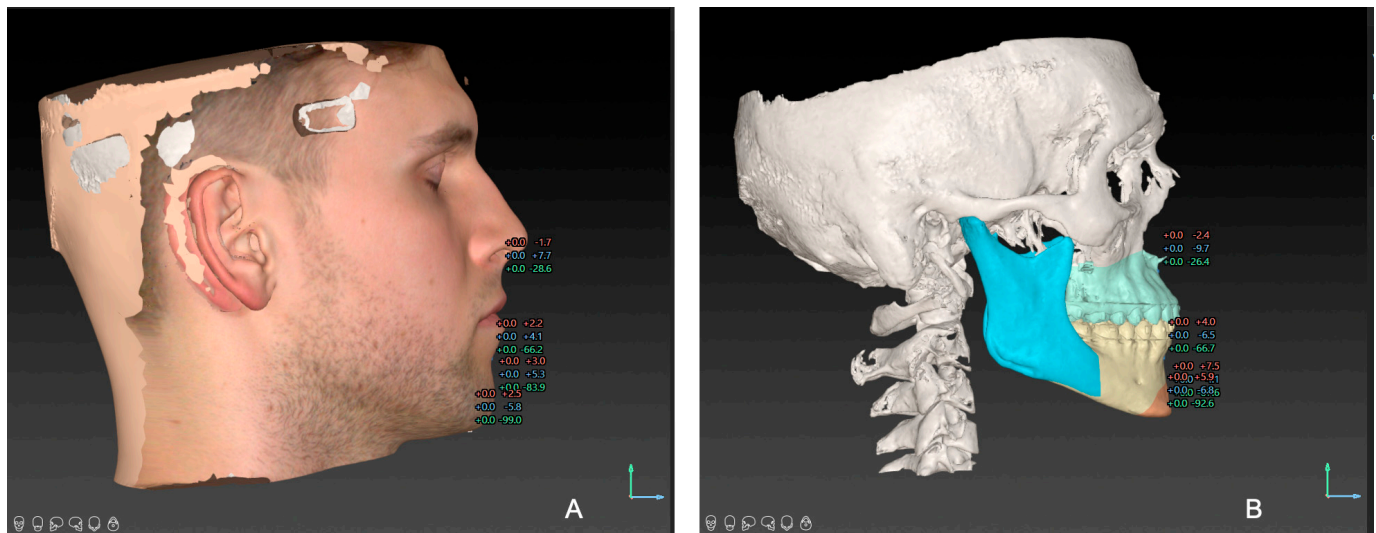


Figure 3. Point A, Point B, Pogonion, and Menton were selected on the soft tissues overlaid onto the facial scan (A) and on the hard tissues (B), with the corresponding Cartesian coordinates.

The color-coded map displayed surface differences between the one-month postoperative reference scan and the scans acquired at 3 and 6 months, using a scale ranging from -1.5 mm to $+1.5$ mm. Surface deviations within the range of -0.5 mm to $+0.5$ mm (green) were considered clinically negligible and represented stable soft-tissue regions. Positive deviations ($>+0.5$ mm), displayed in yellow, orange, and red, reflected an increase in soft-tissue volume and were interpreted as residual postoperative edema. Conversely, negative deviations (<-0.5 mm), displayed in light blue and blue, indicated a reduction in tissue volume relative to the reference scan, consistent with edema resolution and postoperative soft-tissue remodeling. A tolerance threshold of ± 0.5 mm was adopted, in agreement with the methodology reported by Pellitteri et al. [17].

In addition to the color-coded map, the software calculated the percentages of surface area within tolerance, above tolerance (excess), and below tolerance (deficit). These metrics provided a quantitative measure of volumetric changes over time and were used to assess the evolution of postoperative edema at different follow-up intervals.

2.5. Statistical Analysis

An a priori power analysis was performed to determine the minimum sample size required for the study. Assuming an expected correlation coefficient of 0.75 between skeletal and soft-tissue measurements, a statistical power of 80%, and a significance level (α) of 0.05, a minimum of 11 participants was required.

A descriptive analysis of continuous variables was performed using the median and interquartile range (IQR). Given the limited sample size, all inferential analyses were performed using non-parametric statistical tests.

Statistical significance was set at $p < 0.05$. Because multiple statistical comparisons were performed, p -values were adjusted using the Bonferroni correction. The adjustment was applied separately within each family of homogeneous hypothesis tests (cephalometric comparisons, correlation analyses, and postoperative edema analyses) to control the family-wise error rate while avoiding overcorrection across unrelated analyses. Adjusted p -values were used to determine statistical significance. All analyses were performed using IBM SPSS Statistics (version 30.0; IBM Corp., Armonk, NY, USA) and G*Power software (version 3.1.9.4).

To assess intra-operator reliability, four measurements were repeated by the same examiner after a 30-day interval. Reliability was evaluated using the intraclass correlation coefficient (ICC).

To evaluate the accuracy of digital surgical planning and soft-tissue prediction, the difference (Δ) between the planned and postoperative values was calculated for each landmark. A one-sample Wilcoxon signed-rank test was performed to determine whether the median difference significantly differed from zero. Effect sizes (r) were calculated for the Wilcoxon signed-rank tests and are reported to facilitate interpretation of the magnitude of the observed differences.

For the analysis of skeletal–soft-tissue relationships, displacement magnitude was calculated as the Euclidean distance between preoperative and postoperative coordinates according to the following equation:

$$\sqrt{(\text{post}_{xaxis} - \text{pre}_{xaxis})^2 + (\text{post}_{zaxis} - \text{pre}_{zaxis})^2 + (\text{post}_{yaxis} - \text{pre}_{yaxis})^2}$$

where x , y , and z represent the Cartesian coordinates of the landmark.

The association between skeletal and soft-tissue displacements was subsequently assessed using Spearman’s rank correlation coefficient. Simple linear regression analyses were performed for landmark–axis combinations with a nominal (unadjusted) p -value < 0.05 to quantify the relationship between skeletal and soft-tissue displacement; regression coefficients are reported as exploratory estimates, regardless of statistical significance after Bonferroni correction.

Postoperative edema was evaluated by comparing volumetric measurements obtained at 1, 3, and 6 months after surgery. Differences between follow-up time points were analyzed using the Wilcoxon signed-rank test for paired samples.

3. Results

Intra-operator reliability was excellent for all repeated measurements (ICC range: 0.920–0.998). Detailed ICC values are reported in Appendix A, Table A1.

3.1. Digital Planning Accuracy and Soft-Tissue Prediction

The preoperative, planned, and postoperative values of the nine cephalometric angles evaluated in the study are summarized in Table 1.

Table 1. Descriptive statistics of the nine cephalometric angles at the preoperative, planned, and postoperative time points. Data are presented as median [IQR].

Cephalometric Angle	Preoperative, Median [IQR]	Planned, Median [IQR]	Postoperative, Median [IQR]
ANB	−0.82 [−2.28; 1.15]	2.83 [0.26; 3.94]	3.29 [1.41; 4.66]
SNA	81.20 [78.58; 83.04]	85.45 [81.31; 88.77]	84.41 [82.93; 85.62]
SNB	80.83 [76.97; 83.52]	82.03 [79.86; 83.62]	80.15 [79.46; 82.66]
Skeletal facial angle	89.46 [85.55; 92.88]	83.99 [82.10; 89.05]	85.22 [83.73; 88.15]
Mandibular plane angle	36.79 [31.40; 40.64]	31.59 [28.68; 34.98]	35.27 [30.28; 38.25]
Facial angle	167.01 [157.50; 174.42]	166.36 [163.63; 167.83]	165.32 [163.16; 166.17]
Mentolabial angle	142.10 [135.28; 146.51]	136.92 [134.34; 144.87]	136.16 [132.39; 144.87]
Nasolabial angle	94.15 [72.74; 106.53]	86.92 [79.19; 114.02]	97.76 [82.60; 115.81]
Z angle	83.35 [74.01; 85.35]	80.61 [77.80; 82.10]	80.60 [75.67; 81.90]

Comparison between the planned and postoperative measurements revealed statistically significant differences for the SNB angle and the Mandibular Plane Angle before

adjustment for multiple comparisons (Table 2). After Bonferroni correction, only the SNB angle remained statistically significant. Effect size estimates are also reported in Table 2.

Table 2. Comparison between planned and postoperative cephalometric measurements. Data are presented as median differences (Δ) and [IQR]. Statistical significance was assessed using the one-sample Wilcoxon signed-rank test. Bonferroni-adjusted p -values and effect sizes (r) are reported. Z Statistic = standardized test statistic.

Parameter	Median (Δ)	IQR	Z Statistic	p -Value	Adjusted p -Value	Effect Size (r)
ANB angle	−0.37	[−1.09; 1.34]	0	>0.99	>0.99	0.00
Facial angle	−0.55	[−2.74; 0]	−1.153	0.249	>0.99	0.36
Mandibular Plane Angle	2.37	[1.33; 4.36]	2.667	0.008	0.072	0.77
Mentolabial angle	0	[−6; 0]	−0.405	0.686	>0.99	0.13
Nasolabial angle	0	[−0.26; 9.78]	0	>0.99	>0.99	0.00
Z angle	−0.14	[−1.35; 0.02]	−1.682	0.093	0.837	0.53
SNA angle	−1	[−2.97; 0.39]	−1.295	0.195	>0.99	0.37
SNB angle	−1.22	[−2.08; −0.08]	−2.8245	0.005	0.045	0.82
Skeletal facial angle	1.01	[−0.33; 3.05]	1.255	0.209	>0.99	0.36

3.2. Relationship Between Skeletal Movement and Soft-Tissue Response

Spearman's correlation analysis was performed to investigate the association between changes in skeletal landmarks and the corresponding soft-tissue landmarks (Table 3).

No statistically significant correlations were observed for Point A or Menton along any of the three spatial axes after Bonferroni correction (adjusted $p > 0.05$).

Point B demonstrated significant positive correlations between skeletal and soft-tissue displacements along the x - and y -axes after Bonferroni correction, whereas the correlation along the z -axis did not remain statistically significant. Linear regression analysis showed that each unit increase in skeletal displacement was associated with an average increase of 0.485 units (95% CI: 0.225–0.745) along the x -axis, 0.596 units (95% CI: 0.203–0.990) along the z -axis, and 1.158 units (95% CI: 0.633–1.683) along the y -axis in the corresponding soft tissue. When displacement was expressed using the displacement index, each unit increase in skeletal displacement corresponded to an average increase of 0.660 units (95% CI: 0.207–1.113) in soft-tissue displacement (Figure 4A).

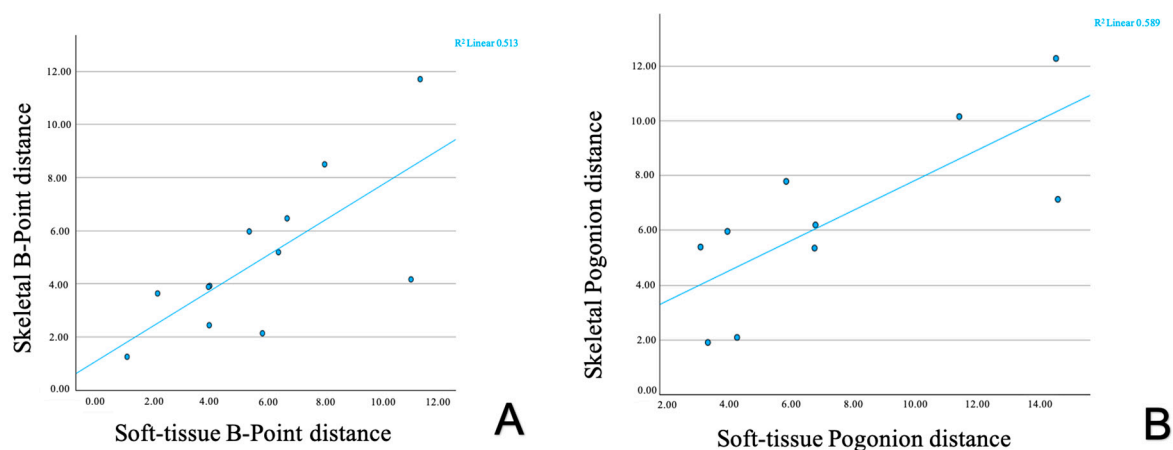


Figure 4. Simple linear regression analysis of Point B (A) and Pogonion (B).

For Pogonion, only the correlation along the z-axis remained statistically significant after Bonferroni correction, whereas the correlations along the x- and y-axes were not statistically significant. Linear regression analysis demonstrated that each unit increase in skeletal displacement corresponded to an average increase of 0.820 units (95% CI: 0.242–1.398) along the x-axis and 0.800 units (95% CI: 0.663–0.937) along the z-axis in the overlying soft tissue. Analysis based on the displacement index showed that each unit increase in skeletal displacement was associated with an average increase of 0.550 units (95% CI: 0.176–0.925) in soft-tissue displacement (Figure 4B). No statistically significant correlations were observed.

Table 3. Spearman correlation analysis and simple linear regression between skeletal and corresponding soft-tissue displacements. Data are presented as Spearman’s rho coefficients (ρ), 95% confidence intervals (95% CI), unadjusted and Bonferroni-adjusted p -values, sample size (N), and unstandardized regression coefficients (β) with their 95% confidence intervals. Regression was performed only for landmark–axis combinations with a nominal (unadjusted) p -value < 0.05; a dash (–) indicates that no linear regression was performed. The displacement index corresponds to the Euclidean displacement magnitude.

Landmark	Axis	ρ	95% CI (ρ)	p -Value	Adjusted p	N	Slope (β)	95% CI (β)
Point A	x	0.291	−0.357 to 0.750	0.359	>0.99	12	–	–
	y	0.448	−0.189 to 0.819	0.145	>0.99	12	–	–
	z	0.503	−0.118 to 0.842	0.095	>0.99	12	–	–
Point B	x	0.769	0.333 to 0.934	0.003	0.048	12	0.485	0.225 to 0.745
	y	0.797	0.395 to 0.943	0.002	0.032	12	1.158	0.633 to 1.683
	z	0.713	0.218 to 0.916	0.009	0.144	12	0.596	0.203 to 0.990
	Displacement index	–	–	–	–	12	0.660	0.207 to 1.113
Pogonion	x	0.685	0.075 to 0.922	0.029	0.464	10	0.820	0.242 to 1.398
	y	0.564	−0.124 to 0.886	0.090	>0.99	10	–	–
	z	0.988	0.945 to 0.997	<0.001	<0.016	10	0.800	0.663 to 0.937
	Displacement index	–	–	–	–	10	0.550	0.176 to 0.925
Menton	x	0.115	−0.562 to 0.685	0.751	>0.99	10	–	–
	y	0.285	−0.431 to 0.770	0.425	>0.99	10	–	–
	z	−0.418	−0.826 to 0.275	0.229	>0.99	10	–	–

3.3. Postoperative Edema and Volumetric Assessment

The median percentages of facial surface areas classified as below tolerance, within tolerance, and outside tolerance at the 1–3- and 1–6-month follow-up intervals are reported in Table 4. The results of the three-dimensional superimposition analysis are shown in Figure 5A,B. Before adjustment for multiple comparisons, the percentage of facial surface area within tolerance was lower at 6 months than at 3 months ($p = 0.028$). However, this difference did not remain statistically significant after Bonferroni correction (adjusted $p = 0.084$). No statistically significant differences were observed for any of the evaluated surface area categories after correction for multiple comparisons (Table 4).

Color-map analysis showed positive surface deviations (red) in the chin and lower facial regions, whereas negative surface deviations (blue) were mainly observed in the middle third of the face (Figure 6A,B).

Table 4. Comparison of the percentages of facial surface areas classified as below tolerance, within tolerance, and outside tolerance between the 1–3- and 1–6-month postoperative follow-up intervals. Data are presented as median [IQR]. Differences between follow-up intervals were assessed using the Wilcoxon signed-rank test. Bonferroni-adjusted *p*-values and effect sizes (*r*) are reported.

Surface Area Category	1–3 Months, Median [IQR] (%)	1–6 Months, Median [IQR] (%)	Z Statistic	<i>p</i> -Value	Adjusted <i>p</i> -Value	Effect Size (<i>r</i>)
Below tolerance	28.59 [23.79–40.83]	35.36 [23.01–51.72]	1.886	0.059	0.177	0.60
Within tolerance	44.47 [35.11–50.50]	38.94 [27.01–48.80]	6.000	0.028	0.084	0.69
Outside tolerance	20.57 [17.40–29.85]	21.96 [20.64–25.99]	0.866	0.386	>0.99	0.27

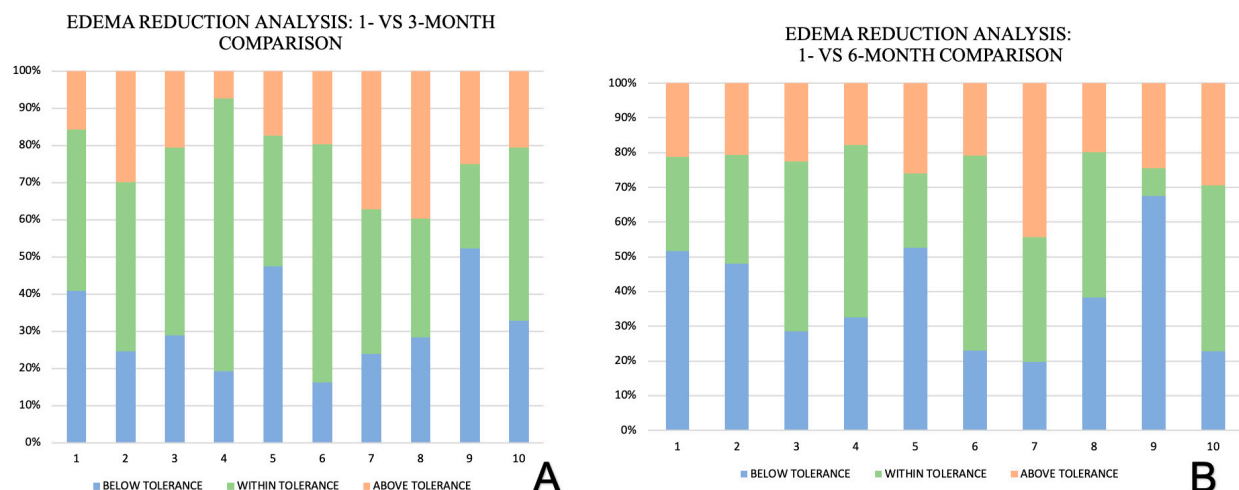


Figure 5. Graphical representation of the percentage values for each patient in the three tolerance categories comparing 1 and 3 months postoperatively (A) and 1 and 6 months (B).

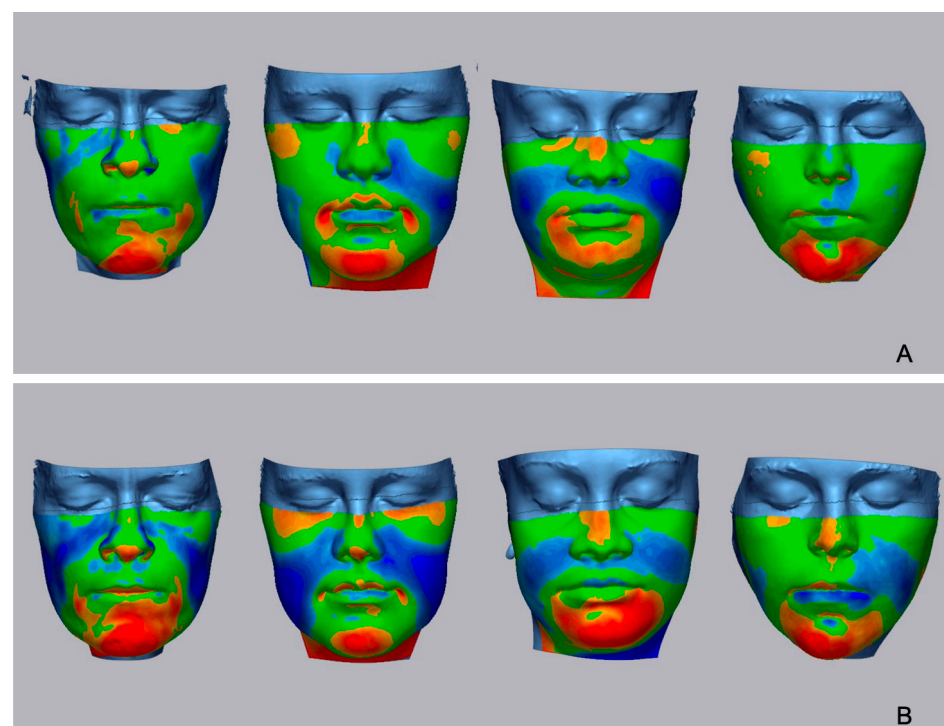


Figure 6. Examples of three-dimensional facial scan superimpositions at the 1–3-month (A) and 1–6-month (B) postoperative follow-up intervals. An increase in edema (red) is observed in the chin and lower third of the face, whereas a progressive reduction in edema (blue) is observed in the middle third.

4. Discussion

Facial scanning has become an increasingly valuable tool in dentistry because it offers a non-invasive, rapid, and reproducible method for facial soft-tissue assessment. These characteristics make it particularly suitable for repeated assessments over time. Three-dimensional facial imaging enables detailed evaluation of facial soft-tissue morphology and aesthetics, monitoring of growth-related changes [17], and assessment of asymmetries and treatment outcomes in orthognathic patients [18].

The introduction of three-dimensional facial scanning has also provided a non-invasive and quantitative approach to the evaluation of postoperative changes. Technologies such as stereophotogrammetry and structured-light scanning have been shown to provide an accurate assessment of soft-tissue volume, facilitating the monitoring of postoperative edema and facial symmetry [12]. Furthermore, the possibility of comparing facial scans acquired at different time points supports longitudinal evaluation of treatment outcomes.

The integration of facial scans with CBCT data may represent a viable adjunct component of contemporary orthognathic surgery planning, enabling comprehensive three-dimensional visualization of both hard and soft tissues. However, the accuracy of image registration depends largely on the stability of the selected reference areas. Previous studies have shown that the forehead, nasal dorsum, and malar regions provide the most reliable landmarks for superimposition and longitudinal comparisons [16].

Overall, the combined use of cephalometric analysis, CBCT imaging, and three-dimensional facial scanning allows a more comprehensive and patient-specific evaluation, enhancing surgical planning, treatment predictability, and assessment of postoperative outcomes.

4.1. Digital Planning and Soft-Tissue Prediction

Accurate prediction of both skeletal and soft-tissue changes is a fundamental prerequisite for successful orthognathic treatment, as functional stability and patient satisfaction are closely related to the final aesthetic outcome. Consequently, the reliability of virtual surgical planning has become a major focus of contemporary research.

Several studies comparing virtual planning with postoperative outcomes have demonstrated the overall reliability of three-dimensional simulation software, although certain limitations persist, particularly in the lower facial third. Early investigations reported prediction errors exceeding 3 mm particularly in the lower facial region, mainly due to inaccuracies in dataset integration and the limited ability of software algorithms to reproduce soft-tissue biomechanics [19]. Technological advances have progressively improved predictive performance; however, the lower facial region remains the most variable area.

Recent evidence indicates clinically acceptable levels of accuracy, with mean prediction errors generally below 1 mm and most measurements falling within 2 mm of the actual postoperative outcome. Nevertheless, larger discrepancies have been reported in cases involving extensive skeletal movements and in anatomically complex regions such as the lower lip and labial commissures, where soft-tissue behavior is strongly influenced by muscular activity [20,21]. In contrast, structures located in the upper facial third, including the nose and upper lip, appear to be more predictable [22].

The introduction of quantitative metrics such as the Planning Accuracy Coefficient (PAC) has further confirmed the high accuracy of virtual planning for skeletal structures while highlighting the greater biological variability of soft-tissue responses [23]. Consequently, a prediction error within ± 2 mm is generally considered clinically acceptable for soft-tissue outcomes.

The findings of the present pilot study are consistent with the existing literature. The comparison between the planned and postoperative measurements revealed a high

level of agreement for most of the evaluated cephalometric parameters. After adjustment for multiple comparisons using the Bonferroni correction, only the SNB angle remained significantly different between the planned and postoperative measurements, whereas the difference observed for the Mandibular Plane Angle did not retain statistical significance. The small discrepancy observed for the SNB angle may reflect minor deviations between the planned and achieved surgical movements, postoperative skeletal adaptation, differences in mandibular positioning during postoperative CBCT acquisition, or the intrinsic limitations of the virtual planning workflow in reproducing complex mandibular movements. Given the limited magnitude of this difference and the pilot nature of the study, it was not possible to determine the relative contribution of each of these factors.

For all other measurements, the close agreement between planned and achieved outcomes supports the accuracy of the surgical VTO in reproducing both skeletal and soft-tissue changes. This observation is in line with recent reports demonstrating a high level of concordance between virtual planning and postoperative outcomes, despite the persistence of minor discrepancies, particularly in sagittal movements and pitch rotations [24]. These findings further support the use of virtual surgical planning in orthognathic surgery, although intraoperative clinical verification remains essential to optimize both occlusal and aesthetic outcomes.

Overall, the present findings are consistent with the growing role of digital surgical planning as a key component of contemporary orthognathic treatment, contributing to more predictable, stable, and patient-specific functional and aesthetic outcomes.

4.2. Relationship Between Skeletal Movement and Soft-Tissue Response

The relationship between skeletal movements and soft-tissue response represents one of the most challenging aspects of orthognathic surgery because of the considerable interindividual variability in skin thickness, muscle tone, and soft-tissue volume [25]. Previous studies have demonstrated a strong correlation between mandibular displacement and soft-tissue changes in the lower facial third, particularly in the chin region, whereas vertical movements appear less predictable because of the influence of muscular and soft-tissue factors [25]. Similarly, high correlations between skeletal and soft-tissue movements have been reported for the chin, while weaker associations have been observed for the upper lip and subnasale [26].

Overall, soft tissues tend to follow the direction of the underlying skeletal movements, although the magnitude of the response is generally attenuated and influenced by individual anatomical characteristics [27]. Consequently, horizontal and sagittal movements are considered more predictable than vertical displacements [28]. Among facial regions, the nasal tip has been identified as one of the least predictable landmarks following orthognathic surgery [29], whereas the chin and lower lip typically exhibit a more direct and linear response to skeletal repositioning [30].

These observations are consistent with the findings of Rupperti et al. [31], who reported a moderate correlation between skeletal and soft-tissue movements following Le Fort I osteotomy. In their study, soft-tissue Point A and the upper lip closely followed skeletal displacement, whereas subnasale showed a weaker response and a mean prediction error of approximately 2 mm.

Despite the growing body of evidence, a standardized three-dimensional quantification of the relationship between hard- and soft-tissue movements is still lacking [32]. Nevertheless, there is broad agreement that mandibular sagittal movements are among the most predictable skeletal changes, whereas vertical movements and upper-lip responses remain more variable.

The results of the present pilot study are generally consistent with the available literature. After Bonferroni correction for multiple comparisons, significant positive correlations were observed between skeletal and soft-tissue displacements at Point B along the x - and y -axes, whereas the correlation along the z -axis did not remain statistically significant. At Pogonion, only the correlation along the z -axis remained statistically significant after adjustment. In these regions, soft-tissue movements generally followed the corresponding skeletal displacements, although with a smaller magnitude of displacement. Conversely, no significant correlations were found for Point A or Menton, possibly reflecting the greater biological variability of soft tissues in these regions.

It should also be considered that a subset of patients underwent genioplasty in addition to bimaxillary surgery. Whenever performed, genioplasty was digitally planned as an integral component of the virtual surgical workflow. Nevertheless, because genioplasty directly modifies the position of the chin, it may have acted as a confounding factor in the evaluation of the skeletal–soft-tissue relationship at Pogonion and Menton. Therefore, the findings at these landmarks should be interpreted with caution, as they may reflect the combined effects of mandibular repositioning and genioplasty. Owing to the limited sample size, separate analyses according to the presence or absence of genioplasty were not feasible.

This variability may also be influenced by the heterogeneity of the study sample, which included patients with skeletal Class II and Class III malocclusions, open bite, and facial asymmetry. These conditions are characterized by distinct craniofacial morphologies and soft-tissue adaptation patterns that may affect both the magnitude and direction of soft-tissue response following skeletal repositioning. Consequently, part of the variability observed in the skeletal–soft-tissue correlations may be attributable to differences in the underlying dentofacial deformity, in addition to individual biological variability. Because of the limited sample size, subgroup analyses according to malocclusion type were not feasible. Future studies, including larger cohorts, should stratify patients according to the underlying dentofacial deformity to determine whether skeletal–soft-tissue relationships differ among specific malocclusion groups.

4.3. Postoperative Edema and Volumetric Changes

Postoperative edema is a physiological consequence of surgical trauma and represents one of the main factors affecting the early postoperative aesthetic appearance. In recent years, three-dimensional facial scanning has enabled objective quantification of edema-related volumetric changes, providing a reliable method for monitoring postoperative soft-tissue evolution over time [12].

Previous studies have shown that facial edema decreases rapidly during the first weeks after surgery, followed by a more gradual reduction that may continue for up to 6–12 months postoperatively [10,11]. Most swelling resolves within the first month, and facial morphology progressively approaches the preoperative condition by approximately three months after surgery [11,33]. Patient-reported outcomes also indicate that edema tends to persist longer than other postoperative sequelae, although only a small proportion of patients continue to perceive significant swelling after the first month [34]. Based on this evidence, the 1-month postoperative scan was selected as the first follow-up time point, as it represents the transition between the acute postoperative phase and the subsequent period of soft-tissue remodeling. The additional evaluations at 3 and 6 months allowed assessment of the intermediate stages of edema resolution and the progressive stabilization of the facial soft tissues.

The extent and duration of postoperative edema are influenced by several surgical and patient-related factors, including the magnitude of mandibular setback, the use of

compressive dressings, and masseter muscle thickness [9]. Furthermore, edema has been reported to be more pronounced following bimaxillary procedures than after single-jaw surgery [33].

In the present study, a tolerance threshold of ± 0.5 mm was adopted to distinguish minor surface deviations from more pronounced postoperative soft-tissue changes. Although no universally accepted cutoff exists for three-dimensional facial surface analysis, this threshold is consistent with previously published methodologies and provides a conservative criterion for interpreting postoperative soft-tissue changes [17].

The findings of the present study suggest that three-dimensional facial scanning may be a useful tool for the longitudinal evaluation of postoperative volumetric changes. The technique provided a reproducible and non-invasive method for the longitudinal evaluation of postoperative volumetric changes. Over the follow-up period, both areas above and below the tolerance threshold increased, suggesting the coexistence of regions characterized by residual edema and areas undergoing progressive volume reduction. At six months, the greater extent of areas below the threshold indicated a general trend toward edema resolution and soft-tissue adaptation.

A characteristic spatial pattern was also observed. The lower facial third, particularly the chin region, tended to exhibit persistent volumetric enlargement, whereas the midfacial region showed a progressive reduction in volume over time. This finding may reflect regional differences in tissue response and remodeling following orthognathic surgery.

The only statistically significant difference between the analyzed follow-up intervals involved the percentage of surface area within tolerance, which was lower at 6 months than at 3 months. Although the percentage of surface area within tolerance showed a nominally significant difference before adjustment for multiple comparisons, this finding did not remain statistically significant after Bonferroni correction. Therefore, the observed trend should be interpreted with caution. Moreover, the observed surface deviations were generally small, with most deviations remaining within or close to the predefined tolerance threshold of ± 0.5 mm. Consequently, the detected changes are more likely to reflect physiological postoperative soft-tissue remodeling than clinically meaningful differences. Overall, these findings suggest that postoperative soft-tissue changes do not simply reflect edema resolution but also involve ongoing morphological adaptation and remodeling during the healing process.

4.4. Limitations

This study was conducted using a standardized protocol, and all included patients underwent bimaxillary surgery. Although the a priori power analysis confirmed an adequate sample size for this pilot investigation, the main limitation of this study is the relatively small sample size and the unbalanced sex distribution, which may limit the generalizability of the findings. A larger cohort would improve the robustness and generalizability of the findings. Moreover, the limited sample size did not allow subgroup analyses according to diagnosis, type of malocclusion, or surgical procedure (including the presence or absence of genioplasty), preventing the evaluation of their potential influence on the study outcomes. Future studies should stratify patients according to malocclusion type and surgical treatment, distinguishing among Class II, Class III, open-bite, and facial asymmetry cases. Furthermore, longer follow-up periods would provide a more comprehensive understanding of postoperative soft-tissue adaptation and remodeling. Furthermore, the Bonferroni correction applied to control for multiple comparisons provides a conservative approach that reduces the risk of false-positive findings but may have decreased the ability to detect small but potentially relevant effects, particularly in this pilot study with a limited sample size.

Another limitation relates to the operator-dependent identification of anatomical landmarks, which may introduce measurement variability, particularly for soft-tissue points. Despite the high intra-operator reliability observed in the present study, this potential source of error should be considered when interpreting the results.

Finally, two patients were excluded from specific analyses because of incomplete postoperative imaging or unreliable landmark identification. Although these exclusions were unavoidable, they reduced the sample size available for some comparisons and may have decreased the statistical power of those analyses. Therefore, the corresponding findings should be interpreted with caution. Nevertheless, despite these limitations, as a pilot study, the present investigation provides preliminary evidence on the application of three-dimensional digital planning and facial scanning in orthognathic surgery and may serve as a foundation for future prospective studies, including larger and more homogeneous patient cohorts.

5. Conclusions

The present findings suggest that the digital surgical planning workflow provided a good agreement between the planned and postoperative outcomes, supporting its use for orthognathic treatment planning. Significant positive correlations between skeletal and soft-tissue displacements were observed at Point B and Pogonion in specific spatial directions, highlighting the value of three-dimensional analysis for investigating postoperative skeletal–soft-tissue relationships. Overall, soft tissues tended to follow the underlying skeletal movements, although with a reduced magnitude of displacement. Although postoperative soft-tissue changes showed considerable interindividual variability, longitudinal three-dimensional facial scanning suggested progressive soft-tissue remodeling during the healing period. As a pilot study, these findings should be considered preliminary and warrant confirmation in larger prospective studies, including larger and more homogeneous patient cohorts.

Author Contributions: Conceptualization, L.L., and F.C.; methodology, M.R.; formal analysis, M.R.; investigation, M.R.; data curation, M.R.; writing—original draft preparation, M.R.; writing—review and editing, C.P.; visualization, C.P.; supervision, F.C., L.V., and R.T.; clinical management and surgical procedures, R.T., and L.V.; project administration, L.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Area Vasta Emilia Centro (CET-AVEC), Emilia-Romagna, Italy (protocol code CET-AVEC 133/2025/Oss/AOUFe; approval date: 21 May 2025).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors on request.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Table A1. Intra-operator reproducibility. Reliability was assessed using the intraclass correlation coefficient (ICC). Values are reported with their corresponding 95% confidence intervals (CI).

Measurements	ICC	95% CI Lower Bound	95% CI Upper Bound
Preoperative ANB angle	0.998	0.969	1.000
Preoperative Mandibular Plane Angle	0.920	0.218	0.995
Postoperative skeletal Point A (x-axis)	0.984	0.775	0.999
Preoperative skeletal Point A (z-axis)	0.996	0.936	1.000

References

1. Al-Asfour, A.; Waheedi, M.; Koshy, S. Survey of patient experiences of orthognathic surgery: Health-related quality of life and satisfaction. *Int. J. Oral Maxillofac. Surg.* **2018**, *47*, 726–731. [\[CrossRef\]](#)
2. Cabral, R.C.; Canellas, J.V.; Tiwana, P.S.; Medeiros, P.J.; Ritto, F.G. Impact of orthognathic surgery on quality of life and comparison of patients' postoperative experience after single- and double-jaw surgery: A longitudinal study. *Oral Surg. Oral Med. Oral Pathol. Oral Radiol.* **2021**, *132*, 633–640. [\[CrossRef\]](#) [\[PubMed\]](#)
3. Park, K.E.; Maniskas, S.; Allam, O.; Pourtaheri, N.; Steinbacher, D.M. Orthognathic Surgery to Improve Facial Profile: Assessment, 3-Dimensional Planning, and Technique. *Aesthet. Surg. J. Open Forum* **2020**, *3*, oja051. [\[CrossRef\]](#) [\[PubMed\]](#)
4. Arnett, G.W.; Bergman, R.T. Facial keys to orthodontic diagnosis and treatment planning. Part I. *Am. J. Orthod. Dentofac. Orthop.* **1993**, *103*, 299–312. [\[CrossRef\]](#)
5. Arnett, G.W.; Jelic, J.S.; Kim, J.; Cummings, D.R.; Beress, A.; Worley, C.M., Jr.; Chung, B.; Bergman, R. Soft tissue cephalometric analysis: Diagnosis and treatment planning of dentofacial deformity. *Am. J. Orthod. Dentofac. Orthop.* **1999**, *116*, 239–253.
6. Larson, B.E. Orthodontic preparation for orthognathic surgery. *Oral Maxillofac. Surg. Clin. N. Am.* **2014**, *26*, 441–458. [\[CrossRef\]](#)
7. Lee, Y.C.; Kim, S.G. Redefining precision and efficiency in orthognathic surgery through virtual surgical planning and 3D printing: A narrative review. *Maxillofac. Plast. Reconstr. Surg.* **2023**, *45*, 42. [\[CrossRef\]](#) [\[PubMed\]](#)
8. Holte, K.; Sharrock, N.E.; Kehlet, H. Pathophysiology and clinical implications of perioperative fluid excess. *Br. J. Anaesth.* **2002**, *89*, 622–632. [\[CrossRef\]](#) [\[PubMed\]](#)
9. Shibata, M.; Takahara, N.; Kaneko, T.; Oki, M.; Sasaki, Y.; Tomomatsu, N.; Kurasawa, Y.; Nakakuki, K.; Yoda, T. Risk factors for postoperative facial swelling at 1 week after bimaxillary orthognathic surgery in Class III patients. *J. Stomatol. Oral Maxillofac. Surg.* **2023**, *124*, 101516. [\[CrossRef\]](#) [\[PubMed\]](#)
10. van der Vlis, M.; Dentino, K.M.; Vervloet, B.; Padwa, B.L. Postoperative swelling after orthognathic surgery: A prospective volumetric analysis. *J. Oral Maxillofac. Surg.* **2014**, *72*, 2241–2247. [\[CrossRef\]](#) [\[PubMed\]](#)
11. Yamamoto, S.; Miyachi, H.; Fujii, H.; Ochiai, S.; Watanabe, S.; Shimozato, K. Intuitive Facial Imaging Method for Evaluation of Postoperative Swelling: A Combination of 3-Dimensional Computed Tomography and Laser Surface Scanning in Orthognathic Surgery. *J. Oral Maxillofac. Surg.* **2016**, *74*, 2506.e1–2506.e10. [\[CrossRef\]](#) [\[PubMed\]](#)
12. van der Meer, W.J.; Dijkstra, P.U.; Visser, A.; Vissink, A.; Ren, Y. Reliability and validity of measurements of facial swelling with a stereophotogrammetry optical three-dimensional scanner. *Br. J. Oral Maxillofac. Surg.* **2014**, *52*, 922–927. [\[CrossRef\]](#) [\[PubMed\]](#)
13. Pellitteri, F.; Scisciola, F.; Cremonini, F.; Baciliero, M.; Lombardo, L. Accuracy of 3D facial scans: A comparison of three different scanning system in an in vivo study. *Prog. Orthod.* **2023**, *24*, 44. [\[CrossRef\]](#) [\[PubMed\]](#)
14. Jindanil, T.; Ponbuddhichai, R.; Massant, C.; Xu, L.; Fontenele, R.C.; de Llano-Pérula, M.C.; Jacobs, R. Three-Dimensional Facial Imaging: A Comparative Assessment of the Clinical Applicability of State-of-the-Art Technologies for Three-Dimensional Facial Imaging. *Int. J. Dent.* **2025**, *2025*, 8822293. [\[CrossRef\]](#) [\[PubMed\]](#)
15. Pellitteri, F.; Bruculeri, L.; Spedicato, G.A.; Siciliani, G.; Lombardo, L. Comparison of the accuracy of digital face scans obtained by two different scanners. *Angle Orthod.* **2021**, *91*, 641–649. [\[CrossRef\]](#) [\[PubMed\]](#)
16. Aljawad, H.; Kang, N.; Lee, K.C. Integration accuracy of craniofacial cone-beam computed tomography images with three-dimensional facial scans according to different registration areas. *Angle Orthod.* **2023**, *93*, 66–70. [\[CrossRef\]](#) [\[PubMed\]](#)
17. Pellitteri, F.; Albertini, P.; Bruculeri, L.; Cremonini, F.; Guiducci, D.; Falconi, V.; Lombardo, L. Soft tissue changes during orthopedic therapy: An in vivo 3-dimensional facial scan study. *Am. J. Orthod. Dentofac. Orthop.* **2025**, *167*, 154–165. [\[CrossRef\]](#)
18. Hajeer, M.Y.; Millett, D.T.; Ayoub, A.F.; Siebert, J.P. Applications of 3D imaging in orthodontics: Part I. *J. Orthod.* **2004**, *31*, 62–70. [\[PubMed\]](#)
19. Terzic, A.; Combescure, C.; Scolozzi, P. Accuracy of computational soft tissue predictions in orthognathic surgery from three-dimensional photographs 6 months after completion of surgery: A preliminary study of 13 patients. *Aesthetic Plast. Surg.* **2014**, *38*, 184–191. [\[PubMed\]](#)

20. Schendel, S.A.; Jacobson, R.; Khalessi, S. 3-dimensional facial simulation in orthognathic surgery: Is it accurate? *J. Oral Maxillofac. Surg.* **2013**, *71*, 1406–1414. [[CrossRef](#)]
21. Lee, K.J.C.; Tan, S.L.; Low, H.Y.A.; Chen, L.J.; Yong, C.W.; Chew, M.T. Accuracy of 3-dimensional soft tissue prediction for orthognathic surgery in a Chinese population. *J. Stomatol. Oral Maxillofac. Surg.* **2022**, *123*, 551–555. [[CrossRef](#)] [[PubMed](#)]
22. Awad, D.; Reinert, S.; Kluba, S. Accuracy of Three-Dimensional Soft-Tissue Prediction Considering the Facial Aesthetic Units Using a Virtual Planning System in Orthognathic Surgery. *J. Pers. Med.* **2022**, *12*, 1379. [[CrossRef](#)] [[PubMed](#)]
23. Grab, P.P.; Szałwiński, M.; Jagielak, M.; Rożko, J.; Jurkiewicz, D.; Chloupek, A.; Sobol, M.; Rot, P. Evaluating Virtual Planning Accuracy in Bimaxillary Advancement Surgery: A Retrospective Study Introducing the Planning Accuracy Coefficient. *J. Clin. Med.* **2025**, *14*, 3527. [[CrossRef](#)] [[PubMed](#)]
24. Varazzani, A.; Tognin, L.; Corre, P.; Bouletreau, P.; Perrin, J.-P.; Menapace, G.; Bergonzani, M.; Pedrazzi, G.; Anghinoni, M.; Poli, T. Virtual surgical planning in orthognathic surgery: A prospective evaluation of postoperative accuracy. *J. Stomatol. Oral Maxillofac. Surg.* **2025**, *126*, 102025. [[CrossRef](#)] [[PubMed](#)]
25. Kim, K.A.; Chang, Y.J.; Lee, S.H.; An, H.J.; Park, K.H. Three-dimensional soft tissue changes according to skeletal changes after mandibular setback surgery by using cone-beam computed tomography and a structured light scanner. *Prog. Orthod.* **2019**, *20*, 25. [[CrossRef](#)] [[PubMed](#)]
26. Kaklamanos, E.G.; Kolokitha, O.E. Relation between soft tissue and skeletal changes after mandibular setback surgery: A systematic review and meta-analysis. *J. Cranio-Maxillofac. Surg.* **2016**, *44*, 427–435. [[CrossRef](#)]
27. Paek, S.J.; Yoo, J.Y.; Lee, J.W.; Park, W.-J.; Chee, Y.D.; Choi, M.G.; Choi, E.J.; Kwon, K.-H. Changes of lip morphology following mandibular setback surgery using 3D cone-beam computed tomography images. *Maxillofac. Plast. Reconstr. Surg.* **2016**, *38*, 38. [[CrossRef](#)] [[PubMed](#)]
28. Ajmera, D.H.; Singh, P.; Leung, Y.Y.; Gu, M. Three-dimensional evaluation of soft-tissue response to osseous movement after orthognathic surgery in patients with facial asymmetry: A systematic review. *J. Cranio-Maxillofac. Surg.* **2021**, *49*, 763–774. [[CrossRef](#)]
29. Koerich, L.; Brunetto, D.P.; Ohira, E.T.B. The effect of hard tissue surgical changes on soft tissue displacement: A pilot CBCT study. *Dent. Press J. Orthod.* **2017**, *22*, 39–46. [[CrossRef](#)]
30. Jung, J.; Lee, C.H.; Lee, J.W.; Choi, B.J. Three dimensional evaluation of soft tissue after orthognathic surgery. *Head. Face Med.* **2018**, *14*, 21. [[CrossRef](#)] [[PubMed](#)]
31. Rupperti, S.; Winterhalder, P.; Krennmair, S.; Holberg, S.; Holberg, C.; Mast, G.; Rudzki, I. Changes in the facial soft tissue profile after maxillary orthognathic surgery. Veränderungen des fazialen Weichgewebeprofiles nach maxillärer orthognathier Chirurgie. *J. Orofac. Orthop.* **2022**, *83*, 215–220. [[PubMed](#)]
32. Olate, S.; Zaror, C.; Mommaerts, M.Y. A systematic review of soft-to-hard tissue ratios in orthognathic surgery. Part IV: 3D analysis—Is there evidence? *J. Cranio-Maxillofac. Surg.* **2017**, *45*, 1278–1286. [[CrossRef](#)]
33. Kau, C.H.; Cronin, A.J.; Richmond, S. A three-dimensional evaluation of postoperative swelling following orthognathic surgery at 6 months. *Plast. Reconstr. Surg.* **2007**, *119*, 2192–2199. [[CrossRef](#)] [[PubMed](#)]
34. Phillips, C.; Blakey, G., 3rd; Jaskolka, M. Recovery after orthognathic surgery: Short-term health-related quality of life outcomes. *J. Oral Maxillofac. Surg.* **2008**, *66*, 2110–2115. [[CrossRef](#)] [[PubMed](#)]

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.