scientific reports

OPEN

Perception of facial esthetics and cephalometric correlations in Class II patients: a comparison between two-phase and one-phase treatments

Wener Chen, Chaoning Zhan, Sze Man Chung & Yifan Lin✉

An effective orthodontic treatment should not only aim for satisfactory occlusal outcomes but also consider its impact on facial esthetics. The study aims to evaluate and compare the perception of profile esthetics of skeletal Class II patients treated with two orthodontic modalities: (1) Two-phase approach involving functional appliances followed by fixed appliances with premolar extractions, or (2) One-phase approach using fixed appliances with premolar extractions. Additionally, the study aims to evaluate the correlation between the perceived esthetics and the corresponding cephalometric measurements. The study included 40 skeletal Class II adolescents who underwent either two-phase (n = 20, mean age = 12.38 ± 1.18) or one-phase (n = 20, mean age = 12.53 ± 0.79) orthodontic treatments. Eighty profile silhouettes (pre- and post-treatment) were assessed by 64 raters, including 23 orthodontists, 21 general dental practitioners, and 20 laypersons. The raters used a visual analog scale (VAS) to access profiles, upper and lower lips, and chin esthetics. At pre-treatment, all three groups of raters gave significantly lower scores to the profile silhouettes of the two-phase group compared to the one-phase group ($P < 0.01$); however, after treatment, they rated the two-phase group significantly higher ($P \leq 0.001$). The two-phase group exhibited greater improvements in profile and upper and lower lip esthetics as perceived by all raters ($P \leq 0.001$). Furthermore, cephalometric results revealed greater reductions in SNA, ANB, Wits appraisal, and G′-Sn-Pog′ in the two-phase group compared to the one-phase group ($P < 0.05$). Five cephalometric parameters (SNB, SNPog, overjet, overbite, and UL-SnPog′) demonstrated significant correlations with VAS scores given by orthodontists ($P < 0.05$). In conclusion, the two-phase group showed greater subjective and objective improvements in facial esthetics than the one-phase group. Additionally, the anteroposterior mandibular position and upper lip protrusion may be the primary cephalometric parameters correlated with subjective facial profile perceptions.

Keywords Class II malocclusion, Two-phase treatment, Profile esthetics, Cephalometric correlation

Facial esthetics is crucial in our social life and interpersonal relationships. Nowadays, the objectives of orthodontic treatments have expanded beyond merely correcting dental anomalies to also achieving a harmonious facial profile[1]. Class II division 1 malocclusion is often characterized by mandibular deficiency, convex facial profile, accompanied by decreased mentolabial angle, retruded lower lip, lip incompetence, and a short chin-to-neck length[2]. These characteristics can impair an individual's facial attractiveness and may negatively affect self-esteem and quality of life. Treatment of Class II malocclusions depends on patient age and severity. However, the optimal timing for treatment of children with Class II malocclusions remains controversial. It is typically conducted in either two phases—involving functional appliances followed by fixed appliances—or in one phase camouflage orthodontic treatment[3,4]. Functional appliance treatment is usually regarded as the first phase of treatment, conducted around before the adolescent growth spurt, followed by a second phase of comprehensive treatment in the permanent dentition. In contrast, one-phase treatment involves direct comprehensive treatment without growth modification[5].

Division of Paediatric Dentistry and Orthodontics, Faculty of Dentistry, The University of Hong Kong, Orthodontics, Prince Philip Dental Hospital, No.34 Hospital Road, Sai Ying Pun, Hong Kong, SAR, China. ✉email: yflin@hku.hk

In Asian populations, Class II division 1 patients often exhibit a convex profile with protruded upper and lower lips, crowding, and proclined upper and lower incisors[6,7]. Treatment with functional appliances may not prevent the need for extraction in these cases. Frequently, premolar extractions are required following functional appliance therapy to alleviate crowding, retract the upper anterior segment, normalize the overjet, and improve the facial profile[8,9]. Patients who have undergone extractions may experience more prominent chin contours due to lip retraction, which promotes passive lip seal. This change can potentially enhance facial esthetics. Nevertheless, the potential additional benefits of functional appliances for patients who require extractions during fixed appliance treatment remain underexplored. Our previous cephalometric study assessed the treatment effects of two approaches for Class II division 1 malocclusion: functional appliances followed by fixed appliance treatment with extractions (two-phase approach) and fixed appliance treatment with extractions (one-phase approach)[10]. The results demonstrate that patients in the two-phase group experienced greater improvements in intermaxillary relationships and facial convexity compared to those in the one-phase group.

Cephalometric measurements have been extensively used in studies to analyze facial profiles[11,12]. These objective measurements aim to establish desirable normative values in an attempt to quantify facial esthetics[13]. However, due to the complexity of the human face, it is insufficient to quantify or define attractive facial features using a limited set of line or angle measurements. Consequently, it is essential for orthodontists to remain aware of both their subjective esthetic preferences and the patients' perceptions. Profile silhouettes, created from the soft tissue of lateral cephalograms, can be a subjective tool for scoring patients' profiles using a visual analog scale (VAS)[14,15]. This method has been proven to be valid and reliable, and it can eliminate the influence of other facial features—such as cosmetics, skin complexion, and hair color—on raters' evaluations[16]. Sloss et al. assessed the esthetic outcomes of Herbst and headgear treatments on facial profiles using silhouettes, revealing significant profile improvements for both appliances[17]. O'Brien et al. reported that children treated with the Twin-block appliance were perceived to be more attractive than untreated children[18]. Rocha observed similar facial attractiveness between extraction and Forsus appliance treatments in Class II malocclusions[15]. However, several studies have presented conflicting results when comparing the perceptions of orthodontists and laypeople. Some research indicates similar outcomes between orthodontists and laypeople[19,20], while others suggest disagreements[21,22]. Patients' satisfaction with their facial and dental appearance can be a predictor of their expectations regarding orthodontic treatment[23]. Therefore, it is essential to consider the opinions of various groups of raters, including laypeople—who represent the targets for orthodontic therapies—when evaluating facial esthetics.

The primary objective of this study is to evaluate the impact of two-phase versus one-phase orthodontic treatment on the facial esthetics of Class II division 1 malocclusion patients, particularly focusing on those requiring premolar extractions. We aim to clarify the differences in perceptions of treatment outcomes by various raters, including orthodontists, general dental practitioners (GDPs), and laypersons. Furthermore, we seek to establish a correlation between subjective VAS scores and objective cephalometric measurements to identify the cephalometric parameters that most significantly influence the perception of facial attractiveness.

Materials and methods

This study was approved by the Institutional Review Board of the University of Hong Kong/ Hospital Authority Hong Kong West Cluster (Reference number: UW 22-501) and was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants.

Sample size calculation

A minimum sample size of 20 patients per group was sufficient for achieving 80% power at a significance level of 0.05 to detect a difference of 2.8° in the facial convexity angle (G'-Sn-Pog'), based on a standard deviation of 3.0°[24]. Regarding the number of raters, a minimum of 16 raters per group is sufficient to achieve a statistical power of 80% and a significance level of 0.05[22].

Sample selection

The study design includes a retrospective collection of orthodontic patients, while the assessment of profile silhouettes by raters is cross-sectional. The patient sample consisted of 40 skeletal Class II patients from the Prince Philip Dental Hospital at the University of Hong Kong. The inclusion criteria were as follows: (1) Age between 10 and 15 years at the start of treatment, (2) Skeletal Class II with an ANB angle ≥ 4°, (3) Class II division 1 malocclusion with an initial overjet ≥ 6 mm, and (4) Treatment with either a functional appliance followed by fixed appliances with premolar extractions (two-phase) or direct fixed appliances with premolar extractions (one-phase). The exclusion criteria were hypodontia, cleft lip and palate, or other craniofacial abnormalities.

The two-phase group consisted of 20 patients (9 males and 11 females). The first phase involved the use of Twin Block (7 patients) or Herbst appliances (13 patients) to correct the sagittal discrepancy and achieve Class I molar relationships. In phase II, four premolars were extracted, and treatment continued with pre-adjusted fixed orthodontic appliances with 0.022" × 0.028" bracket slots. Initial alignment was achieved using nickel-titanium archwires, while retraction and space closure were performed with 0.019" × 0.025" stainless steel archwires. The one-phase group also consisted of 20 patients (9 males and 11 females). A single-phase treatment with fixed appliance therapy was performed using 0.022" × 0.028" brackets. After the extraction of four premolars, the teeth were aligned and leveled with nickel-titanium archwires, followed by retraction and space closure using 0.019" × 0.025" stainless steel archwires.

Cephalometric analysis and facial silhouettes evaluation

All lateral cephalograms were taken in the natural head position with lips at rest and teeth positioned in centric occlusion. These images were taken and assessed at baseline (T1) and at the end of the fixed appliance treatment

(T2). They were digitized using Dolphin Imaging Software version 11.5 (Dolphin Imaging and Management Solutions, Patterson Dental Supply, Inc., Chatsworth, CA, USA). A total of 14 cephalometric variables were measured; six skeletal variables (SNA, SNB, ANB, SNPog, SN/MnPl, and Wits), four dental variables (U1/MxPl, L1/MnPl, Overjet, and Overbite), and four soft tissue variables (G'-Sn-Pog', Nasolabial angle, UL-SnPog', and LL-SnPog'). In addition, the cephalograms were traced and transformed to solid black silhouettes using CorelDRAW software (version 2017, Corel Corporation, Ottawa, Canada) (Fig. 1). A questionnaire package containing the 80 silhouettes (pre- and post-treatment) of the 40 patients was created. A total of 64 raters participated in the study including the following three groups: 23 orthodontists (16 males and 7 females), 21 GDPs (10 males and 11 females) with no orthodontic specialist training; and 20 laypersons (9 males and 11 females). The raters received the package of printed questionnaires containing all 80 silhouettes from 40 patients and were given 1 min to analyze each page. A sample questionnaire is presented in Supplementary Table S1. The initial and final facial profile silhouettes of each patient were presented in pairs on the same A4-size page. For each pair of photos, the raters were asked to fill out a questionnaire consisting of five questions, each accompanied by a VAS for recording responses. In Questions 1 and 2, the facial profiles before and after treatment were assessed using a 10 cm VAS. On this scale, '0' represented the most negative outcome on the left, while '10' indicated the most positive outcome on the right. Questions 3 through 5 assessed changes in the upper lip, lower lip, and chin, respectively. Each question utilized a 15 cm VAS, with a score of '-10' on the left end indicating a highly unfavorable change, and '10' on the right end signifying a highly favorable change. The sequence of patients was randomized, and raters were blinded to patients' information, such as age, gender, and treatment methods.

Error of method

The VAS scores from three raters per group and the cephalometric measurements of five patients per group were reassessed after four weeks from the initial evaluation. The intra-rater reliability coefficient of examiners ranged from 0.892 to 0.950, indicating high reliability.

Statistical analysis

Statistical analyses were conducted using SPSS software (version 26; IBM Armonk, NY, USA). Data were tested for normality with the Shapiro–Wilk test. Parametric or nonparametric tests were applied for data following or not following normal distribution, respectively. An independent t-test or a nonparametric Wilcoxon rank sum test were used to compare the mean difference for pre-treatment, post-treatment, and treatment changes between the two-phase and the one-phase group. The correlation between cephalometric parameters and VAS

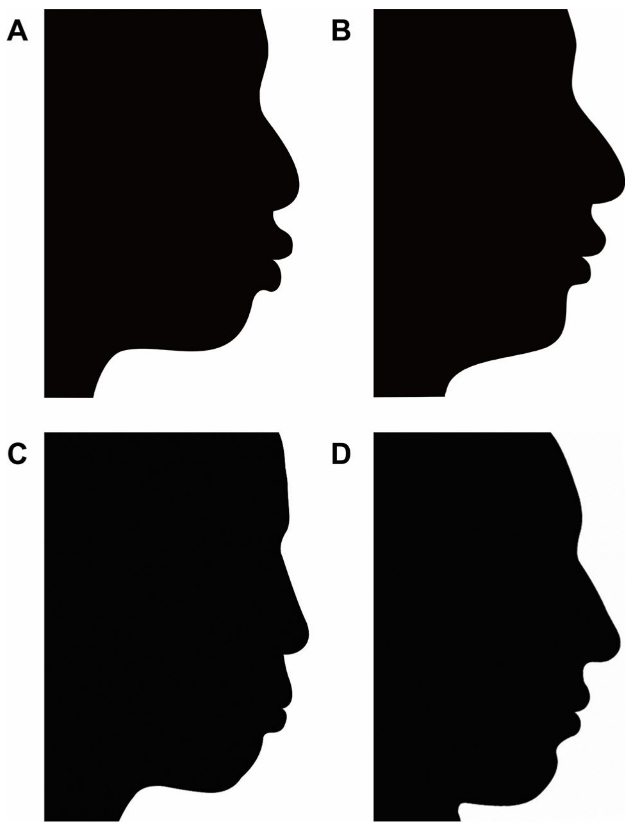

Fig. 1. Examples of silhouettes generated from patients' lateral cephalograms: (**A**) pre-treatment and (**B**) post-treatment silhouettes of a patient who underwent a two-phase treatment, and (**C**) pre-treatment and (**D**) post-treatment silhouettes for a patient who received a one-phase treatment.

scores was evaluated using Spearman rank correlation test. A statistical significance level of 0.05 was applied to all tests.

Results

Demographic characteristics of the study patients

The demographic characteristics of the two-phase group and one-phase group are shown in Table 1. No significant differences were detected between the two groups in terms of age ($P=0.630$), gender ($P=1.000$), and cervical vertebral maturation (CVM) stage at T1 ($P=0.806$). The total treatment duration was significantly longer in the two-phase group (average $=4.09\pm1.21$ years) than in the one-phase group (average $=3.02\pm0.71$ years, $P=0.002$).

Comparison of VAS scores

Comparison of profile VAS scores at pre-treatment, post-treatment and treatment changes between the one-phase and two-phase groups is shown in Table 2 and Fig. 2(A, B, and C). Comparison of VAS score changes of upper lip, lower lip and chin between the two groups is shown in Table 3 and Fig. 2(D, E, and F). At pre-treatment, all three groups of raters gave significantly higher scores to the profile silhouettes of the one-phase group than those of the two-phase group ($P<0.01$). This indicates that the two-phase group exhibited a less attractive facial profile compared to the one-phase group. However, at post-treatment, all three groups of raters provided significantly higher scores for the facial profile of the two-phase group than the one-phase group ($P\leq0.001$). When comparing the treatment changes between the one-phase and two-phase groups, the two-phase group demonstrated greater facial profile improvements as perceived by all three groups of raters ($P<0.001$). In addition, the two-phase group exhibited greater upper and lower lip improvements as perceived by all three groups of raters ($P\leq0.001$). However, no significant difference was observed in the changes in chin esthetics between the two treatment groups ($P>0.05$).

Comparison of cephalometric characteristics

Table 4 presents the comparison of pre-treatment, post-treatment, and treatment changes of cephalometric characteristics between the two treatment groups. At baseline, both groups exhibited similar skeletal patterns and dental inclinations. However, the two-phase group had a more convex soft tissue profile, with significantly greater facial convexity (G'-Sn-Pog') compared to the one-phase group ($P=0.032$). After treatment, no significant differences were observed in any parameters between the two treatment groups ($P>0.05$). When comparing the overall treatment changes between the two groups, the reduction of G'-Sn-Pog', SNA, and ANB in the two-phase group were significantly greater than those in the one-phase group by 2.31° ($P=0.042$), 1.26° ($P=0.029$), and 0.41° ($P=0.036$) respectively. A significant reduction in Wits appraisal occurred only in the two-phase group ($P=0.039$).

Correlation between VAS scores and cephalometric parameters

The correlation between VAS scores of profile change, as rated by three groups of raters, and cephalometric measurement changes are presented in Table 5. Five cephalometric measurements demonstrated a statistically significant correlation with VAS scores given by orthodontists ($P<0.05$). Specifically, the SNB angle ($r=0.323$, $P=0.042$) and SNPog angle ($r=0.428$, $P=0.006$) exhibited positive correlations with VAS scores, whereas the overjet ($r=-0.377$, $P=0.016$) and overbite ($r=-0.338$, $P=0.033$) displayed weak negative correlations with VAS scores. Furthermore, the upper lip protrusion (UL-SnPog') ($r=-0.522$, $P=0.001$) revealed a moderate negative correlation with VAS scores. No significant correlation was detected between cephalometric changes and VAS scores as rated by GDPs and laypersons ($P>0.05$).

Discussion

An effective orthodontic treatment plan should not only focus on achieving satisfactory occlusal outcomes but also consider its impact on facial esthetics[1]. Various methods can be employed to assess the esthetics of a facial profile, with the silhouette generated from cephalograms being particularly effective, as it mitigates the influence of confounding factors such as age, sex, ethnicity, hair, eyes, and makeup[16]. In this study, the VAS was

	Two-phase (n = 20)	One-phase (n = 20)	*P* value
Mean age (years)	12.38 ± 1.18	12.53 ± 0.79	0.630#
Gender			1.000##
Male	9	9	
Female	11	11	
Treatment time (years)	4.09 ± 1.21	3.02 ± 0.71	0.002#
Cervical vertebral maturation (CVM) stage			0.806##
CVM Stage 2	1	1	
CVM Stage 3	12	10	
CVM Stage 4	7	9	

Table 1. Demographic characteristics of the study patients. #Independent t-test; ##Chi-square test.

Group	Pre-treatment profile (T1)						Post-treatment profile (T2)						Profile changes (T2-T1)					
	Two-phase (n = 20)		One-phase (n = 20)				Two-phase (n = 20)		One-phase (n = 20)				Two-phase (n = 20)		One-phase (n = 20)			
	Mean	SD	Mean	SD	Diff	*P* value	Mean	SD	Mean	SD	Diff	*P* value	Mean	SD	Mean	SD	Diff	*P* value
Orthodontists (n = 23)	3.27	0.95	3.52	0.99	− 0.25	0.005	6.25	0.72	5.78	0.92	0.47	< 0.001	2.98	1.05	2.26	0.90	0.72	< 0.001
General dental practitioners (n = 21)	3.36	0.83	3.94	0.80	− 0.59	< 0.001	5.80	0.70	5.41	0.91	0.39	0.001^	2.44	0.91	1.47	1.02	0.97	< 0.001
Laypersons (n = 20)	4.00	1.21	4.63	1.14	− 0.63	< 0.001	6.40	0.82	5.93	0.95	0.47	< 0.001	2.40	1.07	1.30	0.87	1.10	< 0.001

Table 2. Comparison of pre- and post-treatment profile VAS scores and treatment changes between the two treatment groups as perceived by three groups of raters. Diff = Two-phase – One-phase. ^Wilcoxon Signed Ranks Test.

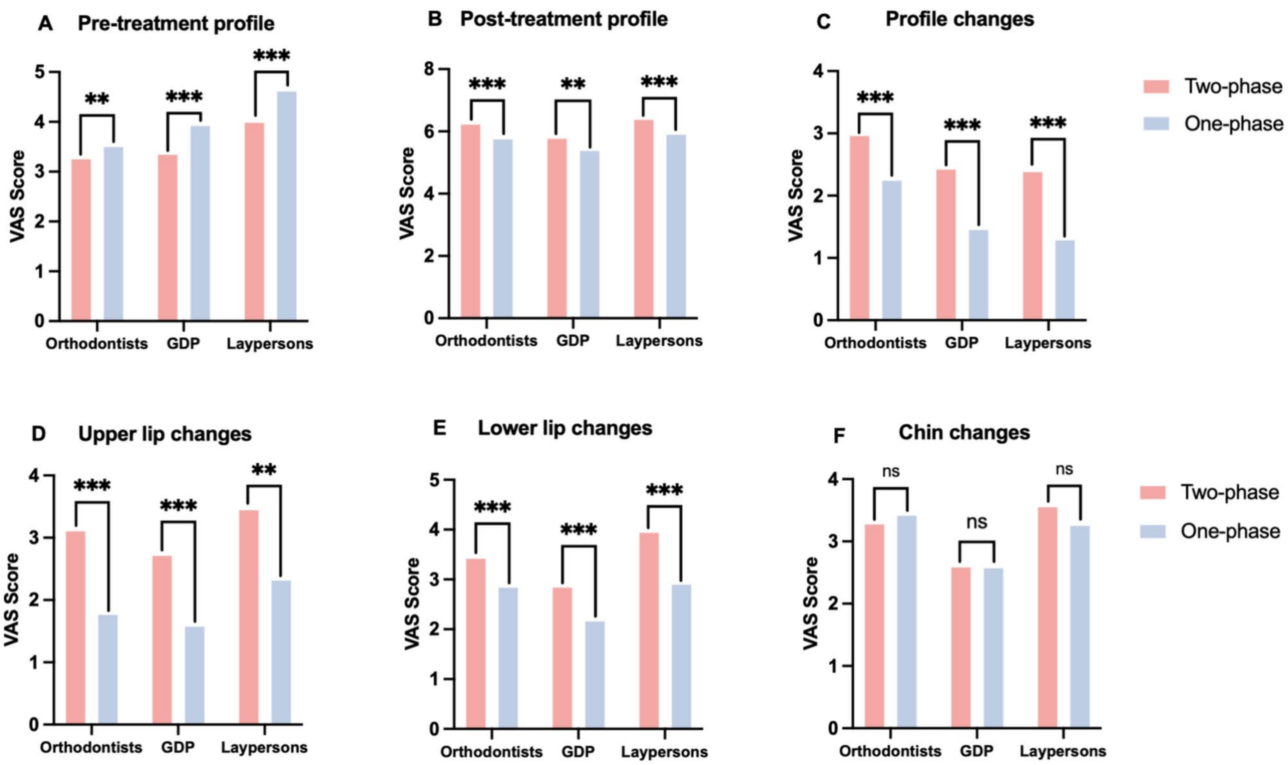

Fig. 2. Comparison of VAS scores regarding (**A**) pre-treatment profile, (**B**) post-treatment profile, (**C**) profile changes, (**D**) upper lip changes, (**E**) lower lip changes, and (**F**) chin changes between the two treatment groups, as perceived by three groups of raters. (**$P<0.01$; ***$P<0.001$; ns, not significant).

utilized to quantitatively evaluate the subjective perceptions of orthodontists, GDP, and laypersons concerning the treatment changes in both two-phase and one-phase groups, with regards to the overall profile, upper and lower lips, and chin.

The optimal timing for treating Class II malocclusions in children is still debated. Treatment can be done in two phases, starting with functional appliances before adolescence, followed by comprehensive orthodontic treatment, or in a single phase involves direct comprehensive treatment without growth modification. Evaluating the benefits of the two modalities is challenging due to variability in initial conditions, treatment responses, and the beliefs, goals, techniques, and skills of orthodontists[5]. Recently, several studies have assessed the profile changes of Class II patients with functional appliance treatment without extractions, reporting a positive impact on facial attractiveness[22,25,26]. However, in certain Class II cases with crowded and protrusive dentition, functional appliances alone cannot fully address the issues, and premolar extractions are necessary to alleviate crowding and enhance the facial profile[8,9]. Therefore, it is crucial to determine whether functional appliances provide additional benefits in improving facial attractiveness for patients requiring premolar extractions during fixed appliance treatment. This study aims to compare the facial profile esthetics of Class II patients undergoing two-phase and one-phase treatment modalities, with both groups having four premolar extractions during fixed appliance treatment.

The two treatment groups were comparable in age, gender, and skeletal Class II patterns, minimizing potential confounders. Initially, all three groups of raters gave lower VAS scores to the two-phase group, indicating a less attractive facial profile compared to the one-phase group. However, after treatment, all three groups of raters rated the two-phase group significantly higher. In contrast to VAS profile evaluations, cephalometric measurements showed no significant differences between the treatment groups pre- and post-treatment, except for increased G'-Sn-Pog' angle in the two-phase group before treatment. This discrepancy may result from the inherent differences between objective cephalometric measurements and subjective profile esthetic evaluations. Lateral cephalometry objectively assesses sagittal and vertical skeletal relationships, teeth, and soft tissue parameters using various lines and angles[13], while facial silhouette evaluation subjectively determines treatment effects on facial esthetics[14]. Consequently, the latter method might be more sensitive and detect greater facial profile changes than lateral cephalometry. Cephalometric normative data should not be regarded as treatment targets for orthodontists in every case[27], and it is unwise to base treatment decisions solely on cephalometric data without considering facial profile perceptions. Moreover, understanding the variance of cephalometric parameters is as crucial as knowing their mean values[28].

In terms of treatment changes, all three groups of raters gave higher scores to the two-phase group, indicating greater facial profile improvement from pre- to post-treatment compared to the one-phase group. In relation to cephalometric parameters, the reductions in G'-Sn-Pog' angle, SNA, ANB, and Wits appraisal were significantly

Group	Upper lip changes (T2-T1)						Lower lip changes (T2-T1)						Chin changes (T2-T1)					
	Two-phase (n = 20)		One-phase (n = 20)				Two-phase (n = 20)		One-phase (n = 20)				Two-phase (n = 20)		One-phase (n = 20)			
	Mean	SD	Mean	SD	Diff	*P* value	Mean	SD	Mean	SD	Diff	*P* value	Mean	SD	Mean	SD	Diff	*P* value
Orthodontists (n = 23)	3.12	1.12	1.78	1.06	1.34	< 0.001	3.44	1.32	2.86	1.23	0.59	< 0.001	3.29	1.22	3.43	1.11	− 0.14	0.293
General dental practitioners (n = 21)	2.73	1.59	1.59	1.67	1.14	< 0.001	2.86	1.65	2.18	1.69	0.68	< 0.001	2.60	1.68	2.59	1.70	0.01	0.963
Laypersons (n = 20)	3.46	1.77	2.33	1.92	1.13	0.001	3.96	1.75	2.92	1.93	1.05	< 0.001	3.57	2.03	3.27	2.08	0.30	0.188

Table 3. Comparison of VAS score changes of upper lip, lower lip, and chin between the two treatment groups as perceived by three groups of raters. Diff = Two-phase – One-phase.

Variables	Pre-treatment (T1)					Post-treatment (T2)					Treatment changes (T2-T1)				
	Two-phase (n = 20)		One-phase (n = 20)			Two-phase (n = 20)		One-phase (n = 20)			Two-phase (n = 20)		One-phase (n = 20)		
	Mean	SD	Mean	SD	*P* value	Mean	SD	Mean	SD	*P* value	Mean	SD	Mean	SD	*P* value
SNA (°)	81.91	2.84	81.29	3.13	0.519	80.29	3.36	80.94	2.57	0.496	− 1.62	1.85	− 0.36	1.68	0.029*
SNB (°)	76.46	2.62	75.76	3.00	0.437	76.83	3.50	76.42	2.71	0.681	0.38	2.18	0.66	1.61	0.634
ANB (°)	5.45	1.08	5.63	1.45	0.659	4.03	1.42	4.62	1.63	0.122	− 1.43	1.08	− 1.02	1.13	0.036*
SNPog (°)	76.53	3.07	75.69	3.32	0.414	77.24	3.79	76.94	3.07	0.781	0.72	2.00	1.25	2.29	0.440
SN/MnPl (°)	35.71	5.95	37.35	7.29	0.441	36.39	5.79	37.05	7.29	0.753	0.68	2.36	− 0.31	3.26	0.283
Wits (mm)	− 1.12	2.87	− 2.24	2.21	0.177	− 4.10	3.36	-2.18	4.83	0.153	− 2.98	4.40	0.06	4.56	0.039*
U1/MxPl (°)	123.77	5.65	120.32	5.86	0.119	110.09	4.99	110.98	7.14	0.650	− 13.68	8.46	− 8.35	10.24	0.080
L1/MnPl (°)	100.78	6.49	100.77	7.52	0.995	96.65	6.50	95.74	8.35	0.701	− 4.13	5.78	− 5.03	8.20	0.690
Overjet (mm)	7.88	2.13	6.51	2.70	0.082	3.22	0.66	3.35	0.74	0.234	− 4.67	2.31	− 3.16	3.04	0.061
Overbite (mm)	2.97	1.57	3.27	2.08	0.604	1.65	0.78	1.86	0.81	0.409	− 1.32	1.50	− 1.42	1.87	0.860
G'-Sn-Pog' (°)	19.20	3.94	16.73	3.01	0.032*	14.53	4.34	14.37	3.96	0.904	− 4.67	3.33	− 2.36	3.96	0.042*
Nasolabial angle (°)	90.21	12.52	95.18	9.63	0.168	96.97	8.12	96.54	12.42	0.898	6.76	13.41	1.36	9.46	0.149
UL-SnPog' (mm)	7.23	1.65	8.24	2.03	0.091	6.17	1.60	6.36	2.13	0.751	− 1.06	1.35	− 1.88	1.84	0.115
LL-SnPog' (mm)	6.38	2.97	7.05	2.40	0.441	4.35	1.56	4.45	2.33	0.868	− 2.04	2.20	− 2.60	2.52	0.458

Table 4. Comparison of the cephalometric variables at pre-treatment, post-treatment, and treatment changes between the two treatment groups. *$P < 0.05$.

Variables	Orthodontists (n = 23)		General dental practitioners (n = 21)		Laypersons (n = 20)	
	r	*P* value	r	*P* value	r	*P* value
SNA (°)	0.065	0.690	0.097	0.550	0.117	0.470
SNB (°)	0.323	0.042*	0.187	0.247	0.202	0.212
ANB (°)	− 0.289	0.070	− 0.121	0.458	− 0.098	0.549
SNPog (°)	0.428	0.006*	0.252	0.116	0.256	0.111
SN/MnPl (°)	− 0.124	0.444	− 0.089	0.586	− 0.072	0.661
Wits (mm)	− 0.125	0.442	− 0.046	0.776	− 0.075	0.645
U1/MxPl (°)	− 0.078	0.634	− 0.098	0.546	− 0.071	0.664
L1/MnPl (°)	0.055	0.735	0.155	0.339	0.146	0.368
Overjet (mm)	− 0.377	0.016*	− 0.290	0.070	− 0.233	0.148
Overbite (mm)	− 0.338	0.033*	− 0.090	0.580	− 0.160	0.323
G'-Sn-Pog' (°)	− 0.028	0.866	− 0.092	0.573	− 0.075	0.646
Nasolabial angle (°)	0.166	0.306	0.060	0.715	0.041	0.801
UL-SnPog' (mm)	− 0.522	0.001*	− 0.253	0.115	− 0.258	0.108
LL-SnPog' (mm)	− 0.236	0.142	− 0.086	0.598	− 0.047	0.772

Table 5. Correlation between VAS scores given by three groups of raters and cephalometric changes. $^*P < 0.05$.

greater in the two-phase group than in the one-phase group. This suggests that the functional appliance notably enhanced skeletal and soft tissue during the treatment process by inhibiting maxillary growth, promoting mandibular growth, improving intermaxillary relationship, and resulting in better facial convexity[29]. Comparing treatment changes in upper and lower lips between the two groups, the VAS changes in the two-phase group were significantly greater than those in the one-phase group. Lip protrusion is a crucial soft tissue element in facial esthetics and plays a significant role in achieving a harmonious profile[30]. The combination of maxillary growth inhibition from the functional appliance and the retraction of upper and lower incisors due to premolar extractions may explain the greater lip change perception in the two-phase group.

It is important to note that treatment duration may also influence the results. Two-phase treatment involving functional appliances followed by fixed appliances typically takes longer than one-phase fixed appliance approach[31,32]. In this study, the treatment duration of the two-phase approach (average = 4.09 ± 1.21 years) was significantly longer than that of the one-phase approach (average = 3.02 ± 0.71 years). As treatment duration increases, the impact of facial growth on treatment outcomes in the two-phase group becomes more significant, affecting final facial contours alongside orthodontic treatment. The growth process can potentially impact the entire soft-tissue profile, including nose, lips, and chin[33], often leading to a noticeable reduction in facial convexity[34]. Therefore, it is essential to take into account the effects of growth while assessing treatment outcomes.

The correlation between objective cephalometric changes and subjective VAS changes of facial attractiveness was also examined. Among 14 cephalometric measurements, five parameters—SNB, SNPog, overjet, overbite, and UL-SnPog'—exhibited a significant correlation with VAS scores. This suggests that the anteroposterior dimension, rather than the vertical dimension, played a more prominent role in the subjective evaluation of facial esthetics. As a result, a relative improvement in the anteroposterior relationship was perceived as more attractive. Similarly, a study by Kannan et al. reported that the ANB angle had a significant negative correlation with the VAS scores in patients treated with Herbst appliances, as rated by orthodontists[22]. Regarding the vertical dimension, hyperdivergent facial patterns were perceived as less attractive[35,36]; however, no significant correlation was found between the mandibular plane angle and VAS scores in the current study. This might be because the mandibular plane cannot be easily identified on the silhouettes generated from cephalograms. Furthermore, lip position is one of the most crucial factors in determining facial esthetics[30,37]. Our findings revealed that upper lip protrusion was significantly correlated with VAS scores, implying that a reduction in upper lip protrusion leads to an esthetic improvement, which concurs with Mazz et al.[38]. Notably, all significant correlations were identified by orthodontists, which might be attributed to their professional knowledge of cephalometric measurements and facial esthetics.

This study has limitations. The lack of an untreated control group made it impossible to quantify the natural growth of the mandible. However, by recruiting patients with similar ages and CVM stages for both treatment groups, the confounding factors of natural growth were minimized. Another limitation is the use of two-dimensional (2D) facial profiles, as facial esthetics encompasses more than a simple 2D representation of silhouettes and soft tissue measurements. To determine the factors associated with optimal facial attractiveness outcomes, it is better to employ three-dimensional cephalometrics and facial photos.

Conclusions

Both the two-phase and one-phase treatment positively impacted facial profile esthetics, with the two-phase group showing greater subjective and objective improvement in facial profile than the one-phase group. Additionally, the anteroposterior mandibular position and upper lip protrusion may be the primary cephalometric parameters correlated with subjective facial profile perceptions.

Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Received: 22 March 2024; Accepted: 4 November 2024
Published online: 08 November 2024

References

1. Little, A. C., Jones, B. C. & DeBruine, L. M. Facial attractiveness: evolutionary based research. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* **366**, 1638–1659 (2011).
2. McNamara, J. A. Jr. Components of Class II malocclusion in children 8–10 years of age. *Angle Orthod.* **51**, 177–202 (1981).
3. Koretsi, V., Zymperdikas, V. F., Papageorgiou, S. N. & Papadopoulos, M. A. Treatment effects of removable functional appliances in patients with Class II malocclusion: A systematic review and meta-analysis. *Eur. J. Orthod.* **37**, 418–434 (2015).
4. George, S. M., Campbell, P. M., Tadlock, L. P., Schneiderman, E. & Buschang, P. H. Keys to Class II correction: A comparison of 2 extraction protocols. *Am. J. Orthod. Dentofacial Orthop.* **159**, 333–342 (2021).
5. Tulloch, J. C., Proffit, W. R. & Phillips, C. Outcomes in a 2-phase randomized clinical trial of early Class II treatment. *Am. J. Orthod. Dentofacial Orthop.* **125**, 657–667 (2004).
6. Soh, J., Sandham, A. & Chan, Y. H. Occlusal status in Asian male adults: Prevalence and ethnic variation. *Angle Orthod.* **75**, 814–820 (2005).
7. Gu, Y., McNamara, J. A. Jr., Sigler, L. M. & Baccetti, T. Comparison of craniofacial characteristics of typical Chinese and Caucasian young adults. *Eur. J. Orthod.* **33**, 205–211 (2011).
8. Lv, Y., Yan, B. & Wang, L. Two-phase treatment of skeletal class II malocclusion with the combination of the twin-block appliance and high-pull headgear. *Am. J. Orthod. Dentofacial Orthop.* **142**, 246–255 (2012).
9. Tadic, N. & Woods, M. Contemporary Class II orthodontic and orthopaedic treatment: A review. *Aust. Dent. J.* **52**, 168–174 (2007).
10. Wong, K. F., Chen, W., Ren, J., Yang, Y. & Lin, Y. Effects of Two-phase treatment with functional appliances followed by extraction versus one-phase treatment with extraction in Class II growing patients: A case-control study. *J. Clin. Med.* **11**, 7428 (2022).
11. O'Brien, K. et al. Effectiveness of treatment for Class II malocclusion with the Herbst or twin-block appliances: A randomized, controlled trial. *Am. J. Orthod. Dentofacial Orthop.* **124**, 128–137 (2003).
12. Hemmatpour, S., Mokhtar, A. & Rakhshan, V. Effects of Sabbagh Universal Spring 2 fixed functional appliance on Class II/1 patients at their postpubertal-peak growth period compared with the extraction method : A randomized clinical trial. *J. Orofac. Orthop.* **78**, 41–51 (2017).
13. Dinçer, B., Yetkiner, E., Aras, I., Attin, T. & Attin, R. Influence of lateral cephalometric radiographs on extraction decision in skeletal Class I patients. *Head Face Med.* **9**, 1–7 (2013).
14. Salehi, P., Azadeh, N., Beigi, N. & Farzin, M. Influence of age on perception of best esthetical profile. *J. Dent.* **20**, 16 (2019).
15. Rocha, A. D. et al. Esthetic perception of facial profile changes after extraction and nonextraction Class II treatment. *Braz. Oral Res.* **34**, e003 (2020).
16. Hockley, A., Weinstein, M., Borislow, A. J. & Braitman, L. E. Photos vs silhouettes for evaluation of African American profile esthetics. *Am. J. Orthod. Dentofacial Orthop.* **141**, 161–168 (2012).
17. Sloss, E. A. et al. Comparison of soft-tissue profiles after treatment with headgear or Herbst appliance. *Am. J. Orthod. Dentofacial Orthop.* **133**, 509–514 (2008).
18. O'Brien, K. et al. Early treatment for Class II Division 1 malocclusion with the Twin-block appliance: A multi-center, randomized, controlled trial. *Am. J. Orthod. Dentofacial Orthop.* **135**, 573–579 (2009).
19. Maple, J. R., Vig, K. W., Beck, F. M., Larsen, P. E. & Shanker, S. A comparison of providers' and consumers' perceptions of facial-profile attractiveness. *Am. J. Orthod. Dentofacial Orthop.* **128**, 690–696 (2005).
20. Mergen, J. L. et al. Treatment outcomes of growing Class II Division 1 patients with varying degrees of anteroposterior and vertical dysplasias, Part 2. Profile silhouette evaluation. *Am. J. Orthod. Dentofacial Orthop.* **125**, 457–462 (2004).
21. Pozza, O. A. et al. Attractiveness of the facial profile: Comparison of Class II patients treated with Twin Force® or intermaxillary elastics. *Dental Press J. Orthod.* **26**, e212014 (2021).
22. Kannan, A. & Padmanabhan, S. Comparative evaluation of soft tissue profile changes with herbst and twin block appliances in Class II malocclusion patients: A perception study. *Turk. J. Orthod.* **35**, 173 (2022).
23. Kiekens, R. M., Maltha, J. C., Hof van't, M. A., Straatman, H. & Kuijpers-Jagtman, A. M. Panel perception of change in facial aesthetics following orthodontic treatment in adolescents. *Eur. J. Orthod.* **30**, 141–146 (2008).
24. Gazzani, F., Franchi, L., Lione, R., Cozza, P. & Pavoni, C. Soft tissue evaluation of functional therapy in growing patients with Class II malocclusion: A long-term study. *Eur. J. Orthod.* **44**, 37–42 (2022).
25. Santori, F. et al. Effect of Class II functional treatment on facial attractiveness, as perceived by professionals and laypeople. *Sci. Rep.* **11**, 13989 (2021).
26. Paduano, S., Rongo, R., Bucci, R., Carvelli, G. & Cioffi, I. Impact of functional orthodontic treatment on facial attractiveness of children with Class II division 1 malocclusion. *Eur. J. Orthod.* **42**, 144–150 (2020).
27. Chew, M. T., Sandham, A., Soh, J. & Wong, H. B. Outcome of orthognathic surgery in Chinese patients: A subjective and objective evaluation. *Angle Orthod.* **77**, 845–850 (2007).
28. Huang, Y.-P. & Li, W.-R. Correlation between objective and subjective evaluation of profile in bimaxillary protrusion patients after orthodontic treatment. *Angle Orthod.* **85**, 690–698 (2015).
29. Quintão, C., Helena, I., Brunharo, V. P., Menezes, R. C. & Almeida, M. A. Soft tissue facial profile changes following functional appliance therapy. *Eur. J. Orthod.* **28**, 35–41 (2006).
30. Hayashida, H., Ioi, H., Nakata, S., Takahashi, I. & Counts, A. L. Effects of retraction of anterior teeth and initial soft tissue variables on lip changes in Japanese adults. *Eur. J. Orthod.* **33**, 419–426 (2011).
31. Popowich, K., Nebbe, B., Heo, G., Glover, K. E. & Major, P. W. Predictors for Class II treatment duration. *Am. J. Orthod. Dentofacial Orthop.* **127**, 293–300 (2005).
32. Mir, C. F. One-phase or two-phase orthodontic treatment?. *Evid. Based Dent.* **17**, 107–108 (2016).
33. Buschang, P. H., Roldan, S. I. & Tadlock, L. P. *Seminars in orthodontics* 321–335 (Elsevier, USA, 2017).
34. Hoffelder, L. B., de Lima, E. M. S., Martinelli, F. L. & Bolognese, A. M. Soft-tissue changes during facial growth in skeletal Class II individuals. *Am. J. Orthod. Dentofacial Orthop.* **131**, 490–495 (2007).
35. Oh, H. S. et al. Correlations between cephalometric and photographic measurements of facial attractiveness in Chinese and US patients after orthodontic treatment. *Am. J. Orthod. Dentofacial Orthop.* **136**, 762 (2009).
36. Buschang, P. H., Jacob, H. & Carrillo, R. *Seminars in Orthodontics* 212–226 (Elsevier, USA, 2013).
37. Evrard, A., Tepedino, M., Cattaneo, P. M. & Cornelis, M. A. Which factors influence orthodontists in their decision to extract? A questionnaire survey. *J. Clin. Exp. Dent.* **11**, e432 (2019).
38. Maaz, M. & Fida, M. Dental, skeletal, and soft-tissue changes in adult orthodontic patients treated with premolar extraction and nonextraction: A cross-sectional study. *Am. J. Orthod. Dentofacial Orthop.* **162**, 360–366 (2022).

Author contributions
W.C. acquired and interpreted the data and drafted the manuscript. C.Z. acquired and interpreted the data. S.M.C. acquired the data. Y.L. designed the study, acquired and interpreted the data, and critically revised the manuscript. All authors read and approved the final manuscript.

Declarations

Competing interests
The authors declare no competing interests.

Additional information
Supplementary Information The online version contains supplementary material available at https://doi.org/10.1038/s41598-024-78740-5.

Correspondence and requests for materials should be addressed to Y.L.

Reprints and permissions information is available at www.nature.com/reprints.