Journal of Dental Sciences 20 (2025) 1148–1157

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.e-jds.com

Original Article

The study of three-dimensional smile changes on orofacial morphology

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Received 20 November 2024; Final revision received 9 January 2025
Available online 30 January 2025

KEYWORDS
3D scanner;
Face;
Soft-tissue analysis;
3D stereophoto grammetry;
Smile analysis

Abstract *Background/purpose:* Traditionally, two-dimensional (2D) frontal and lateral facial views have provided an incomplete understand true three-dimensional (3D) relationships. This study aimed to investigate the 3D changes in orofacial soft tissues during smiling and to examine the influence of craniofacial and dental morphology on these changes.
Materials and methods: 131 individuals aged 18–30 with attractive facial features were recruited. Rest and posed smile 3D facial photos captured by 3D camera and cone-beam computed tomography (CBCT) scans were taken. Data were recorded and analyzed in rest, smile images, and smiling change measurements, including 23 landmarks, 11 linear, and 6 angular measurements. Statistical methods were used to analyze the frequency distribution, the significant difference between rest and smile variables, and the relationship between craniofaciodental tissue and 3D smile changes.
Results: The study involved 65 males (mean age 23.5 ± 3.2 years) and 66 females (mean age 22.5 ± 1.5 years). The soft tissue landmarks changed during smiling reveals that 21 landmarks in z-plane, 22 landmarks in y-plane, and 15 landmarks in x-plane landmarks showed significant differences. In addition, a significant correlation was noted between upper lip length (sn-uli) ($r = 0.46$, $P = 0.057$), lower lip length (lls-SB) ($r = 0.44$, $P = 0.022$), and the hard tissue measurement Id-Me.
Conclusion: The significant 3D change of soft tissue landmarks during smiling occurs mostly in z and y-plane, rather than x-plane. Clinically, all dimensions should be considered in orthodontic diagnosis and treatment planning, especially in the z plane the change cannot be seen in the traditional 2D analysis.

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https://doi.org/10.1016/j.jds.2025.01.010

Introduction

Facial attractiveness significantly boosts self-confidence and fosters social relationships, employment prospects, and business achievements today.[1,2] Historically, achieving a balanced occlusion and stable dental arches were the primary goals of orthodontic treatments.[3,4] However, in contemporary orthodontics, the emphasis has shifted beyond functional aspects to include aesthetic considerations, particularly concerning facial attractiveness and the creation of a harmonious and appealing smile.[5,6] Today, achieving an aesthetically pleasing smile has become a significant concern for orthodontic practitioners and patients.[7,8] As a result, investigating the factors influencing smile aesthetics and their correlation with craniofacial features has become a crucial area of research in contemporary orthodontics (see Fig. 1).[9,10]

While traditional orthodontic analysis relied on 2D imaging, which limited the comprehensive assessment of a smile, modern advancements in technology have revolutionized the field.[5,11] Contemporary 3D imaging techniques provide a more accurate and detailed representation of the craniofacial structure, allowing for a better understanding of smile dynamics and the intricate interplay between teeth, lips, and facial muscles.[5,9] Previous research has extensively explored static 3D imaging; however, studies focusing on the dynamic changes of the smile in three dimensions are still lacking. Contemporary 3D imaging techniques provide a more accurate and detailed representation of the craniofacial structure, allowing for a better understanding of smile dynamics and the intricate interplay between teeth, lips, and facial muscles.[12,13] The purpose of this research was to establish 3D smile norms and to examine the influence of craniofacial and dental morphology on these 3D changes.

Materials and methods

The present study protocol was approved by the Institutional Review Board of Taipei Medical University Hospital (approval no.: N202308043). A total of 131 subjects, consisting of 65 males and 66 females aged between 18 and 30 years, were recruited between September 2023 and April 2024. There was no statistically significant difference in age between the male and the female ($P > 0.05$). The data were assessed for normality using the Shapiro–Wilk test, and the results confirmed that the data followed a normal distribution ($P > 0.05$).

The inclusion criteria were as follows: (1) aged 18–30 years, (2) full dentition, no missing tooth, (3) no previous or current orthodontic treatment, (4) Angle's Class I malocclusion, (5) Normal overjet and overbite. The exclusion criteria for this study were as follows: (1) abnormal BMI (<17 kg/m^2, >31 kg/m^2), (2) a history of face deformity that was either congenital, traumatic, or post-operative, (3) with facial filler injection or plastic surgery.

Skull CBCTs (Planmeca, Helsinki, Finland) were taken according to the manufacturer's instructions and orthodontic standard CBCT imaging techniques. The 3D surface-imaging structured light method was employed.[14,15] 3D face scans were taken at about 45 cm from the Accu3D Scan camera (Digident Image Technology Co., Ltd., Taichung, Taiwan) using standard room lighting. Participants were photographed in two positions: (1) Rest position: with their mouths closed or relaxed (lip incompetence may be noted) and (2) Smile position: posed smile. (As the participant saying "cheese") The photographic assistants in our department instructed patients to say "seven" or "cheese" while the photo was being taken to achieve the posed smile. Before the pictures were taken, the participants practiced smiling three times while maintaining a natural relaxed head posture. Each subject's face was scanned four times: frontally and at 45° on the right, left, and chin sides for 0.7 s each. All 3D virtual models were oriented at a standardized position based on the Cephalometric Reference System by Swennen et al.[16] Landmark identification was performed by the same operator (Y.C.H) and double-checked by another faculty. 34 landmarks were identified using the 3D cephalometry module of Dolphin® imaging software version 11.9 (Dolphin Imaging, Chatsworth, CA, USA) by a single click using a cursor driven by the mouse. To

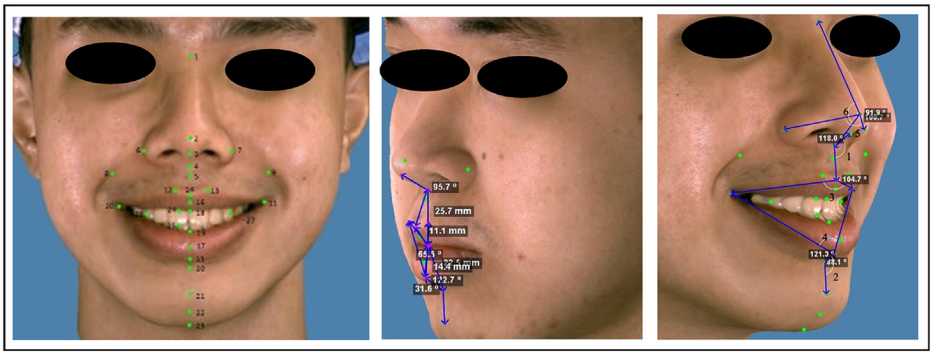

Figure 1 Soft tissue landmarks and linear and angular measurements.

assess reproducibility, twenty 3D soft tissue images and CBCT from ten individuals were randomly chosen. Measurements were performed twice over a 4-week interval by a single examiner. The horizontal plane (X) was through the right and left orbitale and the midpoint between right and left porions, i.e., the Frankfurt horizontal (FH) plane. The midsagittal plane (Y) was defined by passing the nasion, basion, and perpendicular to the FH plane. The coronal plane (Z) was created by passing sella turcica and perpendicular to the midsagittal plane and FH plane. Patients' 3D rest and smile pictures were superimposed on the forehead and nasal root region of the CBCT scans separately.

Twenty-three landmarks' positions on resting and smiling were measured as distances from landmarks to the three planes. 3D displacements of the landmarks were calculated with positive and negative values indicating changes in position and direction. In the x-plane, "+" represented a leftward position, and "-" represented a rightward position. In the y-plane, "+" and "−" indicated upper and upward displacements, respectively. In the z-plane, "+" and "−" represented forward and backward movements, respectively. Eleven 3D linear measurements and six angular measurements were performed. Statistical analyses were performed using SPSS software (Released 2008. SPSS Statistics for Windows, Version 17.0. SPSS Inc., Chicago, IL, USA). A *P*-value of 0.05 was considered statistically significant. Descriptive statistics were performed. Independent t-tests were used to examine the gender and measurements of smiling change differences. Pearson correlation coefficients were calculated to measure the linear relationship between each pair of soft and hard tissue variables.

Results

Demographic characteristics of the participants

131 subjects were recruited, including 65 males and 66 females. There was no statistically significant difference in age between the male and the female ($P < 0.05$).

Frequency distribution of linear and angular measurement in 3D CBCT image

Among the 25 linear measurements, 5 dental and 9 skeletal measurements were found to have gender disparities. In dental measurements, for example, Id-Me, the protrusion of the lower incisor (L1 Protrusion), and the transpalatal width showed significant differences between males and females. In skeletal measurements, the skull width (sCR-sCL), molar length (sM1R-sM1L), the distance between the Gonion points (GoR-GoL), the right and left midface lengths (R Co-A and L Co-A), and mandibular lengths (R Co-Gn and L Co-Gn) showed significant differences between males and females. The detailed measurement changes are in Table 1.

Landmarks between rest and smile in 3D soft tissue image

In rest images, among the 23 landmarks, 2 in the x-plane, 6 in the y-plane, and 0 in the z-plane were found to have gender disparity. The left alare (all) and left nasolabial fold (nlfl) both showed gender difference ($P < 0.05$) in the x and y planes (Table 2). In smile images, 5 landmarks in the x-plane were found to have gender disparity ($P < 0.05$), including the right alare (alr), left alare (all), right nasolabial fold (nlfr) and left nasolabial fold (nlfl) (Table 3). The detailed measurement changes are in Tables 2 and 3.

In Table 4, the analysis of soft tissue landmarks during smiling revealed significant landmark changes, with the most pronounced differences observed in the y-plane, followed closely by the z-plane, and the least changes in the x-plane. Specifically, significant changes were detected in 21 z-plane landmarks, 22 y-plane landmarks, and 15 x-plane landmarks. The detailed measurement changes are in Table 4.

Linear measurements between rest and smile in 3D soft tissue image

The length of the upper lip (sn-uli), lower lip (lls-SB), and lower lip vermillion length (lls-li) showed gender dimorphism both in rest and smile views. Most measurements related to the lips and mouth show significant changes during smiling, with the intercommissural width, total lip vermillion length, and interlabial gap showing substantial increases. The upper and lower lip lengths generally decreased, indicating upward and downward movements, respectively (Table 5).

Angular measurements between rest and smile in 3D soft tissue image

The rest angular measurements did not show any significant difference between the male and female groups. However, the nasolabial angle ($107.29° \pm 11.60$) of the female group is higher than the male ($105.62° \pm 8.95$). There were notable changes in the lower lip angle (-14.48 ± 6.29) and nasal protrusion angle ($4.42° \pm 5.24$). The nasolabial (2.66 ± 9.13) and nasal aspect angles ($-2.08° \pm 4.36$) showed moderate changes, while the labiomental ($0.13° \pm 11.94$) and upper lip angles ($-0.25° \pm 6.25$) remained relatively stable (Table 6).

Correlation between smile change measurement and CT measurement

In our study, a medium correlation was observed between upper lip length (sn-uli) and the hard tissue measurement Id-Me ($r = 0.46$, $P = 0.057$) and lower lip length (lls-SB) and the hard tissue measurement Id-Me ($r = 0.44$, $P = 0.022$). This indicated a moderate linear relationship, suggesting that changes in the upper lip length and lower lip length were somewhat predictably associated with changes in the midline point at the most anterior edge on the inferior alveolar ridge to the most inferior midline point at the mental symphysis of the mandible distance (Id-Me) (Table 7).

Discussion

Analysis of 23 landmarks during smiling revealed significant changes in 21 landmarks in the z-plane, 22 in the y-plane, and 15 in the x-plane, indicating the most considerable

Table 1 Frequency distribution of linear and angular measurements in CBCT images.

Linear measurement (°)	All Mean ± SD	Male Mean ± SD	Female Mean ± SD	*P*
1. Ns-Pr	17.59 ± 2.2	17.44 ± 2.43	17.74 ± 1.96	0.596
2. Ss-Pr	11.98 ± 1.81	12.09 ± 1.93	11.87 ± 1.7	0.6422
3. Pr-Id	19.8 ± 2.67	20.39 ± 3.06	19.2 ± 2.08	0.0804
4. Id-Me	30.67 ± 3.42	32.17 ± 3.61	29.12 ± 2.43	0.0003[a]
5. Id-Sm	12.21 ± 3.44	12.42 ± 3.63	11.99 ± 3.28	0.6296
6. Pr-InS	10.98 ± 1.7	11.21 ± 1.6	10.75 ± 1.8	0.2904
7. InI-Id	10.32 ± 1.83	10.22 ± 2.05	10.43 ± 1.6	0.6504
8. sCR-sCL	36.96 ± 2.67	37.94 ± 2.77	35.95 ± 2.17	0.0027[a]
9. iCR-iCL	29.64 ± 2.11	30.19 ± 1.71	29.07 ± 2.35	0.0385
10. sM1R-sM1L	57.56 ± 3.71	59.2 ± 3.58	55.85 ± 3.05	0.0002[a]
11. iM1R-iM1L	54.25 ± 3.8	55.93 ± 3.66	52.52 ± 3.15	0.0003[a]
12. MLR-MLL	48.05 ± 2.87	49.02 ± 2.59	47.05 ± 2.84	0.0066[a]
13. GoR-GoL	96.71 ± 6.48	100.26 ± 5.88	93.03 ± 4.85	0.0000[a]
14. Maxilla skeletal (A-Na perp) (mm)	5.54 ± 4.1	6.27 ± 4.73	4.79 ± 3.23	0.1597
15. Midface length (R Co-A) (mm)	100.43 ± 6.07	103.3 ± 4.99	97.46 ± 5.71	0.0001[a]
16. Midface length (L Co-A) (mm)	104.37 ± 9.02	109.19 ± 8.21	99.4 ± 6.96	0.0000[a]
17. Mandibular length (R Co-Gn) (mm)	124.64 ± 6.88	127.8 ± 6.24	121.38 ± 6.01	0.0001[a]
18. Mandibular length (L Co-Gn) (mm)	128.07 ± 10.09	133.53 ± 9.01	122.43 ± 7.87	0.0000[a]
19. LAFH (ANS-Me) (mm)	65.61 ± 5.25	67.52 ± 5.71	63.65 ± 3.93	0.0032[a]
20. Mx/Md difference (R CoGn-CoA) (mm)	24.22 ± 5.42	24.51 ± 5.36	23.93 ± 5.57	0.6802
21. Mx/Md difference (L CoGn-CoA) (mm)	23.71 ± 6.52	24.35 ± 7.45	23.05 ± 5.45	0.4372
22. Mandibular skeletal (Pg-Na perp) (mm)	9.48 ± 14.3	11.65 ± 19.41	7.25 ± 4.83	0.2300[a]
23. U1 most labial-A (perp to FH) (mm)	7.65 ± 2.35	7.94 ± 2.88	7.34 ± 1.63	0.3238
24. L1 protrusion (L1-APo) (mm)	6.7 ± 3.73	8.4 ± 4.24	4.94 ± 1.97	0.0002[a]
25. Transpalatal width (mm)	35.49 ± 3.53	36.98 ± 4.08	33.95 ± 1.95	0.0006[a]
Angular measurement (°)	**All** **Mean ± SD**	**Male** **Mean ± SD**	**Female** **Mean ± SD**	***P***
1. SNA	82.41 ± 4.2	82.65 ± 4.41	82.16 ± 4.03	0.6575
2. SNB	79.92 ± 4.8	80.34 ± 4.8	79.5 ± 4.85	0.4984
3. ANB	2.48 ± 2.96	2.31 ± 2.76	2.67 ± 3.19	0.639
4. FMA-R	38.24 ± 10.48	37.01 ± 8.41	39.52 ± 12.27	0.3573
5. FMA-L	37.24 ± 11.19	37.42 ± 7.71	37.05 ± 14.05	0.8997
6. Interincisal angle	173.6 ± 7.62	172.01 ± 9.55	175.25 ± 4.51	0.0962

Ns: Nasospinale; Ss: Subspinale; Pr: Prosthion; InS: Incisor superior; InI: Incisor inferior; Id: Infradentale; SM: Supramentale; Me: Menton; sCR: Right Supra canine; sCL: Left Supra canine; iCR: Right Infra canine; iCL: Left Infra canine; sM1R: Right Supra-M1; sM1L: Left Supra-M1; iM1R: Right Infra-M1; iM1L: Left Infra-M1; MLR: Right Mentale; MLL: Left Mentale; GoR: Right Gonion; GoL: Left Gonion; A-Na perp: Nasion perpendicular to point A; R: Right; L: Left; Co: Condylion; A: A point; Gn: Gnathion; LAFH: Lower anterior facial height; ANS: Anterior nasal spine; Me: Menton; Mx: Maxilla; Md: Mandible; Pg-Na perp: Pogonion to nasion perpendicular; FH: Frankfort horizontal plane; U1: Upper incisor; L1: Lower incisor; APo: A-pogonion line; SNA: The angle between the line joining S point and N point and the line joining N point and A point; SNB: The angle between the line joining S point and N point and the line joining N point and B point; FMA: Frankfort mandibular angle.

$P < 0.05$.

[a] Indicates a significant difference.

variations occurred in the y and z-planes compared to the x-plane. Except for both sides of the alare (alr), nasolabial fold (nlfr), and cheilion (chr), other landmarks do not show any significant differences in the x-plane. These may be attributed to the inherent nature of facial movements involved in smiling. Smiling primarily engages the zygomatic major muscle, which pulls the corners of the mouth upwards and slightly outwards, thus emphasizing changes in the vertical and anterior-posterior dimensions more than the lateral dimension.[12]

Vertical changes, such as the elevation of the lip and cheeks, and anterior-posterior changes, including the forward movement of the nasolabial fold, are more pronounced during a smile. These movements result in significant changes in the y and z planes. On the other hand, lateral movements are relatively minor in comparison, as smiling does not significantly alter the width of the face but rather its z-plane and y-plane. Previous studies have corroborated these findings, indicating that vertical and anterior-posterior changes are more substantial during facial expressions.[12]

The research involving three-dimensional facial landmark analysis has the same result as our study demonstrating that spontaneous smiles exhibit higher intensity in

Table 2 Frequency distribution of landmarks in resting 3D facial images.

Soft tissue landmark	x-plane				y-plane				z-plane			
	All	Male	Female		All	Male	Female		All	Male	Female	
	Mean ± SD	Mean ± SD	Mean ± SD	*P*	Mean ± SD	Mean ± SD	Mean ± SD	*P*	Mean ± SD	Mean ± SD	Mean ± SD	*P*
1. Nasion (n)	0.07 ± 1.82	0.23 ± 1.93	−0.09 ± 1.73	0.504	7.03 ± 24.08	1.58 ± 27.97	12.67 ± 18.04	0.072	19.38 ± 21.31	19.76 ± 23.52	18.99 ± 19.16	0.89
2. Pronasale (prn)	0.18 ± 1.83	0.31 ± 1.93	0.04 ± 1.74	0.56	−19.31 ± 12.02	−21.35 ± 14.01	−17.19 ± 9.33	0.179	32.4 ± 28.84	33.53 ± 30.18	31.24 ± 27.86	0.76
3. Columella (col)	0.15 ± 1.75	0.27 ± 1.80	0.02 ± 1.71	0.579	−25.43 ± 11.25	−27.42 ± 13.11	−23.37 ± 8.69	0.162	29.88 ± 27.09	30.47 ± 28.21	29.27 ± 26.36	0.864
4. Subnasale (sn)	0.28 ± 1.69	0.31 ± 1.61	0.25 ± 1.79	0.886	−30.29 ± 11.33	−32.33 ± 13.22	−28.18 ± 8.72	0.155	24.94 ± 23.85	25.43 ± 25.25	24.44 ± 22.74	0.873
5. Subspinale (SA)	0.13 ± 1.71	0.21 ± 1.66	0.04 ± 1.79	0.708	−38.06 ± 13.54	−41.15 ± 15.42	−34.86 ± 10.62	0.069	24.68 ± 23.77	25.31 ± 25.44	24.03 ± 22.34	0.835
6. Right alare (alr)	−19.75 ± 2.17	−20.26 ± 2.25	−19.22 ± 1.98	0.061	−29.56 ± 18.11	−34.05 ± 21.02	−24.93 ± 13.34	0.048[a]	19.1 ± 19.55	19.38 ± 21.01	18.80 ± 18.27	0.908
7. Left alare (all)	19.82 ± 2.02	20.57 ± 1.77	19.06 ± 2.01	0.003[a]	−32.25 ± 21.71	−37.82 ± 25.08	−26.49 ± 16.03	0.041[a]	18.46 ± 18.83	18.46 ± 20.10	18.46 ± 17.76	1.000
8. Right nasolabial fold (nlfr)	−27.41 ± 4.54	−28.11 ± 4.35	−26.70 ± 4.69	0.227	−44.2 ± 21.93	−49.90 ± 25.02	−38.32 ± 16.63	0.038[a]	18.42 ± 20.25	18.49 ± 22.17	18.34 ± 18.43	0.978
9. Left nasolabial fold (nlfl)	28.68 ± 3.74	29.99 ± 3.17	27.33 ± 3.85	0.005[a]	−50.0 ± 29.84	−58.31 ± 33.94	−41.42 ± 22.38	0.026[a]	17.6 ± 19.99	17.35 ± 21.73	17.85 ± 18.40	0.923
10. Right cheilion (chr)	−24.23 ± 3.02	−24.74 ± 2.90	−23.71 ± 3.11	0.188	−47.28 ± 9.52	−46.34 ± 10.99	−48.25 ± 7.78	0.438	17.77 ± 19.51	18.36 ± 21.77	17.15 ± 17.21	0.811
11. Left cheilion (chl)	24.27 ± 2.78	24.73 ± 3.14	23.80 ± 2.32	0.193	−47.17 ± 9.65	−46.40 ± 10.99	−47.96 ± 8.15	0.532	17.51 ± 19.4	17.77 ± 21.49	17.23 ± 17.33	0.914
12. Right crista philtre (cphr)	−6.18 ± 2.21	−6.30 ± 2.00	−6.06 ± 2.43	0.666	−45.64 ± 13.95	−49.31 ± 16.02	−41.85 ± 10.40	0.036[a]	26.56 ± 24.96	27.27 ± 26.58	25.82 ± 23.60	0.822
13. Left crista philtre (cphl)	7.11 ± 2.36	7.36 ± 2.38	6.86 ± 2.35	0.411	−45.64 ± 14.07	−49.38 ± 16.24	−41.78 ± 10.30	0.034[a]	26.33 ± 24.82	27.03 ± 26.46	25.61 ± 23.44	0.825
14. Labiale superius (ls)	0.32 ± 1.96	0.40 ± 1.80	0.23 ± 2.15	0.734	−40.27 ± 9.05	−40.86 ± 10.49	−39.67 ± 7.40	0.612	27.27 ± 25.48	28.02 ± 27.11	26.50 ± 24.12	0.818
15. Labiale inferius (li)	0.45 ± 2.31	0.61 ± 2.13	0.28 ± 2.51	0.578	−53.12 ± 12.61	−51.39 ± 13.93	−54.90 ± 11.05	0.281	24.95 ± 24.13	25.44 ± 25.92	24.44 ± 22.56	0.874
16. Anterior point of the upper lip (ula)	0.31 ± 1.96	0.44 ± 1.76	0.18 ± 2.17	0.615	−48.28 ± 11.27	−50.81 ± 13.01	−45.67 ± 8.60	0.075	26.66 ± 24.96	27.27 ± 26.58	26.03 ± 23.62	0.847
17. Anterior point of the lower lip (lla)	0.51 ± 2.21	0.73 ± 1.94	0.29 ± 2.47	0.443	−55.29 ± 9.31	−56.57 ± 10.82	−53.97 ± 7.41	0.278	25.72 ± 24.48	26.43 ± 26.29	24.99 ± 22.89	0.821
18. Inferior point of the upper lip (uli)	0.4 ± 1.94	0.52 ± 1.68	0.29 ± 2.20	0.653	−56.21 ± 16.15	−60.79 ± 18.11	−51.47 ± 12.43	0.023[a]	24.64 ± 23.75	25.14 ± 25.46	24.13 ± 22.26	0.871
19. Superior point of the lower lip (lls)	0.49 ± 2.06	0.60 ± 1.82	0.37 ± 2.31	0.676	−57.21 ± 15.87	−61.49 ± 18.16	−52.78 ± 11.84	0.031[a]	23.94 ± 23.27	24.26 ± 24.94	23.60 ± 21.82	0.912
20. Sublabiale (SB)	0.44 ± 2.3	0.55 ± 2.01	0.34 ± 2.59	0.722	−65.3 ± 10.49	−66.74 ± 12.01	−63.82 ± 8.60	0.280	21.62 ± 22.26	21.83 ± 24.16	21.41 ± 20.52	0.942
21. Pogonion (pog)	0.6 ± 2.47	0.71 ± 2.29	0.49 ± 2.67	0.739	−72.28 ± 10.24	−73.15 ± 11.12	−71.38 ± 9.36	0.506	21.4 ± 22.53	21.08 ± 24.36	21.72 ± 20.88	0.914
22. Gnathion (gn)	0.7 ± 2.62	0.86 ± 2.48	0.53 ± 2.78	0.618	−57.69 ± 39.91	−47.70 ± 44.71	−67.68 ± 32.18	0.052	20.29 ± 22.31	19.65 ± 24.06	20.95 ± 20.73	0.822
23. Menton (me)	0.62 ± 2.81	0.72 ± 2.55	0.53 ± 3.10	0.798	−62.84 ± 44.44	−51.39 ± 49.72	−74.68 ± 35.27	0.040[a]	14.76 ± 19.49	13.30 ± 20.68	16.26 ± 18.40	0.558

$P < 0.05$.

[a] Indicates a significant difference.

Table 3 Frequency distribution of landmarks in smiling 3D facial images.

Soft tissue landmark	x- plane				y-plane				z-plane			
	All	Male	Female		*All*	Male	Female		All	Male	Female	
	Mean ± SD	Mean ± SD	Mean ± SD	*P*	Mean ± SD	Mean ± SD	Mean ± SD	*P*	Mean ± SD	Mean ± SD	Mean ± SD	*P*
1. Nasion (n)	−0.03 ± 1.78	0.18 ± 1.89	−0.24 ± 1.62	0.3597	23.34 ± 12.4	26.36 ± 15.66	20.21 ± 6.68	0.052	30.06 ± 18.06	26.92 ± 22.99	33.3 ± 10.34	0.170
2. Pronasale (prn)	0.11 ± 1.84	0.31 ± 1.83	−0.08 ± 1.83	0.417	−13.19 ± 11.98	−11.36 ± 15.1	−15.08 ± 7.34	0.229	51.37 ± 16.68	48.83 ± 21.05	53.99 ± 10.17	0.230
3. Columella (col)	0.18 ± 1.76	0.33 ± 1.72	0.03 ± 1.79	0.5162	−20.01 ± 11.63	−18.65 ± 14.76	−21.4 ± 7.09	0.360	47.23 ± 17.02	44.09 ± 21.29	50.47 ± 10.43	0.145
4. Subnasale (sn)	0.33 ± 1.63	0.51 ± 1.4	0.14 ± 1.82	0.3893	−24.28 ± 11.34	−22.79 ± 14.41	−25.81 ± 6.81	0.303	38.75 ± 17.49	35.32 ± 21.75	42.29 ± 10.85	0.121
5. Subspinale (SA)	0.29 ± 1.66	0.58 ± 1.42	−0.01 ± 1.84	0.1712	−28.88 ± 12.0	−27.67 ± 15.44	−30.13 ± 6.92	0.428	37.22 ± 17.32	34.13 ± 21.63	40.43 ± 10.76	0.157
6. Right alare (alr)	−21.35 ± 2.3	−22.03 ± 2.39	−20.65 ± 1.96	0.0188[a]	−16.26 ± 11.76	−14.28 ± 15.24	−18.29 ± 6.1	0.185	30.39 ± 15.71	27.06 ± 19.45	33.83 ± 9.74	0.093
7. Left alare (all)	21.36 ± 2.49	22.29 ± 2.1	20.4 ± 2.49	0.0026[a]	−16.35 ± 11.61	−14.54 ± 15.02	−18.22 ± 6.19	0.219	29.38 ± 15.69	25.95 ± 19.29	32.93 ± 9.96	0.082
8. Right nasolabial fold (nlfr)	−30.26 ± 4.45	−31.84 ± 4.56	−28.63 ± 3.67	0.0043[a]	−27.35 ± 11.49	−25.7 ± 14.78	−29.07 ± 6.43	0.256	26.64 ± 18.23	22.87 ± 22.57	30.53 ± 11.39	0.101
9. Left nasolabial fold (nlfl)	31.48 ± 4.47	33.63 ± 3.72	29.27 ± 4.07	0.0001[a]	−27.13 ± 11.12	−25.42 ± 14.17	−28.9 ± 6.47	0.225	25.51 ± 18.38	21.32 ± 22.55	29.84 ± 11.6	0.070
10. Right cheilion (chr)	−28.74 ± 3.19	−28.73 ± 3.58	−28.76 ± 2.74	0.9705	−45.13 ± 11.5	−44.7 ± 15.1	−45.56 ± 6.11	0.773	20.47 ± 18.02	18.07 ± 22.3	22.96 ± 12.04	0.293
11. Left cheilion (chl)	29.02 ± 3.02	29.36 ± 3.39	28.67 ± 2.52	0.375	−44.77 ± 11.42	−44.21 ± 14.85	−45.35 ± 6.41	0.701	19.95 ± 18.33	16.77 ± 22.61	23.24 ± 12.03	0.170
12. Right crista philtre (cphr)	−7.13 ± 2.76	−7.14 ± 2.51	−7.12 ± 3.0	0.9756	−35.47 ± 12.08	−34.51 ± 15.38	−36.47 ± 7.43	0.532	39.36 ± 17.48	36.45 ± 21.89	42.36 ± 10.88	0.190
13. Left crista philtre (cphl)	8.01 ± 2.23	8.61 ± 2.25	7.39 ± 2.02	0.0324[a]	−35.53 ± 12.06	−34.57 ± 15.31	−36.51 ± 7.53	0.535	39.13 ± 17.39	36.01 ± 21.71	42.36 ± 10.83	0.156
14. Labiale superius (ls)	0.3 ± 1.86	0.57 ± 1.75	0.02 ± 1.92	0.2541	−36.93 ± 12.29	−36.19 ± 15.72	−37.69 ± 7.48	0.636	40.57 ± 17.43	37.56 ± 21.84	43.68 ± 10.75	0.173
15. Labiale inferius (li)	0.74 ± 2.24	1.04 ± 2.14	0.43 ± 2.29	0.2957	−62.77 ± 12.51	−62.81 ± 16.05	−62.73 ± 7.56	0.980	36.56 ± 17.94	33.92 ± 21.97	39.29 ± 12.3	0.245
16. Anterior point of the upper lip (ula)	0.32 ± 1.89	0.6 ± 1.75	0.03 ± 1.98	0.2457	−39.98 ± 12.21	−39.4 ± 15.67	−40.57 ± 7.34	0.713	39.75 ± 17.28	36.66 ± 21.62	42.93 ± 10.68	0.159
17. Anterior point of the lower lip (lla)	0.72 ± 2.24	1.02 ± 2.21	0.41 ± 2.24	0.2937	−57.97 ± 12.22	−57.68 ± 15.58	−58.27 ± 7.6	0.851	37.66 ± 17.75	35.07 ± 21.96	40.33 ± 11.78	0.251
18. Inferior point of the upper lip (uli)	0.38 ± 1.85	0.64 ± 1.64	0.12 ± 2.02	0.2847	−43.18 ± 12.02	−42.59 ± 15.36	−43.79 ± 7.35	0.701	35.98 ± 17.46	32.47 ± 21.66	39.62 ± 10.9	0.111
19. Superior point of the lower lip (lls)	0.63 ± 2.16	0.9 ± 2.05	0.36 ± 2.23	0.34	−52.59 ± 12.16	−52.18 ± 15.61	−53.02 ± 7.34	0.792	33.76 ± 17.99	30.45 ± 22.26	37.18 ± 11.54	0.146
20. Sublabiale (SB)	0.68 ± 2.3	0.87 ± 2.23	0.49 ± 2.35	0.529	−68.51 ± 12.67	−68.52 ± 16.14	−68.5 ± 7.9	0.995	32.64 ± 18.31	29.4 ± 22.17	35.98 ± 12.74	0.162
21. Pogonion (pog)	0.74 ± 2.43	0.9 ± 2.25	0.57 ± 2.6	0.6033	−78.02 ± 11.91	−79.22 ± 14.95	−76.77 ± 7.7	0.427	33.67 ± 18.35	30.24 ± 22.13	37.22 ± 12.83	0.139
22. Gnathion (gn)	0.71 ± 2.57	0.75 ± 2.45	0.67 ± 2.68	0.9069	−85.8 ± 12.57	−86.83 ± 15.85	−84.74 ± 8.05	0.520	33.18 ± 19.43	29.22 ± 23.04	37.27 ± 14.06	0.106
23. Menton (me)	0.76 ± 2.65	0.86 ± 2.44	0.66 ± 2.85	0.7711	−93.79 ± 13.51	−94.61 ± 17.36	−92.94 ± 8.03	0.633	26.71 ± 19.71	21.93 ± 22.44	31.66 ± 15.26	0.053
24. Right incisor or gum point (rgu)	−4.68 ± 4.14	−5.02 ± 5.47	−4.33 ± 1.92	0.5236	−43.35 ± 11.86	−42.88 ± 15.36	−43.84 ± 6.83	0.754	34.57 ± 17.43	30.81 ± 21.51	38.46 ± 10.91	0.087
25. Right incisor maxilla (ril)	−4.13 ± 1.78	−4.01 ± 1.61	−4.26 ± 1.93	0.5804	−49.13 ± 11.95	−47.72 ± 15.49	−50.59 ± 6.54	0.354	32.54 ± 17.77	28.73 ± 21.89	36.47 ± 11.22	0.089
26. Right canine point (cr)	−17.3 ± 3.12	−17.11 ± 3.74	−17.49 ± 2.29	0.6375	−46.13 ± 11.94	−45.17 ± 15.61	−47.13 ± 6.38	0.525	26.42 ± 17.72	23.12 ± 21.76	29.83 ± 11.67	0.141
27. Left canine point (cl)	18.07 ± 2.13	18.38 ± 1.83	17.76 ± 2.36	0.263	−46.06 ± 11.83	−45.13 ± 15.35	−47.02 ± 6.63	0.536	25.35 ± 17.92	21.69 ± 22.01	29.13 ± 11.57	0.106

$P < 0.05$.

[a] Indicates a significant difference.

Table 4 Frequency distribution of landmark changes during smiling in 3D facial images.

Soft tissue landmark	x-plane				y-plane				z-plane			
	Resting	Smiling	Difference		Resting	Smiling	Difference		Resting	Smiling	Difference	
	Mean ± SD	Mean ± SD	Mean ± SD	*P*	Mean ± SD	Mean ± SD	Mean ± SD	*P*	Mean ± SD	Mean ± SD	Mean ± SD	*P*
1. Nasion (n)	0.07 ± 1.82	−0.03 ± 1.78	−0.1 ± 1.27	0.549	7.03 ± 24.08	23.34 ± 12.4	16.30 ± 25.37	0.000[a]	19.38 ± 21.31	30.06 ± 18.06	10.67 ± 18.16	0.000[a]
2. Pronasale (prn)	0.18 ± 1.83	0.11 ± 1.84	−0.06 ± 1.23	0.694	−19.31 ± 12.02	−13.19 ± 11.98	6.12 ± 12.22	0.000[a]	32.4 ± 28.84	51.37 ± 16.68	18.96 ± 27.59	0.000[a]
3. Columella (col)	0.15 ± 1.75	0.18 ± 1.76	0.03 ± 1.11	0.809	−25.43 ± 11.25	−20.01 ± 11.63	5.42 ± 11.29	0.000[a]	29.88 ± 27.09	47.23 ± 17.02	17.35 ± 25.97	0.000[a]
4. Subnasale (sn)	0.28 ± 1.69	0.33 ± 1.63	0.05 ± 1.11	0.740	−30.29 ± 11.33	−24.28 ± 11.34	6.01 ± 11.53	0.000[a]	24.94 ± 23.85	38.75 ± 17.49	13.81 ± 23.30	0.000[a]
5. Subspinale (SA)	0.13 ± 1.71	0.29 ± 1.66	0.16 ± 1.23	0.306	−38.06 ± 13.54	−28.88 ± 12.0	9.18 ± 13.69	0.000[a]	24.68 ± 23.77	37.22 ± 17.32	12.54 ± 22.66	0.000[a]
6. Right alare (alr)	−19.75 ± 2.17	−21.35 ± 2.3	−1.6 ± 1.31	0.000[a]	−29.56 ± 18.11	−16.26 ± 11.76	13.31 ± 18.43	0.000[a]	19.1 ± 19.55	30.39 ± 15.71	11.30 ± 18.61	0.000[a]
7. Left alare (all)	19.82 ± 2.02	21.36 ± 2.49	1.54 ± 1.31	0.000[a]	−32.25 ± 21.71	−16.35 ± 11.61	15.90 ± 21.46	0.000[a]	18.46 ± 18.83	29.38 ± 15.69	10.92 ± 18.30	0.000[a]
8. Right nasolabial fold (nlfr)	−27.41 ± 4.54	−30.26 ± 4.45	−2.84 ± 3.08	0.000[a]	−44.2 ± 21.93	−27.35 ± 11.49	16.85 ± 21.68	0.000[a]	18.42 ± 20.25	26.64 ± 18.23	8.22 ± 18.62	0.001[a]
9. Left nasolabial fold (nlfl)	28.68 ± 3.74	31.48 ± 4.47	2.8 ± 3.1	0.000[a]	−50.0 ± 29.84	−27.13 ± 11.12	22.87 ± 29.34	0.000[a]	17.6 ± 19.99	25.51 ± 18.38	7.91 ± 18.45	0.001[a]
10. Right cheilion (chr)	−24.23 ± 3.02	−28.74 ± 3.19	−4.51 ± 2.51	0.000[a]	−47.28 ± 9.52	−45.13 ± 11.5	2.15 ± 9.01	0.067	17.77 ± 19.51	20.47 ± 18.02	2.70 ± 18.26	0.252
11. Left cheilion (chl)	24.27 ± 2.78	29.02 ± 3.02	4.75 ± 2.66	0.000[a]	−47.17 ± 9.65	−44.77 ± 11.42	2.40 ± 8.88	0.039[a]	17.51 ± 19.4	19.95 ± 18.33	2.45 ± 18.61	0.309
12. Right crista philtre (cphr)	−6.18 ± 2.21	−7.13 ± 2.76	−0.95 ± 1.53	0.000[a]	−45.64 ± 13.95	−35.47 ± 12.08	10.17 ± 13.60	0.000[a]	26.56 ± 24.96	39.36 ± 17.48	12.80 ± 24.00	0.000[a]
13. Left crista philtre (cphl)	7.11 ± 2.36	8.01 ± 2.23	0.9 ± 1.54	0.000[a]	−45.64 ± 14.07	−35.53 ± 12.06	10.12 ± 13.71	0.000[a]	26.33 ± 24.82	39.13 ± 17.39	12.80 ± 23.87	0.000[a]
14. Labiale superius (ls)	0.32 ± 1.96	0.3 ± 1.86	−0.01 ± 1.11	0.918	−40.27 ± 9.05	−36.93 ± 12.29	3.35 ± 8.69	0.004[a]	27.27 ± 25.48	40.57 ± 17.43	13.30 ± 24.47	0.000[a]
15. Labiale inferius (li)	0.45 ± 2.31	0.74 ± 2.24	0.29 ± 1.37	0.104	−53.12 ± 12.61	−62.77 ± 12.51	−9.65 ± 12.40	0.000[a]	24.95 ± 24.13	36.56 ± 17.94	11.61 ± 23.46	0.000[a]
16. Anterior point of the upper lip (ula)	0.31 ± 1.96	0.32 ± 1.89	0.0 ± 1.11	0.982	−48.28 ± 11.27	−39.98 ± 12.21	8.31 ± 10.97	0.000[a]	26.66 ± 24.96	39.75 ± 17.28	13.09 ± 24.05	0.000[a]
17. Anterior point of the lower lip (lla)	0.51 ± 2.21	0.72 ± 2.24	0.21 ± 1.34	0.230	−55.29 ± 9.31	−57.97 ± 12.22	−2.68 ± 8.36	0.015[a]	25.72 ± 24.48	37.66 ± 17.75	11.94 ± 24.00	0.000[a]
18. Inferior point of the upper lip (uli)	0.4 ± 1.94	0.38 ± 1.85	−0.02 ± 1.1	0.871	−56.21 ± 16.15	−43.18 ± 12.02	13.03 ± 15.51	0.000[a]	24.64 ± 23.75	35.98 ± 17.46	11.34 ± 22.93	0.000[a]
19. Superior point of the lower lip (lls)	0.49 ± 2.06	0.63 ± 2.16	0.15 ± 1.33	0.395	−57.21 ± 15.87	−52.59 ± 12.16	4.61 ± 15.00	0.019[a]	23.94 ± 23.27	33.76 ± 17.99	9.82 ± 22.93	0.001[a]
20. Sublabiale (SB)	0.44 ± 2.3	0.68 ± 2.3	0.24 ± 1.28	0.154	−65.3 ± 10.49	−68.51 ± 12.67	−3.21 ± 9.06	0.008	21.62 ± 22.26	32.64 ± 18.31	11.01 ± 21.61	0.000[a]
21. Pogonion (pog)	0.6 ± 2.47	0.74 ± 2.43	0.14 ± 1.21	0.383	−72.28 ± 10.24	−78.02 ± 11.91	−5.74 ± 9.74	0.000[a]	21.4 ± 22.53	33.67 ± 18.35	12.28 ± 21.53	0.000[a]
22. Gnathion (gn)	0.7 ± 2.62	0.71 ± 2.57	0.01 ± 1.56	0.967	−57.69 ± 39.91	−85.8 ± 12.57	−28.44 ± 40.93	0.000[a]	20.29 ± 22.31	33.18 ± 19.43	12.89 ± 21.60	0.000[a]
23. Menton (me)	0.62 ± 2.81	0.76 ± 2.65	0.14 ± 1.7	0.529	−62.84 ± 44.44	−93.79 ± 13.51	−30.95 ± 45.32	0.000[a]	14.76 ± 19.49	26.71 ± 19.71	11.96 ± 18.44	0.000[a]

$P < 0.05$.

[a] Indicates a significant difference.

Table 5 Linear measurement changes in smiling 3D facial images.

Linear measurement (mm)	Resting				Smiling				Difference	
	All	Male	Female		All	Male	Female			
	Mean ± SD	Mean ± SD	Mean ± SD	*P*	Mean ± SD	Mean ± SD	Mean ± SD	*P*	Mean ± SD	*P*
1. Intercommissural width or mouth width (chr-chl)	48.65 ± 3.95	49.57 ± 4.80	47.69 ± 2.58	0.0620	57.99 ± 5.04	58.36 ± 6.14	57.61 ± 3.65	0.56	9.34 ± 4.50	<0.0001[a]
2. Philtrum width (cphr-cphl)	13.46 ± 2.13	13.80 ± 2.30	13.10 ± 1.90	0.1997	15.24 ± 2.65	15.85 ± 2.56	14.61 ± 2.64	0.07	1.78 ± 2.06	<0.0001[a]
3. Upper lip length (sn-uli)	22.78 ± 2.34	23.91 ± 2.04	21.62 ± 2.06	<0.0001[a]	19.38 ± 2.58	20.34 ± 2.42	18.39 ± 2.38	0.0024[a]	−3.40 ± 2.22	<0.0001[a]
4. Upper lip vermillion length (ls-uli)	8.96 ± 1.65	9.25 ± 1.48	8.67 ± 1.77	0.1694	8.16 ± 1.80	8.61 ± 2.22	7.69 ± 1.09	0.046[a]	−0.80 ± 1.67	0.0004[a]
5. Lower lip length (lls-SB)	17.62 ± 2.35	18.46 ± 2.08	16.75 ± 2.32	0.0036[a]	16.22 ± 1.84	16.81 ± 1.54	15.62 ± 1.95	0.010[a]	−1.40 ± 2.05	<0.0001[a]
6. Lower lip vermillion length (lls-li)	11.19 ± 1.94	11.85 ± 1.67	10.51 ± 1.98	0.0057	10.66 ± 1.59	11.39 ± 1.35	9.91 ± 1.49	0.000145[a]	−0.53 ± 1.49	0.0073
7. Total lip vermillion length or mouth height (ls-li)	20.20 ± 4.85	21.31 ± 4.33	19.06 ± 5.15	0.0701	26.72 ± 3.89	27.38 ± 3.99	26.05 ± 3.74	0.184	6.52 ± 4.43	<0.0001[a]
8. Interlabial gap (uli-lls)	2.60 ± 5.87	1.86 ± 2.93	3.36 ± 7.82	0.3247	10.30 ± 3.08	10.16 ± 3.25	10.45 ± 2.93	0.72	7.70 ± 6.45	<0.0001[a]
9. Nasal arch length (n-prn)	42.05 ± 5.62	44.28 ± 3.81	39.75 ± 6.29	0.0012[a]	42.46 ± 3.82	43.81 ± 3.30	41.07 ± 3.86	0.0042[a]	0.41 ± 4.41	0.4711
10. Nasal projection (prn-sn)	16.61 ± 3.13	17.08 ± 1.70	16.11 ± 4.10	0.2289	16.85 ± 2.38	17.75 ± 2.20	15.91 ± 2.23	0.0019[a]	0.24 ± 3.53	0.5955
11. Nasal width (ra-la)	39.80 ± 2.82	41.05 ± 2.68	38.47 ± 2.37	0.00021[a]	42.87 ± 3.50	44.50 ± 3.29	41.18 ± 2.88	0.000097[a]	3.13 ± 1.64	<0.0001[a]

$P < 0.05$.
[a] Indicates a significant difference.

Table 6 Angular measurement changes in smiling 3D facial images.

Angular measurements (°)	Resting				Smiling				Difference	
	All	Male	Female		All	Male	Female			
	Mean ± SD	Mean ± SD	Mean ± SD	*P*	Mean ± SD	Mean ± SD	Mean ± SD	*P*	Mean ± SD	*P*
1.Nasolabial angle (col-sn-ls)	106.44 ± 10.28	105.62 ± 8.95	107.29 ± 11.60	0.5303	109.10 ± 13.40	105.52 ± 10.66	112.81 ± 15.03	0.0324[a]	2.66 ± 9.13	0.0263[a]
2.Labiomental angle (li-SB-pog)	139.00 ± 11.52	140.01 ± 12.76	137.95 ± 10.19	0.4903	139.13 ± 12.80	136.42 ± 11.68	141.94 ± 13.48	0.0924	0.13 ± 11.94	0.9302
3.Upper lip angle (chr-ls-chl)	105.53 ± 6.97	105.91 ± 8.03	105.13 ± 5.79	0.6688	105.27 ± 7.67	105.57 ± 8.35	104.97 ± 7.04	0.7614	−0.25 ± 6.25	0.7536
4.Lower lip angle (chr-li-chl)	115.04 ± 6.65	115.03 ± 7.44	115.06 ± 5.85	0.9826	100.57 ± 6.39	100.05 ± 7.11	101.11 ± 5.60	0.5208	−14.48 ± 6.29	<0.0001[a]
5. Nasal protrusion angle (alr-prn-all)	84.64 ± 8.16	85.14 ± 9.1	84.13 ± 7.19	0.6324	89.06 ± 8.09	88.97 ± 7.34	89.16 ± 8.94	0.9258	4.42 ± 5.24	<0.0001[a]
6.Nasal aspect (n-prn-sn)	103.32 ± 5.49	102.63 ± 6.14	104.03 ± 4.73	0.3233	101.29 ± 6.15	100.56 ± 6.62	102.06 ± 5.62	0.3528	−2.08 ± 4.36	0.0141[a]

$P < 0.05$.
[a] Indicates a significant difference.

Table 7 Pearson correlation between soft tissue and hard tissue variables.

Soft tissue variable	Hard tissue variable	Pearson correlation coefficient (r)	*P*
Upper lip length (sn-uli)	Id-Me	0.46	0.057
Lower lip length (lls-SB)	Id-Me	0.44	0.022[a]

$P < 0.05$.
[a] Indicates a significant difference.

the upper facial regions compared to the lower regions, reinforcing the prominence of y-plane changes.[17,18] Additionally, our study coincides with the previous studies on the effects of orthodontic treatments on facial morphology have highlighted the significant y and z plane changes compared to x-plane changes.[19]

Our study shows significant upward movements in facial landmarks when transitioning from rest to smile states, which aligns with findings from previous studies that observed upward shifts in landmarks like the nasion, pronasale, and subnasale during smiling.[20] In the z-plane, all landmarks moved forward during smiling, with significant gender differences. These align with those in previous studies, demonstrating significant forward movements during smiling.[21]

The length of the upper lip (sn-uli), lower lip (lls-SB), and lower lip vermillion (lls-li), nasal arch length (n-prn) and nasal width (ra-la) exhibit significant differences between males and females, both at rest and during a smile. These findings align with previous research, which has consistently demonstrated gender-based variations in facial soft tissue dimensions.[22,23]

There are notable changes in the nasolabial angle, lower lip angle, nasal protrusion Angle and nasal aspect. This observation contrasts with the results of Anic-Milosevic et al., where no significant gender differences were observed in nasal protrusion angle.[24] The nasolabial and nasal aspect angles show moderate changes, while the labiomental and upper lip angles remain relatively stable. These findings are in partial agreement with Erdinc and Nanda, who found that while some lip and nasal measurements varied by gender, others remained constant.[25] These differences may stem from variations in the characteristics of the study subjects, measurement methods, analytical techniques, research design, and cultural and environmental factors. A further comparison and exploration of the specific differences between these studies can help to understand the reasons more comprehensively behind these changes.

The influence of regional and racial variations on facial morphology and dynamics may also play a significant role in the observed differences. Facial features are known to vary significantly across populations due to genetic, environmental, and cultural factors. For example, studies have reported differences in the dimensions of the nasolabial angle, lip thickness, and nasal protrusion between various ethnic groups, which may affect the results of landmark analyses during smiling.[26,27] Additionally, these variations may influence the observed gender differences in certain parameters.[28] Incorporating diverse regional or racial groups in future studies could provide a more comprehensive understanding of these variations and help delineate whether the observed differences stem from intrinsic anatomical disparities or experimental design limitations.[29]

A moderate linear relationship was found between upper lip length (sn-uli) ($r = 0.46$, $P = 0.057$) and lower lip length (lls-SB) ($r = 0.44$, $P = 0.022$) with the hard tissue measurement Id-Me, indicating that changes in the upper and lower lip lengths are predictably associated with changes in the midline point at the most anterior edge on the inferior alveolar ridge to the most inferior midline point at the mental symphysis of the mandible distance (Id-Me). However, only 2 soft tissue variables reveal correlation with hard tissue variables, which may result from our sample selection of good-looking samples with normal skeletal relationship and Angle's Class I malocclusion. Therefore, our samples cannot reveal the relationship between soft tissue and different types of skeletal pattern. In contrast to Cheng et al., they found that smile patterns on lateral and oblique view photographs can be influenced by various types of malocclusion.[30]

The study of three-dimensional (3D) changes in soft tissue landmarks during smiling reveals significant changes along the y-plane, approximately equal to those in the z-plane, and greater than those in the x-plane. This finding indicates the importance of considering all dimensions, particularly the z-plane, in orthodontic diagnosis and treatment planning. In the orthodontic clinical practice, we should not neglect the z-plane influence of 3D imaging techniques which traditional two-dimensional (2D) analyses often fail to capture.

Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

Acknowledgments

Thank for all faculties of the Department of Dentistry, Taipei Medical University Hospital, Taipei City, Taiwan. For the contribution to data collection.

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