Retrospective Clinical Research Report

Journal of
INTERNATIONAL
MEDICAL RESEARCH

Journal of International Medical Research
48(7) 1–13

DOI: 10.1177/0300060520936854
journals.sagepub.com/home/imr
SAGE

Correlations between objective measurements and subjective evaluations of facial profile after orthodontic treatment

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Abstract

Objective: To investigate the correlations between objective measurements and subjective evaluations of post-treatment facial attractiveness.

Methods: Ten orthodontists rated the subjective visual analog scale (VAS) scores of the facial profiles of 95 patients who had undergone orthodontic treatment. Post-treatment cephalograms and photographs were used. Eleven soft tissue measurements and eight maxillary incisor measurements were constructed and analyzed. Correlations between objective measurements and subjective VAS scores were evaluated using Pearson correlation and quadratic regression analysis.

Results: The VAS scores of different facial proportions were all correlated with the total VAS score. Among soft tissue measurements, the distances from the upper and lower lips to the E line, H angle, forehead inclination, distance from lower lip to the H line, and pogonion-menton angle were negatively correlated with the VAS scores. The Z angle, with a parabolic distribution, was also correlated with the VAS scores. Among maxillary incisor measurements, the distance from the maxillary incisors to the forehead's anterior limit line and the angulation of the maxillary incisors to the APo line were negatively correlated with the VAS scores.

Conclusions: Several soft tissue and maxillary incisor position measurements were correlated with facial profile evaluation and therefore might be used to evaluate facial attractiveness.

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Keywords
Esthetics, soft tissue, maxillary incisor position, subjective evaluation, objective measurement, facial profile

Date received: 18 November 2019; accepted: 3 June 2020

Introduction

One of the most important treatment goals in modern orthodontics is to harmonize facial attractiveness in a satisfactory way.[1] Different facial parts, including the forehead, nose, chin morphology, and labial position, should be harmoniously coordinated to achieve facial attractiveness. Orthodontists routinely use patients' photographs as records to assist with treatment planning and evaluation of treatment outcomes. Assessment of facial attractiveness based on a photograph is often subjective. Visual analog scale (VAS) evaluation performed on lateral profile photographs is considered valid and reliable.[2–4] In addition to subjective evaluation of photographs, orthodontists also rely on implementing objective measurements to establish a treatment plan and evaluate the treatment outcomes. Therefore, it is important to clarify the relationship between subjective evaluation of facial attractiveness based on photographs and objective measurements.

Numerous soft tissue cephalometric analyses, such as the esthetic plane, H angle, and Z angle,[5–8] have been developed to evaluate soft tissue attractiveness.[9–12] These variables are mainly focused on the structures of the lower third of the face. Soft tissue measurements of other facial parts, including the forehead and nose, are rarely performed.

Apart from soft tissue analysis, the underlying craniofacial morphology can also affect the assessment of facial attractiveness.[13] A major contributing factor to evaluation of the soft tissue profile is the maxillary incisor position.[14–16] Measurements of both the maxillary incisor position and inclination were traditionally developed using cephalometric analysis.[17] External facial landmarks on the forehead and the corresponding facial reference lines were also used to evaluate the maxillary incisor position.[18–20] Some researchers have explored the relationship between cephalometric measurements of the lip position and facial esthetics; however, the results are far from conclusive.[21–24] Additionally, few studies have investigated the contributions of different facial parts to the entire facial esthetics. The potential correlation between objective measurements and subjective evaluations of different facial parts requires further examination.

The present study was performed to (1) investigate the correlations between objective measurements and subjective evaluations of post-treatment facial photographs and (2) examine the appropriate measurements of the soft tissue and maxillary incisor position in evaluating the post-treatment facial profile of orthodontic patients.

Methods

Patients

The study sample comprised 95 patients (70 female, 25 male) who received orthodontic treatment from 2016 to 2018. Their ages ranged from 14 to 26 years in the pretreatment stage. Forty-nine patients were adolescents and the remaining were adults. The study was approved by the Ethics Committee of Peking University School of Stomatology (Approval No. 201626002). Consent to participate and for publication of data was obtained from all patients or, in the case of children, their parent or legal guardian.

The inclusion criteria were an Angle Class I molar relationship and skeletal Class I relationship ($0^\circ \leq \text{ANB} \leq 4^\circ$) before treatment; available post-treatment cephalograms and lateral facial photographs with fully bared forehead; and no syndromes, craniofacial anomalies, or history of orthognathic or cosmetic facial surgery.

Subjective evaluations of post-treatment lateral photographs

Facial attractiveness based on standardized post-treatment lateral photographs was evaluated by 10 experienced orthodontic clinicians (5 men and 5 women; age range, 40–53 years). Photographs with a fully bared forehead were randomly presented as a slide show and evaluated using a VAS from 0 (very unpleasant) to 100 (very pleasant) as previously described.[24] Six duplicate photographs were randomly inserted into the series to evaluate the reproducibility of the measurements. The VAS was also used to evaluate different facial parts including the forehead morphology, nose morphology, lip position, and chin morphology.

Objective measurements of soft tissue and maxillary teeth

In total, 11 soft tissue measurements and 8 maxillary incisor measurements were constructed and analyzed (Table 1). All post-treatment cephalograms were standardized into the original size according to a ruler, digitized, and traced by the primary investigator using cephalometric software (Dolphin Imaging Systems, Canoga Park, CA, USA). All measurements were repeated three times by the same examiner with a time interval of 1 week. The mean value of these measurements was used for the statistical analysis. To evaluate the intraobserver reliability, the cephalograms of 10 patients were randomly selected for retracing and remeasurement 1 month later. Intraobserver reliability was calculated by means of the intraclass correlation coefficient. All intraclass correlation coefficients for the repeated objective measurements were >0.80.

Forehead landmarks and facial reference lines were used to detect the maxillary incisor position as described by Andrews.[19] Briefly, post-treatment lateral cephalograms and lateral photographs with a fully bared forehead were standardized into the original size according to a ruler. The standardized lateral photographs were imported into Adobe Photoshop software (Adobe Systems Inc., San Jose, CA, USA) and rotated to an estimated upright head position as described by Andrews.[19] These photographs were then superimposed onto the standardized lateral cephalograms using maximum superimposition of the forehead and with the nasion point as the rotation center. The forehead landmarks were identified. The superion (S point) is the most superior point of the clinical forehead. The soft tissue glabella (G point) is the most prominent point in the midsagittal plane of the forehead. The facial-axis point of the forehead (FFA point) is the midpoint of the forehead between the S point and G point. The facial-axis point of the maxillary central incisors (FA point of U1) is the central point of the crown. The vertical reference line through the FFA point is defined as the forehead's anterior limit line (FALL). The forehead inclination was defined as the angle between the line through the G point to the S point and FALL. The superimposed images were

Table 1. Definitions of objective measurements.

	Measurements	Definitions
Soft tissue measurements	Forehead inclination (°)	Angle between FALL and a line through the glabella and superion
	FNA (°)	Frontonasal angle
	Z angle (°)	Angle between Frankfort plane and a line through the pogonion and most prominent point of upper or lower lip
	LL-H (mm)	Distance from lower lip to H line
	H angle (°)	Angle between N'-Pog' and H line
	LL-E (mm)	Distance from lower lip to E line
	UL-E (mm)	Distance from upper lip to E line
	NLA (°)	Angle between the line from the midpoint of the nostril aperture to the subnasale and the line from the subnasale to the upper lip
	NTA (°)	Nasal tip angle
	MLA (°)	Mentolabial angle
	PMA (°)	Pogonion-menton angle
Maxillary incisor position	FA-FALL (mm)	Distance from FA point of upper incisor to FALL
	U1-APo (mm)	Distance from upper incisor edge to APo
	U1-APo (°)	Angle between upper incisor axis and APo
	U1-NA (mm)	Distance from upper incisor edge to nasion/A
	U1-NA (°)	Angle between upper incisor axis and nasion/A
	U1 most labial point-A (perp to FH) (°)	Distance from most labial point of upper incisor to the line through point A and perpendicular to the Frankfort plane
	U1-L1 (°)	Angle between upper incisor axis and lower incisor axis
	U1-SN (°)	Angle between upper incisor axis and sella/nasion

FALL line, forehead's anterior limit line, a vertical line through the FFA point; H line, line tangent to the upper lip and soft tissue pogonion; E line, tip of the nose to soft tissue pogonion; APo, line from A point to pogonion point; Nasion/A, line from nasion to A point.

used to evaluate the distance between the maxillary incisors and the FALL (Figure 1).

Statistical analysis

The statistical analysis was performed using IBM SPSS Statistics for Macintosh, Version 20.0 (IBM Corp., Armonk, NY, USA). The mean, standard deviation (SD), minimum value, and maximum value of the subjective evaluation were calculated for each photograph. Correlations between the VAS scores of facial parts and the entire facial esthetics were evaluated. In addition, the mean, SD, and 95% confidence interval were calculated for each objective measurement. Pearson's correlation and quadratic regression analysis were performed to detect the correlation between each objective measurement and subjective VAS score as well as the correlation between the VAS score of different facial parts and the total VAS score. A P value of ≤ 0.05 indicated statistical significance.

Results

Descriptive data for objective measurements and subjective facial VAS scores

Descriptive data of the objective measurements of the soft tissue and maxillary incisor

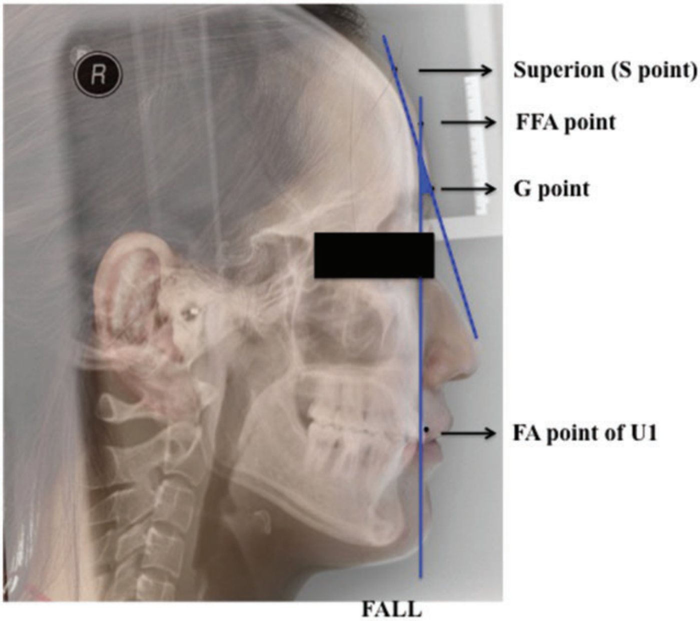

Figure 1. Landmarks and reference lines shown on the superimposed image. Superion (S point): the most superior aspect of the clinical forehead. Soft tissue glabella (G point): the most prominent point in the midsagittal plane of the forehead. Facial-axis point of the forehead (FFA point): the midpoint of the forehead between the S point and G point. Facial-axis point of maxillary central incisors (FA point of U1): the central point of the clinical crown of the maxillary central incisors. Forehead's anterior limit line (FALL): vertical line through the FFA point. Forehead inclination: the angle between the line through the G and S points and the FALL.

positions are shown in Table 2, which lists the mean, SD, and 95% confidence interval. Descriptive data of the facial VAS scores are shown in Table 3, which lists the minimum, maximum, mean, and SD.

Correlation between VAS scores of different facial parts and total facial VAS score

The correlations between the VAS scores of different facial parts and the total facial VAS score are shown in Table 4. Pearson correlation showed that the VAS scores of different facial parts were all correlated with the total VAS score. The VAS scores of chin morphology and lip position showed extremely strong correlations with the total VAS score, with correlation coefficients of 0.857 ($P < 0.001$) and 0.882 ($P < 0.001$), respectively. The VAS scores of forehead and nose morphology were also strongly correlated with the total VAS score, with correlation coefficients of 0.649 ($P < 0.001$) and 0.722 ($P < 0.001$), respectively. In the multiple linear regression, the standardized coefficients showed the impact of different facial parts on the total VAS score. Chin morphology ranked first, with the largest standardized coefficient of 0.414, followed by lip position, forehead morphology, and nose morphology with standardized coefficients of 0.256, 0.253, and 0.189, respectively.

Correlation between objective measurements and total facial VAS score

The results of Pearson correlation and quadratic regression analysis between the total

Table 2. Objective measurements of soft tissue and maxillary incisor position.

	Mean	SD	95% CI	
			Lower	Upper
Soft tissue measurements				
Forehead inclination (°)	17.55	4.91	16.55	18.55
FNA (°)	154.06	5.50	152.93	155.18
Z angle (°)	72.27	4.58	71.33	73.20
LL-H (mm)	0.94	1.33	0.67	1.22
H angle (°)	14.91	3.35	14.23	15.59
LL-E (mm)	−0.20	1.84	−0.57	0.18
UL-E (mm)	−1.97	1.98	−2.38	−1.57
NLA (°)	100.45	10.50	98.31	102.59
NTA (°)	98.59	5.47	97.48	99.71
MLA (°)	124.08	11.82	121.67	126.49
PMA (°)	88.23	8.95	86.41	90.06
Maxillary incisor position				
FA-FALL (mm)	2.89	2.22	2.44	3.34
U1-APo (mm)	5.31	1.61	4.98	5.64
U1-APo (°)	29.94	4.19	29.09	30.79
U1-NA (mm)	3.59	2.41	3.10	4.08
U1-NA (°)	24.81	6.29	23.53	26.09
U1 most labial point-A (perp to FH) (°)	3.80	1.73	3.45	4.15
U1-L1 (°)	123.72	7.22	122.24	125.19
U1-SN (°)	107.37	6.56	106.03	108.70

SD, standard deviation; CI, confidence interval. Measurements are as defined in Table 1.

Table 3. Subjective VAS score given by professional panels.

	Mean	SD	Minimum	Maximum
Total VAS score	68.17	8.01	49.94	82.61
Forehead morphology	72.82	6.30	55.61	84.61
Nose morphology	71.63	7.89	49.89	86.22
Lip position	66.71	8.77	40.61	82.94
Chin morphology	65.30	9.77	37.44	80.89

VAS, visual analog scale; SD, standard deviation.

VAS score and each of the objective measurements are shown in Table 5.

Soft tissue measurements

Pearson correlation showed that six soft tissue measurements [LL-E, H angle, UL-E, forehead inclination, LL-H, and pogonion-menton angle (PMA)] were negatively correlated with the total VAS score, with correlation coefficients of −0.414 ($P < 0.001$), −0.412 ($P < 0.001$), −0.349 ($P < 0.001$), −0.321 ($P = 0.002$), −0.267 ($P = 0.009$), and −0.204 ($P = 0.047$), respectively (Table 5).

In the quadratic regression analysis, most of the variables that showed a significant correlation with the total VAS score

Table 4. Relationships between total VAS score and scores of different facial parts.

	Pearson correlation		Multiple linear regression			
	r	*P*	B	Standardized coefficient	*P*	Order
Chin morphology	0.857	<0.001	0.339	0.414	<0.001	1
Lip position	0.882	<0.001	0.260	0.256	<0.001	2
Forehead morphology	0.649	<0.001	0.231	0.253	<0.001	3
Nose morphology	0.722	<0.001	0.240	0.189	<0.001	4

VAS, visual analog scale.

Table 5. Pearson correlation and quadratic regression between total VAS score and objective measurements.

	Pearson correlation		quadratic regression	
	r	*P*	Adjusted r^2	*P*
Soft tissue measurements				
LL-E (mm)	−0.414	<0.001***	0.190	<0.001***
H angle (°)	−0.412	<0.001***	0.193	<0.001***
UL-E (mm)	−0.349	<0.001***	0.152	0.001**
Forehead inclination (°)	−0.321	0.002**	0.105	0.006**
LL-H (mm)	−0.267	0.009**	0.081	0.020*
PMA (°)	−0.204	0.047*	0.052	0.088
FNA (°)	0.176	0.088	0.032	0.229
MLA (°)	0.102	0.326	0.010	0.619
NLA (°)	−0.100	0.335	0.040	0.150
NTA (°)	0.060	0.564	0.025	0.316
Z angle (°)	0.022	0.829	0.121	0.003**
Maxillary incisor position				
FA-FALL (mm)	−0.330	0.001**	0.112	0.004**
U1-APo (°)	−0.257	0.012*	0.066	0.042*
U1-L1 (°)	0.146	0.159	0.026	0.297
U1-APo (mm)	−0.128	0.217	0.018	0.441
U1-SN (°)	−0.098	0.347	0.015	0.495
U1-NA (mm)	0.036	0.727	0.002	0.906
U1 most labial point-A (perp to FH) (°)	−0.031	0.769	0.001	0.939
U1-NA (°)	−0.026	0.804	0.007	0.715

VAS, visual analog scale. Measurements are as defined in Table 1.
***$P < 0.001$, **$P < 0.01$, *$P < 0.05$.

remained the same. Among all variables, the Z angle changed dramatically, with an adjusted correlation coefficient of 0.121 ($P = 0.003$) (Table 5).

Measurements of maxillary incisor position

Pearson correlation showed that two measurements of the maxillary incisor position (FA-FALL and U1-APo) were negatively correlated with the total VAS score, with correlation coefficients of −0.330 ($P = 0.001$) and −0.257 ($P = 0.012$), respectively. In the quadratic regression analysis, both the FA-FALL and U1-APo angulation were significantly correlated with the VAS scores, with adjusted correlation coefficients of 0.112 ($P = 0.004$) and 0.066 ($P = 0.042$), respectively (Table 5).

Correlation between objective measurements and VAS scores of different facial parts

Objective measurements that were significantly correlated with the total VAS score were further investigated for their correlations with the VAS scores of the corresponding facial parts (Table 6).

Soft tissue measurements

Both Pearson correlation and the quadratic regression analysis showed that the variables of lip position, including the H angle, LL-E, UL-E, and LL-H, were all negatively correlated with the VAS scores of lip position and chin morphology, whereas the forehead inclination was negatively correlated with the VAS scores of forehead morphology and the PMA was negatively correlated with the VAS scores of chin morphology (Table 6). Specifically, the Z angle was correlated with the VAS scores of lip position and chin morphology only when quadratic regression analysis was performed, with adjusted correlation coefficients of 0.078 ($P = 0.024$) and 0.137 ($P = 0.001$), respectively (Table 6).

Measurements of maxillary incisor position

FA-FALL was negatively correlated with the VAS scores of lip position, chin morphology, and forehead morphology, with correlation coefficients of −0.310 ($P = 0.002$), −0.253 ($P = 0.014$), and −0.497 ($P < 0.001$), respectively (Table 6). The U1-APo angulation was negatively correlated with the VAS scores of lip position and chin morphology, with correlation coefficients of −0.228 ($P = 0.026$) and −0.281 ($P = 0.006$), respectively (Table 6).

Discussion

When evaluating orthodontic treatment outcomes, facial attractiveness can be assessed by either performing objective measurements of hard and soft tissues based on cephalograms or subjectively evaluating profile photographs. Whether the objective measurements are correlated with the subjective evaluation of the photographs is an important topic of concern among orthodontists. In this study, Angle Class I and skeletal Class I patients were chosen to investigate the correlation between objective measurements and subjective evaluation of facial attractiveness. Pearson correlation and quadratic regression analysis were used to examine linear and nonlinear correlations.

Correlation between soft tissue measurements and subjective evaluation of photographs

Each facial part might affect the entire facial attractiveness.[25] For this reason, soft tissue measurements of different facial parts were included in this study. Lip position and chin morphology play an important role in the facial attractiveness evaluation.[14,15,26] Among the measurements of lip position, the distances from the upper and lower lips to the E line, Z angle, and H angle have been regarded as suitable assessments in different study samples.[21,22,26–28] In addition, chin prominence and variables related to the contour of the mentolabial fold are sensitive parameters in

Table 6. Pearson correlation and quadratic regression between VAS scores of different proportions and objective measurements.

	Lip position				Chin morphology				Forehead morphology			
	Pearson correlation		Quadratic regression		Pearson correlation		Quadratic regression		Pearson correlation		Quadratic regression	
	r	*P*	Adj r^2	*P*	r	*P*	Adj r^2	*P*	r	*P*	Adj r^2	*P*
H angle (°)	−0.363	<0.001***	0.138	0.001**	−0.417	<0.001***	0.191	<0.001***				
LL-E (mm)	−0.446	<0.001***	0.222	<0.001***	−0.427	<0.001***	0.216	<0.001***				
UL-E (mm)	−0.317	0.002**	0.135	0.001**	−0.354	<0.001***	0.162	<0.001***				
Z angle (°)	0.110	0.287	0.078	0.024*	0.179	0.082	0.137	0.001**				
LL-H (mm)	−0.345	0.001**	0.149	0.001**	−0.288	0.005**	0.103	0.007**				
Forehead inclination (°)									−0.447	<0.001***	0.219	<0.001***
PMA (°)					−0.296	0.004**	0.103	0.007**				
FA-FALL (mm)	−0.310	0.002**	0.096	0.01**	−0.253	0.014*	0.064	0.047*	−0.497	<0.001***	0.260	<0.001***
U1-APo (°)	−0.228	0.026*	0.056	0.069	−0.281	0.006**	0.084	0.018*	−0.108	0.298	0.016	0.471

VAS, visual analog scale; Adj, adjusted. Measurements are as defined in Table 1.
***$P < 0.001$, **$P < 0.01$, *$P < 0.05$.

the facial evaluation.[21,22] Consistent with previous studies, our results demonstrated that the distances from the upper and lower lips to the E line, the H angle, the distance from the lower lip to the H line (all of which represent the lip position), and the PMA (which represents the chin morphology) had a negative influence on the entire facial attractiveness. The Z angle, which showed a parabolic distribution, was also correlated with the subjective facial VAS scores in the quadratic regression analysis.

Forehead contour is also an important component of the facial profile attractiveness.[25,29] However, few studies have shown the contribution of the forehead contour to facial attractiveness. Our results showed that the forehead inclination was negatively correlated with the facial VAS scores, suggesting an important role of forehead inclination in facial attractiveness evaluation. An increase in the forehead inclination, which led to a flatter forehead contour, led to less satisfaction in evaluating facial attractiveness.

The measurements of nose morphology, including the nasal tip angle and nasolabial angle, were not significantly associated with the subjective facial attractiveness evaluation, consistent with previous studies.[22] A possible explanation is that the influence of nose morphology on facial esthetics is constrained by other factors.

Correlation between maxillary incisor measurements and subjective evaluation of photographs

The position of the maxillary incisors is crucial in determining the facial profile.[14,30,31] Previous studies have demonstrated that certain variables of incisor position, such as the distance from the upper and lower incisors to the AP-line, were significantly correlated with the subjective facial evaluation.[22] However, within the linear measurements in our study, only the FA-FALL had a negative impact on the evaluation of profile esthetics.

Oh et al.[21] reported that the correlations between conventional cephalometric measurements and rankings of facial attractiveness were weaker than expected, especially for hard tissue measurements. It is important to identify which specific variable of the incisor position is well correlated with the facial attractiveness evaluation. The FALL, which is generated from landmarks on the forehead, is directly related to the facial profile and can be used to assess the anteroposterior position of the maxillary incisors.[19,20,32,33] The FALL is also considered a relatively reliable facial reference line because the structure of the forehead is stable and shows no significant ethnic differences.[34] In the present study, the distance from the maxillary incisor to the FALL was negatively correlated with the facial profile evaluation. Moreover, the distance from the maxillary incisor to the FALL was correlated with the subjective VAS scores of different facial parts, including forehead morphology, lip position, and chin morphology. This finding suggests that the FALL as a facial reference line can be used to evaluate the facial attractiveness of orthodontic patients.

The labiolingual inclination of the maxillary incisors is also a key factor influencing facial attractiveness.[35,36] Previous studies have shown that normal and slightly proclined maxillary incisors were acceptable, whereas greater proclination of the maxillary incisors received the lowest scores on the esthetic evaluation.[25,37] Our results showed that the angulation of the maxillary incisors to the APo-line had a negative influence on facial esthetics, suggesting that orthodontists must balance the anteroposterior position and the inclination of the maxillary incisors to achieve harmonious facial profiles of orthodontic patients.

Contributions of different parts of the face to entire facial attractiveness

Previous research has mainly focused on the influence of the lower face structures on facial attractiveness.[21,22,27,28] Few studies have considered the impact of other facial parts, such as the forehead, on facial attractiveness. However, it is necessary to consider different facial parts including the forehead, nose, chin morphology, and labial position in a comprehensive way when evaluating facial attractiveness.

In this study, we investigated the influence of different facial parts (forehead, nose, chin morphology, and labial position) on facial profile evaluation using multiple linear regression and found that all facial parts contributed to facial attractiveness in a comprehensive way. Chin morphology played the most significant role because it had the largest standardized coefficients, followed by the lip position, forehead morphology, and nose morphology. In addition, Pearson correlation showed that among all facial parts, the evaluations of chin morphology and lip position showed extremely strong correlations with the entire facial profile evaluation. The evaluations of forehead and nose morphology were strongly correlated with the entire facial profile evaluation. Our results are consistent with those of previous studies, which showed that lip position and chin morphology were critical factors in achieving facial esthetics.[12] Nevertheless, orthodontists' main concern is focused on the lower third of the face; therefore, the results may be biased to some extent because of their professions.

Our study also showed that the forehead and nose morphology were well correlated with the entire facial attractiveness. This finding supports proper coordination of all facial parts to achieve harmonious facial attractiveness.

Nevertheless, both objective measurements and subjective evaluation of facial attractiveness show significant differences among different ethnic groups. Compared with Caucasians, Asians have a higher degree of lip protrusion and a more convex facial profile.[34,38,39] Therefore, the results of this study should be cautiously interpreted. Moreover, the conclusions of this study are limited to skeletal Class I patients. Further studies should be performed to illustrate the relationship between objective measurements and subjective evaluations of the skeletal Class II and III patients. In addition, because three-dimensional views can provide a more holistic view of the face, further studies should be performed to investigate the correlations between subjective evaluations and objective measurements of facial attractiveness using three-dimensional photographs and three-dimensional cone-beam computed tomography reconstructions in the future.

Conclusions

Several soft tissue measurements of different facial parts were correlated with the subjective facial profile evaluation. The distance between the maxillary incisors and FALL and the angulation of the maxillary incisors to the APo-line can be used to evaluate facial attractiveness. All of the different facial parts contributed to facial attractiveness, among which chin morphology and labial position played the most important roles.

Availability of data and material

The datasets used and/or analyzed during the current study are available from the corresponding author upon request.

Declaration of conflicting interest

The authors declare that there is no conflict of interest.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was supported by the National Science Foundations of China No. 81600893 (D. H) and 81970979 (Y. G).

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