

Comparative Evaluation of Soft-Tissue Profile Among Skeletal Class I, Class II and Class III Malocclusions Using Z-Angle, E-Line and Nasolabial Angle: A Retrospective Cephalometric Study

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Abstract:

➤ *Background:*

Assessment of the soft-tissue profile formed an important part of orthodontic diagnosis because changes in the underlying skeletal and dental structures were reflected, to varying degrees, in the facial appearance. Sagittal skeletal discrepancies were commonly accompanied by differences in lip prominence, facial convexity and the relationship between the nose, lips and chin. The Z-angle, Ricketts E-line and nasolabial angle provided simple cephalometric methods for evaluating these characteristics.

➤ *Aim:*

The study aimed to compare selected soft-tissue profile characteristics among skeletal Class I, Class II and Class III malocclusions using the Z-angle, upper and lower lip position relative to the E-line, and nasolabial angle.

➤ *Materials and Methods:*

A retrospective cross-sectional cephalometric study was conducted using pretreatment lateral cephalograms from orthodontic records. Ninety subjects were included in the model dataset and were equally divided into skeletal Class I, Class II and Class III groups. Skeletal classification was based on the ANB angle. The Z-angle, upper lip-to-E-line, lower lip-to-E-line and nasolabial angle were measured on standardized lateral cephalograms. Intraobserver reliability was assessed using the intraclass correlation coefficient. Intergroup differences were evaluated using one-way analysis of variance followed by Tukey post-hoc testing. Pearson correlation was used to examine the relationship between ANB and the selected soft-tissue measurements. Statistical significance was set at $p < 0.05$.

➤ *Results:*

In the model dataset, the mean Z-angle was $72.43 \pm 4.21^\circ$ in Class I, $68.17 \pm 4.56^\circ$ in Class II and $77.26 \pm 4.38^\circ$ in Class III subjects. Significant differences were observed among the three groups for Z-angle, upper lip-to-E-line, lower lip-to-E-line and nasolabial angle. The Class II group showed the smallest Z-angle and the least negative lip-to-E-line measurements, whereas the Class III group showed the largest Z-angle and the most negative lip-to-E-line measurements. The nasolabial angle was greatest in the Class II group and lowest in the Class III group. ANB showed a moderate negative correlation with Z-angle and moderate positive correlations with the E-line measurements.

➤ *Conclusion:*

The model analysis demonstrated differences in selected soft-tissue profile measurements among skeletal Class I, Class II and Class III subjects. Z-angle, E-line measurements and nasolabial angle appeared to provide complementary

information regarding facial soft-tissue morphology and could be useful adjuncts to conventional skeletal and dental assessment.

Keywords: Cephalometry; Soft-Tissue Profile; Skeletal Malocclusion; Skeletal Class I; Skeletal Class II; Skeletal Class III; Z-Angle; E-Line; Nasolabial Angle; Orthodontic Diagnosis.

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I. INTRODUCTION

Orthodontic treatment is directed not only toward establishing an acceptable occlusion but also toward achieving a balanced facial appearance. For this reason, evaluation of the soft-tissue profile has remained an important part of orthodontic diagnosis and treatment planning.

The relationship between the facial soft tissues and the underlying skeletal structures is complex. A sagittal discrepancy between the maxilla and mandible can alter the apparent position of the lips and chin and can consequently influence facial convexity. However, the soft-tissue response is not always directly proportional to the underlying skeletal discrepancy. Differences in lip thickness, nasal morphology, soft-tissue chin thickness, incisor inclination and individual variation can modify the final facial appearance.

Several cephalometric analyses have been developed to quantify the soft-tissue profile. The Z-angle described by Merrifield evaluates the relationship between the facial profile and the Frankfort horizontal plane and incorporates the position of the most prominent lip and soft-tissue pogonion. It has subsequently been used to assess facial profile changes associated with orthodontic treatment.

Ricketts' E-line provides another commonly used reference for evaluating lip prominence. The line is constructed between pronasale and soft-tissue pogonion, and the perpendicular distances from the line to the upper and lower lips are measured. Because the E-line is influenced by both nasal and chin morphology, its interpretation requires consideration of the overall facial profile rather than the lips in isolation.

The nasolabial angle provides information about the relationship between the nasal base and upper lip. It is particularly relevant during orthodontic treatment planning because changes in upper incisor position and upper-lip posture can alter the appearance of this region.

Previous studies have demonstrated differences in soft-tissue morphology among skeletal malocclusion groups. A retrospective study of 237 subjects found that the nasolabial angle was greatest in skeletal Class II and lowest in skeletal Class III subjects, although several other soft-tissue parameters did not show significant differences across all groups.

More recent work has examined relationships among skeletal pattern, nasal morphology and soft-tissue measurements, including Z-angle and E-line measurements. A 2025 study of 180 pretreatment cephalograms found significant differences in several nasal parameters between skeletal groups and reported correlations between nasal morphology and soft-tissue cephalometric variables.

An Indian study involving 162 pretreatment cephalograms also evaluated skeletal Class I, II and III groups and investigated the relationship between the upper nasolabial angle, skeletal measurements and nasal morphology. The study used ANB-based skeletal classification, with Class I defined as ANB 2–4°, Class II as ANB >4° and Class III as ANB <2°.

Despite the availability of these measurements, interpretation of the soft-tissue profile remains dependent on the population and the combination of skeletal and soft-tissue characteristics. The present study was therefore designed to compare three commonly used soft-tissue parameters among skeletal Class I, Class II and Class III subjects.

➤ Aim

The study aimed to evaluate and compare the soft-tissue facial profile among skeletal Class I, Class II and Class III malocclusions using the Z-angle, E-line and nasolabial angle.

➤ Objectives

The objectives of the study were:

- To compare the Z-angle among skeletal Class I, Class II and Class III subjects.
- To compare upper lip-to-E-line measurements among the three skeletal groups.
- To compare lower lip-to-E-line measurements among the three skeletal groups.
- To compare the nasolabial angle among the three skeletal groups.
- To determine the correlation between ANB angle and the selected soft-tissue parameters.

II. MATERIALS AND METHODS

➤ Study Design

A retrospective, observational, cross-sectional cephalometric study was designed using pretreatment lateral cephalograms obtained from orthodontic records.

➤ Study Setting

The study was conducted in the Department of Orthodontics and Dentofacial Orthopaedics, [Institution], Karnataka, India.

➤ Study Period

The study included records obtained between [Month Year] and [Month Year].

➤ Ethical Considerations

Ethical approval was obtained from the Institutional Ethics Committee of [Institution] before commencement of the study.

- IEC Approval Number: [Insert actual number]

The study was conducted in accordance with the ethical requirements of the institution.

RGUHS's current postgraduate synopsis process requires institutional ethics clearance among the documents submitted as part of the synopsis process.

➤ Sample Size

For the model analysis presented in this manuscript, 90 subjects were considered, with 30 subjects in each skeletal group.

The actual study sample size should be determined before analysis using a formal sample-size calculation based on the predefined primary outcome and an appropriate effect size obtained from previous literature or pilot observations.

The number of subjects used in the final manuscript should therefore be replaced by the actual calculated sample size.

➤ Grouping of Subjects

Subjects were divided into three groups according to their sagittal skeletal relationship based on ANB angle.

Table 1 Grouping of Subjects

Group	Skeletal relationship	ANB criterion	Model sample
Group I	Skeletal Class I	2–4°	30
Group II	Skeletal Class II	>4°	30
Group III	Skeletal Class III	<2°	30
Total			90

The ANB-based classification was consistent with classifications used in recent Indian cephalometric research.

➤ Inclusion Criteria

Subjects were included when they:

- Had permanent dentition.
- Had a pretreatment lateral cephalogram available in the orthodontic record.
- Had a radiograph of sufficient quality for reliable landmark identification.
- Fulfilled the predetermined skeletal classification criteria.
- Had not undergone previous orthodontic treatment.
- Had no history of orthognathic surgery.

➤ Exclusion Criteria

Subjects were excluded when they had:

- Cleft lip and/or palate.
- Craniofacial syndromes.
- Congenital craniofacial anomalies.
- Significant facial trauma.
- Previous orthodontic treatment.
- Previous orthognathic surgery.
- Gross facial asymmetry.
- Poor-quality or distorted cephalograms.
- Soft-tissue abnormalities that prevented reliable landmark identification.

➤ Cephalometric Analysis

All lateral cephalograms were analyzed using [software name and version].

The following landmarks were identified:

• Hard-Tissue Landmarks

- ✓ Nasion (N)
- ✓ Point A
- ✓ Point B

• Soft-Tissue Landmarks

- ✓ Pronasale (Prn)
- ✓ Labrale superius (Ls)
- ✓ Labrale inferius (Li)
- ✓ Soft-tissue pogonion (Pg')
- ✓ Columella (Cm)

➤ Cephalometric Measurements

• Anb Angle

The ANB angle was measured as the angle formed by Point A, Nasion and Point B. It was used to determine the sagittal skeletal relationship.

• Z-Angle

The Z-angle was measured according to Merrifield's soft-tissue analysis. It represented the relationship between the facial profile line and the Frankfort horizontal plane.

A lower Z-angle indicated a relatively more prominent/convex soft-tissue profile, whereas a larger value was generally associated with a relatively straighter profile.

- *E-Line*

Ricketts' E-line was constructed by joining pronasale and soft-tissue pogonion.

The perpendicular distance from the E-line to:

- ✓ Labrale superius, and
- ✓ Labrale inferius was measured in millimetres.

More negative values represented greater distance of the lips posterior to the E-line.

- *Nasolabial Angle*

The nasolabial angle was measured between the columella tangent and the upper-lip tangent.

It was used to evaluate the relationship between the nasal base and upper lip.

➤ *Method of Measurement*

The cephalograms were coded before analysis.

The skeletal landmarks were identified first and the ANB angle was recorded. Subjects were then allocated to the appropriate skeletal group.

The soft-tissue landmarks were subsequently identified, followed by measurement of the Z-angle, upper and lower lip-to-E-line distances and nasolabial angle.

All measurements were recorded in a standardized data collection sheet.

No additional schematic arrows or flowchart-style representations were used in the manuscript body; the methodology was described sequentially in conventional journal format.

➤ *Error of Method*

Twenty cephalograms were randomly selected for repeat measurement after a two-week interval.

The same investigator performed the second set of measurements.

Intraobserver reliability was assessed using the intraclass correlation coefficient (ICC).

Random error was additionally intended to be assessed using Dahlberg's formula:

$$ME = \sqrt{\frac{\sum d^2}{2n}}$$

Where d represented the difference between the first and second measurements and n represented the number of repeated measurements.

➤ *Statistical Analysis*

The data were entered into Microsoft Excel and analyzed using IBM SPSS Statistics version [XX].

The Shapiro-Wilk test was used to assess normality.

For normally distributed continuous variables, one-way analysis of variance (ANOVA) was used to compare the three skeletal groups. Tukey's post-hoc test was used for pairwise comparisons.

Pearson's correlation coefficient was used to assess the relationship between ANB and the soft-tissue measurements when the assumptions for parametric correlation were satisfied.

The level of statistical significance was set at $p < 0.05$.

III. RESULTS

➤ *Important:*

The numerical results in this section represented a simulated model dataset and were not derived from actual patient records.

➤ *Demographic Characteristics*

The model dataset included 90 subjects, with 30 subjects in each skeletal group.

Table 1 Demographic Characteristics

Variable	Class I (n=30)	Class II (n=30)	Class III (n=30)	p-value
Age, mean $\pm$ SD (years)	20.83 $\pm$ 2.41	21.17 $\pm$ 2.58	20.97 $\pm$ 2.63	0.86
Male, n (%)	14 (46.7)	15 (50.0)	13 (43.3)	0.88
Female, n (%)	16 (53.3)	15 (50.0)	17 (56.7)	0.88

The model analysis showed no statistically significant differences among the groups with respect to age or sex distribution.

➤ *Comparison of Cephalometric Parameters*

Table 2 Comparison of Skeletal and Soft-Tissue Parameters

Parameter	Class I Mean ± SD	Class II Mean ± SD	Class III Mean ± SD	ANOVA p-value
ANB (°)	2.84 ± 0.72	5.62 ± 1.01	-1.18 ± 1.04	<0.001
Z-angle (°)	72.43 ± 4.21	68.17 ± 4.56	77.26 ± 4.38	<0.001
Upper lip–E-line (mm)	-3.21 ± 1.42	-2.08 ± 1.35	-4.16 ± 1.51	<0.001
Lower lip–E-line (mm)	-1.84 ± 1.38	-0.72 ± 1.29	-3.18 ± 1.47	<0.001
Nasolabial angle (°)	96.21 ± 7.18	99.84 ± 7.42	91.36 ± 7.61	<0.001

The model ANOVA demonstrated statistically significant differences among the three groups for all four soft-tissue parameters.

➤ *Pairwise Comparison*

Table 3 Tukey Post-Hoc Comparison

Parameter	Class I vs Class II	Class I vs Class III	Class II vs Class III
Z-angle	0.002*	<0.001*	<0.001*
Upper lip–E-line	0.004*	0.018*	<0.001*
Lower lip–E-line	0.006*	0.001*	<0.001*
Nasolabial angle	0.041*	0.009*	<0.001*

*Statistically Significant at p<0.05.

The model post-hoc analysis demonstrated significant pairwise differences for all evaluated soft-tissue parameters.

➤ *Correlation Analysis*

Table 4 Correlation Between ANB and Soft-Tissue Parameters

Parameter	Pearson's r	p-value	Direction/strength
Z-angle	-0.61	<0.001*	Moderate negative
Upper lip–E-line	0.48	<0.001*	Moderate positive
Lower lip–E-line	0.52	<0.001*	Moderate positive
Nasolabial angle	0.21	0.047*	Weak positive

*Statistically Significant at p<0.05.

The model analysis showed a moderate inverse relationship between ANB and Z-angle. Positive correlations were observed between ANB and both E-line measurements.

➤ *Intraobserver Reliability*

Table 5. Intraobserver reliability

Parameter	ICC	95% CI
ANB	0.96	0.92–0.98
Z-angle	0.94	0.89–0.97
Upper lip–E-line	0.93	0.87–0.96
Lower lip–E-line	0.95	0.90–0.97
Nasolabial angle	0.92	0.85–0.96

The model measurements demonstrated excellent intraobserver agreement.

IV. DISCUSSION

The present study was designed to evaluate whether selected soft-tissue characteristics differed among skeletal Class I, Class II and Class III malocclusions. The model analysis showed differences in all four soft-tissue variables that were examined.

The Z-angle was lowest in the skeletal Class II group and highest in the skeletal Class III group. This pattern was compatible with the expected difference in overall facial convexity between the two sagittal skeletal relationships. A relatively smaller Z-angle was associated with greater soft-tissue convexity, whereas a larger angle was associated with a straighter or more concave profile.

The E-line measurements followed a similar pattern. The Class II group had the least negative upper and lower lip-to-E-line measurements, indicating greater relative lip prominence. In contrast, the Class III group had the most

negative values. These findings were consistent with the general clinical observation that sagittal skeletal pattern and incisor position can influence the apparent prominence of the lips.

The E-line, however, should not be interpreted as a measurement of lip position alone. The line depends on both pronasale and soft-tissue pogonion. Consequently, an apparently prominent or retrusive lip may partly reflect differences in nasal projection or chin morphology. This limitation was particularly relevant when comparing subjects with different skeletal patterns.

The nasolabial angle was largest in the Class II group and smallest in the Class III group in the model dataset. This finding was similar in direction to the results reported by Chaudhary et al., who studied 237 subjects and reported mean nasolabial angles of approximately 95.18° for Class I, 98.67° for Class II and 91.35° for Class III. Their study also reported a statistically significant difference in nasolabial angle between Class II and Class III groups.

The similarity in the direction of the nasolabial-angle findings was notable, although the present model values should not be interpreted as replication of that study. The actual measurements from the proposed RGUHS study would be needed to determine whether the same pattern was observed in the local population.

The relationship between skeletal morphology and facial soft tissue had also been investigated in recent literature. A 2025 study of 180 Malay subjects evaluated five angular nasal parameters and seven soft-tissue cephalometric variables, including upper and lower lip-to-E-line measurements, H-angle and Z-angle. Significant differences were found in several nasal parameters among skeletal groups, and multiple correlations were observed between nasal and soft-tissue variables.

Similarly, an Indian observational study evaluated 162 pretreatment cephalograms and classified subjects according to ANB angle. The authors examined the upper nasolabial angle together with skeletal and nasal measurements and further considered vertical growth pattern.

These findings highlighted an important point for orthodontic diagnosis: skeletal classification alone did not completely describe facial appearance. Two patients with a similar ANB value could have different soft-tissue profiles because of differences in lip thickness, incisor inclination, nasal morphology and chin prominence.

The correlation analysis in the model dataset demonstrated a moderate negative relationship between ANB and Z-angle. The positive correlations between ANB and E-line measurements suggested that changes in sagittal skeletal relationship were accompanied by systematic changes in lip position relative to the E-line. However, these correlations did not imply that ANB could be used to predict an individual's soft-tissue profile.

From a clinical perspective, this distinction was important. Orthodontic treatment planning should not be based on a single cephalometric parameter. Rather, skeletal relationships, dental compensation, soft-tissue characteristics and the patient's facial objectives should be considered together.

➤ *Clinical Relevance*

The clinical value of the present study lay in combining three relatively simple soft-tissue measurements rather than relying on a single facial-profile parameter.

The Z-angle provided information about overall facial profile.

The E-line measurements provided information regarding the relative position of the lips.

The nasolabial angle provided information regarding the relationship between the upper lip and nasal base.

Together, these measurements could therefore provide a more complete description of the sagittal soft-tissue profile.

This was particularly relevant in treatment planning involving extraction or non-extraction therapy, incisor compensation, camouflage treatment and referral for orthognathic assessment.

V. LIMITATIONS

➤ *The Study had Several Limitations.*

- First, the retrospective design limited control over the conditions under which the original cephalograms had been obtained.
- Second, lateral cephalometry provided a two-dimensional representation of a three-dimensional facial structure.
- Third, soft-tissue measurements could be influenced by lip posture at the time of radiographic exposure.
- Fourth, the E-line depended on nasal and chin morphology in addition to lip position.
- Fifth, ANB angle had recognized limitations as an isolated indicator of sagittal skeletal discrepancy because it could be affected by vertical facial pattern and the position of Nasion.

Finally, the findings from a particular Indian orthodontic population might not be directly applicable to populations with different ethnic and facial characteristics.

VI. CONCLUSION

Within the limitations of the proposed study, selected soft-tissue profile measurements differed among skeletal Class I, Class II and Class III malocclusions.

The model analysis showed that Class II subjects had a smaller Z-angle and relatively more prominent lips in relation to the E-line, whereas Class III subjects had a larger Z-angle and relatively more retrusive lip positions. The nasolabial angle was greatest in Class II and lowest in Class III subjects.

The findings supported the use of Z-angle, E-line measurements and nasolabial angle as complementary components of soft-tissue cephalometric assessment. These parameters could be considered alongside skeletal and dental measurements when establishing individualized orthodontic treatment objectives.

DECLARATIONS

➤ Ethics Approval

Ethical approval was obtained from the Institutional Ethics Committee of [Institution].

- IEC approval number: [Actual number]

➤ Informed Consent

Because the study used retrospective orthodontic records, the requirement for individual informed consent was [insert the exact wording approved by the Institutional Ethics Committee].

➤ Funding

No external funding was received for the study.

➤ Conflict of Interest

The authors declared that they had no conflict of interest.

➤ Data Availability

The study data were available from the corresponding author upon reasonable request, subject to institutional and ethical restrictions.

➤ Author Contributions

- [Author 1]: Study conception, data collection, cephalometric analysis, statistical analysis and manuscript preparation.
- [Author 2]: Study supervision, methodology, interpretation and critical revision of the manuscript.
- [Author 3]: Statistical guidance, interpretation and manuscript revision.

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