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ORIGINAL RESEARCH

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Facial profile esthetics and its correlation with cephalometric measurements in Class II patients before and after functional orthodontic treatment: perception of orthodontists and laypersons

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Abstract

Orthodontists heavily rely on cephalometric measurements to evaluate the esthetic outcomes of orthodontic treatments, while patients' assessments of profile attractiveness are influenced by their personal esthetic preferences. The objective of this study was to compare facial esthetic evaluations between orthodontists and laypersons, examine the correlation between cephalometric measurements and assessments of facial attractiveness, and identify the cephalometric measurements that are most associated with profile attractiveness in teenage Class II patients. This study included 28 patients (17 boys and 11 girls, mean age of 11.83 $\pm$ 1.48 years) who fulfilled the inclusion criteria and were treated with activator appliances. An experienced orthodontist conducted objective cephalometric analyses before and after the treatment. The standard profiles of patients, pre- and post-treatment, were independently evaluated by 10 orthodontists and 20 laypersons. Pearson correlation analysis was used to analyze the relationships between objective cephalometric values and subjective facial esthetic ratings. The results indicated that laypersons generally assigned lower ratings to facial attractiveness compared to orthodontists. Significant differences in evaluations between orthodontists and laypersons were noted in the ratings of the upper lip position before treatment and the ratings of overall attractiveness, lower lip position and chin position after treatment. In addition, there were substantial correlations between objective measurements and the subjective scores provided by orthodontists. In contrast, the esthetic evaluations by laypersons correlated with only a limited set of objective measurements. The positions of the upper and lower incisors, the relationship of the upper and lower lip to E-line, and the Mentocervical Angle showed significant correlations with esthetic scores. In conclusion, the study reveals that laypersons were more critical of facial profiles compared to orthodontists. Notably, the positions of the upper and lower incisors, the E-line and the Mentocervical Angle had a significant impact on facial esthetics, highlighting their importance in evaluating orthodontic outcomes.

Keywords

Class II malocclusion; Removable functional appliance; Facial esthetics; Cephalometrics

1. Introduction

Patients with Class II division 1 malocclusion frequently present with distinct facial characteristics, including a prominent upper lip, mandibular retrusion and reduced lower facial height, which may adversely affect their facial appearance [1]. These negative facial features often results in diminished confidence and can impact their social interactions, including exposure to derogatory comments from peers, potentially affecting their personality development [2–4]. Thus, enhancing the facial profile attractiveness of these patients at an early stage is deemed beneficial [5–8].

There is a consensus indicating that functional treatment of Class II malocclusion can effectively decrease overjet and improve facial profile attractiveness [9–13]. However, attractiveness is considered a subjective concept influenced by various factors, including nationality, culture, historical context, race and occupation [14]. While orthodontists and patients may share some common perceptions of beauty, differences in their individual esthetic preferences are also observed [15–19], which may lead to medical disputes and significantly influence treatment decisions [20, 21].

Orthodontists primarily utilize cephalometric measurements

to evaluate the esthetic outcomes of orthodontic treatments, while patients assess profile attractiveness based on subjective impressions and their personal esthetic preferences. Prior research has investigated the relationships between objective cephalometric measurements and subjective assessments of facial esthetics in adult patients [22–26]. However, the correlation between subjective and objective evaluations in teenage Class II patients undergoing treatment with functional appliances remains unexplored. Therefore, this study aims to examine the differences in facial esthetic evaluations between orthodontists and laypersons, explore the concordance between objective cephalometric measurements and subjective facial esthetic ratings, and identify crucial cephalometric measurements significantly associated with profile attractiveness in teenage patients with mandibular retrognathia.

2. Materials and methods

2.1 Participants

In this retrospective clinical study, the data of 28 patients diagnosed with mandibular retrognathia between 2021 and 2023 at the Stomatology Hospital of Zhejiang Chinese Medical University, China, were retrieved and assessed. The inclusion criteria were as follows: (1) usage of an overjet >5 mm; (2) a Class II molar relationship, defined by at least half a cusp width distal molar relationship; (3) a skeletal Class II malocclusion characterized by an ANB angle over 4°; (4) patients were in the growth phase, specifically between stages CS2 and CS3 (cervical vertebral maturation stage, CS) of cervical vertebrae development; and (5) had no history of orthodontic treatment.

The cohort comprised 17 boys and 11 girls, with an average age of 11.83 years (standard deviation (SD): 17.81 months), and all of them were treated using activator therapy, with a single seasoned orthodontist administering the treatments. The activator appliance, a bimaxillary acrylic body that enveloped the incisal third of the lower incisors, was used in the study. Briefly, the patients were instructed to wear the appliance for no less than 12 hours daily. To facilitate the eruption of the mandibular posterior teeth and achieve a Class I dental relationship, the occlusal surfaces of the activator were progressively trimmed throughout the treatment period. Standard lateral cephalograms and profile photographs were taken both before and after the intervention.

2.2 Objective measurements of cephalograms

To ensure the uniformity, cephalograms were resized to original dimensions with a ruler serving as the reference. A total of 23 cephalometric variables were recorded for study analysis by an investigator using Dolphin Imaging's Cephalometric Tracking and Analysis software (version 11.8, Dolphin Inc., Canoga Park, CA, USA) (Table 1 and Fig. 1). To evaluate reproducibility, all measurements were conducted again after a two-week interval, and the mean of these measurements was used for statistical analysis.

2.3 Subjective evaluations of facial esthetics

The pretreatment and posttreatment profile photographs were converted into black silhouettes using Adobe Photoshop (Version 22, Adobe Systems Inc, San Jose, CA, USA) and aligned horizontally according to the alar-tragus line to reduce the influence of head posture on the assessments. The silhouette evaluations were performed using Wenjuanxing (Changsha Ranxing IT Ltd., Changsha, Hunan, China), a specialized online survey platform. Evaluators were tasked with rating various aspects of the profile silhouettes, such as overall attractiveness and the positions of the upper lip, lower lip and chin. Each attribute was evaluated on a 10-point visual analog scale, where 1 represented the most unattractive and 10 denoted the most attractive (Fig. 2). All evaluators had no prior knowledge of the patients' information or the cephalometric analysis, ensuring an unbiased subjective evaluation.

To provide the evaluators with maximum concentration and allow thorough assessment, they were tasked to perform their analysis in a quiet environment and were allowed to adjust their attractiveness ratings before finalizing their responses. The silhouettes were displayed in a randomized sequence to prevent any order bias during the evaluation process. For the purpose of measuring intrarater reliability, 10 silhouettes were randomly selected to appear twice in the survey, enabling a comparison of scores for consistency among individual evaluators.

Those silhouettes were evaluated by 10 orthodontists (4 males and 6 females, mean age of 27.09 ± 2.45 years) and 20 laypersons (3 males and 17 females, mean age of 22.27 ± 3.12 years). For this study, orthodontists were defined as individuals who had received comprehensive orthodontic training within a structured program. Conversely, laypersons were defined as individuals without any formal orthodontic training. None of the orthodontists were involved in the treatment process at any stage.

2.4 Statistical analysis

Statistical analysis were conducted using the SPSS software (version 25.0, IBM Corp., Armonk, NY, USA). The Shapiro-Wilk and Kolmogorov-Smirnov tests were used to assess the normality of the distribution for continuous variables. Continuous variables with normal distribution are presented as mean ± SD, while those with non-normal distribution are expressed as median (interquartile range, IQR). The paired *t*-test was used to evaluate differences in paired samples/variables. For comparing normal and non-normal independent continuous variables, the independent two-sample *t*-test and the Mann-Whitney U test were used, respectively. Intraclass correlation coefficients (ICC) were calculated to assess repeated measures. Pearson correlation analysis was conducted to examine the relationships between objective cephalometric measurements and subjective facial esthetic evaluations. A *p*-value of less than 0.05 was considered statistically significant.

TABLE 1. Cephalometric measurements.

	Name	Scale	Definitions
1	SNA	deg	Angle formed by the SN plane and A-nasion line
2	SNB	deg	Angle formed by the SN plane and B-nasion line
3	ANB	deg	Angle formed by the A-nasion line and B-nasion line
4	Y-Axis	deg	Angle formed by Y-axis (S-Gn) and SN plane
5	Convexity	deg	Angle formed by the A-nasion line and A-Pog plane
6	Facial Angle	deg	Angle formed by the intersection of the line nasion-pogonion with the frankfort horizontal plane
7	MP-FH (FMA)	deg	Angle formed by the intersection of the mandibular plane with the frankfort horizontal plane
8	Sum of Angles	deg	The sum of N-S-Ar and S-Ar-Go and Ar-Go-Me
9	Overjet	mm	Distance from the lower incisor tip to the upper incisor tip along the occlusal plane
10	U1-SN	deg	Angle fromed by the long axis of the upper incisor and the SN plane
11	L1-MP	deg	Angle formed by the long axis of the lower incisor and the mandibular plane
12	U1-NA	mm	Distance from the upper incisor tip to A-nasion line
13	L1-NB	mm	Distance from the lower incisor tip to B-nasion line
14	U1-APo	mm	Distance from upper incisor tip to A-Pog plane
15	L1-APo	mm	Distance from lower incisor tip to A-Pog plane
16	U1-L1	deg	Angle formed by the long axis of the upper and lower incisor
17	Nasolabial Angle	deg	Angle formed by the Cm-Sn line and UL-Sn line
18	Mentolabial Angle	deg	Angle formed by the B'-LL line and B'-Pg' line
19	Upper Lip to E-line	mm	Distance from the upper lip anterior point to the E-line
20	Lower Lip to E-line	mm	Distance from the lower lip anterior point to the E-line
21	Z Angle	deg	Angle formed by frankfort horizontal plane and a line through the soft tissue pogonion and the most prominent point of upper or lower lip
22	Chin Thickness	mm	Distance from Pogonion to soft tissue Pogonion
23	Mentocervical Angle	deg	Angle formed by the G'-Pg' line and C-Me' line

SNA: sella nasion subspinale angle; SNB: sella nasion supramental angle; ANB: subspinale nasion supramental angle; MP: mandibular plane; FH: frankfort horizontal plane; U1: upper incisor; L1: lower incisor; SN: anterior cranial base plane; NA: nasion-A point plane; NB: nasion-B point plane; Apo: subspinale-pogonion plane.

3. Results

The intraobserver consistency, indicated by the ICC between the initial and subsequent evaluations of the photographs, was 0.755. The ICC values among different evaluators within each category were considered acceptable, with orthodontists recording an ICC of 0.875 and laypersons recording an ICC of 0.842. In addition, the ICCs for repeated cephalometric measurements approached 1.00, denoting near-perfect reliability. The descriptive statistics for cephalometric measurements before treatment (T1) and after treatment (T2) for each participant are shown in Table 2, and the facial esthetic scores assigned by orthodontists and laypersons are documented in Table 3.

3.1 Differences in esthetic scores between orthodontists and laypersons

The differences in esthetic scores between orthodontists and laypersons are summarized in Table 4. Laypersons assigned significantly lower scores for the upper lip position at T1 ($p < 0.001$) and for overall attractiveness ($p = 0.003$), upper lip position ($p < 0.001$) and lower lip position ($p = 0.001$) at T2. Furthermore, in terms of changes from T1 to T2 (ΔT2 − T1), laypersons reported significantly lesser improvements in overall attractiveness ($p = 0.026$), lower lip position ($p = 0.027$) and chin position ($p = 0.007$) compared to orthodontists.

3.2 Correlations between the facial esthetic scores of post-treatment profile and cephalometric measurements

The results presented in Tables 5 and 6 indicate a stronger prevalence of statistically significant correlations within the evaluations made by orthodontists compared to those made by laypersons. For orthodontists, a series of negative correlations were identified between overall attractiveness and several cephalometric parameters: L1-NB ($r = -0.404$, $p = 0.033$), U1-APo ($r = -0.456$, $p = 0.015$), L1-Apo ($r = -0.383$, $p = 0.044$) and Mentocervical Angle ($r = -0.487$, $p = 0.009$). Additionally, the position of the upper lip showed negative correlations with U1-SN ($r = -0.402$, $p = 0.034$), U1-NA ($r = -0.393$, $p = 0.038$), L1-NB ($r = -0.421$, $p = 0.026$) and U1-APo ($r = -0.489$, $p = 0.008$), but it was positively correlated with U1-L1 ($r = 0.401$, $p = 0.035$). The lower lip position value was negatively correlated with the Upper Lip to E-line ($r = -0.592$, $p = 0.001$), Lower Lip to E-line ($r = -0.526$, $p = 0.004$), and Mentocervical Angle ($r = -0.527$, $p = 0.004$), but exhibited a positive correlation with the Z Angle ($r = 0.397$, p

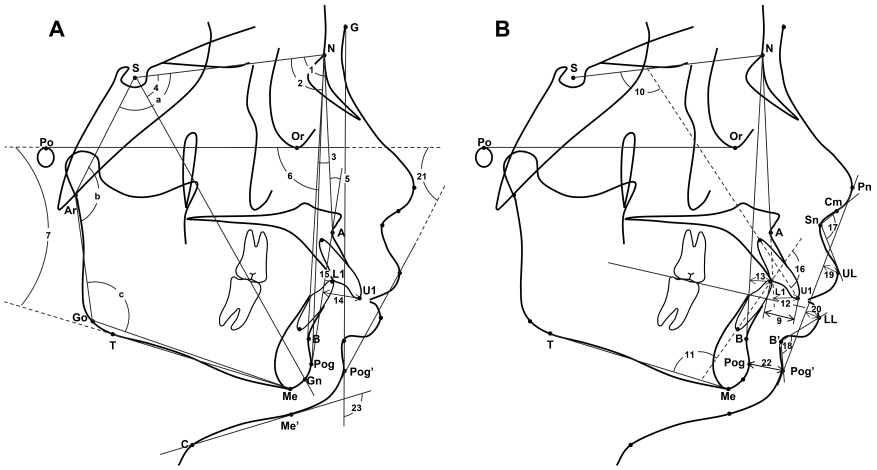

FIGURE 1. Illustrations of the cephalometric measurements. (A) (1) SNA (deg), (2) SNB (deg), (3) ANB (deg), (4) Y-Axis (deg), (5) Convexity (deg), (6) Facial Angle (deg), (7) MP-FH (FMA) (deg), (8) Sum of Angles (deg) = (a) N-S-Ar (deg), and (b) S-Ar-Go (deg), and (c) Ar-Go-Me (deg), (14) U1-APo (mm), (15) L1-APo (mm), (21) Z Angle (deg), (23) Mentocervical Angle (deg). (B) (9) Overjet (mm), (10) U1-SN (deg), (11) L1-MP (deg), (12) U1-NA (mm), (13) L1-NB (mm), (16) U1-L1 (deg), (17) Nasolabial Angle (deg), (18) Mentolabial Angle (deg), (19) Upper Lip to E-line (mm), (20) Lower Lip to E-line (mm), (22) Chin Thickness (mm). G: glabella; N: nasion; S: sella; Po: porion; Ar: articulare; Go: gonion; Or: orbitale; A: subspinale; L1: lower incisor; U1: upper incisor; B: supramental; Pog: pogonion; Pog': pogonion of soft tissue; Gn: gnathion; Me: menton; Me': menton of soft tissue; LL: lower lip; UL: upper lip; Sn: subnasale; Cm: columella; Pn: pronasale.

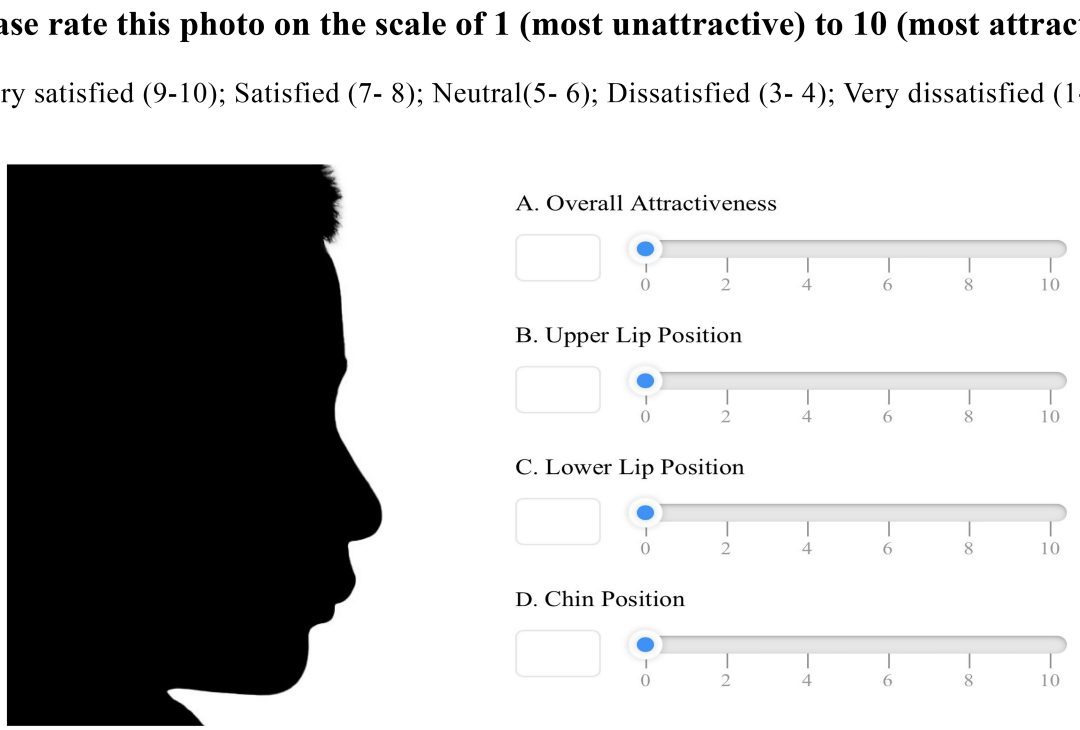

FIGURE 2. Example of the questionnaire's questions. Each evaluator was asked to rate each esthetic item to indicate the intensity of facial beauty.

= 0.037). The evaluation of chin position displayed significant negative associations with the Upper Lip to E-line ($r = -0.657$, $p < 0.001$), Lower Lip to E-line ($r = -0.624$, $p < 0.001$) and Mentocervical Angle ($r = -0.627$, $p < 0.001$), and positive association with the Z Angle ($r = 0.470$, $p = 0.012$).

Comparatively, in the layperson group, the Mentocervical Angle showed significant negative correlations with overall attractiveness ($r = -0.570$, $p = 0.002$), upper lip position ($r = -0.449$, $p = 0.017$), lower lip position ($r = -0.581$, $p = 0.001$) and chin position ($r = -0.703$, $p < 0.001$). The upper lip position value only correlated negatively with ANB ($r = -0.387$, $p = 0.042$). For the lower lip position, there were significant negative correlations with ANB ($r = -0.422$, $p = 0.025$) and a negative correlation with L1-NB ($r = 0.378$, $p =$

TABLE 2. Statistical comparison of the cephalometric variables pre- and post-treatment.

Variables	T1		T2		ΔT2 − T1		*t*	*p* value
	Mean	SD	Mean	SD	Mean	SD		
SNA (°)	81.638	3.078	80.820	3.469	−0.818	0.391	−2.427	0.022*
SNB (°)	76.039	3.185	77.070	3.447	1.030	0.262	4.136	<0.001***
ANB (°)	5.598	1.228	3.755	1.371	−1.843	0.143	−7.580	<0.001***
Y-Axis (°)	71.195	3.602	70.993	3.884	−0.202	0.282	−0.683	0.500
Convexity (°)	11.482	3.406	7.339	4.013	−4.143	0.607	−7.442	<0.001***
Facial Angle (°)	83.648	2.755	84.302	2.506	0.654	−0.250	2.181	0.038*
FMA (°)	27.155	4.771	27.443	4.460	0.287	−0.311	0.743	0.464
Sum of Angles (°)	394.346	5.252	394.325	5.118	−0.021	−0.134	−0.049	0.961
Overjet (mm)	8.470	2.093	4.621	1.523	−3.848	−0.570	−12.293	<0.001***
U1-SN (°)	113.732	8.365	108.384	8.484	−5.348	0.118	−4.195	<0.001***
L1-MP (°)	98.857	7.161	102.137	7.247	3.280	0.086	2.692	0.012*
U1-NA (mm)	7.039	1.876	6.568	2.309	−0.471	0.433	−1.271	0.214
L1-NB (mm)	6.284	2.173	7.429	2.192	1.145	0.019	4.885	<0.001***
U1-APo (mm)	11.054	1.692	9.366	2.308	−1.688	0.617	−5.762	<0.001***
L1-APo (mm)	2.289	2.303	4.795	2.292	2.505	−0.010	8.114	<0.001***
U1-L1 (°)	113.064	7.992	115.155	10.332	2.091	2.339	1.098	0.282
Nasolabial Angle (°)	98.702	11.813	95.588	7.645	−3.114	−4.169	−1.572	0.128
Mentolabial Angle (°)	135.445	14.725	137.488	13.480	2.043	−1.246	1.039	0.308
Upper Lip to E-line (mm)	3.257	1.559	1.980	2.118	−1.277	0.559	−4.997	<0.001***
Lower Lip to E-line (mm)	2.686	2.346	2.998	2.333	0.312	−0.013	1.042	0.307
Z Angle (°)	63.323	6.605	63.730	6.199	0.407	−0.406	0.459	0.650
Chin Thickness (mm)	11.186	2.735	11.632	3.115	0.446	0.380	1.191	0.244
Mentocervical Angle (°)	102.166	8.595	102.166	6.685	0	−1.910	0	1

*SD: standard deviation; p value from paired t-test; *p < 0.05; ***p < 0.001. SNA: sella nasion subspinale angle; SNB: sella nasion supramental angle; ANB: subspinale nasion supramental angle; FMA: mandibular plane to frankfort plane angle, MP-FH; U1: upper incisor; L1: lower incisor; SN: anterior cranial base plane; MP: mandibular plane; NA: nasion-A point plane; NB: nasion-B point plane; Apo: subspinale-pogonion plane; T1: pre-treatment; T2: post-treatment.*

TABLE 3. Comparison of the differences in esthetic scores between pre- and post-treatment.

Variables	T1		T2		ΔT2 − T1		*t*	*p* value
	Mean	SD	Mean	SD	Mean	SD		
Orthodontist								
A. Overall Attractiveness	5.343	1.069	6.623	0.963	1.280	−0.106	6.470	<0.001***
B. Upper Lip Position	5.743	0.943	6.468	0.884	0.725	−0.059	4.186	<0.001***
C. Lower Lip Position	4.804	1.193	6.139	0.948	1.336	−0.245	6.523	<0.001***
D. Chin Position	4.362	1.133	5.780	1.305	1.418	0.172	6.575	<0.001***
Layperson								
A. Overall Attractiveness	5.178	0.703	5.894	0.758	0.716	0.055	4.841	<0.001***
B. Upper Lip Position	4.614	0.695	5.260	0.847	0.646	0.152	4.497	<0.001***
C. Lower Lip Position	4.554	0.680	5.288	0.787	0.734	0.107	4.358	<0.001***
D. Chin Position	4.606	0.832	5.271	0.873	0.664	0.042	4.183	<0.001***

*SD: standard deviation; p value from paired t-test; ***p < 0.001. T1: pre-treatment; T2: post-treatment.*

TABLE 4. Comparison of the differences in esthetic scores between orthodontists and laypersons.

Variables	Orthodontist		Layperson		*t*	*p* value
	Mean	SD	Mean	SD		
T1						
A. Overall Attractiveness	5.343	1.069	5.178	0.703	0.683	0.497
B. Upper Lip Position	5.743	0.943	4.614	0.695	5.097	<0.001***
C. Lower Lip Position	4.804	1.193	4.554	0.680	0.963	0.340
D. Chin Position	4.362	1.133	4.606	0.832	−0.918	0.363
T2						
A. Overall Attractiveness	6.623	0.963	5.894	0.758	3.151	0.003**
B. Upper Lip Position	6.468	0.884	5.260	0.847	5.222	<0.001***
C. Lower Lip Position	6.139	0.948	5.288	0.787	3.658	0.001**
D. Chin Position	5.780	1.305	5.271	0.873	1.717	0.092
ΔT2 − T1						
A. Overall Attractiveness	1.280	−0.106	0.716	0.055	2.284	0.026*
B. Upper Lip Position	0.725	−0.059	0.646	0.152	0.353	0.725
C. Lower Lip Position	1.335	−0.245	0.734	0.107	2.270	0.027*
D. Chin Position	1.418	0.172	0.665	0.041	2.814	0.007**

*SD: standard deviation; p value from two-sample t-test; *p < 0.05; **p < 0.01; ***p < 0.001. T1: pre-treatment; T2: post-treatment.*

TABLE 5. Pearson correlation between the facial esthetic scores of post-treatment profile given by orthodontists and 23 cephalometric measurements.

Variables	A. Overall Attractiveness		B. Upper Lip Position		C. Lower Lip Position		D. Chin Position	
	r	*p* value	*r*	*p* value	*r*	*p* value	*r*	*p* value
SNA (°)	−0.293	0.130	−0.320	0.097	−0.174	0.376	−0.145	0.461
SNB (°)	−0.234	0.232	−0.261	0.179	−0.046	0.817	−0.078	0.693
ANB (°)	−0.158	0.423	−0.146	0.460	−0.327	0.089	−0.176	0.370
Y-Axis (°)	−0.028	0.889	0.030	0.879	−0.203	0.300	−0.143	0.467
Convexity (°)	−0.174	0.376	−0.098	0.619	−0.325	0.091	−0.262	0.178
Facial Angle (°)	−0.126	0.522	−0.183	0.352	0.084	0.670	−0.006	0.977
FMA (°)	−0.115	0.559	0.023	0.908	−0.250	0.200	−0.189	0.335
Sum of Angles (°)	−0.041	0.837	0.103	0.601	−0.194	0.322	−0.180	0.359
Overjet (mm)	−0.099	0.617	−0.221	0.258	0.023	0.908	0.134	0.496
U1-SN (°)	−0.244	0.210	−0.402	0.034*	0.001	0.997	−0.035	0.861
L1-MP (°)	−0.136	0.489	−0.172	0.381	−0.087	0.662	−0.095	0.632
U1-NA (mm)	−0.280	0.150	−0.393	0.038*	−0.010	0.958	−0.067	0.735
L1-NB (mm)	−0.404	0.033*	−0.421	0.026*	−0.351	0.067	−0.340	0.077
U1-APo (mm)	−0.456	0.015*	−0.489	0.008**	−0.290	0.135	−0.297	0.125
L1-APo (mm)	−0.383	0.044*	−0.340	0.077	−0.301	0.120	−0.373	0.050
U1-L1 (°)	0.317	0.100	0.401	0.035*	0.157	0.426	0.185	0.347
Nasolabial Angle (°)	−0.033	0.866	0.139	0.479	−0.090	0.647	−0.234	0.232
Mentolabial Angle (°)	−0.150	0.448	−0.069	0.726	−0.127	0.521	−0.289	0.136
Upper Lip to E-line (mm)	−0.346	0.072	0.034	0.865	−0.592	0.001**	−0.657	<0.001***
Lower Lip to E-line (mm)	−0.370	0.052	−0.050	0.801	−0.526	0.004**	−0.624	<0.001***
Z Angle (°)	0.183	0.350	−0.072	0.717	0.397	0.037*	0.470	0.012*
Chin Thickness (mm)	−0.083	0.675	−0.282	0.146	0.032	0.872	0.215	0.271
Mentocervical Angle (°)	−0.487	0.009**	−0.287	0.139	−0.527	0.004**	−0.627	<0.001***

*p value from Pearson correlation analysis; *p < 0.05; **p < 0.01; ***p < 0.001. SNA: sella nasion subspinale angle; SNB: sella nasion supramental angle; ANB: subspinale nasion supramental angle; FMA: mandibular plane to frankfort plane angle, MP-FH; U1: upper incisor; L1: lower incisor; SN: anterior cranial base plane; MP: mandibular plane; NA: nasion-A point plane; NB: nasion-B point plane; Apo: subspinale-pogonion plane.*

TABLE 6. Pearson correlation between the facial esthetic scores of post-treatment profile given by laypersons and 23 cephalometric measurements.

Variables	A. Overall Attractiveness		B. Upper Lip Position		C. Lower Lip Position		D. Chin Position	
	r	*p* value	*r*	*p* value	*r*	*p* value	*r*	*p* value
SNA (°)	−0.217	0.267	−0.253	0.194	−0.230	0.240	−0.336	0.081
SNB (°)	−0.098	0.620	−0.099	0.615	−0.065	0.744	−0.199	0.311
ANB (°)	−0.304	0.116	−0.387	0.042*	−0.422	0.025*	−0.349	0.068
Y-Axis (°)	−0.128	0.516	−0.154	0.433	−0.178	0.364	0	1.000
Convexity (°)	−0.252	0.196	−0.365	0.056	−0.367	0.055	−0.252	0.196
Facial Angle (°)	0.034	0.864	0.014	0.943	0.048	0.808	0.016	0.934
FMA (°)	−0.225	0.249	−0.159	0.418	−0.203	0.301	−0.205	0.296
Sum of Angles (°)	−0.137	0.486	−0.099	0.616	−0.139	0.480	−0.050	0.799
Overjet (mm)	−0.094	0.634	−0.094	0.636	−0.104	0.598	−0.059	0.767
U1-SN (°)	−0.102	0.606	−0.151	0.442	−0.080	0.687	−0.001	0.994
L1-MP (°)	0	0.998	−0.142	0.472	−0.112	0.570	0.074	0.709
U1-NA (mm)	−0.090	0.650	−0.062	0.752	−0.046	0.816	0.107	0.587
L1-NB (mm)	−0.328	0.088	−0.372	0.052	−0.378	0.047*	−0.163	0.407
U1-APo (mm)	−0.305	0.115	−0.322	0.095	−0.325	0.091	−0.108	0.586
L1-APo (mm)	−0.233	0.233	−0.249	0.201	−0.243	0.213	−0.060	0.762
U1-L1 (°)	0.152	0.440	0.273	0.160	0.214	0.275	−0.025	0.898
Nasolabial Angle (°)	−0.022	0.910	0.026	0.897	−0.156	0.429	0.001	0.995
Mentolabial Angle (°)	−0.022	0.913	0.036	0.854	−0.069	0.729	0.084	0.671
Upper Lip to E-line (mm)	−0.274	0.158	−0.018	0.926	−0.272	0.161	−0.371	0.052
Lower Lip to E-line (mm)	−0.328	0.088	−0.092	0.643	−0.272	0.162	−0.278	0.153
Z Angle (°)	0.235	0.228	0.085	0.666	0.180	0.358	0.152	0.440
Chin Thickness (mm)	−0.153	0.436	−0.365	0.056	−0.224	0.251	−0.194	0.322
Mentocervical Angle (°)	−0.570	0.002**	−0.449	0.017*	−0.581	0.001**	−0.703	<0.001***

*p value from Pearson correlation analysis; *p < 0.05; **p < 0.01; ***p < 0.001. SNA: sella nasion subspinale angle; SNB: sella nasion supramental angle; ANB: subspinale nasion supramental angle FMA: mandibular plane to frankfort plane angle, MP-FH; U1: upper incisor; L1: lower incisor; SN: anterior cranial base plane; MP: mandibular plane; NA: nasion-A point plane; NB: nasion-B point plane; Apo: subspinale-pogonion plane.*

0.047).

3.3 Correlations between the change in facial esthetic scores and cephalometric measurements change

Tables 7,8 show the correlations between the change in facial esthetic scores and cephalometric measurements. In the orthodontist group, scores for overall attractiveness were found to be negatively correlated with the changes in U1-NA (r = −0.500, p = 0.007) and U1-APo (r = −0.522, p = 0.004). The scores for upper lip position were negatively correlated with changes in U1-NA (r = −0.603, p = 0.001), U1-APo (r = −0.510, p = 0.006), L1-APo (r = −0.429, p = 0.023) and Nasolabial Angle (r = −0.420, p = 0.026) and the scores for lower lip position were negatively correlated with changes in U1-APo (r = −0.471, p = 0.011). Furthermore, scores for chin position were negatively associated with changes in U1-NA (r = −0.379, p = 0.047) and U1-APo (r = −0.454, p = 0.015), while positively correlated with change in Facial Angle (r = 0.388, p = 0.041).

In the layperson group, changes in Overjet (r = −0.407, p = 0.032) and U1-APo (r = −0.397, p = 0.036) negatively correlated with changes in scores for chin position. However, no correlation was found between any of the cephalometric measurements and the scores of overall attractiveness, upper lip position and lower lip position.

The scatterplots for each highly statistically significant measurement ($p < 0.01$) are shown in Fig. 3. Fig. 3A,B show the distributions of the relationship between the attractiveness scores given by orthodontists and laypersons and the value of the cephalometric measurements. These figures reveal that while ideal measurement values do exist within the data, they infrequently align with the central distribution. Notably, data points indicating higher attractiveness tend to cluster closer to a designated vertical red line, suggesting a pattern where certain cephalometric values correlate with perceived attractiveness. Fig. 3C illustrates the distribution of changes in subjective attractiveness scores against the corresponding changes

TABLE 7. Pearson correlation between the change in facial esthetic scores (T2 − T1) given by orthodontists and cephalometric measurements change (T2 − T1).

Variables	A. Overall Attractiveness		B. Upper Lip Position		C. Lower Lip Position		D. Chin Position	
	r	*p* value	*r*	*p* value	*r*	*p* value	*r*	*p* value
Δ SNA (°)	0.091	0.644	0.089	0.651	−0.008	0.966	0.116	0.558
Δ SNB (°)	−0.075	0.703	−0.190	0.332	−0.025	0.899	−0.032	0.872
Δ ANB (°)	0.202	0.304	0.331	0.086	0.008	0.968	0.182	0.353
Δ Y-Axis (°)	−0.038	0.847	0.009	0.962	−0.117	0.553	0.079	0.688
Δ Convexity (°)	0.144	0.464	0.309	0.110	−0.054	0.785	0.053	0.789
Δ Facial Angle (°)	0.086	0.662	−0.151	0.445	0.043	0.830	0.388	0.041*
Δ FMA (°)	0.034	0.863	−0.007	0.971	0.010	0.961	−0.026	0.894
Δ Sum of Angles (°)	0.084	0.670	−0.026	0.894	−0.003	0.987	0.200	0.308
Δ Overjet (mm)	−0.206	0.294	−0.11	0.578	−0.230	0.239	−0.165	0.402
Δ U1-SN (°)	−0.349	0.068	−0.372	0.051	−0.331	0.086	−0.290	0.134
Δ L1-MP (°)	−0.193	0.324	−0.106	0.593	−0.116	0.555	−0.234	0.232
Δ U1-NA (mm)	−0.500	0.007**	−0.603	0.001**	−0.349	0.069	−0.379	0.047*
Δ L1-NB (mm)	−0.126	0.524	−0.215	0.272	−0.132	0.504	−0.090	0.648
Δ U1-APo (mm)	−0.522	0.004**	−0.510	0.006**	−0.471	0.011*	−0.454	0.015*
Δ L1-APo (mm)	−0.330	0.086	−0.429	0.023*	−0.216	0.269	−0.268	0.169
Δ U1-L1 (°)	0.339	0.078	0.323	0.094	0.298	0.124	0.299	0.122
Δ Nasolabial Angle (°)	−0.203	0.300	−0.420	0.026*	−0.069	0.727	0.057	0.774
Δ Mentolabial Angle (°)	−0.012	0.950	−0.278	0.153	0.068	0.729	0.054	0.785
Δ Upper Lip to E-line (mm)	−0.111	0.575	0.121	0.538	−0.290	0.134	−0.050	0.802
Δ Lower Lip to E-line (mm)	0.167	0.395	0.173	0.378	0.138	0.483	0.154	0.434
Δ Z Angle (°)	−0.254	0.191	−0.257	0.187	−0.228	0.244	−0.085	0.667
Δ Chin Thickness (mm)	−0.225	0.251	−0.139	0.480	−0.198	0.312	−0.260	0.182
Δ Mentocervical Angle (°)	−0.236	0.227	0.086	0.663	−0.221	0.259	−0.353	0.065

*p value from Pearson correlation analysis; *p < 0.05; **p < 0.01. SNA: sella nasion subspinale angle; SNB: sella nasion supramental angle; ANB: subspinale nasion supramental angle FMA: mandibular plane to frankfort plane angle, MP-FH; U1: upper incisor; L1: lower incisor; SN: anterior cranial base plane; MP: mandibular plane; NA: nasion-A point plane; NB: nasion-B point plane; Apo: subspinale-pogonion plane; Δ: Delta.*

in cephalometric measurements from before to after treatment. This figure aims to visually represent how variations in specific cephalometric parameters are associated with alterations in perceived facial esthetics.

4. Discussion

Enhancing facial attractiveness is a fundamental goal of orthodontic therapy. The current study revealed that changes in cephalometric dimensions, such as SNB, ANB, Convexity, Facial Angle, U1-SN, U1-APo and Upper Lip to E-line (Table 2), suggest the activator appliance's capability to not only modulate mandibular growth and positioning but also to retract the upper incisors, thereby improving facial profile esthetics, which align with those of prior investigations [13]. Moreover, subjective assessments by both orthodontists and laypersons indicated an improvement in facial profile attractiveness post-treatment, corroborating the findings of earlier studies [15, 16].

In the present study, profile silhouettes were employed as a tool to evaluate facial profile attractiveness by minimizing the effects of extraneous factors such as age, hair, skin and eye color. The utility of this approach in assessing facial profile attractiveness has been validated by earlier research [27–29]. Nonetheless, these prior investigations predominantly concentrated on the general perception of the profile without delving into the influence of distinct facial components on the attractiveness of profile silhouettes. To address this gap and explore how different facial features affect subjective attractiveness scores, this study included targeted questions regarding the positions of the upper lip, lower lip and chin in our questionnaire (Fig. 2).

Numerous studies have aimed to understand the agreement between orthodontists and laypersons in perceiving facial esthetics. Some research indicated a consensus in esthetic judgments between these groups, whereas other findings suggest discrepancies [15, 16, 18]. In this present investigation, we observed satisfactory internal consistency among evaluators within and across groups, indicating that members of each

TABLE 8. Pearson correlation between the change in facial esthetic scores (T2 − T1) given by laypersons and cephalometric measurements change (T2 − T1).

Variables	A. Overall Attractiveness		B. Upper Lip Position		C. Lower Lip Position		D. Chin Position	
	r	*p* value	*r*	*p* value	*r*	*p* value	*r*	*p* value
Δ SNA (°)	−0.089	0.652	−0.003	0.987	−0.104	0.599	−0.167	0.396
Δ SNB (°)	−0.102	0.604	−0.092	0.643	−0.084	0.672	−0.046	0.817
Δ ANB (°)	−0.028	0.888	0.089	0.652	−0.066	0.739	−0.193	0.326
Δ Y-Axis (°)	0.009	0.962	−0.006	0.976	−0.023	0.906	0.033	0.867
Δ Convexity (°)	−0.094	0.633	0.052	0.793	−0.129	0.511	−0.248	0.203
Δ Facial Angle (°)	0.186	0.343	0.033	0.868	0.048	0.809	0.238	0.223
Δ FMA (°)	−0.194	0.322	−0.168	0.394	−0.090	0.650	−0.281	0.147
Δ Sum of Angles (°)	−0.030	0.879	−0.098	0.618	−0.048	0.810	−0.087	0.661
Δ Overjet (mm)	−0.193	0.325	−0.134	0.498	−0.233	0.233	−0.407	0.032*
Δ U1-SN (°)	−0.140	0.477	−0.174	0.375	−0.195	0.321	−0.283	0.145
Δ L1-MP (°)	0.066	0.739	0.043	0.830	0.032	0.870	0.146	0.459
Δ U1-NA (mm)	−0.224	0.251	−0.315	0.102	−0.216	0.270	−0.203	0.299
Δ L1-NB (mm)	−0.080	0.686	−0.097	0.624	−0.033	0.868	0.029	0.883
Δ U1-APo (mm)	−0.355	0.064	−0.331	0.085	−0.338	0.078	−0.397	0.036*
Δ L1-APo (mm)	−0.150	0.446	−0.216	0.270	−0.094	0.636	0.063	0.750
Δ U1-L1 (°)	0.059	0.766	0.112	0.571	0.121	0.540	0.117	0.555
Δ Nasolabial Angle (°)	−0.087	0.659	−0.226	0.247	−0.087	0.662	0.119	0.545
Δ Mentolabial Angle (°)	−0.235	0.229	−0.330	0.086	−0.335	0.081	−0.194	0.323
Δ Upper Lip to E-line (mm)	0.057	0.771	0.059	0.766	−0.135	0.493	0.061	0.758
Δ Lower Lip to E-line (mm)	0.165	0.402	0.166	0.399	0.147	0.455	0.374	0.050
Δ Z Angle (°)	−0.258	0.184	−0.321	0.096	−0.288	0.138	−0.316	0.101
Δ Chin Thickness (mm)	−0.257	0.187	−0.227	0.245	−0.207	0.291	−0.361	0.059
Δ Mentocervical Angle (°)	−0.128	0.516	−0.025	0.900	−0.118	0.550	−0.232	0.234

*p value from Pearson correlation analysis; *p < 0.05. SNA: sella nasion subspinale angle; SNB: sella nasion supramental angle; ANB: subspinale nasion supramental angle; FMA: mandibular plane to frankfort plane angle, MP-FH; U1: upper incisor; L1: lower incisor; SN: anterior cranial base plane; MP: mandibular plane; NA: nasion-A point plane; NB: nasion-B point plane; Apo: subspinale-pogonion plane; Δ: Delta.*

group shared similar views in their assessments of facial esthetics. However, it was observed that laypersons generally awarded lower scores to various facial aspects, except for the chin position prior to treatment (Table 4), which might be attributed to the fact that our layperson cohort was predominantly young, a demographic known to have increased esthetic expectations [17, 18]. Notably, both before and after treatment, laypersons consistently rated the upper lip position less favorably than orthodontists (Table 4). This finding suggests that laypersons may have stricter criteria for the upper lip's placement, which is concordant with a previous study that highlighted a preference among Asian populations for less protrusive facial profiles [30]. Such preferences likely mirror cultural or regional beauty standards that influence lay evaluations, highlighting the need for culturally attuned standards in esthetic assessments and orthodontic treatment planning.

In contrast to orthodontists, laypersons awarded higher scores only for chin position before treatment (Table 4), suggesting a possible leniency among laypersons towards a retrusive mandible [31]. Barroso *et al.* [32] indicated that laypersons might struggle to recognize mandibular deficiency, whereas orthodontists, due to their increased sensitivity to mandibular retraction, often assign lower scores. Post-treatment, as the chin advances, orthodontists more accurately perceive this improvement, reflected in their scoring. Our findings revealed that the esthetic score changes noted by laypersons were generally lower than those given by orthodontists (Table 4). Such differences are understandable, given orthodontists' deeper knowledge of facial esthetics [18]. Nonetheless, laypersons evaluate facial attractiveness by also considering additional factors, such as the nose and chin's shape [19]. These variations in assessment could lead orthodontists to overestimate how satisfied patients are with their treatment outcomes, possibly leading to disagreements. Therefore, it is important for orthodontists to comprehensively understand patients' esthetic desires and communicate effectively, aiming to fulfill both the clinical objectives and

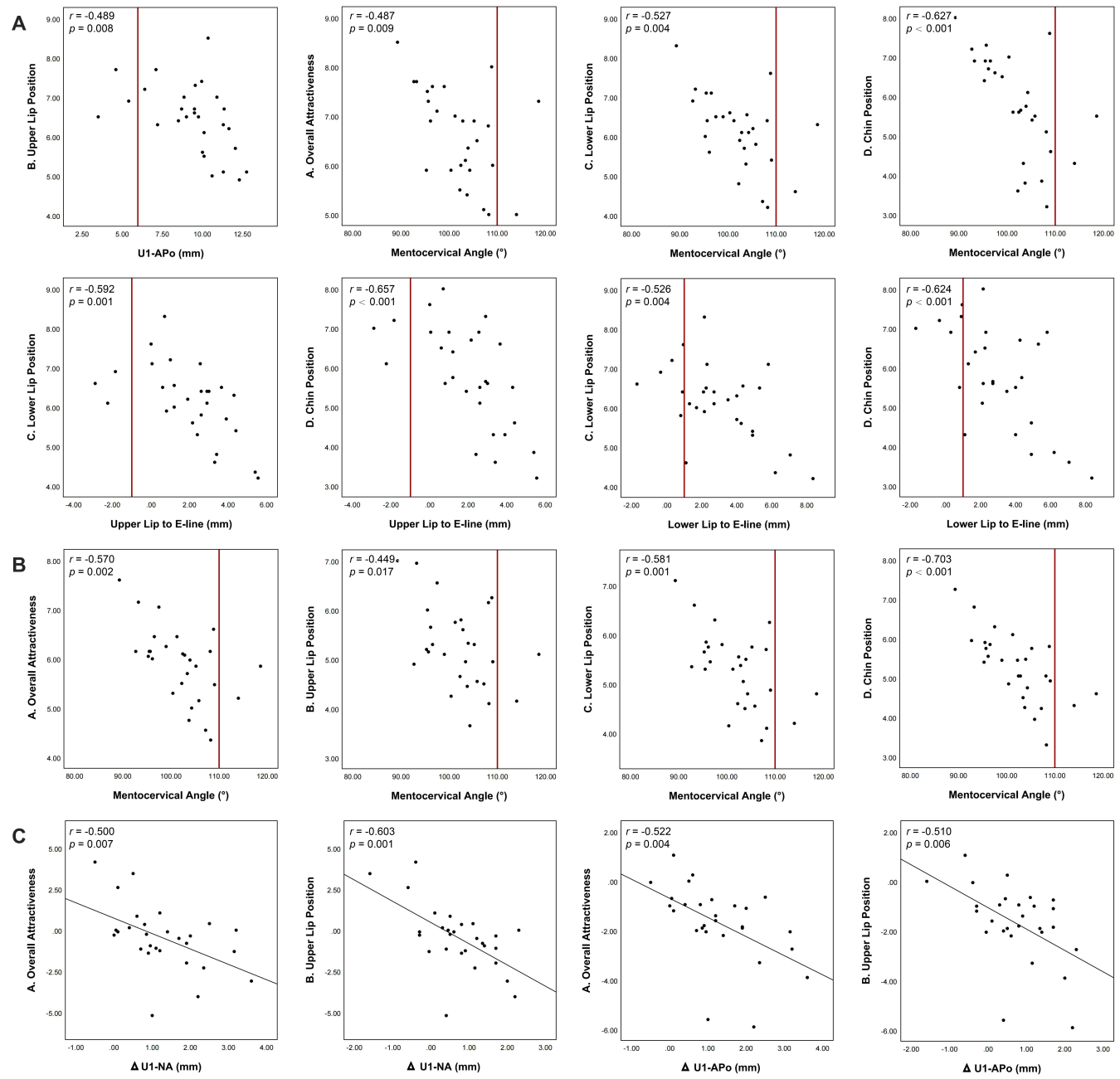

FIGURE 3. Distributions of the relationship between the highly significant cephalometric measurements and attractiveness scores. (A), (B) and (C) represent the values from Tables 5,6,7 respectively. The vertical red line represents the ideal value of the cephalometric measurement from A and B. The black oblique lines represent the fitted lines of the scatter plot from C. U1: upper incisor; APo: subspinale-pogonion plane; NA: nasion-A point plane.

patient satisfaction.

This study utilized Pearson correlation analysis to explore the association between cephalometric measurements and attractiveness ratings for different facial features (Tables 5,6,7,8). We observed a significant discrepancy between the responses of orthodontists and laypersons. Notably, there were significant correlations between objective measurements and the subjective evaluations made by orthodontists, which can likely be attributed to the detailed and systematic knowledge that orthodontists have that distinctly impacts their subjective esthetic evaluations. Consequently, the esthetic scores from orthodontists show consistency and stability. In contrast, laypersons' subjective esthetic scores correlated with only a limited set of objective measurements, highlighting the variability and unpredictability in the esthetic judgments made by the general public.

The positioning of the upper and lower central incisors significantly influences the positioning of the upper and lower lips [33]. Additionally, the vertical positioning of the maxillary incisor tip is important in determining the vertical position and contour of the lower lip [34]. Prior research showed that the retraction of incisors positively affects facial esthetics [25, 26]. In this study, a negative correlation was found between L1-NB and U1-APo measurements and overall attractiveness. More-

over, U1-SN, U1-NA, L1-NB and U1-Apo were negatively correlated with the position of the upper lip, whereas U1-L1 showed a positive correlation. These results highlighted the critical role orthodontists play in carefully adjusting the angles and positions of the upper and lower incisors to achieve harmonious facial profiles in Class II patients. Our findings align with those of Işıksal *et al*. [35], who also found that an increase in the U1-SN angle could detrimentally affect facial esthetics.

The E-line, an important parameter in orthodontic profile analysis, connects the tip of the nose to the soft tissue pogonion [36]. Hsu [37] highlighted its widespread use in orthodontics due to its straightforward definition, which simplifies the assessment of the esthetic profile for orthodontists. Ng *et al*. [38] found that the E-line is highly sensitive in assessing the esthetic position of the lips. Additionally, the configuration of the E-line depends on the form and placement of the nose tip and chin [39]. Functional orthodontic treatment can significantly alter the chin's position in the anteroposterior dimension, impacting the E-line's positioning [13]. Our findings indicate a negative correlation between the measurements of Upper Lip to E-line and Lower Lip to E-line with the attractiveness ratings of the lower lip and chin, corroborating previous research [24, 26]. Earlier studies have suggested that a pronounced chin enhances facial profile attractiveness [40], consistent with our data showing a positive correlation between the Z-angle, indicative of chin positioning and the attractiveness ratings of the chin position, consistent with earlier findings [25, 26].

The morphology of the chin also significantly influences the facial profile [41], and the Mentocervical Angle is a crucial index for analyzing chin shape [42]. Despite its importance, few studies have explored its effect on facial esthetics. Haddad and Ghafari [43] reported that an increased Mentocervical Angle could lead to a flatter chin contour, which is generally perceived as less attractive. Consistent with this, our study found a negative correlation between the Mentocervical Angle and subjective esthetic scores across all facial features, as rated by both orthodontists and laypersons. Specifically, a smaller Mentocervical Angle was associated with higher esthetic ratings, highlighting the critical role of chin morphology in treatment planning for enhancing facial attractiveness. Interestingly, initial analyses revealed no correlation between the Mentocervical Angle and esthetic assessments by orthodontists and laypersons before treatment. This may suggest that prior to treatment, the focus might be more on the chin's positioning rather than its shape. However, after functional treatment leads to an improved chin position, its morphology emerges as a key determinant of esthetic evaluation.

The present study had several limitations. Firstly, the relatively small sample size may have limited the statistical power to detect more subtle effects. Future research with a larger cohort is necessary to address this limitation. Secondly, the inclusion of all patients with mandibular contraction from a single hospital could restrict the generalizability of the results. It is important to note the substantial variability in the subjective evaluation of facial attractiveness among different ethnic groups [17, 44]. Therefore, the findings of this study, while applicable to patients with mandibular contraction, may not necessarily extend to individuals with different types of malocclusion. Further studies are warranted to examine the correlations between objective measurements and subjective assessments in a broader range of malocclusions.

5. Conclusions

In conclusion, laypersons demonstrated a more critical perspective on facial profiles compared to orthodontists. The associations between objective cephalometric measurements and subjective attractiveness scores were stronger among orthodontists, suggesting a more uniform esthetic judgment. This contrasts with the varied and less predictable esthetic opinions of laypersons. Key factors influencing facial esthetics included the positioning of the upper and lower incisors, the E-line and the Mentocervical Angle. These findings highlighted the complexity of facial attractiveness assessments and the importance of considering both orthodontist insights and layperson perceptions in orthodontic treatment planning.

AVAILABILITY OF DATA AND MATERIALS

The data presented in this study are available on reasonable request from the corresponding author.

AUTHOR CONTRIBUTIONS

YLZ and XNL—designed the research study. YLZ and XYC—performed the research. XZ and YL—provided help and advice. YLZ and XZ—analyzed the data. YLZ, XNL and YL wrote the manuscript. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was approved by the institutional Ethics Committee of the Stomatology Hospital of Zhejiang Chinese Medical University (ZCMUSSIRB-20230730004). All methods were carried out in accordance with relevant guidelines and regulations. Informed consent was obtained from all subjects and/or their legal guardian(s).

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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