Effects of orthodontic extraction on facial soft and hard tissue changes among average-angle skeletal class Ⅰ Chinese adults females:A 3D geometric morphometric study

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Abstract

Background: This study aimed to investigate changes in the facial soft and hard tissues changes among the average-angle skeletal class Chinese adult females receiving extraction orthodontic treatment, as well as the correlations between them.

Methods:

The 3dMD® stereo photography technology was used to explore facial soft tissue changes, and lateral cephalograms and cone beam computed tomography (CBCT) to explore hard tissue changes. A total of 23 adult females were recruited, among which 11 patients were with teeth extraction, 12 patients without teeth extraction treatment.

Results:

Among the 3D distance measurements, decreased soft tissue changes of 1/3 Face height, Stomatological height, Chin height and Lip width were observed (p<0.005), in which Lip width was found to have a moderate correlation with the decreased hard tissue change of upper inter-first molar width (d5) (r^a=0.619, p<0.005). Among the 3D angle measurements, decreased soft tissue changes of Chin-lips angle and Lip angle, were found, in which Lip angle was found to have a moderate correlation with the decreased hard tissue changes of ∠U1-SN (r^a=0.659, p<0.005). While the Soft tissue angle and Nasolabial angle increased post-orthodontics (p<0.005). In addition, moderate negative correlations between Nasolabial angle and hard tissue changes of ∠U1-SN and d1 were found (r^a=-0.668; -0.763, p<0.005).

Conclusion:

Extraction orthodontic treatment showed a good control for facial protrusion cases, making the patients profile more attractive and harmonious. Changes in position and inclination of anterior teeth were also related to changes of facial soft tissues. There is no significant collapse in buccal and temporal region of patients with teeth extraction treatment compared with those without teeth extraction.

Background

With the advancement of living life, the adult popular begin to pay more and more attention to their dental alignment and appearance, and thus seeking for orthodontic treatment. However, in recent years, the concept of "bracketed face" has emerged and troubled the adult popular, which refers to a characteristic facial soft tissue change during the orthodontic process, mainly featured as: prominent cheekbones, depressed temples and cheeks, resulting an old and haggard face. There are few studies on the relationship between the appearance of "bracketed face" and orthodontic treatment up to now. The possible reasons may be that the Caucasian [1] has prominent facial features, high cheekbones, and thin cheeks. Therefore, doctors and patients in western countries do not pay much attention to facial thinning.

But for the Asians, their faces are relatively flat[2]. And in their view, women with too high cheekbones are not so pretty. Adult female patients often complain about their prominent cheekbones, depressed temples and cheeks post-orthodontics. Therefore, it is particularly meaningful for us to study the impact of orthodontic treatment on the facial changes among adult female patients.

The previous study methods of facial soft tissue mainly rely on two-dimensional (2D) images, e.g. digital photos and X-ray films, but their accuracy and repeatability of the images were affected by many factors, such as patient head position, camera angle, distance, and the level of the photographer[3]. Although 2D images provides data with linear, angular measurements through lateral cephalograms and panorama, the placement of soft tissue landmarks might not be represented the “truth” in 2D images, because the distortion caused by overlapping of bilateral structures is often present during the measurements. Besides, 2D imaging is despised for its inability to volume measurements and accurately capture the surface realistic colour and texture data onto the geometric shape, thus it fails to offer more options for analyses[4]. Therefore, novel methodology with more accuracy and three-dimensional measurement is evolved.

In recent years, the 3D photogrammetry technology has gradually entered the medical field, among which the 3dMD® facial 3D imaging system is more commonly used. The line spacing, angle and volume data can be obtained though using 3dMD® facial 3D imaging system. Zhu *et al.*[4] proved that there was no statistically significant difference between the soft tissue measurement data obtained by 3dMD® and the direct measurement method of the human body, proving that the accuracy and precision of 3dMD® are great, and it can be applied in clinical practice. In addition, the combined utilization of 3dMD® and cone beam computed tomography (CBCT) is gaining importance in evaluating the effects of orthodontic treatment, so that the skeletal, dental and facial soft tissue changes can be observed and explained together, or even the relationship between them be associated[5, 6, 7].

In this study, we take advantages of combination use of 3dMD® with CBCT to evaluate the effects of orthodontic extraction on the facial soft and hard tissue changes among skeletal class Chinese adult female patients. The patients were divided into two groups according to their treatment need, with teeth extraction or without. This study aims to provide more knowledge and evidence on facial soft and hard tissues changes for adult women with orthodontic treatment.

Methods

Patients

This study was approved by the Research Ethics Board of Hospital of Stomatology, Sun Yat-sen University (KQEC-2020-04). All patients gave informed consent prior to participation. Patients were recruited from consecutive adult patients visiting the Department of Orthodontics, Hospital of Stomatology, Sun Yat-sen University, Guangzhou, China. A total of 23 females aged 18–27 years were included. The mean age of the patients were 23.3 years old. Among the 23 patients, 11 received orthodontic treatment with extraction of four first or second premolars for mean treatment period of 26.9±7.4 months, while the others received orthodontic treatment without tooth extraction for 19.6±5.6 months(Appendix Table 1).

Inclusion criteria were: (1) Chinese; (2) Adult females; (3) Aged 18–36 years; (4) Average-angle, 27.3°

Patients would be included in the extraction group if the required spacing was greater than 4 mm, and the crowding could not be obtained by dental arch expansion or interproximal enamel reduction (IPR). The main characteristics of extraction group were: (1) moderate crowding (>4mm); (2) protrusion of upper and lower lips: The nasolabial angle (normal 95.0 ± 5.0°) is too small and/or the mandibular central incisor protrusion (normal 92.6 ± 7.0°) is too large; (3) deep curve of Spee (>2mm). Otherwise, the non-extraction treatment was adopted.

All procedures followed the guidelines of the Declaration of Helsinki (2013) and given approval by the ethics committee of Hospital of Stomatology, Sun Yat-sen University (approval number IRBKQEC-2020-04). Written informed consent was obtained from all the patients.

Orthodontic process

All patients were treated the same deputy chief physician, using the American Ormco Damon Q self-ligating labial brackets system (0.022×0.028-inch bracket slot) and Straight-Wire Technique. The main treatment process was as following. Stage 1: The nickel-titanium(NiTi) archwire was changed from thin to thick, from round to square, aligning and leveling the dentition. Stage 2: For extraction patients, the extraction spaces were closed by sliding method with the stainless steel(SS) archwire. Stage 3: Fine adjustment to establish a normal overbite and overjet of the anterior teeth, and obtain a class I relationship in term of molars and canines. For all tooth extraction cases, different anchorage requirements were selected according to the patient’s diagnosis and protrusion without any internal or external anchorage devices.

3D Facial soft-tissue imaging

The 3dMD® facial three-dimensional imaging system was used to capture 3D facial soft-tissue before treatment and after treatment (Appendix Fig. 1). Patients were asked to sit on a height-adjustable and rotatable backrest chair with a distance of 100-110cm from the camera, relax all over the body, look straight ahead with his eyes, gently close lips, maintain a natural facial expression and occlusal cusp-fossa contact relationships after swallowing. The instrument automatically focused and captured a 180° facial image between the ears when shooting. Data was analyzed by 3dMD vultus analysis software[2, 8].

Facial soft tissue landmarks and measurement items

Facial 3D soft tissue features were measured before and after orthodontic treatment. There were 18 soft tissue landmarks in this study, and the landmarks refers to previous literatures[2, 9, 10, 11](Appendix

Table 2) (Appendix Fig. 2). Measurement items of 14 line distances, 8 angles, and 6 volumes were measured according to the marker points (Table 1) (Fig. 1).

Table 1
Measurement of 14 line distances, 8 angles, and 6 volumes

Measurement	Definition
Line distances(mm)	
1/3 Face height (Sn-Me’)	Distance between Subnasale - Menton
Right back face height (Tra_R-Go’_R)	Distance between Tragion right - Gonion right
Left back face height (Tra_L-Go’_L)	Distance between Tragion left - Gonion left
Lip height (Ls-Li)	Distance between Labiale superius - Labiale inferius
Stomatological height (Sto-Me’)	Distance between Stomion - Menton
Chin high (Sl-Me’)	Distance between Sublabiale - Menton
Right face deep (Sn-Tra_R)	Distance between Subnasale - Tragion right
Left face deep (Sn-Tra_L)	Distance between Subnasale - Tragion left
Right mandible length (Go’-Me’_R)	Distance between Gonion right - Menton
Left mandible length (Go’-Me’_L)	Distance between Gonion left - Menton
Face width (Tra_R-Tra_L)	Distance between Tragion right - Tragion left
Mandible width (Go’_R-Go’_L)	Distance between Gonion right - Gonion left
Cheek width (Ck_R-Ck_L)	Distance between Cheek right - Cheek left
Lip width (Ch_R-Ch_L)	Distance between Cheilion right - Cheilion left
Angle measurement(°)	

Measurement	Definition
Line distances(mm)	
Soft tissue angle (N’-Sn-Pg’)	Angle of Nasion-Subnasale-Pogonion
Soft tissue ANB angle (Sn-N’-Sl)	Angle of Subnasale-Nasion-Sublabiale
Nasolabial angle (Prn-Sn-Ls)	Angle of Pronasale-Subnasale-Labiale superius
Chin-lips angle (Li-Sl-Pg’)	Angle of Labiale inferius-Sublabiale-Pogonion
Mandibular angle (Go’_R-Pg’-Go’_L)	Angle of Gonion right-Pogonion-Gonion left
Lip angle (Ls-Sto-Li)	Angle of Labiale superius-Stomion-Labiale inferius
Right mandibular angle (Tra_R-Go_R-Me’)	Angle of Tragion right-Gonion right-Menton
Left mandibular angle (Tra_L-Go_L-Me’)	Angle of Tragion left-Gonion left-Menton
Volume measurement	
Nose (V-nose)	The upper boundary is the root point of the nose, the lower boundary is the base of the nose, and the two sides are the line connecting the inner canthus and the alar point
Lips (V-lip)	The upper boundary is the base of the nose, the two sides are the labial groove, and the lower boundary is the chin-labial groove and the chin
Chin (V-chin)	The upper boundary is the chin-labial groove, the two sides are the vertical lines of the corners of the mouth, and the lower boundary is the lower edge of the mandible
Cheek (V-chk)	The anterior border is the lip and chin, the posterior border is the anterior border of the masseter muscle, the upper border is parallel to the horizontal plane of mouth corner, and the lower border is the lower border of the mandible
Zygomatic (V-zy)	The upper border is the upper border of the zygomatic arch, the lower border is the lower border of the zygomatic bone, the anterior border is the root of the maxillary zygomatic process, and the posterior border is the hairline of the rear end of the zygomatic arch

Measurement	Definition
Line distances(mm)	
Temporal (V-tem)	The posterior border is the hairline, the inferior border is the superior border of the zygomatic arch, and the anterior superior border is the superior temporal line

A: V-nose B: V-lip C: V-chin D: V-chk E: V-zy F: V-tem

Maxillofacial hard-tissue imaging (Radiographic scan)

The CBCT System(DCTPro, Vatech, Korea) and Dolphin Imaging Software (Dolphin Imaging & Management Solutions, Chatsworth, USA) were used in this study to capture maxillofacial hard-tissue for each individual. The shooting parameters were set at 90kVp, 6.2mA, exposure time of 15s and a field of view of 16cm×7cm in the same head positions: following the manufacture's recommendations, the clinician centered the patients' head in the focal trough with the Frankfort plane parallel to the floor and the mid-sagittal plane perpendicular to the floor[12].

Lateral cephalograms and CBCT measurements

Cephalometric lateral radiographs and CBCT images were analyzed by Dolphin Imaging Software. Measurement items∠U1-SN, d1, d2, d3 were designed for cephalometric analysis (Table 2) (Fig. 2). Six hard tissue indexes for CBCT images of d4, d5, d6, d7, d8 and d9 were measured referring to previous literatures [13,14,15](Table 2 and Fig. 2).

Table 2
Hard tissue measurements

Measurements	Definition
∠U1-SN	Angle between anterior skull base plane SN and maxillary central incisor U1
d1	Crown position, which is UI-UI' distance
d2	Apical position, which is A-A' distance
d3	First molar position, which is M6-M6' distance
d4	Upper intercuspid canine width, which is U3-U3' distance
d5	Upper inter-first molar width, which is UMB6-UMB6' distance
d6	Maxillary central incisor U1 vertical position, which is U1VP-U1VP' distance
d7	Mandibular central incisor L1 vertical position, which is L1VP-L1VP' distance
d8	Maxillary first molar U6 vertical position, which is U6VP-U6VP' distance
d9	Mandibular first molar L6 vertical position, which is L6VP-L6VP' distance

Statistical Methods

All the items were measured twice with an interval of two weeks, and the average measurements was taken. If the variables were normally distributed and the variances uniform, an independent samples t-test was used. If not, the two-sided Spearman correlation analysis was used. The level of significance was set at 0.05. All data were analysed by using SPSS 20.0 software (IBM, USA).

Results

Comparison of facial soft tissue changes in 3D line distance

The changes in distance of 1/3 Face height (Sn-Me'), Chin high (Sl-Me') and Lip width (Ch_R-Ch_L) in the extraction group were decreased, while the changes in the non-extraction group were increased, and the changes between two groups showed significant differences ($p < 0.05$). For Stomatological height (Sto-Me'), it decreased in both groups, but the change in extraction group was bigger in extraction group. No statistical differences were found in other 3D line distance measurements (Table 3).

Table 3
Change of facial soft tissue in line distance(mm, X̄ ±SD)

	Extraction (n = 11)	Non-extraction (n = 12)	t	P
1/3 Face height	−0.359 ± 0.922	0.948 ± 1.183	−2.935	0.008*
Right back face height	−4.169 ± 13.360	−0.081 ± 5.158	−0.985	0.336
Left back face height	−5.685 ± 12.829	−0.3167 ± 5.298	−1.333	0.197
Lip height	−0.292 ± 1.639	0.162 ± 1.491	−0.698	0.493
Stomatological height	−1.206 ± 0.579	−0.053 ± 1.464	−2.440	0.024*
Chin height	−0.887 ± 1.701	0.497 ± 1.239	−2.245	0.036*
Right face depth	2.170 ± 4.809	0.362 ± 1.798	1.215	0.238
Left face depth	−0.109 ± 5.296	0.050 ± 2.224	−0.096	0.925
Right mandible length	0.835 ± 3.060	−0.316 ± 3.704	0.808	0.428
Left mandible length	1.396 ± 4.065	−0.330 ± 3.651	1.074	0.295
Face width	−0.194 ± 2.189	0.420 ± 1.137	−0.856	0.402
Mandible width	0.032 ± 3.758	−0.995 ± 3.059	0.723	0.478
Cheek width	−1.045 ± 3.422	−1.476 ± 3.557	0.296	0.770
Lip width	−0.564 ± 0.660	0.732 ± 1.764	−2.291	0.032*

Note: * means $p < 0.05$, the difference is statistically significant; ** means $p < 0.001$, the difference is statistically significant.

Comparison of changes in facial soft tissue in 3D angle

For angle measurements, soft tissue angle (N’-Sn-Pg’) and Nasolabial angle (Prn-Sn-Ls) showed a statistical changes between two groups (extraction group: 0.41°and 4.97°vs. non-extraction group: -0.91°and 1.65°, respectively, $p < 0.05$). The decreased changes in angle of Chin-lips angle (Li-Sl-Pg’) of patients in the extraction group were observed (extraction group: -3.96°vs. non-extraction group: 3.31°, $p < 0.05$). Similarly, the change in Lip angle (Ls-Sto-Li) was significant (extraction group: -12.72°vs. non-extraction group: 3.64°, $p < 0.05$). These results implies the retracting effect of orthodontic extraction to prominent mouth. No statistical differences were found in Soft tissue ANB angle, Mandibular angle, Right mandibular angle and Left mandibular angle between two groups after treatment (Table 4).

Table 4
Change of facial soft tissue in angle(°, X̄±SD)

	Extraction (n = 11)	Non-extraction (n = 12)	t	P
Soft tissue angle	0.415 ± 0.971	−0.913 ± 1.765	2.207	0.039*
Soft tissue ANB angle	0.332 ± 0.623	0.560 ± 1.041	−0.630	0.536
Nasolabial angle	4.972 ± 3.788	1.655 ± 2.089	2.631	0.016*
Chin-lips angle	−3.961 ± 3.202	3.315 ± 3.396	−5.274	0.000**
Mandibular angle	−0.147 ± 3.851	0.174 ± 4.697	−0.178	0.860
Lip angle	−12.725 ± 7.265	3.648 ± 10.052	−4.439	0.000**
Right mandibular angle	2.610 ± 2.846	2.025 ± 2.645	0.511	0.614
Left mandibular angle	2.312 ± 3.020	2.259 ± 2.792	0.044	0.965

Note: * means $p < 0.05$, the difference is statistically significant; ** means $p < 0.001$, the difference is statistically significant.

Comparison of changes in facial soft tissue in volume

Changes in volume of facial soft tissue were statistically significant for Lips, Chin and Cheek region after extraction orthodontic treatment, which were − 1.13cm^3, -0.39cm^3 and − 1.49cm^3 in extraction group while − 0.08cm^3, 0.46cm^3 and − 0.11cm^3 in non-extraction group respectively ($p < 0.05$). However, no significant differences were observed in the changes of Nose, Zygomatic and Temporal volumes (Table 5).

Table 5
Change of facial soft tissue in volume(cm3,X̄±SD)

	Extraction (n = 11)	Non-extraction (n = 12)	t	P
Nose	0.167 ± 0.955	0.342 ± 0.564	−0.540	0.595
Lips	−1.135 ± 1.093	−0.087 ± 1.144	−2.239	0.036*
Chin	−0.399 ± 0.517	0.468 ± 0.837	−2.954	0.008*
Cheek	−1.493 ± 1.817	−0.111 ± 1.136	−2.207	0.039*
Zygomatic	0.581 ± 0.534	0.287 ± 0.355	1.567	0.132
Temporal	0.009 ± 0.129	0.123 ± 0.533	0.802	0.432

Note: * means $p < 0.05$, the difference is statistically significant; ** means $p < 0.001$, the difference is statistically significant.

Comparison of changes in facial hard tissue

For sagittal measurements, a statistical change ∠U1-SN after treatment was observed between two groups (extration group: -6.29°vs. non-extraction group: 1.08°, $p < 0.05$). Similarly, the change in d1 was significant (extraction group: -4.96mm vs. non-extraction group: -0.03mm, $p < 0.05$). For vertical measurements, only d5 showed a statistical difference between two groups after treatment (extraction group: -0.67 mm vs. non-extraction group: 2.52mm, $p < 0.01$). Horizontally, the change of d7 in the extraction group was − 1.53mm compared with 0.56mm in the non-extraction group ($p < 0.05$). No statistical differences were seen in d2, d3, d4, d6, d8 and d9 between two groups after treatment (Table 6).

Table 6
Change of facial hard tissue in dental features($\bar{X}$±SD)

	Extraction (n = 11)	**Non-extraction (n = 12)**	**t**	**P**
∠U1-SN(°)	−6.290 ± 5.444	1.083 ± 5.830	−3.127	0.005*
d1(mm)	−4.963 ± 4.405	−0.033 ± 3.852	−2.863	0.009*
d2(mm)	−0.390 ± 4.484	−0.341 ± 3.038	−0.031	0.976
d3(mm)	2.036 ± 2.654	0.600 ± 2.876	1.241	0.228
d4(mm)	2.22 ± 1.896	0.900 ± 1.754	1.669	0.111
d5(mm)	−0.672 ± 1.834	2.527 ± 1.575	−4.389	0.000**
d6(mm)	0.372 ± 1.841	0.836 ± 1.541	−0.640	0.529
d7(mm)	−1.536 ± 1.083	0.563 ± 1.760	−3.369	0.003*
d8(mm)	0.081 ± 1.078	−0.409 ± 1.012	1.101	0.284
d9(mm)	0.509 ± 1.333	0.600 ± 1.453	−0.153	0.880

Note: * means $p < 0.05$, the difference is statistically significant; ** means $p < 0.001$, the difference is statistically significant.

Correlation analysis of facial soft tissue and hard tissue changes

Among sagittal direction in 3D measurements, only the Nasolabial angle was found to have a moderate negative correlation with decreased changes of ∠U1-SN and d1 (r^a=-0.668 and − 0.763, respectively, $p < 0.05$). The correlation between decreased changes of Lip angle (Ls-Sto-Li) and ∠U1-SN was also found to be moderately positive (r^a=0.659, $p < 0.05$). For horizontal direction, there was also a moderate positive correlation between the decreased changes of Lip width and distance d5 (r^a=0.619, $p < 0.05$). Regarding to vertical direction, no significant correlation between facial soft tissue and hard tissue changes was found (Table 7 and Fig. 3).

Table 7
Ratio and correlation coefficients between soft and hard tissue changes in patients treated with extraction

Variables(S/H)	Soft tissue(S)	Hard tissue(H)	S/H	r[a]	P
Sagittal direction					
Soft tissue angle/∠U1-SN (°)	0.415	−6.290	−0.065	−0.235	0.487
Soft tissue angle/d1 (°/mm)	1.366	−4.963	−0.275	−0.162	0.634
Nasolabial angle/∠U1-SN (°)	4.972	−6.290	−0.790	−0.668	0.025*
Nasolabial angle/d1 (°/mm)	4.972	−4.963	−1.001	−0.763	0.006*
Chin-lips angle/∠U1-SN (°)	−3.961	−6.290	0.629	−0.162	0.633
Chin-lips angle/d1 (°/mm)	−3.961	−4.963	0.798	−0.040	0.906
Lip angle/∠U1-SN (°)	−12.723	−6.290	2.022	0.659	0.028*
Lip angle/d1 (°/mm)	−9.359	−4.963	1.885	−0.82	0.810
Horizontal direction					
Lip width/d5 (mm)	−0.564	−0.672	0.839	0.619	0.042*
Vertical direction					
1/3 Face height/d7 (mm)	−0.359	−1.536	0.233	−0.185	0.586
Stomatological height/d7 (mm)	−1.206	−1.536	0.785	−0.265	0.431
Chin high/d7 (mm)	−0.887	−1.536	0.577	−0.389	0.237

[a]Pearson’s correlation coefficient for soft and hard tissue changs.

Note: * means $p < 0.05$, the difference is statistically significant; ** means $p < 0.001$, the difference is statistically significant.

Discussion

Nowadays, the proportion of adult orthodontic patients is on the rise, accounting for more than 1/3 of the total, and there is continuous an upward trend [16], of which women account for the vast majority. Our study found that the orthodontic extraction showed a good control for facial protrusion cases in term of soft and hard tissues, such as the decreased Stomatological height, Lip width, volume of Lips, ∠U1-SN, d1 and increased Nasolabial angle, which met their chief complaint and treatment demands. To our knowledge, this is the first study that investigated the effects of orthodontic extraction on soft and hard tissue facial changes, and investigating their associations among average-angle skeletal class Chinese adults females orthodontic patients using 3dMD®, lateral cephalograms and CBCT.

In terms of line distance in soft tissue, the statistical results of this study showed that the lip width showed a decreased change in the extraction group and an increased change in the non-extraction group.The non-extraction correction requires the buccal movement of the canines for alignment due to lack of space, resulting in the fullness of the lips, while the anterior teeth retraction in extraction group would reduce the lip volume and thus reduce the lip width. Upper canines were important teeth that support the corners of the mouth. Though canines in extraction group were moved distally mainly in order to retract the maxillary anterior and close the extraction space, then d4 increase naturally along the alveolar bone. Such an increase of d4 in extraction will not lead to soft tissue lips widening, because they moved distally and may cause lips retracted. In the study of adult patients with bimaxillary protrusion, Leonardi *et al.* [17] found that the upper and lower lips were moved backward by 2 to 3.2 mm and 2 to 4.5 mm respectively after the extraction of the first premolar, indicating that the rebuilding in soft tissue of the lips will occur with the movement of the teeth. Adults lack the ability to remodel soft tissue, suggesting that adult patients with thick lip can obtain better lip shape after tooth extraction, which is consistent with the research conclusions of some studies [18, 19]. In addition, we also observed a decreased change in 1/3 face height and chin high and opposite in soft tissue angle in the extraction group, which might be that these cases were designed as moderate anchorage, and the molars move mesially, resulting in a counterclockwise rotation of the mandible[20, 21]. It is suggested that orthodontists need to predict the changes of lip shape and consider patients' requirements when designing orthodontic treatment plans, and well communication with patients.

In terms of angle, nasolabial angle showed an increased change, which had significant correlation with ∠U1-SN and d1 in the extraction group, related to a retracting effect on maxillary anterior teeth. The lip angle decreased in both groups and the difference was more significant in the extraction group. The retracting effect on maxillary anterior teeth of ∠U1-SN and d1 suggests that some patients may have anterior teeth tipping tilt with lips incomplete closure before orthodontic treatment. After the establishment of normal overbite coverage and the vermilion in a relaxed state, the eversion of lip is reduced. Our findings agree with previous studies that maxillary incisor retraction help soft tissue profile change[22]. A systematic review indicated that a significant association was seen between patient age and treatment-induced increase in nasolabial angle, with the fact that a greater increase was showed in older patients rather than younger patients[23]. This might be explained from long nose growth or age-related lip changes before adulthood. As for the chin-lips angle, it decreased in the extraction group and increased in the non-extraction group. This might be that the non-extraction orthodontic treatment generally requires the anterior teeth tilt, creating a gap to align the lower dentition, making the lower lip more prominent and the ditch becomes shallow. Wen *et al.*[24] found that the basic development of the chin in females is completed around the age of 12, while that in males can continue until the age of 17, but individual differences are large. It is suggested that when designing the treatment plan, patients with a protruding chin are allowed to tilt the incisors and lips, and the possibility of non-extraction correction is high, obtaining the nose, lips and chin more harmonious and beautiful.

In terms of volume, both the entire set of facial volume analysis converged in revealing thinner lips and cheek region. The changes in these regions were likely associated with changes in occlusion and masticatory muscle during orthodontic treatment. In clinical practice, patients were suggested to have lip closing training assisting anterior teeth retraction for saving anchorage. For the extraction group, the narrowing tendency in inter-molar width (d5) of smaller dental arch may contribute to loss of tooth support on the face. Dietary disturbance, atrophy of the masticatory muscles and physiological changes with aging also caused the cheek to collapse [25]. Otasevic M *et al.* indicated that oral mucosa ulcer caused by bracket or ligature wire are the important factors to patients reporting strong pain and tend to avoid chewing [26]. This change reduces the compliance of the masticatory muscles, leading to progressive muscle atrophy and degeneration [27], which in turn may contribute to cheek region invagination observed in this study. Gosain *et al.* [28] used MRI to study the volume of facial fat, they found that the superficial fat on the cheeks of the elderly was thicker than that of the young. Although the buccal volume in the extraction group showed a statistically significant reduction compared with that in the non extraction group, the difference was small. Whether this small difference could be reflected in the facial change of each patient needs to be discussed individually. However, this suggests that it should be cautious in orthodontic extraction for adult women patients with high cheekbones and thin cheeks. No statistical changes in the volumes of zygomatic and temporal soft tissues, therefore, this study does not support the argument that orthodontic extraction is more likely to cause a "bracketed face" than non-extraction.

In conclusion, changes of facial characteristics after extraction orthodontic treatment showed a good control for facial protrusion cases, making the patients profile more attractive and harmonious among average-angle skeletal class Chinese adults females, these changes were characterized by retracted anterior teeth and lips-related regions. The soft tissue buccal volume in both extraction and non-extracted patients decreased to a certain extent, but no significant changes were found in temporal and zygomatic regions. It should be emphasized and fully communicated with adult women patients with high cheekbones and thin cheeks in orthodontic extraction.

Limitations

Several limitations in this study should be noted. Firstly, more detailed changes in patients' quality of life, level of satisfaction and subjective evaluation to the facial changes could be extended further[29]. Secondly, our analysis focused on facial changes after the orthodontic treatment. Longitudinal study and longer periods of follow-ups are necessary to gain a complete understanding of facial changes post-treatment. Thirdly, our study sample is comprised of only Chinese, which could only reflect Asian populations. Lastly, the patient's BMI related indicators may also affect the results[30].

Declarations

Ethics approval and consent to participate

This study was approved by the Research Ethics Board of the Hospital of Stomatology of Sun Yat-sen University (KQEC-2020-04). All patients gave informed consent prior to participation. We confirm that all methods were performed in accordance with the relevant guidelines and regulations. Written informed consent to participate was obtained from each adult patient and adolescent patient's parent and/or legal guardian.

Consent for publication

Written informed consent for publication were obtained from the adult patients and parents of the adolescent patients.

Availability of data and materials

All data generated or analyzed during this study are included in this published article and its supplementary files.

Competing interests

The authors declare that they have no competing interests.

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Author contributions

Zhaoxiang Wen performed the clinical investigations. Yiqi Tang and Tingyu Wang interpreted the data and drafted the manuscript. Sihui Su and Dongru Chen contributed to the data collection. Zhaoxiang Wen and Dongru Chen contributed to critically read and revise the manuscript. Dongru Chen and Liping Wu were responsible for the study design, data analysis, manuscript revision and financial support. All authors read and approved the final manuscript.

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References

1. Janson G, Quaglio CL, Pinzan A, et al. Craniofacial characteristics of Caucasian and Afro-Caucasian Brazilian subjects with normal occlusion[J]. J Appl Oral Sci. 2011;19(2):118–24. 10.1590/s1678-77572011000200007.
2. Guilherme J, Camila LQ, Arnaldo P, et al. Three-dimensional soft tissue changes in orthodontic extraction and non-extraction patients: A prospective study[J]. Orthod Craniofac Res. 2021;24(Suppl 2):181–92. 10.1111/ocr.12506.
3. Resnick CM, Dang RR, Glick SJ, et al. Accuracy of three-dimensional soft tissue prediction for Le Fortâ… osteotomy using Dolphin 3D software: a pilot study[J]. Int J Oral Maxillofacial Surg. 2017;46(3):289–95. 10.1016/j.ijom.2016.10.016.
4. Zhu S, Yang Y, Khambay B. A study to evaluate the reliability of using two-dimensional photographs, three-dimensional images, and stereoscopic projected three-dimensional images for patient assessment[J]. Int J Oral Maxillofac Surg. 2017;46:394–400.
5. Asutay F, Ozcan-Kucuk A, Alan H, et al. Three-dimensional evaluation of the effect of low-level laser therapy on facial swelling after lower third molar surgery: A randomized, placebo-controlled study[J]. Niger J Clin Pract. 2018;21(9):1107–13. 10.4103/njcp.njcp_38_18.
6. Cheung T, Oberoi S. Three dimensional assessment of the pharyngeal airway in individuals with nonsyndromic cleft lip and palate[J]. PLoS ONE. 2012;7(8):e43405. 10.1371/journal.pone.0043405.
7. Lane C, Harrell W Jr. Completing the 3-dimensional picture[J]. Am J Orthod Dentofacial Orthop. 2008;133:612–20.
8. Souccar NM, Kau CH. Methods of measuring the three dimensional face[J]. Semin Orthod. 2012;18:187–92.
9. Ahmed A, Fida M, Sukhia RH. Cephalometric predictors for optimal soft tissue profile outcome in adult Asian class I subjects treated via extraction and non-extraction. A retrospective study[J]. Int Orthod. 2021;19(4):641–51. 10.1016/j.ortho.2021.08.002.
10. Gul A, de Jong MA, de Gijt JP, et al. Three-dimensional soft tissue effects of mandibular midline distraction and surgically assisted rapid maxillary expansion: an automatic stereophotogrammetry landmarking analysis[J]. Int J Oral Maxillofac Surg. 2019;48(5):629–34. 10.1016/j.ijom.2018.10.016.
11. Baysal A, Ozturk MA, Sahan AO, et al. Facial soft-tissue changes after rapid maxillary expansion analyzed with 3-dimensional stereophotogrammetry: A randomized, controlled clinical trial[J]. Angle Orthod. 2016;86(6):934–42. 10.2319/111315-766.1.
12. Adibi S, Shahidi S, Nikanjam S, et al. Influence of Head Position on the CBCT Accuracy in Assessment of the Proximity of the Root Apices to the Inferior Alveolar Canal[J]. J dentistry (Shiraz Iran). 2017;8(3):181–6.
13. Anuwongnukroh N, Dechkunakorn S, Kunakornporamut K, et al. Modifications desarcades dentaires après contention dans les cas de Classe II division 1 avec extractions[J]. Int Orthod. 2017;15(2):208–20. 10.1016/j.ortho.2017.03.006.

14. Singh S, Saraf BG, Indushekhar KR et al. Estimation of the Intercanine Width, Intermolar Width, Arch Length, and Arch Perimeter and Its Comparison in 17-year-old Children of Faridabad[J].International journal of clinical pediatric dentistry, 14(3):369–375. DOI: 10.5005/jp-journals-10005-1957.
15. Garg H, Khatria H, Kaldhari K, et al. Intermolar and Intercanine width Changes among Class I and Class II Malocclusions Following Orthodontic Treatment[J]. Int J Clin Pediatr dentistry. 2021;14(Suppl 1):4–S9. 10.5005/jp-journals-10005-2049.
16. Garg H, Khatria H, Kaldhari K, et al. Intermolar and Intercanine width Changes among Class I and Class II Malocclusions Following Orthodontic Treatment[J]. Int J Clin Pediatr dentistry. 2021;14(Suppl 1):4–S9. 10.5005/jp-journals-10005-2049.
17. Leonardi R, Annunziata A, Licciardello V, et al. Soft tissue changes following the extraction of premolars in Nongrowing patients with bimaxillary protrusion[J]. Angle Orthod. 2010;80(1):211–6. 10.2319/010709-16.1.
18. Wan Zhuqing S, Guofang G, Haijun, et al. Evaluation of the postoperative stability of a counter-clockwise rotation technique for skeletal class II patients by using a novel three- dimensional position-posture method[J]. Sci Rep. 2019;9(1):13196. 10.1038/s41598-019-49335-2.
19. Espinosa DG, Cruz CMV, Normando D. The effect of extraction of lower primary canines on the morphology of dental arch: A systematic review and meta-analysis[J]. Int J Pediatr Dent. 2021;31(5):583–97. 10.1111/ipd.12726.
20. Leonardi R, Annunziata A, Licciardello V, et al. Soft tissue changes following the extraction of premolars in Nongrowing patients with bimaxillary protrusion[J]. Angle Orthod. 2010;80(1):211–6. 10.2319/010709-16.1.
21. Wen YF, Wong HM, McGrath CP. A Longitudinal Study of Facial Growth of Southern Chinese in Hong Kong: Comprehensive Photogrammetric Analyses[J]. PLoS ONE. 2017;12(10):e0186598. 10.1371/journal.pone.0186598.
22. Kuhn M, Markic G, Doulis I, et al. Effect of different incisor movements on the soft tissue profile measured in reference to a rough-surfaced palatal implant[J]. Am J Orthod Dentofacial Orthop. 2016;149(3):349–57. 10.1016/j.ajodo.2015.08.017.
23. Konstantonis D, Vasileiou D, Papageorgiou SN, et al. Soft tissue changes following extraction vs. nonextraction orthodontic fixed appliance treatment: a systematic review and meta-analysis[J]. Eur J Oral Sci. 2018;126(3):167–79. 10.1111/eos.12409.
24. Wen YF, Wong HM, McGrath CP. A Longitudinal Study of Facial Growth of Southern Chinese in Hong Kong: Comprehensive Photogrammetric Analyses[J]. PLoS ONE. 2017;12(10):e0186598. 10.1371/journal.pone.0186598.
25. Rauso R, Fragola R, Fasano M, et al. Surgical Lip Remodeling Following Permanent Filler Injection: A Scoping Review[J]. J cranionfacial Surg. 2021. 10.1097/SCS.0000000000007942.
26. Otasevic M, Naini FB, Gill DS, et al. Prospective randomized clinical trial comparing the effects of a masticatory bite wafer and avoidance of hard food on pain associated with initial orthodontic tooth movement[J]. Am J Orthodont Dentofac Orthoped. 2006;130(1):6.

27. Bosse J, Papillon J. Surgical anatomy of the SMAS at the malar region. Transactions of the 9th international congress of plastic and reconstructive surgery, New York:McGraw-Hill, 1987
28. Gosain A, Klein MH, Sudhakar PV, et al. A volumetric analysis of soft-tissue changes in the aging midface using high-resolution MRI: Implications for facial rejuvenation[J]. Plast Reconstr Surg. 2005;115(4):1143–52. 10.1097/01.PRS.0000156333.57852.2F.
29. Sharma R, Drummond R, Wiltshire W, et al. Quality of life in an adolescent orthodontic population[J]. Angle Orthod. 2021;91(6):718–24. 10.2319/062820-592.1.
30. Gao J, Wang X, Qin ZX, et al. Profiles of facial soft tissue changes during and after orthodontic treatment in female adults[J]. BMC Oral Health. 2022;22(1):257. 10.1186/s12903-022-02280-5.

Figures

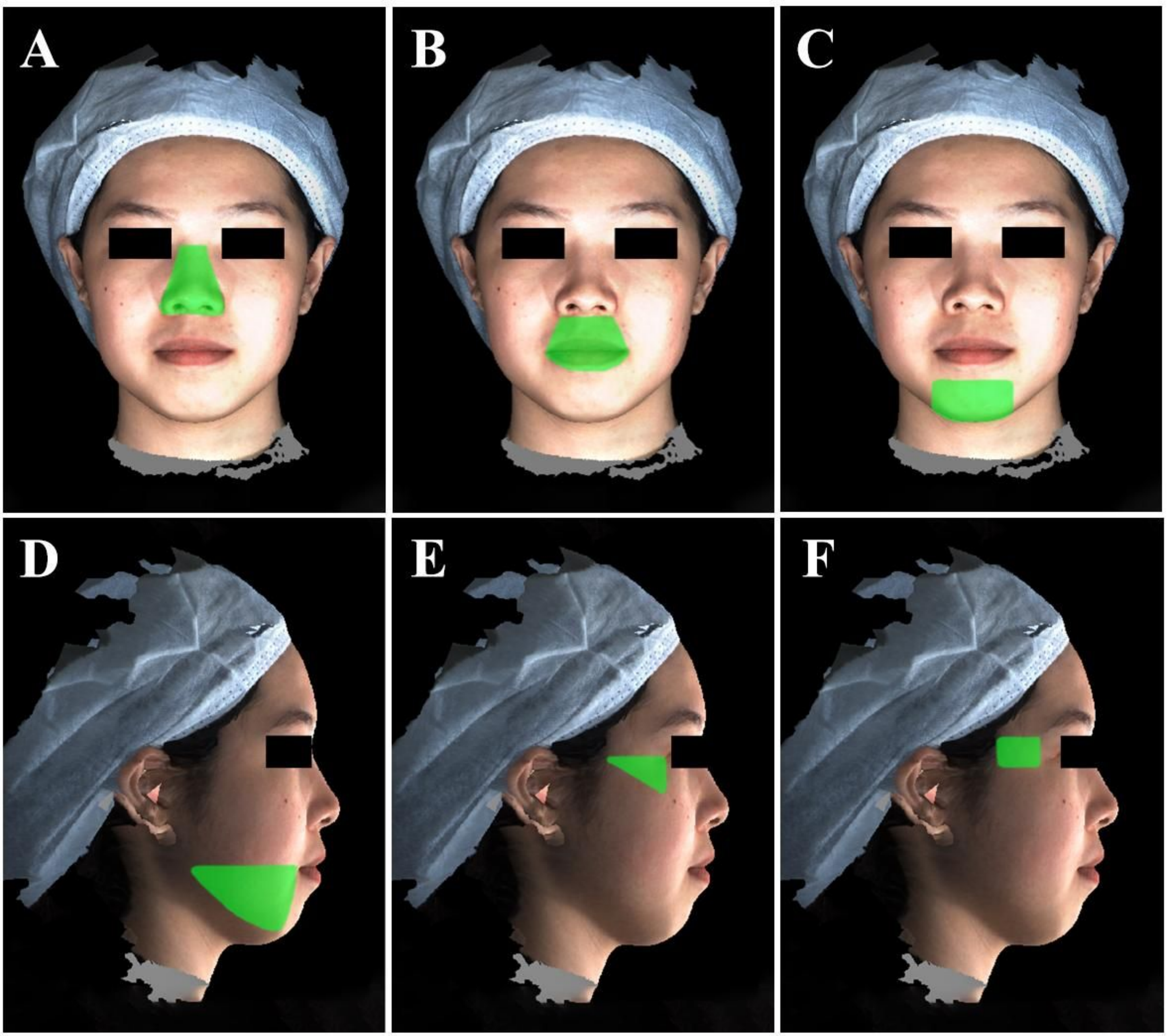

Figure 1

Soft tissue volume measurement area in 3D facial image

A: V-nose B: V-lip C: V-chin D: V-chk E: V-zy F: V-tem

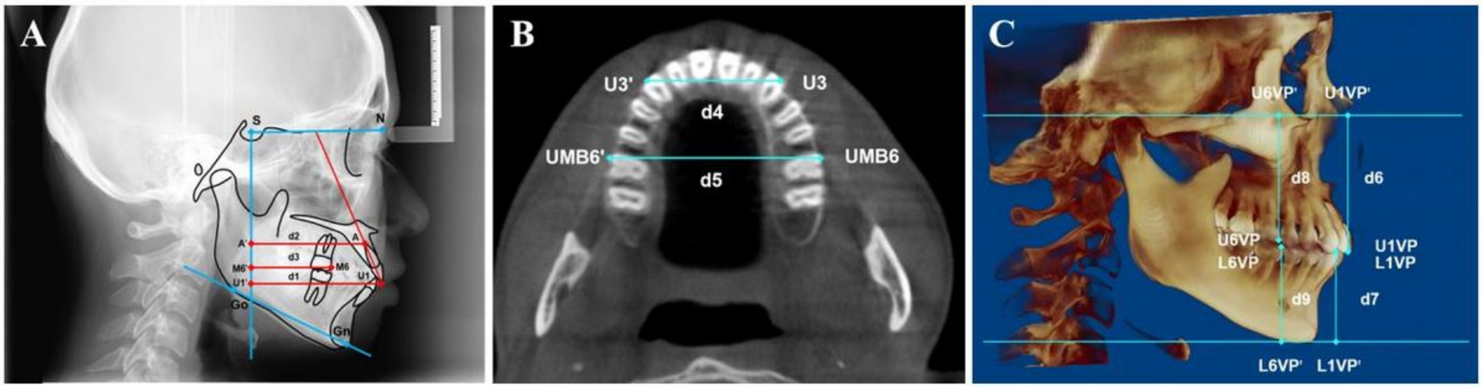

Figure 2

Hard tissue measurement in cephalometric lateral radiographs and CBCT images. **A**Reference points and measurement in lateral cephalometric radiographs; **B**Reference points and measurement in horizontal cross-sectional images of CBCT; **C**Reference points and measurement in 3D virtual images of CBCT

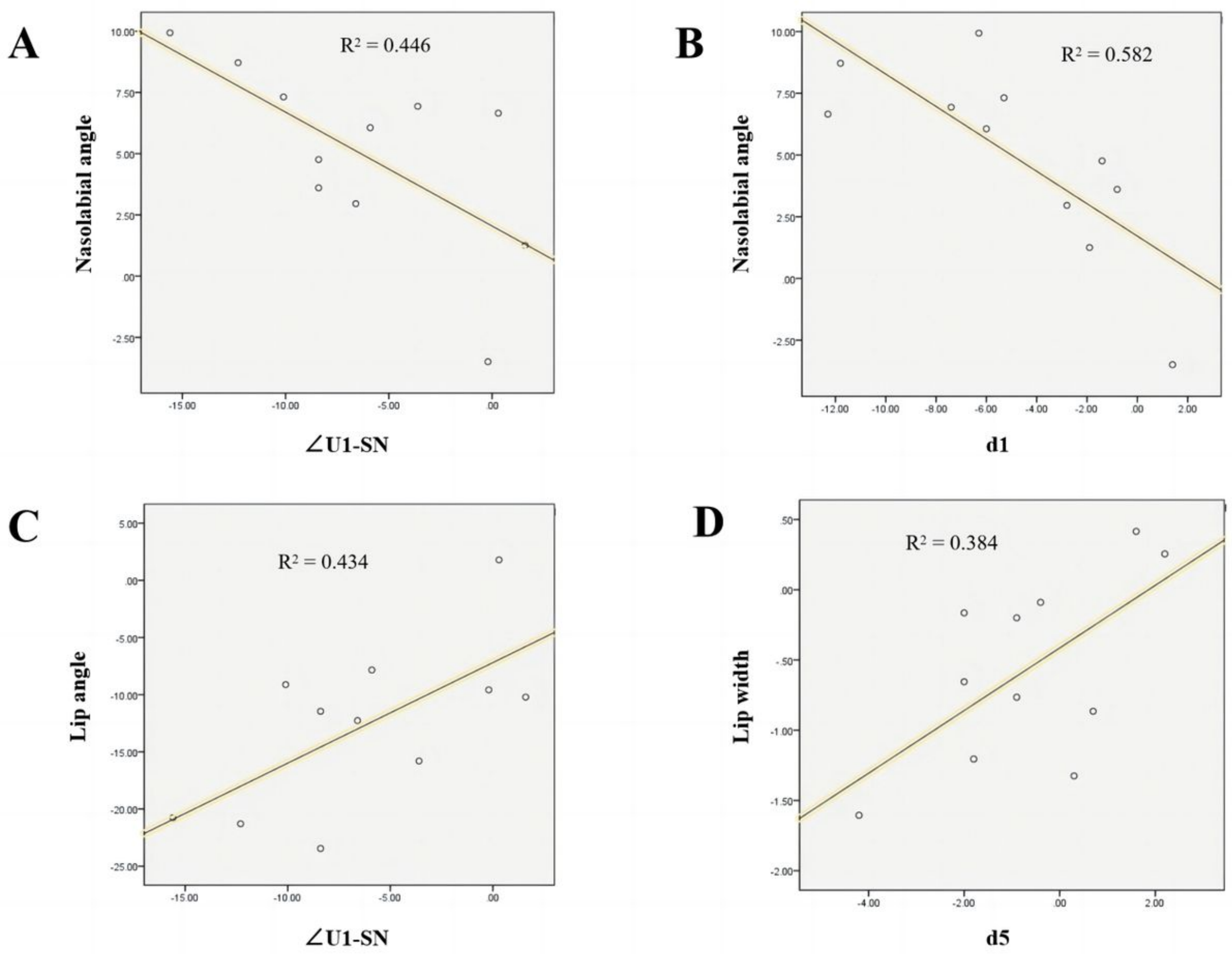

Figure 3

Correlation analysis of facial soft tissue and hard tissue changes after orthodontic treatment. **A** Correlation between Nasolabial angle and ∠U1-SN; **B**Correlation between Nasolabial angle and d1; **C** Correlation between Lip angle and ∠U1-SN; **D** Correlation between Lip width and d5

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