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Original Article

Investigating the postoperative soft tissue changes in different vertical facial divergent patients with mandibular prognathism

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Abstract *Background/purpose:* The extent of three-dimensional soft tissue changes in patients with varied facial skeletal patterns following mandibular setback surgery remains unclear. In this study, we aimed to investigate the postoperative changes in soft tissue chin thickness among mandibular prognathism patients, focusing on those presenting different divergence patterns, such as hyperdivergent and normodivergent patients.
Materials and methods: Cone-beam computed tomography images were obtained from 56 skeletal Class III patients who underwent only mandibular setback. Based on vertical craniofacial skeletal relationship, patients were divided into normodivergent group ($27° < SN-MP < 37°$) and hyperdivergent ($SN-MP > 37°$) group. The three-dimensional displacements of Infradentale (Id), B point (B), and Pogonion (Pog), the soft tissue thickness of Id-Li (Labrale inferius), B-B' (soft tissue B point), and Pog-Pog' (soft tissue Pog point) were measured. Factors influencing the change in soft tissue thickness were investigated.
Results: Preoperative B-B' and Pog-Pog' thickness were significantly thinner in the hyperdivergent group than normodivergent group. Postoperative changes in B-B' and Pog-Pog' thickness were significantly larger in the hyperdivergent group than normodivergent group. A significant correlation was found between soft tissue thickness change (B-B' and Pog-Pog') and the preoperative soft tissue thickness and superior movement (B and Pog).
Conclusion: Hyperdivergent patients with skeletal class III have thinner preoperative soft tissue thickness (B-B' and Pog-Pog') than normodivergent patients in the preoperation.

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Postoperative changes in B-B' and Pog-Pog' thickness were significantly larger in the hyperdivergent group than normodivergent group. Postoperative superior movement of B and Pog correlated with postoperative change of soft tissue thickness.

Introduction

As patients increasingly prioritize postoperative facial appearance, changes in postoperative soft tissue have become crucial factors affecting treatment satisfaction and subsequent compliance. With advances in medicine and technology, many manufacturers have developed simulation software to predict facial appearance changes after orthodontic treatment or orthognathic surgery. This software typically utilizes hard tissue displacement to predict soft tissue changes and generate simulation outcomes. However, predicting these changes accurately poses a challenge due to the significant variability in the ratio of changes between soft tissues and hard tissues among different patients. These changes are influenced by various factors, including race, sex, body mass index (BMI), preoperative soft tissue thickness, muscle and soft tissue tension, elasticity, the type of surgery, as well as horizontal and vertical skeletal relationships.[1,2]

In investigating facial growth, the ANB angle is frequently used as a reference standard for determining the sagittal relationship of facial bones. Skeletal classifications for sagittal (anteroposterior) patterns include skeletal Class I (ANB angle between 0° and 4°), Class II (ANB >4°), and Class III (ANB <0°). For the categorization of vertical skeletal patterns, the SN-MP angle is commonly employed to assess the vertical relation of facial bones. Vertical skeletal patterns are classified as hyperdivergent (>37°), normodivergent (28°–37°), and hypodivergent (<28°) growth patterns.[3]

Perovic et al.[4] examined the impact of mandibular divergence on facial soft tissue thickness in skeletal class I patients using lateral cephalograms. They found that hypodivergent patients had significantly thinner soft tissue at B-B' compared to normodivergent and hyperdivergent patients. No significant difference in B-B' length was observed between normodivergent and hyperdivergent patients. Additionally, there was no significant difference in Id-Li and Pog-Pog' soft tissue thickness among the three vertical growth patterns. The objective of this study is to use three-dimensional cone-beam computed tomography (CBCT) to examine the postoperative changes in soft tissue and the factors that influence them in skeletal class III patients who have varying sagittal and vertical growth patterns. We seek to understand how these divergence patterns may influence the postoperative outcomes in terms of soft tissue thickness in the chin region. The 3D changes of soft tissues in patients with different facial skeletal patterns after undergoing mandibular setback surgery are not very clear. Therefore, this research aimed to address whether the patients with the different vertical skeletal patterns could have the various surrounding soft tissue alterations after undergoing mandibular setback surgery.

Materials and methods

CBCT images (NewTom VGi evo; Imola, Italy) of mandibular prognathism patients were obtained from the Department of Dentistry, Kaohsiung Medical University Chung-Ho Memorial Hospital. These CBCT images were imported in Digital Imaging and Communications in Medicine (DICOM) format into Dolphin® 11.0 software (Dolphin Imaging and Management Solutions, Chatsworth, CA, USA) for cephalometric analysis. CBCTs were acquired for all patients in a standardized natural head position, with the teeth in maximum intercuspation. CBCTs included two time points: T1 (Before surgery) and T2 (At least 6 months postoperative follow-up). The CBCT parameters were as follows: irradiation duration of 3.5 s, irradiation dose of 110 kV and 4.59 mA, irradiation area of 24 × 19 cm, and voxel size of 0.3 mm^3.

The enrollment criteria are as follows: (1) Age >18 years;(2) CBCT images acquired both before surgery (T1) and at least 6 months after surgery (T2); (3) Sagittal skeletal class III relationship (ANB <0°); (4) Vertical skeletal patterns: hyperdivergent (SN-MP angle >37°) and normodivergent (SN-MP angle = 28°–37°); (5) Only underwent bilateral intraoral vertical ramus osteotomy. The exclusion criteria are as follows: (1) Previous history of extensive head trauma or other pathological conditions; (2) Previous facial bone plastic surgery; (3) Hypodivergent pattern (SN-MP angle <28°) However, patients with hypodivergent Class III were not included in the study because only a small number of them underwent surgery.

Dolphin 3D (Dolphin Imaging, version 11, Chatsworth, CA, USA) software was used for reading and measurement. Dolphin 3D was used to reconstruct cranial three-dimensional images. The following hard tissue reference points (Figs. 1–3) were labeled, including: (1) S (sella): geometric center of the pituitary fossa; (2) N (nasion): bridge of the nose; (3) Or (orbitale): the lowermost point on the lower margin of the orbit; (4) OrMid: Midpoint of bilateral Or; (5) A point: the deepest point on the curvature of the anterior maxillary alveolar process; (6) Id (Infradentale): intersection between the midline of bilateral mandibular incisors and the alveolar bone; (7) B point: the point of the deepest concavity anteriorly on the mandibular symphysis; (8) Pog (Pogonion): midpoint of the most anterior part of the anterior chin margin; (9)Me (Menton): the midpoint of the most inferior point of the anterior chin margin; (10) Go (Gonion): the most posterior, inferior point

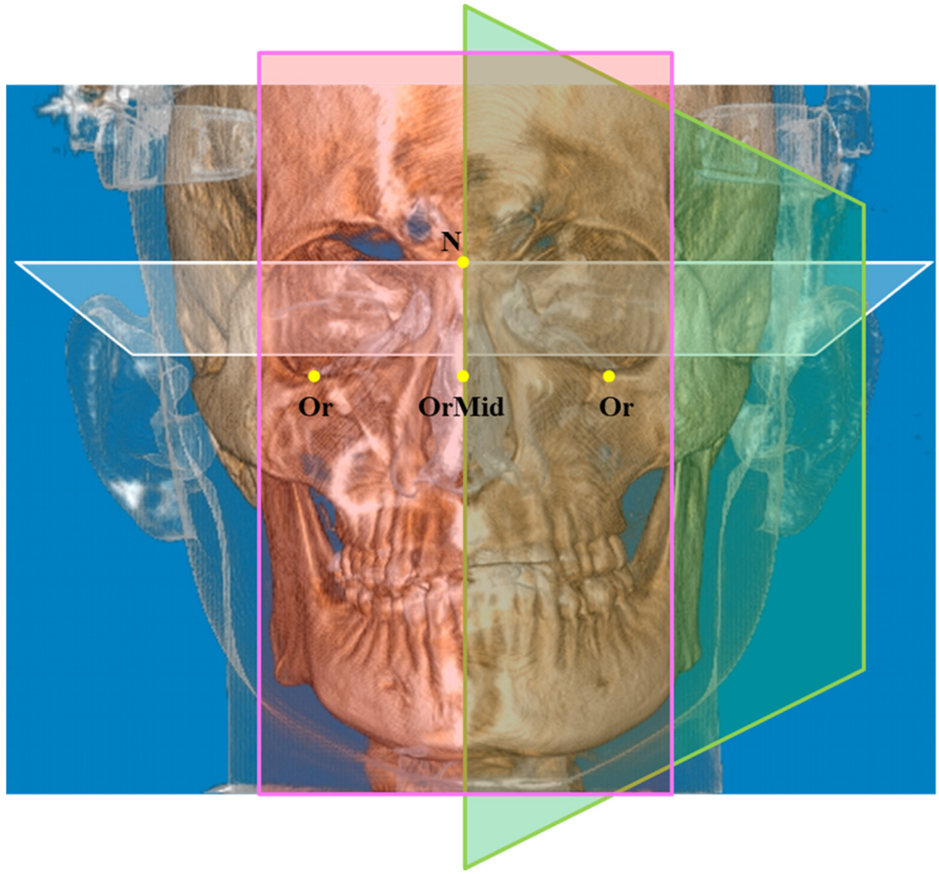

Figure 1 Three reference planes and reference points of the head are defined as follows: (1) Sagittal reference plane (green color): A plane passing through S (sella), N (nasion) and OrMid (midpoint of bilateral orbitale) (2) Horizontal reference plane (white color): Passing through the S and N points and perpendicular to the sagittal plane; (3) Coronal reference plane (pink color): Perpendicular to both sagittal and horizontal planes (4) The N point is an intersection between the three reference planes, and its coordinates are (0, 0, 0)

on the mandibular angle.(11) MP: mandibular plane: formed by connecting Go to Me.(12) ANB angle: the angle formed by point A, Nasion and point B.(13) SN-MP angle: SN plane to the mandibular plane angle.

The following soft tissue reference points (Fig. 2) were labeled, including:(4) Li (Labrale inferius): Midpoint of the most anterior point of the lower lip;(5) B' (Soft tissue B point): Most depressed point of the mandibular soft tissue anterior margin; (6) Pog' (Soft tissue Pog point): Most protruding point of the mandibular soft tissue anterior margin. The distance measured between the corresponding soft tissue and hard tissue represents soft tissue thickness, including (4) Id-Li, (5) B-B', (6) Pog-Pog'.

The three reference planes and reference points of the head are defined as follows (Fig. 1): (1) Sagittal reference plane: A plane passing through three points (S point, N point, and the midpoint of both orbits); (2) Horizontal reference plane: Passing through the S and N points and perpendicular to the sagittal plane; (3) Coronal reference plane: Perpendicular to both sagittal and horizontal planes (4) The N point is an intersection between the three reference planes, and its coordinates are (0, 0, 0).(5) Following the identification of the origin point (N point), we proceeded to measure the displacements of soft and hard tissue landmarks in the mediolateral, superoinferior, and anteroposterior directions relative to three reference planes. (6) Using the N point as the origin, positive values were assigned to landmark coordinates to its right, superior, and anterior, while negative values were assigned to coordinates to its left, inferior, and posterior. The ANB angle and SN-MP angle (Fig. 3) measured in lateral skull radiograph superimposed using CBCT were used for classifications of sagittal and vertical skeletal patterns. ANB angle $<0^\circ$ was used to determine sagittal skeletal class III. Additionally, the SN-MP angle was used to categorize patients into hyperdivergent (Group H, SN-MP $> 37^\circ$) and normodivergent (Group N, SN-MP $= 28^\circ$–37°). Landmarks and soft tissue thickness were measured as follows: (1) Hard tissue coordinates: The 3D coordinates of Id, B, and Pog at T1 and T2 were recorded; (2) Soft tissue coordinates: The 3D coordinates of Li, B'point, and Pog' at T1 and T2 were recorded; (3) Soft tissue thickness measurement: The measurements of Id-Li, B-B', and Pog-Pog' at T1 and T2 were recorded.

SPSS (Version 20; IBM, Armonk, NY, USA) was employed as statistical analysis software. A difference with a *P* -value <0.05 was considered statistically significant. The analysis included the following: (1) Descriptive statistics:

Figure 2 Hard tissue reference points: Id (Infradentale), B point, and Pog. Soft tissue reference points: Li (Labrale inferius), B' (Soft tissue B point) and Pog' (Soft tissue Pog point).

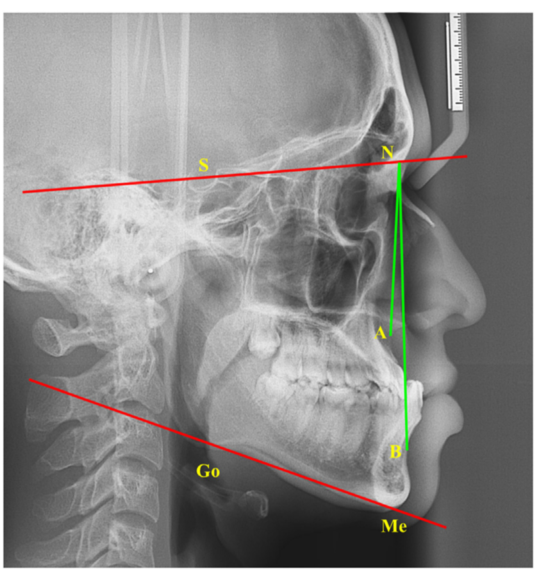

Figure 3 ANB angle: the angle formed by point A, Nasion and point B. SN-MP angle: SN plane to the mandibular plane (Go to Me) angle.

Descriptive statistics were analyzed, encompassing the mean and standard deviation of the statistical data; (2) Mann–Whitney U test: The Mann–Whitney U test was utilized to analyze differences in age, sex, and ANB between the normodivergent and hyperdivergent groups; (3) Spearman's rank correlation coefficient: Spearman's rank correlation coefficient was used to analyze the correlation between changes in soft tissue thickness and preoperative soft tissue thickness and superoinferior hard tissue displacement; (4) Multiple linear regression: Multiple linear regression was employed to assess the explanatory power of preoperative soft tissue thickness and superoinferior hard tissue displacement on changes in soft tissue thickness before and after surgery.

Results

A total of 56 patients had cone beam computed tomography images, including 24 males and 32 females (Tables 1 and 2). In Group N (32 subjects, 14 males, 18 females), the mean age was 25.38 $\pm$ 4.82 years, the mean ANB angle was $-4.31 \pm 2.24°$, and the mean SN-MP angle was $31.5 \pm 3.00°$. In Group H (24 subjects, 10 males, 14 females), the mean age was 25.71 $\pm$ 6.01 years, the mean ANB angle was $-4.14 \pm 2.19°$, and the mean SN-MP angle was $39.98 \pm 3.48°$. Statistical differences were observed only in the SN-MP angle between the two groups, with no significant differences in age and ANB angle. Preoperatively, the mean B-B' and Pog-Pog' distances in Group N (12.20 mm and 10.76 mm) were significantly larger than in Group H (10.53 mm and 9.17 mm).

After more than 6 months of follow-up (Table 3), the mean Pog (anteroposterior direction) was set back 10.81 mm in Group N and 10.45 mm in Group H. Upon investigating postoperative changes in hard tissue (Table 3), intergroup comparisons revealed no significant differences, except for vertical Pog displacement (Group N $=$ 0.53 $\pm$ 1.97 mm, Group H $=$ 1.17 $\pm$ 2.54 mm,

Table 1 Summary of preoperative (T1) characteristics in the normodivergent group (Group N) and hyperdivergent group (Group H).

	Total (n = 56)		Group N (n = 32)		Group H (n = 24)		*P* value
	Mean	SD	Mean	SD	Mean	SD	
Age (year)	25.52	5.32	25.38	4.82	25.71	6.01	0.848
ANB (degree)	−4.24	2.18	−4.31	2.24	−4.14	2.19	0.823
SN-MP (degree)	35.13	5.25	31.50	3.00	39.98	3.48	<0.001*
Id-Li (mm)	11.83	2.28	12.11	2.38	11.45	2.17	0.301
B-B’ (mm)	11.49	1.70	12.20	1.47	10.53	1.57	<0.001*
Pog-Pog’ (mm)	10.08	1.78	10.76	1.74	9.17	1.47	<0.001*

Intergroup comparison; *: Statistically significant, $P < 0.05$.

Table 2 Intragroup and intergroup comparisons of gender between normodivergent group (Group N) and hyperdivergent group (Group H) in the preoperation (T1).

		Id-Li		B-B’		Pog-Pog’	
Intragroup comparison		Mean	SD	Mean	SD	Mean	SD
Group N (n = 32)	Men (n = 14)	12.71	3.01	12.81	1.73	10.93	1.95
	Women (n = 18)	11.59	1.67	11.73	1.04	10.63	1.60
	P value	0.193		0.011*		0.667	
Group H (n = 24)	Men (n = 10)	11.58	2.54	10.42	1.65	9.29	1.77
	Women (n = 14)	11.36	1.96	10.61	1.57	9.08	1.28
	P value	0.796		0.841		0.931	
Intergroup comparison							
Men	*P* value	0.212		0.001*		0.036*	
Women	*P* value	0.896		0.037*		0.004*	

* : Statistically significant, $P < 0.05$.

$P = 0.017$). Regarding the increment of postoperative thickness (Table 4), the mean B-B’ and Pog-Pog’ of Group H (1.75 mm and 1.79 mm) were significantly larger than those of Group N (0.46 mm and 0.43 mm). In Table 5, Spearman’s rank correlation coefficient was used to analyze the correlation between postoperative soft tissue thickness changes (T21) and hard tissue displacement (T21). The results showed weak positive correlations between the superoinferior displacement of the B point and Pog with changes in B-B’ ($r = 0.350$; $P < 0.01$) and Pog-Pog’ ($r = 0.300$; $P < 0.05$) thickness. In Group N, the setback amounts for B and Pog were 10.06 mm and 10.81 mm, respectively. The soft-hard tissue ratio was 100% for B’/B and 93.1% for Pog’/Pog. In Group H, the setback amounts for B and Pog were 10.00 mm and 10.45 mm, respectively. The soft-hard tissue ratio was 95.8% for B’/B and 86.5% for Pog’/Pog.

In Group N, two participants did not exhibit any movement at the Pog, yet there was an increase in the distance between Pog and Pog’. Regarding the postoperative

Table 3 Amount of three-dimensional setback (T21) in the normodivergent group (Group N) and hyperdivergent group (Group H).

		Total (n = 56)		Group N (n = 32)		Group H (n = 24)		*P* value
Landmarks		Mean	SD	Mean	SD	Mean	SD	
Id (mm)	Mediolateral	−0.59	1.93	−0.63	2.14	−0.54	1.69	0.724
	Superoinferior	0.59	2.05	0.28	2.10	1.00	2.00	0.160
	Anteroposterior	−8.17	3.28	−8.20	3.33	−8.13	3.34	0.980
B (mm)	Mediolateral	−0.96	2.09	−1.00	2.21	−0.92	1.20	0.987
	Superoinferior	0.70	2.56	0.28	2.37	1.25	2.79	0.129
	Anteroposterior	−10.04	2.73	−10.06	2.73	−10.00	2.83	0.973
Pog (mm)	Mediolateral	−0.98	2.62	−0.94	2.88	−1.04	2.35	0.688
	Superoinferior	1.04	2.27	0.53	1.97	1.71	2.54	0.017*
	Anteroposterior	−10.66	3.32	−10.81	3.58	−10.45	3.07	0.784

Intergroup comparison; *: Statistically significant, $P < 0.05$.

Table 4 Summary of postoperative changes (T21) in the normodivergent group (Group N) and hyperdivergent group (Group H).

	Total (n = 56)		Group N (n = 32)		Group H (n = 24)		
Landmarks	Mean	SD	Mean	SD	Mean	SD	*P* value
ANB (degree)	5.39	1.70	5.55	1.71	5.17	1.70	0.408
SN-MP (degree)	3.32	3.61	4.65	3.21	1.54	3.39	0.001*
Id-Li (mm)	1.59	2.14	1.69	2.1	1.46	2.28	0.880
B-B' (mm)	1.02	1.46	0.46	0.84	1.75	1.80	0.002*
Pog-Pog' (mm)	1.02	1.51	0.43	1.19	1.79	1.59	0.003*

Intergroup comparison; *: Statistically significant, $P < 0.05$.

Table 5 Postoperative changes (T21) of soft tissue thickness in Spearman's rank correlation coefficient test.

	Id-Li (T21)	B-B' (T21)	Pog-Pog' (T21)
ANB (T21)	0.150	−0.030	−0.120
SN-MP (T21)	−0.020	−0.160	0.020
Hard tissue displacment			
Mediolateral (T21)	−0.100	0.040	−0.700
Superoinferior (T21)	−0.060	0.350*	0.300*
Anteroposterior (T21)	−0.150	−0.070	−0.210

* : Statistically significant, $P < 0.05$

superior displacement (upward) of the Pog, Group N showed a decrease of 0.31 mm in the Pog-Pog' distance in 10 participants, while Group H had an increase of 1.67 mm in the Pog-Pog' distance in 6 participants. Investigating postoperative inferior displacement (downward) of the Pog, both Group N and Group H showed an increase in the distance between the Pog and Pog' in 20 and 18 participants. The measurements recorded were 0.62 mm and 1.78 mm, respectively.

In the multiple linear regression analysis (Table 6), our results indicated that preoperative soft tissue thickness (T1), vertical displacement of corresponding hard tissue (T21), and gender collectively contributed to the explanatory power (R^2) of 48%, 33.5%, and 17.4%, respectively, toward postoperative changes (T21) in Id-Li, B-B', and Pog-Pog' thicknesses. In addition, only preoperative soft tissue thickness (T1) showed significant differences ($P < 0.001$; $P < 0.001$; and $P = 0.030$). The vertical displacement of the corresponding hard tissue (T21) was not significant ($P = 0.114$; $P = 0.292$; $P = 0.205$). Additionally, gender did not exhibit a statistically significant difference in the postoperative change (T21) of Id-Li, B-B', and Pog-Pog' thicknesses.

Discussion

Cephalometric analysis is traditionally performed on lateral skull radiographs for the evaluation of orthodontic treatment and orthognathic surgery. The strengths of lateral skull radiographs include convenience, speed, low cost, easy obtainability, and provision of valid data to orthodontists and surgeons. However, disadvantages such as image disparity, magnification, overlapping structures, limited image quality, and the inability to present transverse facial information are inherent to this method. [5] Schlicher et al.[6] examined the consistency and accuracy of 3D image points on basal bone after CBCT reconstruction. Their findings indicated high consistency and accuracy of specific points. Moreover, no significant differences were

Table 6 Preoperative (T1) soft tissue thickness and postoperative (T21) incremental changes in the multiple linear regression.

Dependent variable	Independent variables	B	SE	β	*P* value	R^2
Id-Li (T21)	Id-Li (T1)	−0.657	0.096	−0.698	< 0.001*	0.480
	Id Superoinferior (T21)	−0.175	0.109	−0.168	0.114	
	Sex	0.760	0.452	0.175	0.098	
B-B' (T21)	B-B' (T1)	−0.464	0.102	−0.542	< 0.001*	0.335
	B Superoinferior (T21)	0.071	0.067	0.124	0.292	
	Sex	0.179	0.338	0.061	0.599	
Pog-Pog' (T21)	Pog-Pog' (T1)	−0.251	0.113	−0.298	0.030*	0.174
	Pog Superoinferior (T21)	0.114	0.089	0.171	0.205	
	Sex	−0.379	0.385	−0.125	0.329	

* : Statistically significant, $P < 0.05$

observed in hard tissue landmarks labeled using CBCTs compared to lateral skull radiographs.

In facial appearance, the common characteristics of mandibular prognathism patients are depressed middle third of the face. The sagittal position of the upper lip is typically behind the aesthetic reference line, accompanied by a smaller nasolabial angle, a protruding lower lip, and an indistinct mentolabial sulcus. [7] The etiology of mandibular prognathism is complex, involving environmental and genetic factors and their interactions. Most patients with mandibular prognathism require a combination of orthodontic treatment and orthognathic surgery to address occlusion, speech, aesthetics, and, in some cases, pharyngeal airway problems. Mandibular prognathism poses a significant challenge in treatment due to its impact on dental occlusion, the maxilla—mandibular complex, facial soft tissue, pharyngeal airway spaces, and changes in these components before and after surgery. A mandibular setback operation involves sagittal, vertical, and transverse directions, emphasizing the importance of addressing each aspect. Applications of CBCT in orthodontics and orthognathic surgery encompass the evaluation of dental malocclusions, skeletal pattern development, 3D virtual surgical planning, and assessment of postoperative results.[8] The increasing use of CBCT in orthodontic treatment and orthognathic surgery reflects its capability to overcome the limitations associated with traditional lateral skull radiographs.

A reference coordinate system is essential to standardize cone beam computed tomography (CBCT) images taken at different time points. Schlicher et al.[6] conducted a study indicating that the hard tissue landmark, S point, exhibited the highest consistency and accuracy in CBCT across different observers and time points. Midline points were observed to have higher consistency and accuracy than bilateral points. Consequently, we adopted the S point and midline N point, identified as having the highest accuracy, as the basis for establishing the 3D coordinate system. In this system, the N point served as the origin, providing a reference coordinate system with high repeatability after repeated measurements.

In a study by Saadeh et al.[9], the evaluation of facial soft tissue thickness differences among different vertical facial patterns revealed that hyperdivergent patients have significantly thicker soft tissue at the B point and Pog compared to normodivergent patients. Conversely, hypodivergent patients exhibited no significant difference in B point and Pog soft tissue thickness compared to normodivergent and hyperdivergent patients. Celikoglu et al.,[10] using CBCT, compared soft tissue thickness at the chin area among skeletal class I patients with different vertical growth patterns. Their findings indicated that hyperdivergent patients were significantly thinner than normodivergent patients. Choi et al.[2] evaluated soft-tissue thickness changes after bimaxillary surgery according to vertical facial patterns in patients with skeletal class III malocclusion and mandibular prognathism. They found that preoperative Pog-Pog' thickness was significantly less in the hyperdivergent group than in the normodivergent group. In our study, we observed that B-B' and Pog-Pog' soft tissue thickness in hyperdivergent patients were significantly thinner than in normodivergent patients, aligning with the reports of Celikoglu et al.[10] and Choi et al.[2] Additionally, we found no significant difference in Id-Li soft tissue thickness between normodivergent and hyperdivergent patients, similar to the report by Saadeh et al.[9]

Several factors contribute to the thickness of soft tissue in the chin, including race, gender, age, BMI, and skeletal relationships. The influence of these factors on chin soft tissue thickness can vary. For instance, studies suggest that men generally exhibit thicker chin soft tissue compared to women. It's important to note that while this trend is commonly observed in the literature, variations and individual differences exist.[11,12,13] Choi et al.[2] also reported no significant differences between men and women in the Id-Li, B-B', and Pog-Pog' thickness of the hyperdivergent group and normodivergent group, respectively. In contrast, Celikoglu et al.[10] found that Id-Li lengths in men were significantly thicker than women among three vertical growth patterns. However, B-B' and Pog-Pog' soft tissue thickness showed no significant differences among the three vertical growth patterns.

In our report, we observed that only B-B' length in men was significantly thicker than in women among the normodivergent patients. Celikoglu et al.[10] found that Id-Li and Pog-Pog' lengths in normodivergent women were significantly thicker than hyperdivergent women. Moreover, Celikoglu et al.[10] reported that the three vertical growth patterns of men had no significant differences in Id-Li, B-B', and Pog-Pog' thickness. Our findings revealed that the B-B' and Pog-Pog' thickness of normodivergent men and women were significantly thicker than hyperdivergent men and women, respectively.

The correlation between the 3D displacement of hard tissue and changes in soft tissue thickness was examined, revealing a weak positive correlation between the changes in B-B' and Pog-Pog' and the superoinferior displacement of the corresponding B and Pog points. For a more nuanced understanding of this relationship, clinicians may consider examining the actual correlation coefficients and their significance levels. In a related study by Paek et al.,[14] the impact of mandibular setback surgery on lip morphology in skeletal class III patients was assessed. Their findings demonstrated that the relaxation of the lower lip, induced by the tension caused by the lower teeth and alveolar bone, was alleviated after surgery. This resulted in the elimination of lip incompetence and the formation of a better lip seal. Importantly, this supports the notion that a greater superior movement of the mandible corresponds to a more substantial increase in soft tissue thickness.

In this study, we conducted a comparative analysis of the correlation between preoperative soft tissue thickness and postoperative increment. The results revealed a significant negative correlation for all three soft tissue measurements (Id-Li, B-B', Pog-Pog'). This implies that patients with thinner preoperative soft tissue thickness experience a greater increase in postoperative soft tissue thickness. This finding aligns with the conclusions drawn in a study by Celikoglu et al.[10], where surgery was found to significantly decrease soft tissue thickness in patients with thicker preoperative soft tissue, while postoperative thickness showed a significant increase in patients with thinner preoperative soft tissue. Moreover, our Spearman's rank correlation coefficient test demonstrated a correlation between soft tissue thickness changes and the superoinferior displacement of the corresponding hard tissue (B-B' and Pog-Pog'). This suggests that the observed changes in soft tissue thickness are associated with the vertical displacement of the underlying hard tissue. Understanding these correlations contributes to a more comprehensive assessment of the outcomes of orthognathic surgery and may aid in treatment planning and patient management.

Therefore, multiple linear regression was conducted to assess the correlation between changes in original soft tissue thickness, superoinferior displacement of hard tissue, and gender. The postoperative increments (T21) of soft tissue thickness (Id-Li, B-B', and Pog-Pog') exhibited a significant correlation with the original soft tissue thickness (T1). However, the correlation with superoinferior hard tissue displacement was found to be diluted and did not reach statistically significant differences. Notably, the R2 values for Id-Li, B-B', and Pog-Pog' were 0.48, 0.335, and 0.174, respectively, indicating the proportion of variance in postoperative soft tissue thickness increments attributed to the original soft tissue thickness.

The chin, being the site most easily affected by muscle tone, showed sensitivity to various factors such as head shaking and neck muscle extension or contraction.[15] Pog, being closest to neck muscles, was also significantly influenced. These factors contributed to the lower explanatory power observed for Pog soft tissue changes. Our study revealed that patients with hyperdivergent characteristics who had thinner chin soft tissue experienced a greater increase in postoperative soft tissue thickness. This increase originated from the loosening of the chin soft tissue and helped to offset the amount of setback in soft tissue, resulting in a smaller soft-hard tissue ratio. This observation holds significant clinical relevance, particularly for doctors managing patients with greater facial divergence and anterior open bite. Such individuals are likely to experience a more pronounced postoperative increase in soft tissue thickness compared to other patients. Understanding these correlations can aid clinicians in better planning and anticipating outcomes in orthognathic surgery cases.

The main limitations of present study are that (1) it did not conduct 3D uperimpositions, despite their higher complexity and challenging (2) the uneven sample size for gender in both groups and (3) the absence of a hypodivergent group.(4) Given the diversity in mandibular prognathism, variations in soft tissue thickness of the lower lip and chin may be influenced by different ethnicities.(4) The relationship between age and soft tissue thickness, as well as the impact of other factors such as race, BMI, and bony relationships, can further contribute to the complexity of understanding soft tissue variations in the chin region. Exploring these factors in the context of mandibular prognathism and postoperative changes can provide valuable insights into the multifaceted nature of facial anatomy and its responses to surgical interventions.

In conclusion, hyperdivergent patients with mandibular prognathism exhibit a significant thinning in soft tissue thickness, particularly in the regions of B-B' and Pog-Pog', when compared to normodivergent patients. Correlation analysis revealed that the increase in soft tissue thickness was notably correlated with preoperative soft tissue thickness. Additionally, superior displacement of corresponding hard tissue demonstrated a correlation with the increase in soft tissue thickness. Further, linear regression analysis was conducted to assess the relative contributions of preoperative soft tissue thickness, superior displacement of hard tissue, and gender to the increase in soft tissue thickness. The results indicated that preoperative soft tissue thickness exhibited a stronger correlation with the increase in soft tissue thickness compared to the superior displacement of hard tissue and gender.

Declaration of competing interest

None.

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