Original Article

Correlation between objective and subjective evaluation of profile in bimaxillary protrusion patients after orthodontic treatment

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ABSTRACT

Objective: To correlate the objective cephalometric measurements with subjective facial esthetics in patients with bimaxillary protrusion.

Materials and Methods: The sample consisted of 60 Asian-Chinese patients with bimaxillary protrusion who met the inclusion criteria. The facial esthetics of posttreatment profile and the change of profile on standardized lateral photographs were rated by a panel of 10 orthodontists and a panel of 10 lay persons with bimaxillary protrusion. All of the pretreatment and posttreatment cephalograms were digitized and traced. Twenty-five cephalometric measurements were constructed and analyzed. Correlations between the subjective facial esthetic scores and each cephalometric measurement were evaluated.

Results: The cephalometric measurements correlated with the facial esthetic scores of posttreatment profile given by the orthodontist and the lay persons were basically the same. For the evaluation of posttreatment profile in bimaxillary protrusion patients, the upper and lower lip to E-line, upper and lower incisor tip to AP plane, Pg-NB distance, mentolabial angle, and sulcus depth correlated significantly with the esthetic score. For the evaluation of profile change during orthodontic treatment, retraction of upper incisor relative to AP plane or the perpendicular line through sella (line Y), change of upper incisor inclination, change of mentolabial sulcus depth, and retraction of lips relative to E-line were correlated positively with the esthetic value.

Conclusions: Cephalometric measurements of lip position, incisor position, and chin morphology were key parameters correlated to facial esthetics. (*Angle Orthod.* 2015;85:690–698.)

KEY WORDS: Facial esthetics; Cephalometrics; Bimaxillary protrusion

INTRODUCTION

Bimaxillary protrusion is a condition characterized by proclined upper and lower incisors and an increased procumbency of the lips.[1] The negative perception of protruding lips leads many patients to seek orthodontic treatment. It is important to improve profile as well as to establish a functional occlusion for these patients. Samples of studies focused on the change of dentofacial tissues after orthodontic treatment and confirmed the retraction of maxillary and mandibular incisors with a resultant decrease in soft tissue convexity.[1–4] However, whether the cephalometric changes correlated with facial esthetics or not has not been further investigated.

The concept of facial beauty is abstract and subjective, but society seems to have an implicit standard for facial esthetics.[5] Photographs are close to the natural state of the subject and show the surface structures of the face in detail. The judgment of facial esthetics from the photographs performed on visual analog scale (VAS) is demonstrated to be valid and reliable.[6–8]

For the soft tissue assessment, extensive studies and measurements have been developed by analysis of lateral cephalograms to quantify ''facial esthetics'' since the 1950s, such as esthetic plane,[9–11] B-line,[12] H-angle,[13] Z-angle,[14] and nasolabial angle.[12] Moreover, the underlying craniofacial morphology can also affect the judgment of facial attractiveness.[15,16] However, these cephalometric measurements developed as markers of facial attractiveness were commonly based

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on author's preference, and the contribution of these objective measurements in the subjective assessment of facial esthetics is still elusive. Some previous studies have explored the correlation between cephalometric measurements and photographic facial esthetics,[17–19] but the available findings are far from conclusive and none had dealt with the profile esthetics of bimaxillary protrusion patients.

The purpose of this study was to investigate the concordance between the objective measurements of cephalometry and the subjective but highly reliable facial esthetics. First, we correlated the cephalometric measurements with facial esthetics of posttreatment profile, and then correlated the change of cephalometric measurements with facial esthetics of profile change to detect the key cephalometric measurements representing facial esthetic judgment in orthodontic patients with bimaxillary protrusion.

MATERIALS AND METHODS

A sample of 90 Asian-Chinese patients clinically diagnosed with bimaxillary protrusion and treated by one of the authors was chosen from the files from 2008 to 2013 at the Department of Orthodontics, Peking University School and Hospital of Stomatology, China. The study was approved by the Institutional Ethics Committee of Peking University School and Hospital of Stomatology (PKUSSIRB-201412011). From this parent sample, 60 patients who met the following selection criteria were included in this study:

- Orthodontic treatment consisting of the extraction of the four first premolars with subsequent retraction of anterior teeth;
- Pretreatment and posttreatment cephalometric radiographs and standardized facial photographs of adequate diagnostic quality;
- At the time of pretreatment, Class I molar relationship, interincisal angle less than 125 degrees, the most anterior points of upper and lower lips in advance of E-line; and
- No syndromes, craniofacial anomalies, and no orthognathic or cosmetic facial surgery.

The sample (age range 11 to 36 years) consisted of 45 female and 15 male patients. Thirty-seven patients were adolescent, and the remaining were adults. All of the patients in the sample were treated with maximum anchorage mechanics to retract the anterior teeth, including the extraoral headgear and miniscrew anchorage.

Subjective Evaluation of Facial Esthetics

Facial esthetics was evaluated by a panel of 10 orthodontic clinicians (five men and five women, age range 28 to 53 years) chosen by stratified random sampling among senior, medium, and junior faculties in the Department of Orthodontics at Peking University School and Hospital of Stomatology. To detect the difference in perception of facial beauty between professionals and lay persons, 10 adult lay persons with bimaxillary protrusion treated in our department were also selected to evaluate the facial esthetics (five men and five women, age range 24 to 38 years). The standardized digital facial photographs were assessed under constant conditions in a laboratory. First, the posttreatment profile image was evaluated on VAS from 0 (very unpleasing) to 100 (very pleasing). The nasolabial relationship, interlabial relationship, lip position, and chin morphology were also rated from 0 to 100 (Figure 1A). Then, simultaneously showing pretreatment and posttreatment profile views, the

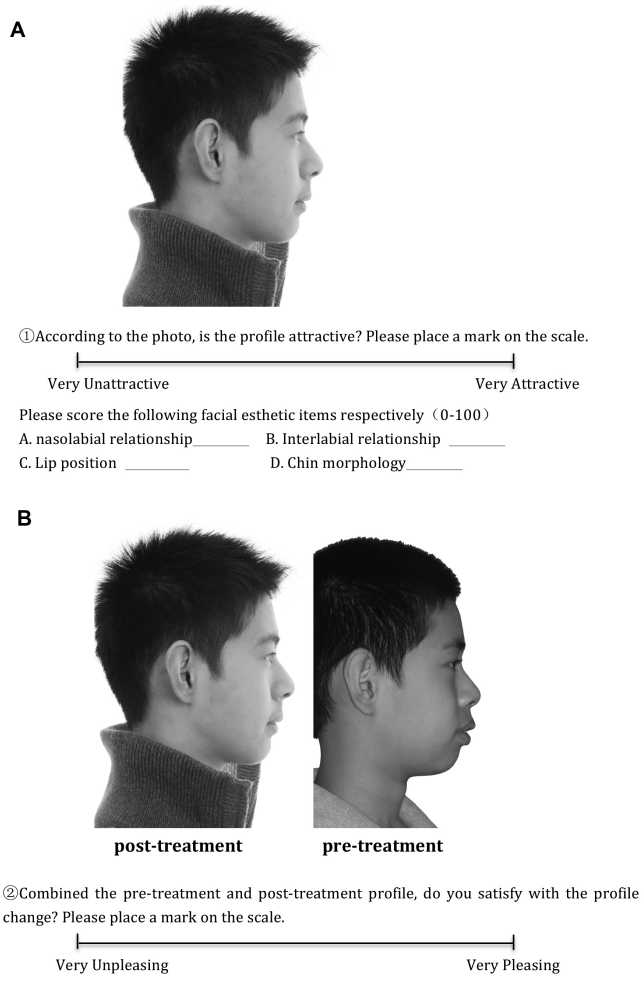

Figure 1. Example of subjective evaluation of facial esthetics. (A) Standardized lateral photograph of posttreatment was presented. Each judge was asked to place a mark on a VAS and rate each esthetic item to indicate the intensity of facial beauty. (B) Pretreatment and posttreatment profile images were simultaneously presented. Judgment was performed on a VAS to indicate the preference of the change.

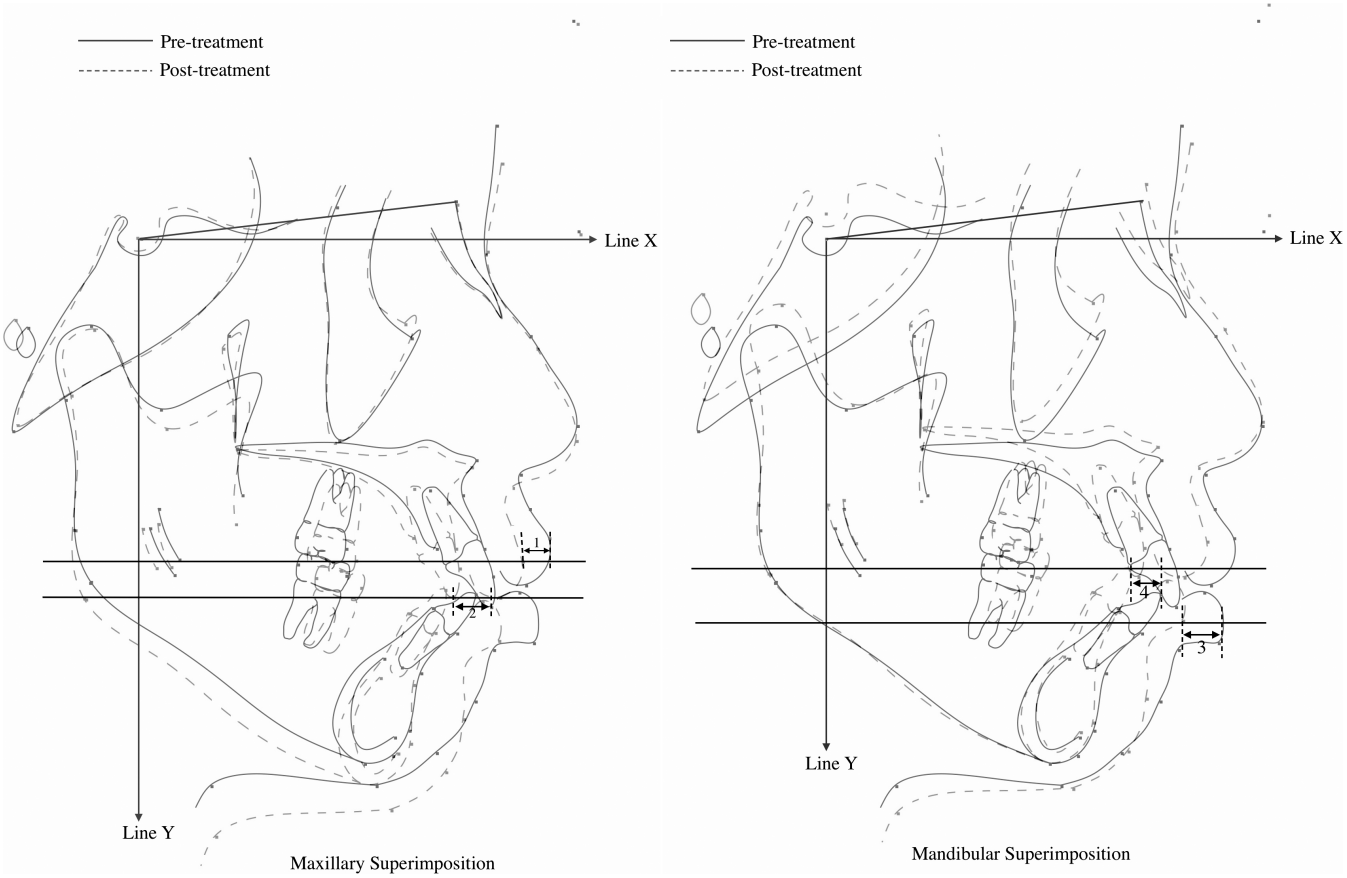

Figure 2. Superimpositions and cephalometric measurements for horizontal change of lips and incisors. (A) Maxillary superimpositions: 1, ΔLs-H; 2, ΔtU1-H. (B) Mandibular superimpositions: 3, ΔLi-H; 4, ΔtL1-H.

change of profile was assessed using VAS score (Figure 1B). These sets of pictures were presented in random order as a slide show. Means and standard deviations (SD) of the ratings by the panel were calculated for each set of photographs.

Objective Measurements of Cephalograms

All pretreatment (T1) and posttreatment (T2) cephalograms were digitized and traced by the primary investigator using Dolphin Imaging's Cephalometric Tracing and Analysis software (Dolphin Imaging System, Canoga Park, Calif). Magnification differences between cephalostats were corrected before data analysis. The pretreatment and posttreatment tracings for each subject were superimposed by the method of maxillary and mandibular superimpositions recommended American Board of Orthodontics (ABO) (Figure 2). In order to evaluate the horizontal changes of soft and hard tissue landmarks, two reference lines were constructed at the radiograph of T1. The horizontal reference line X was registered on sella and oriented 7° inferior to the sella-nasion (SN) line. The reference line Y was perpendicular to line X through sella. Twenty-five linear and angular measurements for soft and hard tissue were constructed and analyzed (supplementary Table 1).

Reliability Analysis

To test the reproducibility and validity of subjective facial esthetics, the assessments were performed in the same way by three judges 1 month later. For the purpose of cephalometric error testing, pretreatment and posttreatment cephalograms of 15 patients selected randomly were traced by the same operator 1 month later.

Statistical Methods

The statistical analysis was performed by SPSS 20.0 manager, IBM SPSS statistics for Macintosh, Version 20.0, Armonk, NY, USA. The mean and standard deviation were calculated for each variable. In the statistical evaluation of the reproducibility of the measuring system, the intraobserver consistency was calculated by intraclass coefficient (ICC). For interrelation calculations between the radiographic measurements and subjective facial esthetic scores, the Pearson correlation was applied. Quadratic regression

Table 1. Cephalometric Characteristics of Individual with Bimaxillary Protrusion

	Posttreatment		Pretreatment		Change (Pre–Post)	
	Mean	SD	Mean	SD	Mean	SD
Chin thickness	13.00	2.48	13.17	2.78	0.17	2.37
U-lip length	22.17	1.97	21.23	1.84	−0.95	1.20
L-lip length	45.92	3.46	44.87	3.89	−1.05	2.38
Interlabial gap	1.23	0.55	2.00	1.63	0.76	1.63
Superior sulcus	2.95	0.81	3.56	0.78	0.60	0.65
NLA	100.37	8.49	94.36	9.10	−6.01	6.38
MLA	128.15	13.56	129.48	16.06	1.34	13.25
B′-E	−3.14	1.30	−1.16	1.58	1.98	1.17
Ls-E	−1.05	1.33	0.89	1.62	1.94	1.32
Li-E	1.83	1.27	4.90	1.77	3.07	1.45
ANB	4.26	1.87	4.76	1.91	0.50	1.42
MPA	36.86	5.44	36.66	5.11	−0.20	1.90
Y	73.57	4.12	72.99	3.97	−0.58	1.29
LFH:TFH	54.53	1.73	53.93	1.81	−0.61	1.05
OP/SN	21.01	4.71	18.65	4.13	−2.36	3.48
Pg-NB	−0.16	1.20	−0.95	1.22	−0.79	0.78
U1/SN	98.92	7.26	111.41	7.45	12.49	6.71
L1/MP	89.06	6.19	96.51	4.83	7.45	5.70
U1/L1	131.67	7.79	112.05	8.18	−19.63	9.67
U1-AP	6.22	1.38	10.97	2.16	4.76	2.01
L1-AP	3.20	1.37	6.23	1.95	3.03	1.84

analysis also was performed for these parameters. The significance levels used were $P < .01$ and $P < .05$.

RESULTS

Reliability of Measurement

The intraobserver consistency expressed as the ICC between the first and the second rating of the photographs was 0.760. All of the intraclass coefficients for the repeated cephalometric measurements were greater than 0.80 (supplementary Table 2).

Descriptive Data for Cephalometric Measurements and Facial Esthetics

Descriptive data regarding the characteristics of pretreatment and posttreatment cephalometric radiographs of each subject were determined and are shown in Table 1. The mean and SD are listed. The facial esthetic scores given by the professionals are shown in Table 2. The minimum, maximum, mean, and SD are listed.

Correlation Between Facial Esthetics of Posttreatment Profile and Cephalometric Measurements

Table 3 lists the Pearson correlation between the VAS score of posttreatment profile given by the professional panel and each of the 21 cephalometric measurements. The values are listed in descending order of absolute magnitude. Seven cephalometric measurements correlated moderately with the VAS score of facial photographs with *P* values less than .05. The absolute values of the correlations for the seven measurements ranged from 0.270 to 0.459. The Pg-NB distance correlated positively with the VAS score ($r = 0.343$), whereas the B′-E ($r = -0.459$), Li-E ($r = -0.410$), Ls-E ($r = -0.401$), L1-AP ($r = -0.374$), U1-AP ($r = -0.347$), and MLA ($r = -0.270$) correlated negatively with the VAS score. Scatterplots for these statistically significant measurements are shown in Figure 3. The cephalometric measurements achieving significant association with VAS score given by the lay persons were basically the same as those in the professional panel (supplementary Table 3). Thus, we emphasized the subjective evaluation by the professional panel in detail.

However, the Pearson correlation method is insensitive to nonlinear distribution. And the patients with cephalometric values close to the cephalometric norms may have the highest facial esthetic scores, whereas patients with cephalometric values either higher or lower than the cephalometric norms may tend to be judged less attractive. To detect associations of this type, quadratic regression analysis was also performed. Table 4 shows the adjusted r^2 and *P* values of quadratic regression analysis between the VAS score and each of the 21 cephalometric measurements. The variables achieving significant correlation with the VAS score remained the same. Only mentolabial angle measurement changed dramatically in order—the *P* value moved from .037 to .001 and from the seventh position to the second. The

Table 2. Facial Esthetics Score Given by Professional Panel

		Minimum	Maximum	Mean	SD
Posttreatment profile	VAS[a] score	53.17	83.18	65.98	6.59
	Nasolabial relation	62.00	86.50	78.20	4.24
	Interlabial relation	68.80	87.60	79.23	3.91
	Lip position	61.80	87.60	79.51	5.10
	Chin morphology	61.50	87.40	77.78	6.34
Profile change	VAS[a] score	54.65	90.98	74.63	7.40

[a] VAS indicates visual analog scale.

Table 3. Pearson Correlation Between Visual Analog Scale (VAS) Score of Posttreatment Profile Given by Professional Panel and 21 Cephalometric Measurements

	r	*P*	Order
B′-E	−0.459	<.001**	1
Li-E	−0.410	.001**	2
Ls-E	−0.401	.001**	3
L1-AP	−0.374	.003**	4
U1-AP	−0.347	.007**	5
Pg-NB	0.343	.007**	6
MLA	−0.270	.037*	7
ANB	−0.217	.095	8
Y	−0.190	.147	9
MPA	−0.170	.194	10
U1/SN	0.162	.217	11
U-lip length	−0.160	.222	12
NLA	0.102	.440	13
L-lip length	−0.091	.491	14
L1/MP	−0.051	.697	15
LFH:TFH	−0.050	.705	16
Interlabial gap	0.036	.769	17
OP/SN	−0.031	.813	18
Superior sulcus	0.026	.846	19
Chin thickness	0.016	.904	20
U1/L1	0.007	.959	21

* $P < .05$; ** $P < .01$.

Table 4. Quadratic Regression Analysis Between Visual Analog Scale (VAS) Score of Posttreatment Profile Given by Professional Panel and 21 Cephalometric Measurements

	Adjusted r^2	*P*	Order
B′-E	0.214	.001**	1
MLA	0.209	.001**	2
Li-E	0.168	.005**	3
Ls-E	0.162	.007**	4
L1-AP	0.144	.012*	5
U1-AP	0.129	.019*	6
Pg-NB	0.120	.026*	7
U1/SN	0.098	.053	8
ANB	0.091	.067	9
Y	0.083	.085	10
Interlabial gap	0.082	.086	11
U1/L1	0.070	.125	12
MPA	0.063	.156	13
Chin thickness	0.052	.219	14
OP/SN	0.041	.299	15
Superior sulcus	0.041	.330	16
NLA	0.039	.323	17
U-lip length	0.026	.266	18
L-lip length	0.018	.594	19
LFH:TFH	0.007	.822	20
L1/MP	0.003	.928	21

* $P < .05$; ** $P < .01$.

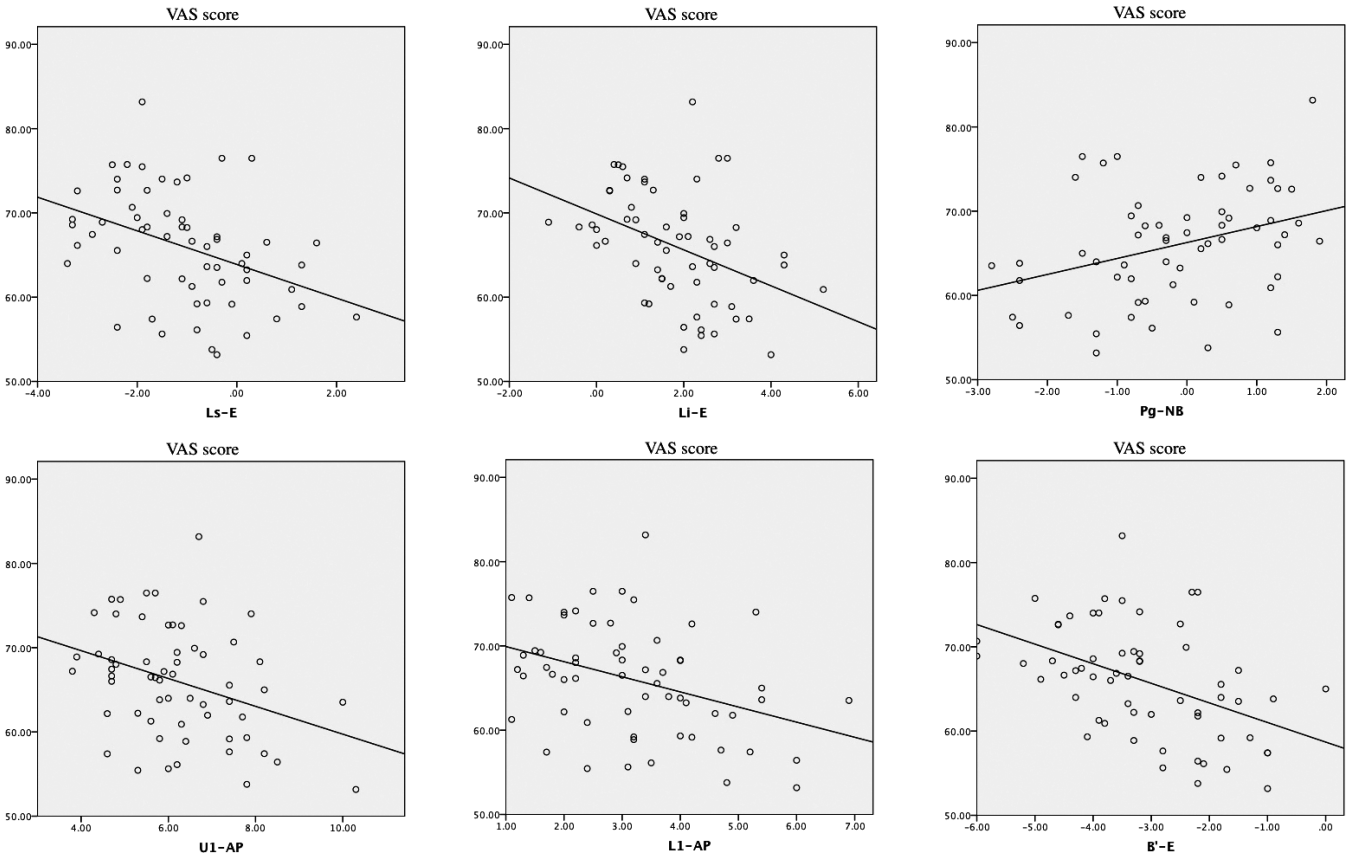

Figure 3. Distributions of the relationship between VAS score of posttreatment profile given by professional panel and six cephalometric measurements for which highly significant associations are shown in Table 3.

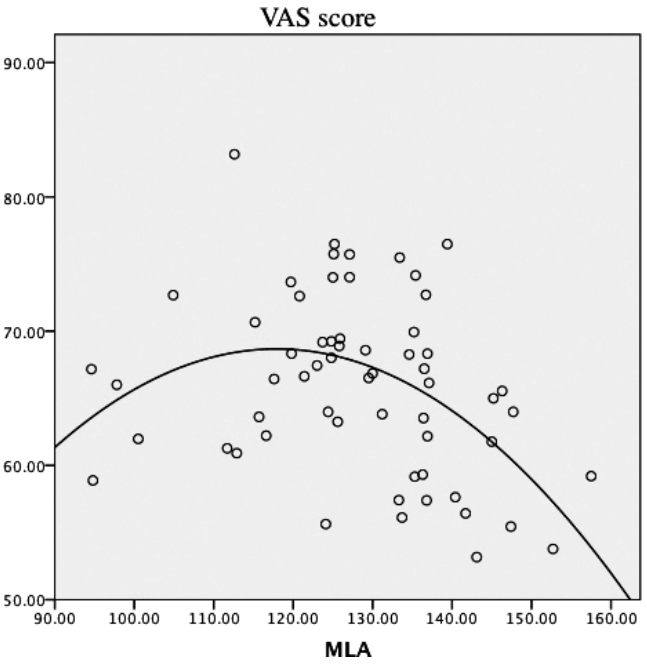

Figure 4. Relation between VAS score of posttreatment profile given by professional panel and mentolabial angle. The scatterplot showed a parabola distribution.

corresponding scatterplot shows a parabola shape (Figure 4).

The Pearson correlation and quadratic regression analysis between facial esthetic scores of nasolabial relationship, interlabial relationship, lip position, or chin morphology and the corresponding cephalometric measurements are listed in Tables 5 and 6. The nasolabial evaluation score failed to correlate with any measurements better than chance. For the interlabial evaluation, the distance of upper and lower lip to E-line showed a significant negative influence on it. The lip prominence value correlated negatively with Ls-E, Li-E, U1-AP, and L1-AP. For the chin morphology evaluation, the B′-E, ANB, Y-axis, mandibular plane angle, and mentolabial angle achieved significantly negative association, while the Pg-NB distance showed a positive association.

Correlation Between Subjective Evaluation of Profile Change and Cephalometric Measurements Change

Among the 19 cephalometric measurements, change of U1-AP distance (ΔU1-AP, $r = 0.414$), change of B′-E distance (ΔB′-E, $r = 0.343$), horizontal retraction of upper incisor tip (ΔtU1-H, $r = 0.327$), reduction of lower lip to esthetic plane (ΔLi-E, $r = 0.317$), change of upper incisor inclination (ΔU1/SN, $r = 0.268$), and reduction of upper lip to esthetic plane (ΔLs-E, $r = 0.257$) showed significantly positive influences on VAS score of profile change given by the professionals. The Pearson coefficient and *P* value of each measurement are shown in Table 7, and the scatterplots for the statistically significant measurements are shown in Figure 5.

DISCUSSION

In this study, soft tissue profile had been assessed from both cephalometric radiographs and lateral photographs, with the emphasis on objective assess-

Table 5. Pearson Correlation Between Facial Esthetic Score Given by Professional Panel and Cephalometric Measurements

	Nasolabial Relation		Interlabial Relation		Lip Position		Chin Morphology	
	r	*P*	*r*	*P*	*r*	*P*	*r*	*P*
NLA	0.102	.440						
Superior sulcus	0.152	.246						
U-lip length	−0.181	.166						
Interlabial gap			0.067	.011				
LiE-LsE			−0.005	.971				
U1AP-L1AP			0.000	1.000				
Ls-E	−0.029	.823	−0.435	.001**	−0.474	<.001**		
Li-E			−0.459	<.001**	−0.539	<.001**		
U1-AP			−0.236	.070	−0.347	.007**		
L1-AP			−0.237	.068	−0.321	.012*		
U1/SN			0.062	.640	−0.031	.813		
L1/MP			−0.134	.091	−0.086	.515		
U1/L1			0.091	.491	0.121	.357		
ANB			−0.185	.157	−0.186	.155	−0.316	.014*
B′-E							−0.548	<.001**
MLA							−0.280	.030*
MPA							−0.263	.042*
Y							−0.350	.006**
Pg-NB							0.307	.017*
Chin thickness							−0.076	.562

* $P < .05$; ** $P < .01$.

Table 6. Quadratic Regression Analysis Between Facial Esthetic Score Given by Professional Panel and Cephalometric Measurements[a]

	Nasolabial Relation		Interlabial Relation		Lip Position		Chin Morphology	
	Adj r^2	*P*	Adj r^2	*P*	Adj r^2	*P*	Adj r^2	*P*
NLA	0.002	.947						
Superior sulcus	0.063	.159						
U-lip length	0.036	.347						
Interlabial gap			0.018	.611				
LiE-LsE			0.015	.656				
U1AP-L1AP			0.028	.446				
Ls-E	0.001	.974	0.221	.001**	0.226	.001**		
Li-E			0.234	.001**	0.324	<.001**		
U1-AP			0.056	.196	0.129	.020*		
L1-AP			0.059	.175	0.106	.041*		
U1/SN			0.050	.229	0.075	.109		
L1/MP			0.031	.431	0.017	.608		
U1/L1			0.057	.187	0.156	.008**		
ANB			0.059	.179	0.079	.095	0.167	.005**
B′-E							0.300	<.001**
MLA							0.186	.003**
MPA							0.124	.023*
Y							0.172	.005**
Pg-NB							0.129	.019*
Chin thickness							0.028	.447

[a] Adj indicates adjusted.
* $P < .05$; ** $P < .01$.

ment for the former and subjective assessment for the latter. An examination of the concordance between them was desirable to evaluate the contribution of objective cephalometric measurements in facial esthetics assessment. Although previous studies have shown that the general public does not rate facial esthetics in the same way as orthodontists,[20] our study found that the cephalometric measurements selected between the professional and the lay person panel were basically the same, indicating the high consensus in facial esthetics of bimaxillary protrusion patients after orthodontic treatment, in agreement with some previous investigations.[8] Thus, we emphasized the results of the professional panel to represent the subjective evaluation of facial esthetics.

Table 7. Pearson Correlation Between Visual Analog Scale (VAS) Score of Profile Change Given by Professional Panel and Cephalometric Change

	r	*P*	Order
ΔU1-AP	0.414	.001**	1
ΔB′-E	0.343	.007**	2
ΔtU1-H	0.327	.011*	3
ΔLi-E	0.317	.014*	4
ΔU1/SN	0.268	.038*	5
ΔLs-E	0.257	.047*	6
ΔU1/L1	−0.230	.077	7
ΔL1-AP	0.182	.165	8
ΔtL1-H	0.164	.211	9
ΔL-lip length	−0.136	.298	10
ΔNLA	−0.135	.305	11
ΔSuperior sulcus	−0.132	.313	12
ΔMLA	0.119	.364	13
ΔLs-H	−0.097	.495	14
ΔLi-H	0.074	.575	15
ΔL1/MP	0.060	.650	16
ΔChin thickness	0.024	.857	17
ΔU-lip length	0.022	.868	18
ΔInterlabial gap	−0.012	.926	19

In bimaxillary protrusion patients, the lip protrusion, the underlying incisor position, and the chin morphology were key objective measurements correlated with the facial esthetics. Consistent with previous studies, lip position and form is a critical factor in achieving facial esthetics.[21,22] The upper and lower lip to E-line and the underlying upper and lower incisor to AP-line had a highly negative influence on profile esthetics, and consequently the decrease of lip prominence and retraction of incisors achieved great improvement in facial esthetics. Furthermore, chin morphology, including Pg-NB distance, mentolabial angle, and mentolabial sulcus (B′-E), is another significant factor in facial esthetics, and the increase of mentolabial sulcus depth improved the evaluation of profile. All of these variables related to the contour of the mentolabial fold, an esthetic feature of the chin,[23] suggesting its important role in facial beauty.

The esthetic plane developed by Ricketts[9–11] was sensitive in facial esthetic assessment of bimaxillary protrusion. The interrelationships of nose, lip, and chin play an important role in perceptions of facial esthetics and several reference lines have been induced.[9–12] Although some studies showed B-line[24] or Z-angle[17] were the best analytic reference line of the horizontal

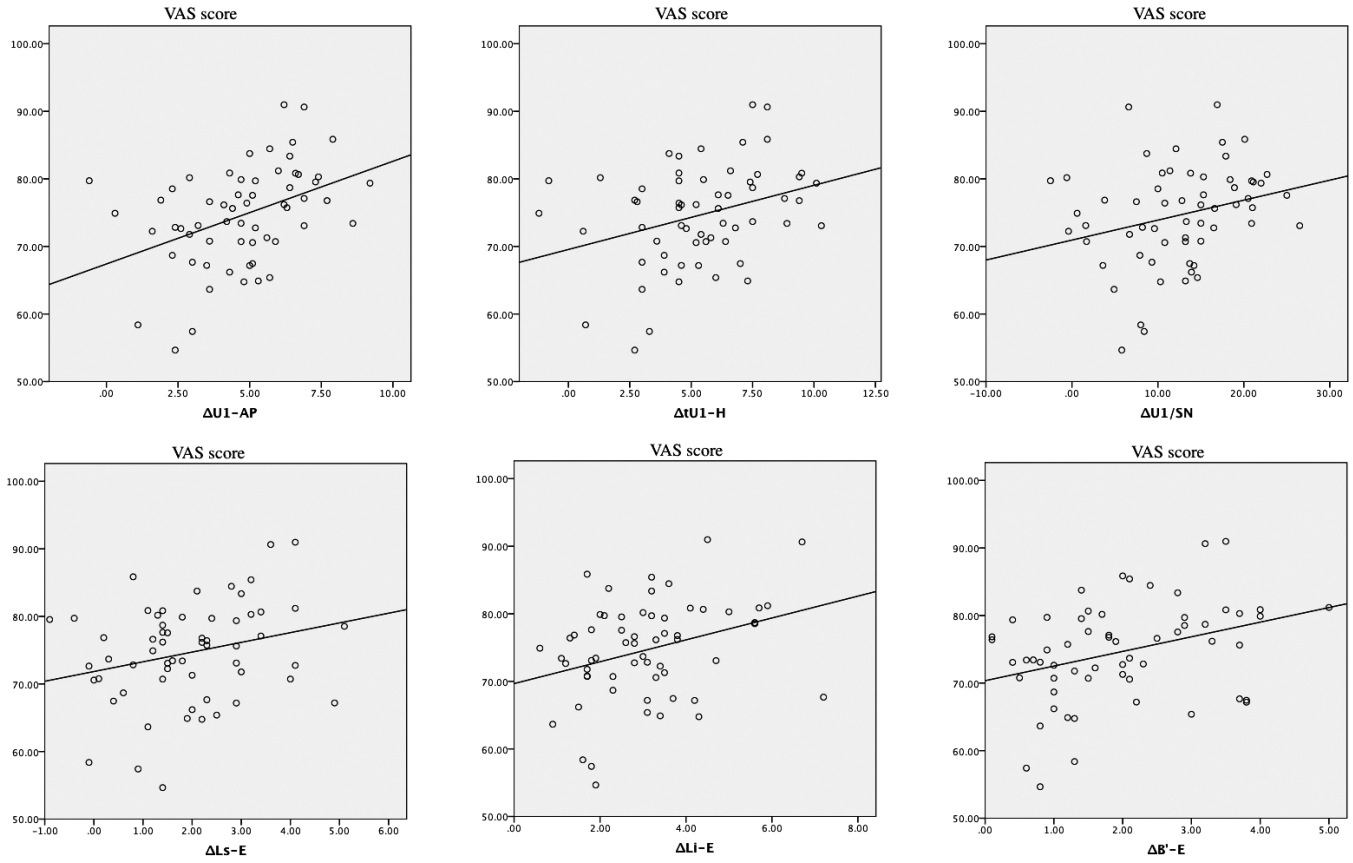

Figure 5. Distributions of the relationship between VAS score of profile change given by professional panel and six cephalometric measures for which highly significant associations are shown in Table 7.

lip position, the E-line, in our study, was sensitive to assess the anteroposterior position of the lips, consistent with the study by Erbay and Caniklioğlu.[25] For the subjective evaluation of profile change during orthodontic treatment, the change of lower lip to the E-line showed stronger correlation with profile change score than the upper lip, whereas the measurements of upper incisor retraction showed stronger correlation than the lower incisor. Bimaxillary protrusion patients always display a mild Class II skeletal pattern with retrusive chin contour.[26,27] Change of the protrusive lower lip could achieve facial "balance" and "harmony" with retrusive chin morphology. However, the behavior of lower lip change mainly depended on the upper incisor position, compared to the lower incisor.[3,4,21] Thus, the retraction of upper incisor and subsequent retraction of upper and lower lip may have remarkable influence on the subjective facial esthetics of bimaxillary protrusion patients.

Interestingly, the nasolabial cephalometric measurements, including nasolabial angle and superior sulcus depth, failed to achieve a significant association with either the VAS score or nasolabial esthetic evaluation. It appears that the nasolabial relationship may be regulated by a variety of factors, such as nose prominence and contour, lip prominence and form, instead of a single measurement.

Besides the mentolabial fold, the skeletal pattern of patients had a significant influence on the subjective evaluation of chin morphology, including the ANB, Y-axis, and mandibular plane angle. When the cranial base developed in a backward direction in addition to obtuse development of the mandible, the chin tends to be assessed as unattractive. Previous studies investigated the morphologic features of bimaxillary protrusion and showed that bimaxillary protrusion was associated with a mild Class II skeletal pattern, diverging facial planes, and vertical growth pattern.[26,27] These skeletal characteristics may result in the unpleasing chin contour and subsequently the unattractive profile.

However, in this study, the limitations of the sample must be considered when reaching a conclusion. All of the bimaxillary protrusion patients and the evaluators were selected from the Peking University School and Hospital of Stomatology, and therefore culture bias might exist. Caution should be exercised before extending the results to other groups. Also, only

moderate correlation between the subjective and objective evaluation of the profile was achieved, indicating that the facial esthetics might be affected by other craniofacial features besides the lower face structure.

CONCLUSIONS

- Cephalometric measurements correlated moderately with subjective facial esthetic evaluation.
- Lip prominence and underlying anterior teeth position and chin morphology are key variables related to facial esthetics.

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