Cephalometric Norms for Chinese Individuals Based on Expert Consensus Evaluation of Lateral Cephalometric Radiographs

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Objective: *To establish cephalometric normative reference values based on the subjective consensus of Chinese orthodontic experts regarding the evaluation of lateral cephalometric radiographs.*

Methods: *This study included 120 patients in the permanent dentition stage who visited the Department of Orthodontics at Peking University School and Hospital of Stomatology between 2022 and 2025. The participants were divided into two groups: an adolescent group (n = 60, aged 14.40 ± 1.70 years, 30 boys and 30 girls) and an adult group (n = 60, aged 24.33 ± 5.65 years, 30 men and 30 women). Lateral cephalometric radiographs were analysed by two PhD students and one postdoctoral researcher from the Department of Orthodontics. Through statistical analysis, cephalometric normative values were established for Tweed, Downs, Steiner and Peking University analysis methods as well as for soft tissue measurements, and comparisons were made between the two age groups.*

Results: *A reference standard for cephalometric normative values was developed, reflecting the consensus of Chinese orthodontic experts in assessing profile harmony. Significant differences (P < 0.05) were identified between the adolescent and adult groups in the normative values of FMA (MPA), GoGN/SN, SE and G-Sn-Pos.*

Conclusion: *Expert consensus evaluation of lateral cephalometric radiographs provides a more objective basis for identifying harmonious samples. This enables the derivation of more accurate cephalometric normative values for sagittal skeletal measurements and soft tissue parameters.*

Keywords: *cephalometric analysis, expert consensus, normative values, profile harmony*

Chin J Dent Res 2026;29(2):151–161; doi: 10.3290/j.cjdr.b7044059

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This work was supported by the National Natural Science Foundation of China (no. 82071172), Beijing Natural Science Foundation (L242037), Beijing Research Ward Excellence Programme (BRWEP2024W194100100) and Clinical Research Foundation of Peking University School and Hospital of Stomatology (PKUSS-2023CRF301).

Introduction

Since the introduction of cephalometric radiography techniques in 1931, researchers from various countries and regions have measured cephalometric norms for their respective populations and established reference values tailored to different ethnic groups.[1-15] However, with advancements in research methodologies and the increasing precision required by clinical practices, earlier studies have revealed significant limitations in several areas, including sample size, selection criteria, representativeness and applicability of results.

Insufficient sample size and limited age range

Earlier studies frequently suffered from small sample sizes and narrow age ranges. For instance, the analysis conducted by Downs[1] included only 20 White adolescents aged 12 to 17 years, with no adult representation. Similarly, the Wits analysis conducted by Jacobson[2] was based on just 21 White men and 25 White women, excluding adolescents. Moreover, the original studies on Steiner[3] and Tweed[4] analyses did not explicitly report sample size, age range or racial composition, relying instead on clinical observations. These deficiencies resulted in a lack of transparency in deriving normative values, insufficient validation in larger samples and limited representativeness. Additionally, the absence of longitudinal growth data hindered the ability to capture developmental trends of the maxilla and mandible, which are critical for devising accurate orthodontic treatment plans.

Inconsistencies in measurement standards and technical limitations

Due to the limitations of mid-20th-century X-ray imaging and the clarity of lateral cephalometric radiographs, earlier studies showed inconsistencies in defining key landmarks. For example, the FH plane in the normative values set out by Downs,[1] Fu and Mao[5] and Fu[6] and Yu and Huang[7] relied on the mechanical porion, which does not accurately represent the anatomical porion. Steiner[3] also noted that head movement could distort the soft tissue around the ear, causing the porion landmark to shift by as much as 7 mm.

Insufficient consideration of profile harmony

Most studies establishing cephalometric norms focused solely on dental alignment as the inclusion criterion, with little attention paid to facial profile harmony. Examples include the Downs[1] analysis, Wits analysis[2] and normative values set out by Fu and Mao[5] and Fu[6] for Chinese individuals. The FMA classification proposed by Tweed[4] entirely disregarded soft tissue compensation. Although the soft tissue norms for Chinese individuals set out by Yu and Huang[7] included profile harmony as a criterion, the selection process relied solely on the researchers' subjective judgment. Such subjectivity is inherently prone to bias, and the persuasive power of selecting harmonious samples based on a single individual's perspective is limited.

From a biological perspective, the evolution of the human craniofacial complex requires simultaneous upright positioning of teeth and flattening of the facial profile.[4] From a mechanical standpoint, the stability of dentition depends on a balance between alveolar bone support and the pressures exerted by the lips and tongue. Solely prioritising dental alignment often leads to unstable treatment outcomes and higher relapse rates. Clinically, patients' growing demand for aesthetic outcomes has raised the standards for orthodontic treatment. Functional treatments that disregard aesthetics (for example aligned teeth with a protrusive profile) or aesthetic treatments that neglect function (for example a straight profile with edge-to-edge bite) fall short of the ideal standards envisioned by orthodontic experts. Thus, cephalometric norms must be further refined to account for both dental alignment and profile harmony.[16]

In summary, early studies suffered from three major limitations: insufficient sample representativeness, technical constraints in measurement and a lack of emphasis on profile harmony. These challenges have limited the applicability of earlier normative values in contemporary clinical practice. This study seeks to address these gaps by employing a newly established expert consensus-based evaluation standard for lateral cephalometric radiographs (CHSA Project ID: T/CHSA 100-2025) to objectively identify harmonious and normatively aligned samples. The resulting cephalometric reference values aim to provide an updated diagnostic standard for the Chinese population.

Materials and methods

This cross-sectional study adhered to the principles of the Declaration of Helsinki and received approval from the Ethics Committee of Peking University School and Hospital of Stomatology (approval no. PKUSSIRB-2024104181).

Establishment of the expert consensus evaluation standard for lateral cephalometric radiographs

In a preliminary study conducted by the research team, 216 post-treatment cases were randomly selected from patients treated at Peking University School and Hospital of Stomatology between 2016 and 2021.[17] Sixty-five Chinese orthodontic experts subjectively ranked and classified the lateral cephalometric radiographs into five categories: excellent, good, average, poor and very poor. Examined by Kendall's coefficient of concordance analysis, the experts demonstrated a moderate level of agreement in their ranking evaluations and rating evaluations of lateral cephalometric radiographs, with values of 0.496 and 0.502, respectively ($P < 0.05$). Two PhD students (HWZ and CDM) and one postdoctoral researcher from the Department of Orthodontics performed cephalometric analyses on these lateral cephalometric radiographs. Statistical analysis identified objective

Table 1 Multiple regression analysis of expert subjective evaluations and objective cephalometric parameters.

Variable	Unstandardised coefficient		Standardised coefficient	t value	*P* value	Confidence interval for B	
	B	Standard error				Lower bound	Upper bound
Constant	1.626	0.110	NA	14.777	< 0.001	1.409	1.843
UL-GPos	0.321	0.080	0.282	4.021	< 0.001	0.164	0.478
Sn-GPos	0.041	0.092	0.034	1.444	0.049	0.041	0.222
Bs-GPos	0.082	0.066	0.069	1.241	0.016	0.048	0.212
L1/MP	0.168	0.043	0.202	3.913	< 0.001	0.083	0.253
U1/PP	0.173	0.044	0.220	3.934	< 0.001	0.086	0.260
ANB	0.119	0.058	0.144	2.051	0.042	0.005	0.232
MPA	0.212	0.058	0.190	4.021	< 0.001	0.097	0.327
Pog-NB	0.218	0.051	0.237	4.319	< 0.001	0.119	0.318

cephalometric parameters associated with the experts' subjective evaluations. Multiple regression analysis was performed to determine the weight of each parameter (Table 1) (R = 0.71).

Based on these results, thresholds for objectively grading harmony of cephalometric radiographs were established. Given the moderate consistency among the 65 experts in their subjective evaluations, the grading results from more than 50% of experts were adopted as the subjective evaluation grade for each sample. By combining expert opinions and their assigned grades, the subjective threshold for determining harmonious versus disharmonious cephalometric radiographs was set at 3.63 (the boundary between average and poor).

Using receiver operating characteristic (ROC) curve analysis, the objective threshold was determined to be 3.30, where the sum of sensitivity and specificity was maximised (Table 2 and Fig 1). This indicates that cephalometric radiographs with an objective score < 3.30 are considered harmonious.[17]

Sample collection and inclusion/exclusion criteria

A total of 120 patients in the permanent dentition stage prior to treatment were included in this study. These patients were recruited from the Department of Orthodontics at Peking University School and Hospital of Stomatology between 2022 and 2025. Participants were divided into two groups: the adolescent group (n = 60, age range 10 to 17 years [mean 14.40 ± 1.70 years], 30 boys and 30 girls) and the adult group (n = 60, age range 18 to 41 years [mean 24.33 ± 5.65 years], 30 men and 30 women). The inclusion criteria were as follows:

- complete pre-treatment clinical records (case history, dental models, facial photographs and lateral cephalometric radiographs);
- Han Chinese ethnicity;
- permanent dentition stage;
- full dentition without missing teeth;
- mild crowding (≤ Class I crowding);
- neutral occlusal relationships with normal horizontal and vertical overlap;
- straight facial profile with an expert consensus evaluation score < 3.30 (harmonious cephalometric radiograph).

The exclusion criteria were as follows:

- presence of supernumerary or malformed teeth;
- severe craniofacial anomalies (e.g., cleft lip and palate);
- history of orthodontic treatment.

Cephalometric measurements

Cephalometric measurements were taken by HWZ and CDM and one postdoctoral researcher trained in professional cephalometric analysis. The evaluations were performed using an online cephalometric analysis platform developed in collaboration with Zhejiang Aishinye Medical Technology (Zhejiang, China). A total of 29 soft and hard tissue parameters were measured across the Tweed, Downs, Steiner, Wits and Peking University analysis methods and soft tissue analyses (Table 3).

Statistical methods

Statistical analyses were conducted using SPSS 27.0 software (IBM, Armonk, NY, USA). The intraclass correlation coefficient (ICC) was employed to assess both intra and inter-observer reliability among the three evaluators. A Shapiro-Wilk test was used to confirm that all measurement results followed a normal distribution, while a Levene test verified the homogeneity of variance. For

Table 2 ROC curve analysis for cephalometric radiograph harmony thresholds (sensitivity, specificity and area under the curve [AUC]).

Harmony/disharmony	Threshold	Sensitivity	Specificity	AUC	Standard error	***P*** **value**
Lateral cephalometric radiographs	3.30	0.844	0.779	0.844	0.031	< 0.001

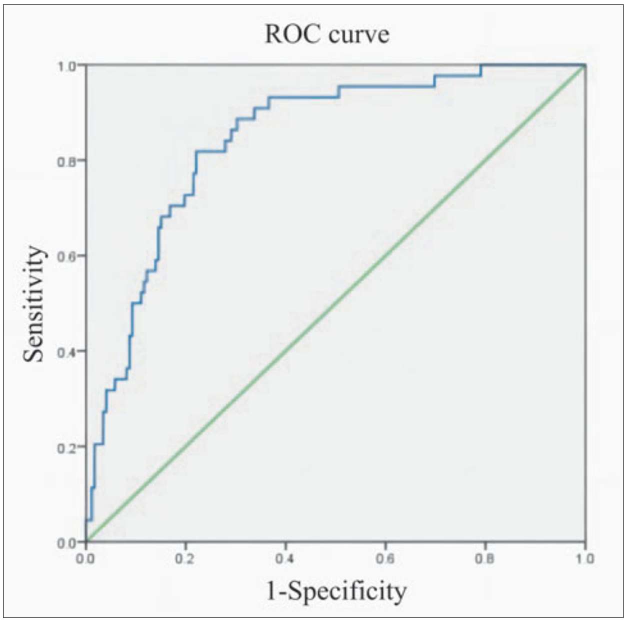

Fig 1 ROC curve analysis for determining the objective threshold of cephalometric radiograph harmony.

normally distributed data with equal variance, descriptive statistics were expressed as mean ± standard deviation ($\bar{x} \pm s$). An independent samples *t* test was applied to compare cephalometric normative values between different age groups. A significance level of two-sided $\alpha = 0.05$ was used for all analyses.

Results

Consistency of objective measurements

The ICC among the three cephalometric researchers was 0.923, indicating strong inter-observer reliability. The intra-observer ICC values ranged from 0.958 to 0.974, demonstrating excellent consistency within individual evaluators.

Cephalometric measurements and intergroup differences by age

A comparison of cephalometric measurements between the adolescent and adult groups is presented in Table 4 and Fig 2 and 3. Statistically significant differences ($P < 0.05$) were observed in hard tissue measurements, namely FMA (MPA), GoGn/SN and SE, and soft tissue measurements, namely G-Sn-Pos. The adult group exhibited a smaller mandibular plane angle compared to the adolescent group. Posterior displacement of the condyle was observed in the adult group. The soft tissue convexity (G-Sn-Pos) was also reduced in the adult group.

Discussion

Comparison with previously reported normative values for Chinese populations

The measurement values of 29 cephalometric parameters in this study were compared with previously reported normative values for Chinese populations. The measurements obtained in this study differ from those reported by Wang et al[18] for a Chinese population with aesthetic facial appearance in cephalometric analysis. Two factors may account for this discrepancy. First, the samples in the study by Wang et al[18] were exclusively derived from art troupes, flight attendants or honour guards, representing an aesthetically pleasing population, which differs from the general population sample with harmonious profiles in this study. Second, the normative cephalometric values established by Wang et al[18] were developed for orthognathic surgery, with an age range of only 18 to 29 years, consisting entirely of adults and lacking samples from adolescents.

Furthermore, significant differences were observed in FMA (MPA), FMIA, NP/FH, Y-axis and OP/FH measurements when compared with the findings of Fu and Mao,[5] Fu[6] and Yu and Huang.[7] These discrepancies can be attributed to differences in the definition of the ear point: Fu and Mao,[5] Fu[6] and Yu and Huang[7] used the mechanical ear point, whereas the present study employed the anatomical ear point. Although the mechanical ear point is easier to identify on lateral cephalometric radiographs, it is subject to significant individual variation, leading to reduced accuracy compared to the anatomical ear point.

Table 3 Definitions of cephalometric measurements.

Measurement	Description
FMA (MPA), degrees	The angle between the mandibular plane and the Frankfort horizontal plane, representing the inclination of the mandibular plane
FMIA, degrees	The angle between the long axis of the mandibular central incisor and the Frankfort horizontal plane, indicating the inclination of the mandibular anterior teeth
IMPA (L1/MP), degrees	The angle between the long axis of the mandibular central incisor and the mandibular plane, reflecting the inclination of the mandibular anterior teeth relative to the mandible
NP/FH, degrees	The posterior inferior angle between the facial plane and the Frankfort horizontal plane, representing mandibular retrusion
NA/PA, degrees	The angle between the Nasion-Point A line and the Pogonion-Point A line, reflecting the relationship between the maxilla and the overall lateral profile
NP/AB, degrees	The superior angle between the facial plane and the alveolar bone plane, indicating the positional relationship between the maxillary and mandibular alveolar bases
Y-axis, degrees	The inferior anterior angle between the Y-axis and the Frankfort horizontal plane, representing the direction of facial growth
OP/FH, degrees	The angle between the occlusal plane and the Frankfort horizontal plane, reflecting the inclination of the occlusal plane
U1/L1, degrees	The posterior angle formed by the long axes of the maxillary and mandibular central incisors, representing their inclination and protrusion relationship
L1/OP, degrees	The inferior anterior angle between the long axis of the mandibular central incisor and the occlusal plane, reflecting the relationship between the mandibular incisors and the functional plane
UI-AP, mm	The perpendicular distance from the incisal edge of the maxillary central incisor to the A-Pog line, representing the protrusion of the maxillary central incisors
SNA, degrees	The angle formed by the sella, nasion and point A, indicating the anteroposterior position of the maxillary base relative to the craniofacial skeleton
SNB, degrees	The angle formed by the sella, nasion and point B, representing the anteroposterior position of the mandibular base relative to the craniofacial skeleton
ANB, degrees	The angle between point A, the nasion and point B, representing the anteroposterior relationship between the maxillary and mandibular bases
SND, degrees	The angle formed by the sella, nasion and the midpoint of the bony chin, reflecting the anteroposterior position of the mandible relative to the cranium
U1/NA, degrees	The superior angle between the long axis of the upper central incisor and the nasion-point A line, representing the inclination of the maxillary central incisors
U1-NA, mm	The perpendicular distance from the incisal edge of the maxillary central incisor to the nasion-point A line, representing the protrusion of the maxillary incisors
L1/NB, degrees	The inferior angle between the long axis of the mandibular central incisor and the nasion-point B line, representing the inclination of the mandibular central incisors
L1-NB, mm	The perpendicular distance from the incisal edge of the mandibular central incisor to the nasion-point B line, reflecting the protrusion of the mandibular incisors
Po-NB, mm	The perpendicular distance from the pogonion to the nasion-point B line, representing the prominence of the bony chin
OP/SN, degrees	The angle between the occlusal plane and the anterior cranial base plane, representing the inclination of the occlusal plane
GoGn/SN, degrees	The angle between the mandibular plane and the anterior cranial base plane, reflecting the slope of the mandibular plane and facial height
SL, mm	The distance from the pogonion perpendicular to the anterior cranial base plane to the sella, indicating the anteroposterior position of the mandible relative to the sella
SE, mm	The distance from the most posterior point of the condyle perpendicular to the anterior cranial base plane to the sella, reflecting the anteroposterior position of the mandibular condyle relative to the sella
U1/SN, degrees	The posterior inferior angle between the long axis of the maxillary central incisor and the anterior cranial base plane, reflecting the inclination of the maxillary incisors relative to the cranial base
Wits, mm	The linear distance between the perpendicular projection of point A and point B onto the functional occlusal plane, indicating the sagittal relationship between the maxilla and mandible
G-Sn-Pos, degrees	The posterior angle between the glabella-subnasale line and the subnasale-soft tissue pogonion line, representing profile convexity
UL-E, mm	The distance from the most anterior point of the upper lip to the aesthetic plane (a line connecting the tip of the nose to the soft tissue pogonion), representing upper lip protrusion
LL-E, mm	The distance from the most anterior point of the lower lip to the aesthetic plane, representing lower lip protrusion

Table 4 Comparison of cephalometric measurements between adolescent and adult groups (x̄ ± s)

Parameter	Adolescent group	Adult group	***T*** value	***P*** value (comparison between adolescent and adult)
FMA (MPA), degrees	26.1 ± 5.5	23.7 ± 4.3	−2.714	< 0.01
FMIA, degrees	58.9 ± 7.5	60.2 ± 7.3	0.970	0.334
IMPA (L1/MP), degrees	96.2 ± 7.3	95.7 ± 6.8	−0.375	0.709
NP/FH, degrees	88.3 ± 2.8	89.0 ± 3.0	1.244	0.216
NA/PA, degrees	4.1 ± 4.7	3.8 ± 4.6	−0.125	0.900
NP/AB, degrees	−4.8 ± 2.6	−4.6 ± 2.9	0.366	0.715
Y-axis, degrees	60.8 ± 2.6	61.1 ± 3.0	0.593	0.555
OP/FH, degrees	7.9 ± 3.8	7.0 ± 4.3	−1.186	0.238
U1/L1, degrees	123.2 ± 10.2	123.2 ± 8.6	0.058	0.981
L1/OP, degrees	113.0 ± 7.1	112.8 ± 2.1	−0.216	0.830
UI-AP, mm	7.4 ± 2.4	7.2 ± 2.2	−0.514	0.608
SNA, degrees	82.7 ± 3.3	83.0 ± 3.7	0.184	0.854
SNB, degrees	80.1 ± 3.1	81.0 ± 4.0	0.187	0.852
ANB, degrees	2.6 ± 1.5	2.1 ± 1.4	−0.148	0.882
SND, degrees	77.5 ± 3.0	77.8 ± 4.3	0.152	0.879
U1/NA, degrees	22.1 ± 5.9	22.5 ± 6.3	0.241	0.810
U1-NA, mm	5.7 ± 2.5	5.9 ± 2.1	0.622	0.535
L1/NB, degrees	28.7 ± 6.7	28.1 ± 6.0	−0.534	0.594
L1-NB, mm	6.5 ± 2.6	6.6 ± 2.4	0.231	0.817
Po-NB, mm	1.5 ± 1.3	1.7 ± 1.1	0.062	0.950
OP/SN, degrees	16.0 ± 6.6	15.2 ± 5.3	−0.785	0.434
GoGn/SN, degrees	33.0 ± 6.1	31.6 ± 4.8	−2.502	< 0.05
SL, mm	46.8 ± 5.7	46.9 ± 8.8	0.090	0.929
SE, mm	18.6 ± 3.3	20.4 ± 3.3	2.975	< 0.01
U1/SN, degrees	105.0 ± 6.6	105.9 ± 7.5	0.629	0.531
Wits, mm	−1.2 ± 3.0	−1.3 ± 3.1	0.180	0.858
G-Sn-Pos, degrees	169.3 ± 4.4	171.4 ± 5.6	2.225	< 0.05
UL-,E mm	−1.1 ± 1.5	−1.5 ± 2.0	−1.202	0.232
LL-E, mm	-0.1 ± 1.7	−0.2 ± 2.2	−0.755	0.452

Skeletal hard tissue measurements

For parameters reflecting the sagittal positional relationships of the maxilla and mandible, significant differences were observed in the NA/PA values for both adolescents and adults, as well as in the ANB values for adolescents, compared with the findings of Fu and Mao[5] and Fu[6] (Table 5). The measurement values in the present study were lower than those reported by Fu,[6] indicating a more posterior position of the maxilla relative to the mandible and a reduction in skeletal convexity. There are three possible explanations for these differences. The first of these is developmental changes. Skeletal convexity decreases with growth and development. The sample populations in the study conducted by Fu,[6] including both adolescents and adults, had younger mean ages than those in this study. In the study by Fu,[6] the maximum age of adult participants was 25 years, whereas the present study included adults aged 18 to 41 years. The second explanation is the sample selection criteria. Variations in sample selection criteria may have influenced the observed skeletal convexity. Fu[6] did not apply specific lateral profile selection criteria for harmonious profiles, which may have indirectly impacted the skeletal measurement values. Third, it is noteworthy that the seminal studies were conducted in the 1960s to 1980s, approximately half a century ago. Over the intervening decades, Chinese society has undergone significant improvements in living standards and nutritional status, accompanied by a dietary transition from coarse to refined foods. Anthropological and orthodontic research has indicated that long-term changes in environmental factors, a potential "secular effect", may drive micro-evolution in craniofacial morphology. This is manifested as a reduction in the masticatory apparatus due to diminished functional stimulation, leading to a trend of maxillomandibular retrognathism, characterized specifically by decreased skeletal profile convexity.[19] Thus, the differences observed in the aforementioned measurements may partially reflect long-term trends in craniofacial development among the Chinese population over recent decades, suggesting that mod-

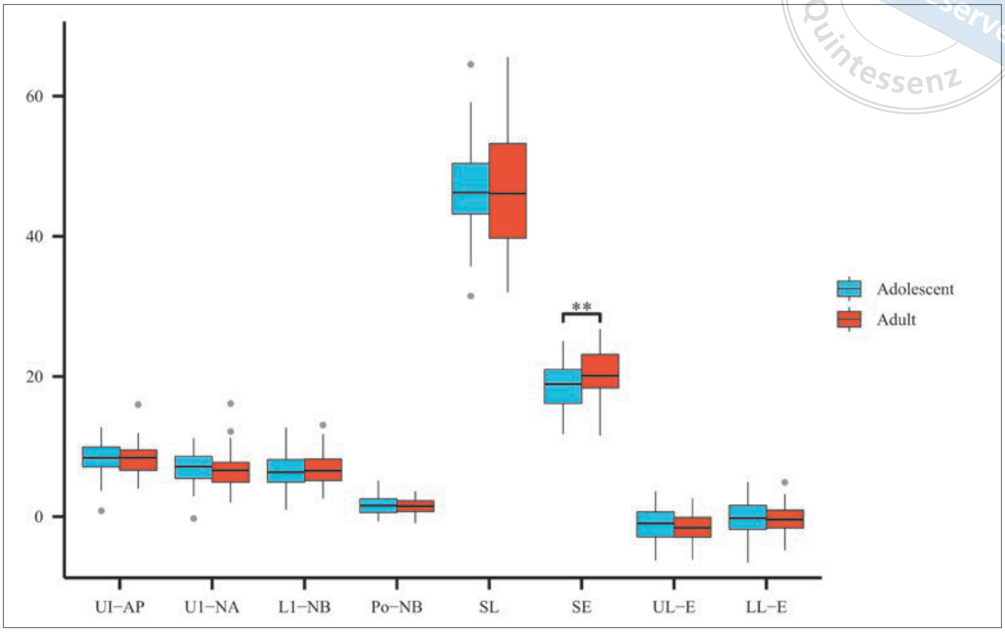

Fig 2 Comparison of angular cephalometric measurements between the adolescent and adult groups (*P < 0.05; *P < 0.01).

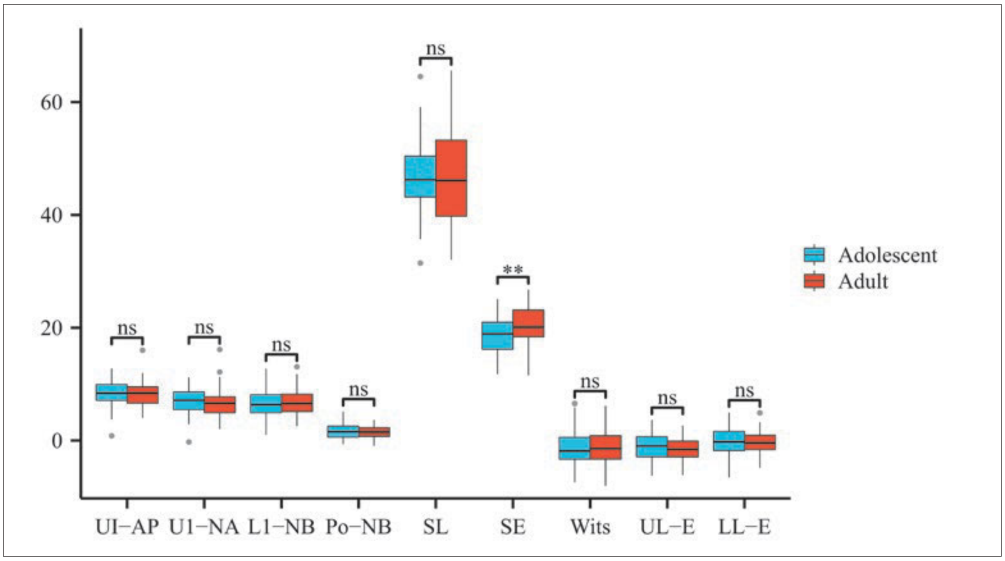

Fig 3 Comparison of linear cephalometric measurements between the adolescent and adult groups (*P < 0.05; **P < 0.01).

ern Chinese individuals may exhibit less skeletal prominence than their predecessors.

In other skeletal measurements, differences were observed in Po-NB and SL values for adults when compared with prior studies. These variations, along with the changes in sagittal skeletal relationships, indicate that the cohort in this study, selected based on expert consensus for harmonious lateral profiles, exhibited reduced skeletal convexity, a more posterior maxilla and a more anterior mandible compared to the findings of Fu and Mao[5] and Fu[6].

When compared with the study conducted by Yu and Huang,[7] no significant differences were found in NA/PA or ANB values, as the selection criteria included considerations for lateral facial harmony. However, in the study by Yu and Huang,[7] the normative values for SNA, SNB, SND and SE, parameters reflecting the position of the maxilla or mandible relative to the cranial base, were smaller than those in the present study. This discrepancy likely arises from the less explicit definition of harmonious profiles by Yu and Huang,[7] which relied solely on subjective researcher judgment rather than integrating expert consensus.

Dental hard tissue measurements

For dental measurements, significant differences were found between this study and the normative values

Table 5 Comparison of normative values for skeletal hard tissue measurements.

Group	Parameter	Present study	Fu and Mao[5] and Fu[6]	Yu and Huang[7]	***P*** value (a)	***P*** value (b)
Adolescents	NA/PA, degrees	4.1 ± 4.7	7.5 ± 4.6	3.5 ± 3.9	< 0.01	0.449
	NP/AB, degrees	−4.8 ± 2.6	−5.2 ± 2.6	NR	0.431	NR
	SNA, degrees	82.7 ± 3.3	82.6 ± 3.2	80.9 ± 3.5	0.875	< 0.05
	SNB, degrees	80.1 ± 3.1	79.1 ± 3.4	78.3 ± 3.4	0.111	< 0.05
	ANB, degrees	2.6 ± 1.5	3.5 ± 1.8	2.5 ± 1.5	< 0.05	0.744
	SND, degrees	77.5 ± 3.0	NR	79.5 ± 3.3	NR	< 0.05
	Po-NB, mm	1.5 ± 1.3	NR	1.9 ± 1.2	NR	0.074
	GoGn/SN, degrees	33.0 ± 6.1	NR	34.3 ± 5.0	NR	0.204
	SL, mm	46.8 ± 5.7	NR	NR	NR	NR
Adults	NA/PA, degrees	3.8 ± 4.6	6.0 ± 4.4	2.4 ± 3.4	< 0.05	0.06
	NP/AB, degrees	−4.6 ± 2.9	−4.5 ± 2.8	NR	0.856	NR
	SNA, degrees	83.0 ± 3.6	83.7 ± 3.8	81.2 ± 3.5	0.331	< 0.05
	SNB, degrees	81.0 ± 4.0	81.0 ± 4.1	79.2 ± 3.2	0.999	< 0.05
	ANB, degrees	2.1 ± 1.4	2.7 ± 1.6	2.1 ± 1.5	0.081	> 0.99
	SND, degrees	77.8 ± 4.3	77.3 ± 3.8	80.2 ± 3.1	0.530	< 0.05
	Po-NB, mm	1.7 ± 1.1	1.0 ± 1.5	2.1 ± 1.3	< 0.01	0.068
	GoGn/SN, degrees	31.6 ± 4.8	32.5 ± 5.2	32.8 ± 5.3	0.351	0.193
	SL, mm	46.9 ± 8.8	52.2 ± 5.4	NR	< 0.01	NR
	SE, mm	20.4 ± 3.3	20.2 ± 2.6	18.3 ± 3.7	0.731	< 0.05

a, compared with Fu and Mao[5] and Fu[6]normative values from Fu and Mao[5] and Fu[6]; b, compared with normative values from Yu and Huang.[7] NR, not reported.

reported by Yu and Huang[7] in parameters related to the angular measurements of the mandibular incisors: IMPA (L1/MP), U1/L1, L1/NB and L1-NB (Table 6). The findings by Yu and Huang[7] suggest that adults had relatively upright mandibular incisors, likely due to subjective preferences for lip morphology.

The OP/SN values in this same study were also higher, likely resulting from greater openness in the lower facial third (GoGn/SN), which caused a steeper occlusal plane.[7] These differences may reflect the authors' subjective biases in selecting samples with harmonious lateral profiles.

In contrast, no significant differences were observed between this study and the results reported by Fu and Mao[5] and Fu[6] for dental measurements, highlighting that harmonious lateral profiles have a greater impact on skeletal measurements than on dental parameters. This underscores the importance of individualised orthodontic treatment: when skeletal structures deviate from the norm, orthodontists must adjust incisor angles and protrusion to compensate for skeletal discrepancies, achieving a relatively harmonious profile.

Soft tissue measurements

Soft tissue measurements were also compared with the normative values reported by Yu and Huang (Table 7).[7] No significant differences were found in G-Sn-Pos values between the present study and the findings of Yu and Huang[7] for either adolescents or adults ($P > 0.05$); however, significant differences were observed in UL-E and LL-E measurements. The values reported by Yu and Huang[7] indicated greater upper and lower lip protrusion ($P < 0.01$ for adolescents, $P < 0.05$ for adults). This suggests that the cohort selected for harmonious lateral profiles in this study exhibited less lip prominence.

It is important to note that Fu and Mao[5] and Fu[6] did not report normative values for soft tissue parameters. Clinically, combining normative values from different studies and treating them as a unified reference for "Chinese norms" is inappropriate. Orthodontists must consider the specific characteristics of the normative values, such as age range, dental alignment and criteria for harmonious profiles, before applying them in clinical practice.

Comparison of normative values between adolescents and adults

When comparing cephalometric measurements between adolescents and adults, adults were found to exhibit smaller mandibular plane angles, reflecting a tendency towards anticlockwise mandibular rotation during growth and development. This emphasises the importance of considering skeletal growth when evaluating vertical control in orthodontic treatment. Adults

Table 6 Comparison of hard tissue dental normative values.

Group	Parameter	Present study	Fu and Mao[5] and Fu[6]	Yu and Huang[7]	***P*** **value (a)**	***P*** **value (b)**
Adolescents	IMPA (L1/MP), degrees	96.2 ± 7.3	96.9 ± 6.0	94.3 ± 5.48	0.594	0.11
	U1/L1, degrees	123.2 ± 10.2	124.2 ± 7.3	126.1 ± 6.53	0.568	0.066
	L1/OP, degrees	113.0 ± 7.1	111.7 ± 5.9	NR	0.309	NR
	UI-AP, mm	7.4 ± 2.4	7.5 ± 2.1	6.8 ± 2.0	0.820	0.135
	OP/SN, degrees	16.0 ± 6.6	NR	18.9 ± 4.5	NR	< 0.05
Adults	IMPA (L1/MP), degrees	95.7 ± 6.8	96.5 ± 7.1	90.5 ± 5.7	0.552	< 0.01
	U1/L1, degrees	123.2 ± 8.6	124.5 ± 7.9	130.8 ± 6.9	0.419	< 0.01
	L1/OP, degrees	112.8 ± 2.1	111.6 ± 6.0	NR	0.152	NR
	UI-AP, mm	7.2 ± 2.2	7.2 ± 2.2	6.6 ± 2.0	> 0.99	0.114
	OP/SN, degrees	15.2 ± 5.3	16.1 ± 5.0	17.4 ± 4.1	0.370	< 0.05
	L1/NB, degrees	28.1 ± 6.0	30.3 ± 5.8	24.6 ± 4.0	0.058	< 0.01
	L1-NB, mm	6.6 ± 2.4	6.7 ± 2.1	5.6 ± 1.9	0.819	< 0.05

a, compared with normative values from Fu and Mao[5] and Fu6; b, compared with normative values from Yu and Huang.[7] NR, not reported.

Table 7 Comparison of soft tissue normative values.

Group	Parameter	Present study	Yu and Huang[7]	***P*** **value**
Adolescents	G-Sn-Pos, degrees	169.3 ± 4.4	169.6 ± 4.0	0.697
	UL-E, mm	−1.1 ± 1.5	−0.1 ± 1.9	< 0.01
	LL-E, mm	−0.1 ± 1.7	1.4 ± 1.9	< 0.01
Adults	G-Sn-Pos, degrees	171.4 ± 5.6	171.1 ± 3.2	0.718
	UL-E, mm	−1.5 ± 2.0	−1.4 ± 1.9	0.770
	LL-E, mm	−0.2 ± 2.2	0.6 ± 1.9	< 0.05

displayed significantly larger SE values, indicating posterior growth of the mandibular condyle during development. The reduced convexity of the lateral profile in adults suggests a gradual decrease in facial protrusion with age. These findings align with previous research on mandibular growth trends. However, Yu andHuang[7] did not show significant changes in facial convexity with age. This discrepancy may be due to differences in criteria for selecting profiles. Unlike the subjective judgments made by Yu and Huang,[7] the present study is the first to establish a standard for harmonious profiles based on expert consensus, making the selected samples more reliable and authoritative.

Limitations

This study established an objective assessment standard for the coordination of lateral cephalometric radiographs by integrating the subjective evaluations of 65 orthodontic experts, thereby proposing cephalometric norms that better align with the profile aesthetics of the Chinese population. However, several methodological limitations must be acknowledged. The reference standard of this study relies on expert consensus. Although superior to assessment by a single researcher, this consensus remains a form of "collective subjectivity" and does not fully escape the domain of human judgment. The expert evaluations themselves inherently carry a degree of subjectivity, which may be influenced by the clinicians' experience, aesthetic preferences and cultural background, potentially introducing bias into the final determination of normative values. The assessment of profile coordination involves complex 3D relationships between hard and soft tissues. The current lack of a fully automated, high-precision objective quantification system means that the standardisation process cannot completely avoid the influence of human subjectivity. Thus, despite the preliminary success achieved with the expert consensus-based evaluation method in this study, future research should leverage multimodal data, artificial intelligence and interdisciplinary approaches to further advance the objectivity, standardisation and personalisation of orthodontic profile assessment. This should be done by integrating 3D facial scan data with lateral cephalometric radiographs to construct 3D craniofacial atlases of hard and soft tissue relationships, enabling a more comprehensive evaluation of profile harmony and mitigating the information loss inherent in 2D projections;[20] utilising artificial intelligence deep learning techniques to train neural network models on large datasets annotated by experts, aiming to automate the scoring and classification of profile coordination, thereby reducing subjective variability and improving evaluation efficiency and consistency;[21] and including mixed dentition samples and conducting long-term longitudinal follow-ups, combined with growth prediction models, to establish normative values covering the entire orthodontic age spectrum. This would allow for complete observation of craniofacial growth trends and dynamic optimisation of cephalometric norms for different age stages, ultimately better serving the clinical needs of early intervention.

Conclusion

In summary, from a craniofacial growth and development perspective, adults exhibit anticlockwise rotation of the mandible, posterior positioning of the condyle and reduced facial convexity compared to adolescents. Based on the evaluation of lateral cephalometric radiographs using expert consensus, the present study offers a more objective approach to selecting harmonious cephalometric profiles. This methodology enables the establishment of more accurate normative values for sagittal skeletal and soft tissue measurements in Chinese individuals.

Conflicts of interest

The authors declare no conflicts of interest related to this study.

Acknowledgements

The authors extend their heartfelt gratitude to all the patients. Their participation was essential to the successful completion of this study.

Author contribution

Dr Han Wei ZHENG contributed to the data curation, formal analysis, investigation and writing of the original draft; Dr Chen Sa MENG contributed to the data curation and formal analysis; Drs Huan Huan CHEN and Yue LAI contributed to the data curation; Dr Guang Ying SONG contributed to the conceptualisation and project guidance; Drs Bing HAN and Tian Min XU contributed to the conceptualisation, funding acquisition and critical revision of the manuscript. All authors gave their final approval and agreed to be accountable for all aspects of the work.

(Received Aug 06, 2025; accepted Nov 13, 2025)

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