

Direction-Dependent Soft Tissue Thickness in Facial Asymmetry: A Three-Dimensional Analysis Using Facial Scanning and Cone Beam Computed Tomography

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Abstract

Background: Facial asymmetry is a common craniofacial condition affecting facial aesthetics and function. Although skeletal discrepancies are the primary determinant, the role of direction-dependent soft tissue thickness in shaping facial morphology remains unclear. **Objective:** To investigate direction-dependent patterns of soft tissue thickness in patients with facial asymmetry using integrated three-dimensional facial scanning and cone beam computed tomography. **Materials and methods:** This cross-sectional study included 60 adults aged 18–35 years undergoing orthodontic and orthognathic evaluation. Cone beam computed tomography and three-dimensional facial scan datasets were fused to construct composite craniofacial models. Bilateral skeletal landmarks were identified, and soft tissue thickness was measured relative to the midsagittal plane in transverse and sagittal directions. Paired statistical tests compared measurements between deviated and contralateral sides. **Results:** Significant skeletal asymmetry was observed at multiple craniofacial landmarks, particularly at the antegonial notch (2.09 ± 4.40 mm), orbitale (1.66 ± 3.16 mm), and anterior ramus notch (1.34 ± 1.94 mm), among others ($P < 0.01$). Direction-dependent patterns of soft tissue thickness was identified. In the transverse, soft tissue was generally thinner on the deviated side at the anterior ramus notch, canini, antegonial notch, and gonion ($P < 0.01$). In contrast, sagittal measurements showed greater soft tissue thickness on the deviated side at the condylion, antegonial notch, and gonion ($P < 0.01$). **Conclusion:** Soft tissue thickness in facial asymmetry demonstrates direction-dependent patterns and only partially reflects skeletal deviations. Integrated three-dimensional imaging may improve evaluation of skeletal–soft tissue relationships and assist orthodontic and orthognathic treatment planning.

Keywords: Cone beam computed tomography, Face, Facial asymmetry, Soft tissue, Imaging three-dimensional

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Introduction

Facial asymmetry is a common clinical condition that affects both facial aesthetics and function, with studies reporting that up to one-third of individuals exhibit some degree of asymmetry, most frequently presenting as chin deviation.^{1,2} The etiology is multifactorial and may involve congenital conditions, developmental disturbances, trauma, and abnormalities in skeletal or muscular growth. Accurate assessment of facial asymmetry is therefore essential for diagnosis, treatment planning, and orthognathic surgical decision-making in craniofacial patients.

Evaluation of facial asymmetry typically involves visual inspection, two-dimensional (2D) photography, and cephalometric analysis. However, these approaches are limited in their ability to capture the complex three-dimensional (3D) relationships of craniofacial structures. Advances in imaging technologies, particularly 3D facial scanning and cone beam computed tomography, have substantially improved the precision and reproducibility of craniofacial assessment.³⁻⁵ The integration of these modalities enables comprehensive visualization of both hard and soft tissues, facilitating accurate landmark identification and spatial evaluation.

Soft tissues play an important role in the clinical manifestation and perception of facial asymmetry due to their close relationship with underlying skeletal structures. Previous studies have demonstrated strong correlations between hard and soft tissue landmarks, with soft tissue generally reflecting rather than fully compensating for skeletal deviations.^{6,7} Even in individuals with normal occlusion, soft tissue asymmetry may range from 0.6 to 4.6 mm, often exceeding the discrepancies observed in the skeletal framework, particularly in the lower and lateral facial regions.⁸ While certain soft tissue components may partially mask skeletal discrepancies, this compensation is inconsistent and often insufficient in moderate to severe asymmetry. Features such as chin position, gonial contour, lip canting, and midline alignment

significantly influence the clinical perception of facial imbalance.^{4,9}

Understanding the relationship between soft tissue thickness and underlying skeletal asymmetry is essential for accurate diagnosis, realistic treatment planning, and prediction of postoperative outcomes in orthodontics and orthognathic surgery.^{1,4,10} However, conventional two-dimensional approaches cannot adequately quantify region-specific or direction-dependent variations in soft tissue thickness. Recent advances in 3D imaging allow simultaneous evaluation of skeletal morphology and overlying soft tissues, enabling more comprehensive analysis of craniofacial asymmetry.^{4,11}

Despite increasing use of 3D imaging, limited studies have investigated how soft tissue thickness varies between deviated and contralateral sides and whether these variations differ according to measurement direction. A clearer understanding of these direction-dependent soft tissue patterns may improve diagnostic accuracy and support individualized orthodontic and orthognathic treatment planning.

Therefore, this study aimed to evaluate differences in soft tissue thickness between deviated and contralateral sides in patients with facial asymmetry using integrated cone beam computed tomography and 3D facial scanning. In addition, the relationship between skeletal deviations and direction-specific soft tissue thickness patterns was investigated across multiple craniofacial landmarks. This study provides a landmark-based, direction-dependent assessment of soft tissue thickness in both the transverse and sagittal dimensions to better characterize soft tissue adaptation to skeletal asymmetry.

Materials and methods

Informed consent was obtained from all participants prior to data acquisition. Sample size calculation was performed using G*Power software (version 3.1.9.7; University of Kiel, Kiel, Germany) with

a significance level of 0.05, statistical power of 80 %, and an effect size of 0.80 based on previously reported bilateral differences in landmark measurements.¹² A minimum sample size of 60 patients was required to detect significant bilateral differences, and 60 eligible patients were included in the study.

Inclusion and exclusion criteria

Facial asymmetry was defined as a skeletal menton deviation of ≥ 2 mm from the midsagittal plane, consistent with previously reported diagnostic thresholds.¹³ This cross-sectional study included adult patients aged 18–35 years presenting with facial asymmetry who were scheduled for orthodontic treatment and orthognathic surgery evaluation between January 2022 and January 2024. None of the participants had received prior orthodontic treatment or were undergoing active orthodontic therapy at the time of imaging. Exclusion criteria included craniofacial syndromes, cleft lip and/or palate, systemic conditions affecting craniofacial development, and a history of facial trauma or craniofacial surgical procedures. CBCT and 3D facial scan datasets from all eligible patients were used to construct virtual 3D craniofacial models for analysis.

Data acquisition and assessment

CBCT scans were obtained using a Planmeca Viso® G7 system (Planmeca Oy, Helsinki, Finland) with the following parameters: voxel size 400 μ m, field of view 30 $\times$ 30 cm, 120 kV, and 8.0 mA. Patients were positioned in natural head posture with teeth in maximum intercuspation and relaxed lips.

Three-dimensional facial scans were obtained using the integrated facial scanning function of the same system under standardized conditions. CBCT and facial scan datasets were imported into Dolphin Imaging software (version 11.9; Dolphin Imaging Systems, Los Angeles, CA, USA) and fused using a surface-based registration approach. Spatial alignment was performed using the Iterative Closest Point algorithm,

which minimizes the root-mean-square error between corresponding surface points to generate accurate composite 3D craniofacial models.

Reference planes were established based on previously validated methods.^{4,12,14,15} The horizontal reference line (HRL) was defined by connecting the right and left Orbitale, while the vertical reference line (VRL) was constructed perpendicular to the HRL and passing through the anterior nasal spine (ANS). The sagittal reference line (SRL) was defined by connecting the anterior nasal spine (ANS) and posterior nasal spine (PNS). These reference planes were used to orient the three-dimensional models for standardized analysis (Figure 1).

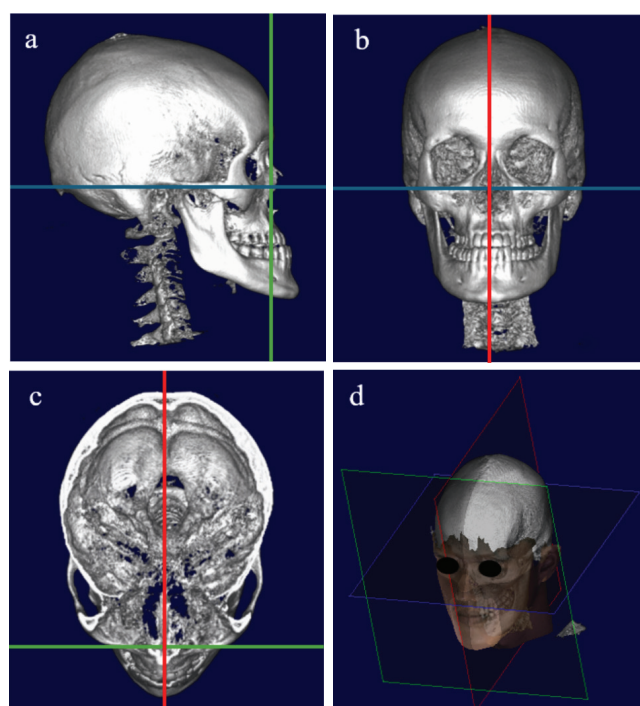


Figure 1 Images of the orientation settings of a 3D virtual head: (a) horizontal reference line (blue line), (b) vertical reference line (red line), (c) sagittal reference line (green line), and (d) final construction of reference planes in a 3D view.

Hard tissue landmarks used in this study are summarized in Figure 2 and included the condylion, zygion, orbitale, sigmoid notch, posterior ramus notch, anterior ramus notch, antegonial notch, canini, and gonion.

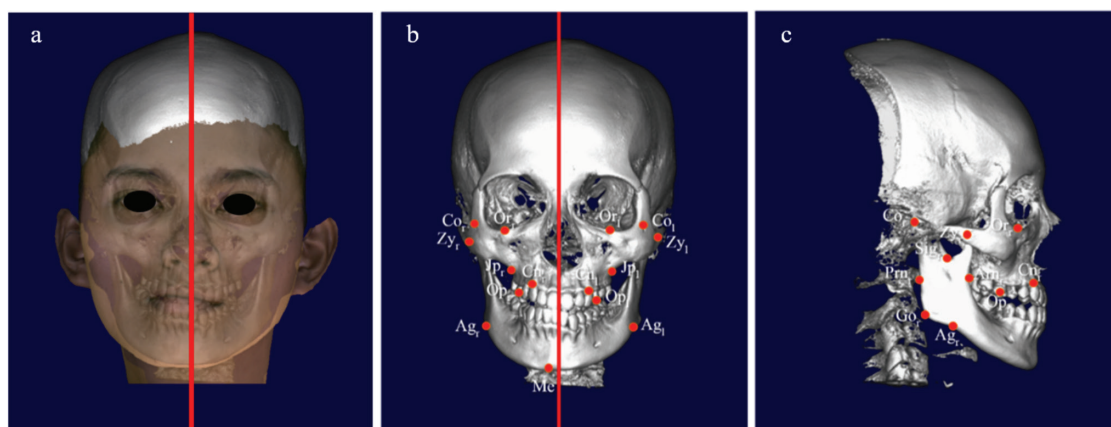


Figure 2 (a) 3D virtual head composed of hard and soft tissue (b) Landmarks of hard tissue in frontal view (c) Landmarks of hard tissue in lateral view

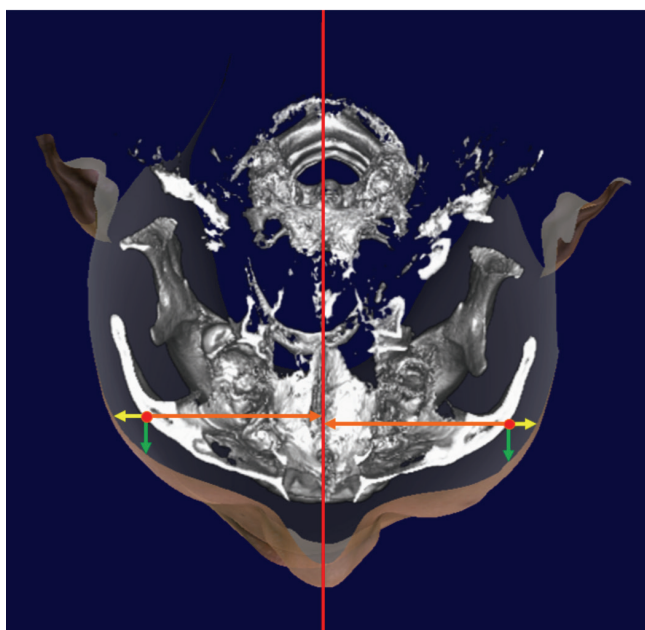


Figure 3 Measurement of soft tissue thickness at each bilateral landmark (red dot) in the transverse direction (yellow arrow), sagittal direction (green arrow). Skeletal asymmetry was assessed as the perpendicular distance from the midsagittal plane (orange arrow).

All landmarks were identified by a single calibrated investigator. Calibration was performed prior to the study using 10 randomly selected cases to ensure consistency in landmark localization.

Measurements were obtained in two stages. Skeletal asymmetry was assessed by measuring the perpendicular distance from each landmark to the

midsagittal plane. Soft tissue thickness was measured in two directions. The transverse direction was defined as the horizontal distance from each skeletal landmark to the corresponding external soft tissue point perpendicular to the midsagittal plane. The sagittal direction was defined as the anteroposterior distance from the skeletal landmark to the outermost soft tissue surface along the sagittal axis. The corresponding soft tissue point was identified as the closest external surface point aligned with each measurement direction using the fused 3D model.

Three parameters were recorded for each landmark: skeletal deviation, transverse soft tissue thickness, sagittal soft tissue thickness, as shown in Figure 3. All measurements were performed twice by the same investigator, and the mean values were used for statistical analysis.

Statistical analysis

Statistical analysis was performed using SPSS software (version 26.0; IBM Corp., Armonk, NY, USA). Descriptive statistics were calculated as means and standard deviations. Data normality was assessed using the Kolmogorov–Smirnov test, which confirmed normal distribution of all variables. Paired t-tests were used to compare measurements between deviated and contralateral sides. Statistical significance was defined as $P < 0.05$.

Prior to data collection, ten cases were used for examiner calibration to ensure consistency in landmark identification. After completion of all measurements, intra-examiner reliability was assessed using 15 randomly selected cases, which were re-measured after a two-week interval, so that the

sample used for ICC calculation was independent from the initial calibration set. Reliability was assessed using the intraclass correlation coefficient, demonstrating excellent reproducibility (ICC = 0.94; 95 % confidence interval, 0.90 – 0.97).

Table 1 General characteristics of the patients including the menton deviation direction.

	Total n = 60	Female n = 33	Male n = 27
Age (year, mean $\pm$ SD)	24.11 $\pm$ 3.88	24.12 $\pm$ 4.34	24.10 $\pm$ 3.45
Menton deviation (mm, mean $\pm$ SD)	3.97 $\pm$ 1.41	4.34 $\pm$ 1.61	3.52 $\pm$ 0.98
Side of menton deviation			
Right	34	23	11
Left	26	10	16

Table 2 Distance from hard tissue landmarks to midsagittal plane

Landmark	Deviated side	Contralateral side	Difference	P value
Condylion (Co)	51.24 $\pm$ 2.91	50.39 $\pm$ 2.89	0.90 $\pm$ 2.66	0.001**
Zygion (Zy)	61.08 $\pm$ 4.22	60.52 $\pm$ 3.74	0.69 $\pm$ 3.10	0.164
Orbitale (Or)	33.39 $\pm$ 4.07	31.94 $\pm$ 2.97	1.66 $\pm$ 3.16	< 0.0001***
Sigmoid notch (Sig)	49.37 $\pm$ 2.12	48.39 $\pm$ 2.34	1.03 $\pm$ 1.52	0.001**
Posterior ramus notch (Pmn)	49.06 $\pm$ 2.08	48.16 $\pm$ 2.20	0.84 $\pm$ 1.68	0.001**
Anterior ramus notch (Arn)	44.63 $\pm$ 1.80	43.33 $\pm$ 1.96	1.34 $\pm$ 1.94	0.001**
Antegonial notch (Ag)	44.79 $\pm$ 3.28	42.71 $\pm$ 5.13	2.09 $\pm$ 4.40	0.001**
Canini (Cn)	19.85 $\pm$ 2.10	19.22 $\pm$ 2.08	0.72 $\pm$ 1.62	0.004**
Gonion (Go)	45.90 $\pm$ 3.34	44.79 $\pm$ 3.19	1.06 $\pm$ 2.24	0.001**

Values are presented as mean $\pm$ standard deviation (SD). Comparisons between the deviated and contralateral sides were performed using paired t-tests.

** P < 0.01; *** P < 0.001.

Results

A total of 60 patients (33 females and 27 males) with facial asymmetry were included in this study. The mean age was 24.11 ± 3.88 years. The mean menton deviation was 3.97 ± 1.41 mm, with greater deviation observed in females (4.34 ± 1.61 mm) than in males (3.52 ± 0.98 mm). Right-sided deviation was observed in 34 patients (56.7 %), whereas 26 patients (43.3 %) showed left-sided deviation. Female patients more frequently exhibited right-sided deviation (69.7 %), while left-sided deviation was more common among male patients (59.3 %) (Table 1).

Distances from hard tissue landmarks to the midsagittal plane are presented in Table 2. Significant differences between the deviated and contralateral sides were observed at multiple landmarks, including the antegonial notch (2.09 ± 4.40 mm, $P < 0.001$), orbitale (1.66 ± 3.16 mm, $P < 0.001$), and anterior ramus notch (1.34 ± 1.94 mm, $P < 0.01$). Additional significant

differences were identified at the condylion, sigmoid notch, posterior ramus notch, canini, and gonion. No significant difference was observed at the zygion.

The total distance from the midsagittal plane to the outermost soft tissue surface at each corresponding hard tissue landmark was evaluated. These measurements, which incorporate both skeletal deviation and overlying soft tissue thickness, are summarized in Table 3 for the deviated and contralateral sides. The largest differences were observed at the orbitale (1.22 ± 4.31 mm), antegonial notch (0.91 ± 4.39 mm), and condylion (0.79 ± 2.95 mm). However, only the anterior ramus notch demonstrated a statistically significant difference (-0.57 ± 2.08 mm, $P < 0.01$). No significant differences were observed at the other landmarks.

Soft tissue thickness in the transverse direction is presented in Table 4. Significant differences between the deviated and contralateral sides were identified at several landmarks. The anterior ramus

Table 3 Total distance from the midsagittal plane to the outermost soft tissue surface

Landmark	Deviated side	Contralateral side	Difference	P value
Condylion (Co)	71.87 ± 2.81	71.13 ± 3.18	0.79 ± 2.95	0.051
Zygion (Zy)	71.08 ± 4.33	71.46 ± 3.54	-0.25 ± 3.12	0.348
Orbitale (Or)	53.35 ± 5.13	52.23 ± 5.45	1.22 ± 4.31	0.051
Sigmoid notch (Sig)	70.05 ± 3.08	69.91 ± 2.99	0.16 ± 1.88	0.058
Posterior ramus notch (Prn)	66.58 ± 2.99	66.44 ± 2.70	0.06 ± 2.38	0.642
Anterior ramus notch (Arn)	65.47 ± 2.36	66.02 ± 2.52	-0.57 ± 2.08	0.001**
Antegonial notch (Ag)	57.05 ± 3.51	56.66 ± 3.41	0.91 ± 4.39	0.300
Canini (Cn)	44.77 ± 5.27	45.40 ± 5.88	-0.63 ± 2.99	0.109
Gonion (Go)	59.51 ± 4.35	59.40 ± 4.43	0.11 ± 2.23	0.692

Values are presented as mean $\pm$ standard deviation (SD). Comparisons between the deviated and contralateral sides were performed using paired t-tests.

** $P < 0.01$; *** $P < 0.001$.

Table 4 Soft tissue thickness in transverse direction

Landmark	Deviated side	Contralateral side	Difference	P value
Condylion (Co)	20.64 ± 2.75	21.49 ± 6.26	-0.10 ± 2.51	0.278
Zygion (Zy)	9.97 ± 2.14	11.23 ± 3.05	-0.95 ± 1.48	0.001**
Orbitale (Or)	19.84 ± 4.10	20.20 ± 4.77	-0.50 ± 2.62	0.303
Sigmoid notch (Sig)	20.68 ± 1.90	22.04 ± 4.15	-0.85 ± 1.57	0.001**
Posterior ramus notch (Prn)	17.55 ± 2.65	19.16 ± 6.75	-0.75 ± 1.75	0.070
Anterior ramus notch (Arn)	20.84 ± 2.12	23.09 ± 3.08	-1.94 ± 1.59	0.001**
Antegonial notch (Ag)	12.29 ± 1.86	14.11 ± 4.93	-1.21 ± 1.68	0.006**
Canini (Cn)	24.84 ± 5.33	26.14 ± 5.35	-1.37 ± 2.76	0.001**
Gonion (Go)	13.67 ± 3.95	15.59 ± 7.97	-0.98 ± 1.41	0.004**

Values are presented as mean ± standard deviation (SD). Comparisons between the deviated and contralateral sides were performed using paired t-tests.

** $P < 0.01$; *** $P < 0.001$.

Table 5 Soft tissue thickness in sagittal direction

Landmark	Deviated side	Contralateral side	Difference	P value
Condylion (Co)	64.36 ± 3.01	63.56 ± 3.90	0.93 ± 2.93	0.004**
Zygion (Zy)	24.26 ± 2.93	24.61 ± 3.37	0.47 ± 5.61	0.368
Orbitale (Or)	8.03 ± 1.67	7.95 ± 1.75	0.26 ± 1.03	0.724
Sigmoid notch (Sig)	51.84 ± 2.98	51.33 ± 3.32	0.57 ± 2.62	0.153
Posterior ramus notch (Prn)	64.93 ± 3.30	64.47 ± 4.17	0.72 ± 3.17	0.281
Anterior ramus notch (Arn)	41.22 ± 2.82	40.85 ± 2.69	0.49 ± 2.86	0.347
Antegonial notch (Ag)	42.82 ± 5.08	41.86 ± 5.69	1.26 ± 4.73	0.006**
Canini (Cn)	17.02 ± 4.64	17.05 ± 4.37	0.12 ± 2.40	0.016
Gonion (Go)	59.30 ± 6.33	58.63 ± 6.51	1.11 ± 3.92	0.004**

Values are presented as mean ± standard deviation (SD). Comparisons between the deviated and contralateral sides were performed using paired t-tests.

** $P < 0.01$; *** $P < 0.001$.

notch showed the greatest difference (-1.94 ± 1.59 mm, $P < 0.01$), followed by the canini, antegonial notch, and gonion. Additional significant differences

were observed at the zygion and sigmoid notch. No significant differences were found at the condylion or orbitale.

Finally, soft tissue thickness in the sagittal direction is shown in Table 5. Significant differences were observed at the condylion (0.93 ± 2.93 mm), antegonial notch (1.26 ± 4.73 mm), and gonion (1.11 ± 3.92 mm), with thicker soft tissue observed on the deviated side. Other landmarks, including the zygion, sigmoid notch, anterior ramus notch, and canini showed no statistically significant differences.

Discussion

The present study evaluated the relationship between skeletal asymmetry and soft tissue thickness in patients with facial asymmetry using integrated 3D facial scanning and cone beam computed tomography. The findings demonstrate that skeletal discrepancies—particularly at landmarks such as the antegonial notch, orbitale, and anterior ramus notch—were more pronounced and consistently significant than those observed in the overlying soft tissues. Although variations in soft tissue thickness was detected at several landmarks, including the orbitale, antegonial notch, and condylion, their magnitude was generally smaller and statistical significance less consistent. These observations are consistent with previous studies reporting that soft tissue typically reflects, rather than compensates for, underlying skeletal asymmetry.^{7,16,17} For instance, in patients with skeletal Class III malocclusion, soft tissue asymmetry is often detectable but rarely offsets skeletal discrepancies, and strong correlations have been reported between corresponding hard and soft tissue landmarks.¹

When analyzed according to measurement direction, a distinct pattern of soft tissue adaptation emerged. In the transverse dimension, soft tissue thickness tended to be thinner on the deviated side. This reduction in soft tissue thickness may partially reduce the prominence of skeletal deviation when viewed from the frontal perspective, thereby providing a limited camouflage effect.^{17,18} However, this effect was inconsistent across anatomical regions and did not fully

compensate for the underlying skeletal discrepancy. In contrast, sagittal measurements demonstrated a tendency for soft tissue to be thicker on the deviated side at several landmarks. This directional difference suggests that soft tissue adaptation does not occur uniformly but varies according to the measurement plane. Similar observations have been reported in previous investigations, indicating that soft tissue responses to skeletal asymmetry are complex and often region-specific.^{17,19}

The presence of thinner soft tissue in the transverse plane and thicker soft tissue in the sagittal plane on the deviated side highlights a direction-dependent pattern of soft tissue adaptation. While mild soft tissue thinning may visually reduce the lateral projection of skeletal deviation, increased soft tissue thickness in the sagittal dimension may accentuate asymmetry in profile or oblique views. These findings support earlier reports suggesting that soft tissue compensation is limited and often inconsistent, particularly in cases with pronounced skeletal discrepancies.²⁰ Furthermore, certain mandibular regions have been shown to demonstrate compensatory responses on the contralateral side, emphasizing the individualized and complex nature of soft tissue adaptation to skeletal imbalance.^{21,22}

Landmark-specific differences in both skeletal deviation and soft tissue thickness was also observed in the present study. Lower facial landmarks—especially the antegonial notch, and gonion,—demonstrated the most pronounced asymmetries. Among these, the antegonial notch exhibited the largest bilateral discrepancy. These results are consistent with previous reports indicating that asymmetry is more prominent in the lower and lateral facial regions, whereas the midfacial structures tend to remain relatively symmetrical.^{4,7,8} This distribution is commonly attributed to the longer growth period and greater biomechanical mobility of the mandible compared with the relatively stable midfacial skeleton.^{1,23}

Although soft tissue generally followed the pattern of skeletal asymmetry, the degree of correspondence varied across anatomical regions. In some areas, soft tissue partially reflected the underlying skeletal imbalance, whereas in others it appeared to exaggerate the visible asymmetry. Notably, regions associated with the condylar and ramal structures sometimes demonstrated inverse relationships between skeletal displacement and soft tissue thickness. These findings emphasize the importance of region-specific three-dimensional analysis when evaluating patients with facial asymmetry and planning orthodontic or orthognathic treatment.²⁴

From a clinical perspective, the present findings highlight the limitations of relying solely on visual assessment or two-dimensional imaging when diagnosing facial asymmetry. Because soft tissue thickness may partially mask or accentuate skeletal discrepancies depending on the measurement direction and anatomical region, two-dimensional evaluation may underestimate the extent of skeletal imbalance. The integration of cone beam computed tomography and three-dimensional facial scanning allows simultaneous visualization of both skeletal structures and the overlying soft tissues, enabling more accurate diagnosis and individualized treatment planning.²⁵⁻²⁷ From a clinical standpoint, these findings suggest that virtual surgical planning should take direction-dependent soft tissue behavior into account when estimating soft tissue-to-hard tissue movement ratios. In the transverse dimension, thinner soft tissue on the deviated side may partially reduce the visible prominence of the underlying bony deviation, meaning that a simple one-to-one skeletal correction may underestimate the remaining soft tissue asymmetry. In contrast, thicker soft tissue in the sagittal dimension on the deviated side may enhance the appearance of asymmetry after mandibular or ramal repositioning. This suggests that adjustments in planned skeletal movements, or consideration of adjunctive soft tissue procedures,

may help achieve more balanced facial contours. Incorporating these direction-specific considerations into three-dimensional simulations may improve the accuracy of aesthetic outcome prediction and help clinicians communicate more realistic expectations to patients with facial asymmetry.

In addition, landmark-based analysis provides valuable information regarding the regional behavior of soft tissues in response to skeletal asymmetry. While mild cases may exhibit limited soft tissue camouflage, more pronounced skeletal deviations often remain clearly visible in the overlying soft tissues. Moreover, postoperative soft tissue responses remain partly unpredictable, and residual asymmetry may persist despite adequate skeletal correction.²⁸⁻³⁰ Consequently, comprehensive three-dimensional evaluation and careful preoperative planning are essential for achieving optimal functional and aesthetic outcomes.

This study has some limitations. First, the cross-sectional design does not allow evaluation of longitudinal changes in soft tissue following surgical correction. Second, the study population consisted of patients seeking orthodontic and orthognathic treatment, which may limit generalizability to the broader population. Future longitudinal studies incorporating postoperative outcomes may further clarify the dynamic relationship between skeletal correction and soft tissue adaptation.

The use of 3D simulation and virtual planning has become a critical tool, allowing clinicians to better predict hard and soft tissue changes and align treatment with patient-specific anatomy and aesthetic goals.^{25,27} Evidence from systematic reviews supports improved outcomes with these approaches, though individual variability in soft tissue response remains a key consideration.²⁸

Overall, the present findings demonstrate that soft tissue thickness in facial asymmetry exhibits a direction-dependent pattern rather than uniform compensation for skeletal deviation. Comprehensive

three-dimensional evaluation of both skeletal structures and soft tissues is therefore essential for accurate diagnosis and effective treatment planning in patients with facial asymmetry.

Conclusion

Soft tissue thickness in facial asymmetry demonstrates direction-dependent patterns rather than uniform compensation for underlying skeletal deviations. In the transverse dimension, soft tissue tends to be thinner on the deviated side, whereas in the sagittal dimension it may be relatively thicker. These findings indicate that soft tissue morphology may partially reflect or even accentuate skeletal asymmetry depending on the anatomical region and measurement direction. Therefore, comprehensive three-dimensional evaluation using cone beam computed tomography combined with facial scanning is essential for accurate diagnosis and individualized orthodontic and orthognathic treatment planning in patients with facial asymmetry.

Author contributions

Tanapat Jearanai: Conceptualization, data curation, formal analysis, investigation, methodology, software, validation, visualization, writing - original draft preparation, writing - review and editing. **Bancha Samruajbenjakun:** Conceptualization, methodology, supervision, validation, visualization, writing - review and editing.

Ethical statement

This study was approved by the Human Research Ethics Committee of the Faculty of Dentistry, Prince of Songkla University (EC6602-006).

Disclosure statement

The authors have no conflict of interest.

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The authors used ChatGPT (OpenAI, GPT-5 series) solely for language editing and manuscript revision. All scientific content was developed and verified by the authors, who take full responsibility for the accuracy and integrity of the manuscript.

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