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Lip Position Differences Across Skeletal Classes Using Steiner's and Ricketts'line : A Cephalometric Study

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Abstract

Objective: To compare sagittal upper and lower lip positions across skeletal Classes I, II, and III using Steiner's(S) Line and Ricketts' (E) Line , and to determine whether these two reference lines can reliably differentiate sagittal soft-tissue variations.
Methods: A retrospective analysis was conducted on 120 normodivergent Yemeni adults (18–35 years) with equal distribution across skeletal Classes I, II, and III (n=40 each). Skeletal classification was determined by ANB angle and confirmed by Wits appraisal. The perpendicular distances from the upper and lower lip landmarks to Steiner's (S) Line and Ricketts' (E) Line were measured and compared across the skeletal classes using EzDent-i cephalometric software. Statistical analysis included descriptive statistics, independent t-tests, ANOVA, Tukey post-hoc tests, and Pearson correlations ($p < 0.05$).
Results: Class II subjects showed the most anterior lip positions relative to both S and E Lines, while Class III subjects demonstrated marked retrusion. Class I individuals exhibited mild protrusion to S Line but moderate retrusion to E Line, representing a balanced soft-tissue profile. ANOVA revealed significant interclass differences for all S and E Line measurements ($p < 0.01$). Gender had no significant influence except for mild E Line variation in Class I ($p < 0.05$). Correlation analysis showed positive association between ANB and lip protrusion on S Line, and negative association on E Line.
Conclusion: Significant differences in lip position were found among the skeletal classes when assessed using Steiner's (S) Line and Ricketts' (E) Line. Both reference lines demonstrated significant differences in sagittal lip position among skeletal classes and may serve as complementary reference lines for soft-tissue assessment during orthodontic diagnosis.
The differences observed between the Yemeni population and the widely used Caucasian norms highlight the importance of using population-specific cephalometric reference values to support individualized orthodontic diagnosis and treatment planning.

Article Info

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S Line, E Line, Lip position, Cephalometry, Skeletal malocclusion, Soft tissue; Orthodontics, Yemen.

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1. INTRODUCTION

Facial esthetics has become a central focus of contemporary orthodontic treatment, reflecting a shift from purely occlusal correction to a more comprehensive approach prioritizing facial balance and harmony. Increasing attention has been placed on soft-tissue evaluation because esthetic perception is strongly linked to lip posture and profile convexity rather than only dental alignment [1].

The lips serve as the visual interface between dentoalveolar structures and the facial profile, and their sagittal position plays a critical role in extraction decisions, orthodontic camouflage, and diagnosis of growth discrepancies [2, 3].
Cephalometric soft-tissue evaluation provides objective tools to assess lip projection, predict treatment outcomes, and quantify aesthetic changes. Among the existing anal-

yses, Steiner's S line and Ricketts' E line are commonly used reference lines because of their simplicity, reproducibility, and clinical relevance.

The sagittal positions of the upper and lower lips are evaluated in both analyses by measuring the perpendicular distance from each lip landmark to the respective reference line. Steiner's S Line, drawn from the midpoint of the columella to the soft-tissue pogonion, provides a direct assessment of lip prominence in relation to facial balance and is useful in orthodontic diagnosis and treatment planning [3, 4]. Ricketts' E Line, extending from the tip of the nose to the soft-tissue pogonion, evaluates facial profile convexity by incorporating the nose and chin into the assessment, allowing a more comprehensive evaluation of soft-tissue harmony [5].

Although originally based on Caucasian esthetic norms, numerous studies have demonstrated that lip posture varies significantly across ethnicities, growth patterns, and gender. Population-specific differences in lip thickness, projection, and soft-tissue convexity have been documented among African, Asian, Middle Eastern, and Latin American groups, emphasizing the limitations of applying Western standards universally [4, 6, 7]. Furthermore, sagittal skeletal relationships (Classes I, II, and III) strongly influence lip projection because soft tissue conforms to underlying maxillomandibular discrepancies [8, 9]. Thus, skeletal morphology must be considered when assessing lip position using S and E Lines, particularly when developing region-specific guidelines [10].

Despite their extensive use, comparative studies using only S Line and E Line across skeletal classes are limited, especially within Middle Eastern populations, where aesthetic norms differ from those of Western societies. Current regional evidence often lacks stratification by skeletal pattern, reducing diagnostic specificity and applicability to orthodontic planning [11, 12]. Consequently, it remains unclear how effectively these two globally relied-upon lines distinguish lip posture across different malocclusion types in this population.

Therefore, this study aims to analyze and compare sagittal lip position across Class I, Class II, and Class III skeletal patterns using Steiner's S Line and Ricketts' E Line, establishing population-specific guidelines for clinical use and orthodontic treatment planning.

2. MATERIALS AND METHODS

2.1. Study Design and Sample

A retrospective cross-sectional cephalometric study was conducted using 120 pretreatment digital lateral cephalograms of Yemeni adults (60 men and 60 women) aged 18–35 years, retrieved from a private radiology center in Sana'a City. The sample was equally distributed among the three skeletal classes (40 subjects per class; 20 men and 20 women in each group).

The sample size was calculated a priori using G*Power software (version 3.1.9). A minimum of 111 subjects was required (power = 95%, α = 0.05, effect size = 0.88); therefore, the sample size was increased to 120 subjects to ensure a balanced group allocation.

Ethical approval was obtained from the Ethical Committee of the Faculty of Dentistry, Sana'a University (approval no. OR:10/10/2024).

Inclusion criteria

- Age ranged between 18–35 years.
- High-quality digital LCRs.
- Patients were classified into skeletal Class I, Class II, or Class III malocclusion based on their ANB angle and confirmed by wits appraisal, with Class I defined as ANB between 0° and 4°, Class II as ANB > 4°, and Class III as ANB < 0°.
- No history of previous orthodontic treatment.
- Fully erupted permanent dentition (excluding third molars).
- No craniofacial syndromes, trauma, or surgery affecting jaw morphology.

Exclusion criteria

- Facial asymmetry or systemic conditions affecting bone structure
- Poor image quality or incomplete or distorted soft-tissue outlines
- Hypodivergent and hyperdivergent subjects, defined according to the SN-GoGn angle, were excluded. Subjects with an SN-GoGn angle <27° were classified as hypodivergent, whereas those with an SN-GoGn angle >36° were classified as hyperdivergent.

2.2. Skeletal Classification

Skeletal sagittal class was determined as follows:

- **ANB angle**
  - Class I: 0–4°
  - Class II: >4°
  - Class III: <0°
- **Wits appraisal** (confirmatory)

2.3. Radiographic Acquisition

All pretreatment digital lateral cephalometric radiographs were obtained using standardized radiographic procedures at a private radiology center. The subjects were positioned in the natural head position (NHP) by a trained radiographic technician, with the Frankfort horizontal plane parallel to the floor, teeth in centric occlusion, and lips in a relaxed position. Only radiographs with clearly identifiable hard- and soft-tissue landmarks were included in the analysis

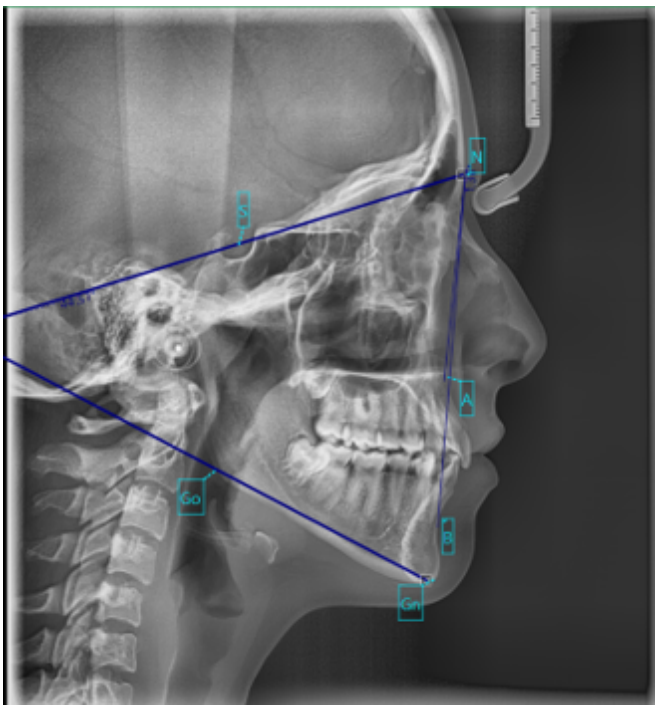

Figure 1. Measurements of ANB and SN-GoGn Angles on cephalometric analysis

2.4. Software and Measurement Protocol

Digital cephalometric measurements were performed using EzDent-i software (version 3.5.0; Vatech, South Korea). Steiner's S line, extending from the midpoint of the columella (Cm) to the soft-tissue pogonion (Pog′) (Figure **??**), and Ricketts' E line, extending from the pronasale (Prn) to the soft-tissue pogonion (Pog′) (Figure **??**), were used as the reference lines. The upper and lower lip positions were measured as the shortest perpendicular distance to each reference line. Positive values indicated protrusion, and negative values indicated retrusion. All landmarks were manually verified prior to the analysis.

2.5. Reliability Testing

To assess measurement reliability, 20 randomly selected lateral cephalometric radiographs were re-measured by the same examiner after a three-week interval under identical conditions. Inter-examiner reliability was evaluated using the same radiograph by an independent examiner. Both examiners were blinded to the subject identification and skeletal classification during the reliability assessment. The intra- and inter-examiner ICC values ranged from 0.88–0.94 and 0.85–0.91, respectively, indicating good to excellent reliability.

2.6. Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics (mean ± standard deviation) were calculated for all variables. Differences among skeletal classes were analyzed using one-way analysis of variance (ANOVA), followed by Tukey's post-hoc test for pairwise comparisons. Sex differences within each skeletal class were assessed using the independent-samples t-test. Pearson's correlation coefficient was used to evaluate the relationship between lip position and ANB angle. Statistical significance was set at $p < 0.05$.

3. RESULTS

3.1. Descriptive Statistics

Table **??** presents the mean ± standard deviation of the upper and lower lip positions relative to the S and E lines for skeletal classes I, II, and III. Differences in lip position were observed among the three skeletal classes for both reference lines.

3.2. Gender Comparison

Table 2 summarizes the comparison of S-line and E-line measurements between males and females within each skeletal class. Statistically significant sex differences were observed only for the E-line measurements in Class I ($p < 0.05$). No statistically significant sex differences were observed in Classes II and III.

Only E-line measurements in Class I showed significant sex differences.

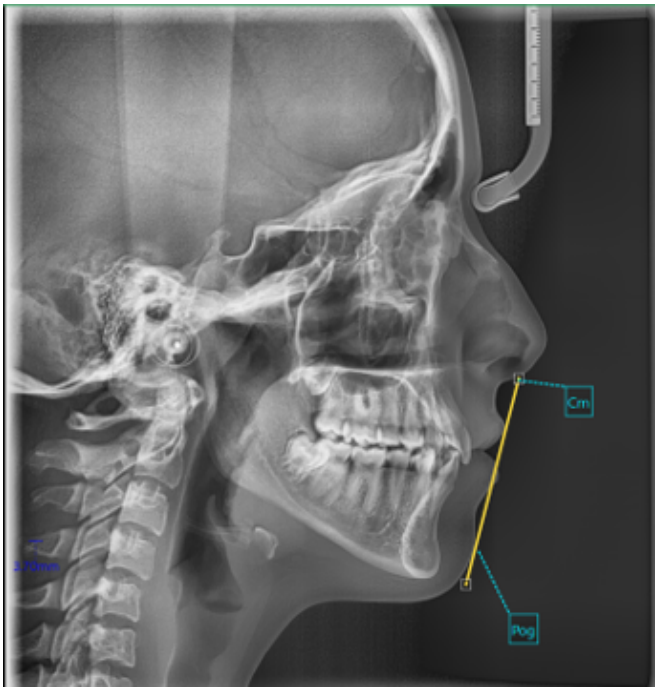

Figure 2. Measurement of lip position relative to Steiner's S Line using EzDent-i software. The S Line is drawn from the midpoint of the columella (subnasale region) to the soft tissue pogonion. The perpendicular distances of the upper and lower lips to this line were measured digitally.

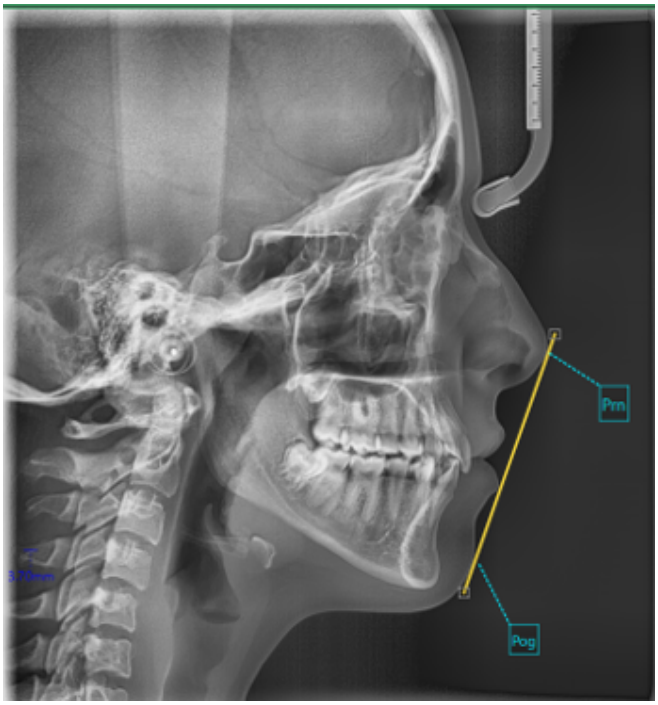

Figure 3. Measurement of lip position relative to Ricketts' E Line (esthetic plane) using EzDent-i software. The E Line extends from pronasale (Prn) to soft tissue pogonion. The upper and lower lip positions were recorded as their horizontal distances to this plane.

Table 1. Sagittal lip positions relative to S and E Lines across skeletal Classes I, II, and III (Mean ± SD, mm)

Reference Line	Lip Position	Class I	Class II	Class III
S Line	Upper Lip	0.5 ± 1.1	1.4 ± 1.3	-0.8 ± 1.2
	Lower Lip	1.1 ± 1.3	2.2 ± 1.3	0.0 ± 1.3
E Line	Upper Lip	-2.8 ± 1.0	-0.1 ± 0.9	-5.8 ± 0.9
	Lower Lip	2.3 ± 0.9	4.2 ± 1.0	-2.2 ± 1.0

Negative values = retrusion behind the line. Positive values = protrusion ahead of the line.

Table 2. Gender comparison of S Line and E Line measurements across skeletal classes

Reference	Class	Male (Mean ± SD)	Female (Mean ± SD)	p-value
S UL	I	0.4 ± 1.2	0.6 ± 1.2	0.412
	II	1.3 ± 1.2	1.5 ± 1.3	0.368
	III	-0.9 ± 1.3	-0.7 ± 1.1	0.458
S LL	I	1.0 ± 1.3	1.2 ± 1.3	0.475
	II	2.0 ± 1.4	2.3 ± 1.3	0.363
	III	-0.1 ± 1.2	0.1 ± 1.3	0.389
E UL	I	-3.0 ± 1.1	-2.6 ± 1.0	0.041*
	II	-0.2 ± 1.0	0.0 ± 0.9	0.276
	III	-5.8 ± 0.9	-5.6 ± 1.0	0.230
E LL	I	2.3 ± 0.8	2.5 ± 0.9	0.037*
	II	4.0 ± 1.0	4.4 ± 1.0	0.272
	III	-2.5 ± 1.0	-1.9 ± 1.1	0.183

3.3. ANOVA comparisons for S Line and E Line across skeletal classes

Table **??** presents the one-way ANOVA results comparing S-line and E-line measurements among the three skeletal classes. Statistically significant differences were observed for both upper and lower lip measurements relative to the S and E lines ($p < 0.05$).

Table 3 presents the one-way ANOVA results comparing the upper and lower lip positions relative to the S and E lines among skeletal class I, II, and III subjects. Statistically significant differences were identified for both upper and lower lip measurements with the S Line (upper lip: $F(2,117) = 6.15$, $p = 0.003$, $\eta^2 = 0.095$; lower lip: $F(2,117) = 7.55$, $p = 0.001$, $\eta^2 = 0.114$) and the E Line (upper lip: $F(2,117) = 8.80$, $p < 0.001$, $\eta^2 = 0.131$; lower lip : $F(2,117) = 9.20$, $p < 0.001$,$\eta^2 = 0.136$). The calculated effect sizes ranged from 0.095 to 0.136**.** The Tukey post-hoc test identified statistically significant pairwise differences for the S Line and E Line measurements between specific skeletal classes.

3.4. Correlation between lip position and ANB

Table 4 presents the Pearson correlation coefficients between the ANB angle and lip position measurements. Significant positive correlations were observed for the S-line measurements, whereas significant negative correlations were observed for the E-line measurements. The negative correlation reflects the direction of E-line measurements rather than an inconsistency in the statistical analysis. Table 4 summarizes the Pearson correlation analysis between the ANB angle and lip position measurements. Significant positive correlations were observed between the ANB angle and upper ($r = 0.42$, 95% CI: 0.26–0.56, $p = 0.001$) and lower ($r = 0.47$, 95% CI: 0.32–0.60, $p < 0.001$) lip positions relative to the S line. Significant negative correlations were identified for the E line, with correlation coefficients of - 0.46 (95% CI: - 0.59 to -0.30 , $p = 0.002$) for the upper lip and - 0.39 (95% CI: - 0.53 to -0.23 , $p = 0.005$) for the lower lip. The coefficients of determination (r^2) ranged from 0.152 to 0.221 .

4. DISCUSSION

This study aimed to determine how the sagittal lip position varies among skeletal Classes I, II, and III using Steiner's S Line and Ricketts' E Line, two of the most widely recognized and clinically relevant cephalometric indicators. These lines were selected because they offer complementary perspectives: the S Line evaluates lip balance independent of nasal projection, while the E Line integrates nasal and chin prominence, offering a broader aesthetic assessment. Evaluating both lines concurrently provides complementary information regarding sagittal soft-tissue relationships and reduces reliance on a single soft-tissue reference, as suggested in previous studies[3, 5, 9].

Table 3. ANOVA for S Line and E Line across skeletal classes

Reference	Lip	F (2,117)	η^2 (Effect size)	p-value	Significance
S Line	Upper	6.15	0.095	0.003	Significant
	Lower	7.55	0.114	0.001	Significant
E Line	Upper	8.80	0.131	<0.001	Highly significant
	Lower	9.20	0.136	<0.001	Highly significant

Table 4. Post-hoc Tukey Pairwise Comparisons for S Line and E Line Measurements

Reference Line	Comparison	p-value
S Line – Upper Lip	Class I vs II	0.041*
	Class I vs III	0.058
	Class II vs III	0.004*
S Line – Lower Lip	Class I vs II	0.052
	Class I vs III	0.041*
	Class II vs III	0.006*
E Line – Upper Lip	Class I vs II	0.031*
	Class I vs III	0.055
	Class II vs III	0.002*
E Line – Lower Lip	Class I vs II	0.044*
	Class I vs III	0.040*
	Class II vs III	0.007*

Sagittal Trends Across Skeletal Classes

Class I individuals demonstrated mild upper and lower lip protrusion relative to the S line. In contrast, the upper lip was retrusive relative to the E line, whereas the lower lip remained slightly protrusive. These findings indicate balanced soft-tissue relationships, although lip position varied according to the reference line used. Similar observations have been reported in Arab, Asian, and African populations, emphasizing the importance of population-specific soft-tissue norms [9, 13, 14].

In Class II subjects, both lips appeared more anterior to the S line and less retrusive to the E line, confirming the convexity associated with maxillary protrusion or mandibular deficiency. These findings are consistent with previous investigations reporting increased lip prominence in Class II malocclusion. This pattern is likely related to the underlying maxillary protrusion and/or mandibular retrusion, which influence the sagittal position of the overlying soft tissues [1, 5, 14].

The lower lip position, often ahead of the E line in Class II, reflects adaptive mentalis activity attempting to maintain oral seal and stability, a phenomenon extensively documented in the soft-tissue literature [15].

In contrast, Class III subjects revealed markedly retrusive lips relative to both reference lines, corresponding to the concave facial appearance caused by maxillary retrusion or mandibular protrusion. This pattern has been similarly observed in CBCT and cephalometric evaluations in Turkish, Sudanese, and East Asian populations [8, 9, 16, 17]. Although the overall trend was similar, the magnitude of lip retrusion may vary among populations because of ethnic differences in craniofacial morphology and soft tissue characteristics.

Moreover, the greater negative values measured relative to the E Line may reflect the influence of nasal and chin prominence on the perceived concavity of Class III profiles, highlighting the usefulness of the E Line for assessing sagittal soft-tissue relationships in such cases [5, 9, 18].

Gender Influence

Gender differences were mostly insignificant, except for E-line values in Class I, where males showed slightly greater lip retrusion than females. This small variation agrees with previous reports of mild sexual dimorphism in upper lip thickness and chin projection [6, 19]. However, as observed here and in other regional studies, skeletal patterns exert a far stronger influence on sagittal lip posture than gender, particularly in Class II and III

Reference	Lip	r	95% CI	r^2 (Effect size)	p-value
S Line	Upper	+0.42	0.26 to 0.56	0.176	0.001
	Lower	+0.47	0.32 to 0.60	0.221	<0.001
E Line	Upper	–0.46	–0.59 to –0.30	0.212	0.002
	Lower	–0.39	–0.53 to –0.23	0.152	0.005

malocclusions [3, 18].

Correlation with Skeletal Convexity

The positive correlation between the ANB angle and S-line measurements indicates that increased skeletal convexity was associated with greater lip protrusion relative to the S-line. In contrast, E-line measurements showed a significant negative correlation with the ANB angle. These findings indicate that the relationship between sagittal skeletal patterns and lip position differed according to the reference line used [20, 21].

Clinical Implications

The slightly more protrusive lips observed in Yemeni adults compared to Caucasian norms highlight the importance of using population-specific soft-tissue reference values during orthodontic diagnosis and treatment planning. The observed differences in the S and E line measurements across skeletal classes support their use as complementary reference lines for sagittal soft-tissue assessment. However, clinicians should also consider the influence of nasal prominence and chin projection, particularly when evaluating facial aesthetics and planning orthodontic or orthognathic treatment[22, 23].

5. CONCLUSION

Significant differences in sagittal lip position were observed among skeletal Classes I, II, and III when assessed using Steiner's S Line and Ricketts' E Line. These findings indicate that the sagittal skeletal pattern has a greater influence on lip position than sex and highlight the importance of considering population-specific soft-tissue characteristics during orthodontic assessment. These population-specific reference values may improve individualized orthodontic diagnosis and treatment planning for Yemeni adults. Future multicenter studies involving larger samples and additional soft-tissue reference lines are recommended to further validate and expand these findings.

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