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## Original Research

### Evaluation of Anterior Cranial Base Length Across Skeletal Malocclusion Patterns in a North Indian Population: A Retrospective Study

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#### ABSTRACT

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**Background:** Anterior cranial base length is an important component of craniofacial morphology and may influence the interpretation of sagittal skeletal relationships. However, its association with different skeletal malocclusion patterns remains insufficiently established across populations.

**Objective:** To evaluate and compare anterior cranial base length (S–N) among skeletal Class I, Class II, and Class III malocclusions in a North Indian population.

**Materials and Methods:** This retrospective cross-sectional study included 90 subjects aged 18–25 years, divided into three skeletal groups (n = 30 each) based on ANB angle criteria. Lateral cephalograms were manually traced, and S–N length was measured. Data were analysed using IBM SPSS Statistics version 21.0, with significance set at  $p < 0.05$ .

**Results:** The mean S–N length was  $66.20 \pm 2.59$  mm in Class I,  $66.60 \pm 3.87$  mm in Class II, and  $67.13 \pm 4.56$  mm in Class III subjects. Although the mean length increased progressively from Class I to Class III, the differences were not statistically significant according to conventional one-way ANOVA ( $F = 0.465$ ,  $p = 0.630$ ). The estimated effect size was small ( $\eta^2 \approx 0.011$ ). Levene's test indicated unequal group variances ( $p = 0.002$ ), warranting confirmation using Welch's ANOVA.

**Conclusion:** No statistically significant difference in anterior cranial base length was detected among the three skeletal malocclusion groups using conventional ANOVA. Further studies employing variance-robust statistical methods and comprehensive cephalometric assessments are needed to clarify this relationship.

**Keywords:** Anterior Cranial Base, Sella–Nasion Length, Skeletal Malocclusion

## INTRODUCTION

Cephalometric analysis is an essential diagnostic tool in orthodontics for evaluating craniofacial morphology and the anteroposterior relationship between the maxilla and mandible. The cranial base provides an important anatomical reference for assessing jaw position and facial skeletal relationships, and variations in its morphology may contribute to differences in sagittal skeletal patterns. <sup>[1]</sup> The anterior cranial base length, commonly measured as the linear distance between sella (S) and nasion (N), is an important cephalometric parameter investigated in relation to skeletal Class I, Class II, and Class III malocclusions. Evidence regarding the association between anterior cranial base length and sagittal skeletal discrepancies remains inconsistent. Arntsen et al. investigated cranial base and other craniofacial dimensions in individuals with severe skeletal malocclusions and controls, highlighting the need to examine these anatomical characteristics across different skeletal patterns. <sup>[2]</sup> In contrast, a meta-analysis by Gong et al., which included 20 studies, reported significantly shorter anterior and total cranial base lengths in skeletal Class III subjects than in Class I and Class II subjects.

Class II subjects also demonstrated greater anterior cranial base length than Class I subjects, suggesting a potential association between cranial base dimensions and sagittal skeletal relationships.<sup>[3-5]</sup> Population-specific differences are another important consideration in cephalometric assessment. Kumari and Bapat investigated anterior cranial base length in Central Indian individuals and emphasized the relevance of population-specific reference values when interpreting craniofacial measurements.<sup>[3]</sup> Differences related to sex, age, and craniofacial growth may also influence cephalometric dimensions. Therefore, findings obtained from one population should be interpreted cautiously when applied to another, and further population-specific investigations are warranted.

Furthermore, sagittal skeletal relationships cannot be reliably characterized by a single measurement in every clinical situation. Although conventional parameters such as the ANB angle are widely used, their interpretation may be influenced by cranial base geometry and the spatial positioning of anatomical landmarks. Alternative parameters, including the Beta angle and Yen angle, have been proposed to assess sagittal jaw relationships using different anatomical reference points.<sup>[4,5]</sup> These methods reinforce the importance of interpreting individual cephalometric measurements within the broader context of craniofacial morphology. Despite existing research on cranial base morphology, further evidence is needed regarding anterior cranial base length across all three skeletal malocclusion groups in North Indian populations. Therefore, this retrospective study aimed to evaluate and compare anterior cranial base length (S–N) among skeletal Class I, Class II, and Class III malocclusions and assess its association with sagittal skeletal patterns in a North Indian population.<sup>[6-10]</sup>

## MATERIALS AND METHODS

**Study Design, Setting, and Data Collection Period:** A retrospective cross-sectional cephalometric study was conducted in the Department of Orthodontics and Dentofacial Orthopaedics. Data were collected from 1 February 2026 to 1 May 2026. Using purposive sampling, 90 subjects aged 18–25 years were selected and categorized into three groups according to their skeletal classification: Class I, Class II, and Class III, with 30 subjects in each group. Skeletal classification was based on ANB angle criteria.

**Eligibility Criteria:** Subjects with complete permanent dentition, excluding third molars, good-quality pretreatment lateral cephalograms, and no history of previous orthodontic treatment or orthognathic surgery were included. Subjects with compromised general health, developmental dental anomalies, multiple

missing teeth, cysts, or tumours were excluded.

**Cephalometric Assessment:** Lateral cephalograms were obtained using a Kodak S8000C panoramic and cephalometric unit and manually traced on acetate sheets using standardized cephalometric techniques. Anterior cranial base length was measured as the linear distance between sella (S) and nasion (N), expressed in millimetres. Intra-observer reliability was assessed by repeating one tracing after a two-week interval.

**Statistical Analysis:** Data were analysed using IBM SPSS Statistics for Windows, version 21.0. Descriptive statistics, including means and standard deviations, were calculated for each group. Data normality was assessed using the Shapiro–Wilk test, while homogeneity of variances was evaluated using Levene’s test. One-way analysis of variance (ANOVA) was used to compare mean S–N length among the three skeletal groups. Statistical significance was set at  $p < 0.05$ , with a 95% confidence level and a protocol-specified statistical power of 80%.

## RESULTS

A total of 90 subjects were included in the study, with 30 subjects in each skeletal malocclusion group. The mean anterior cranial base length (S–N) increased progressively from skeletal Class I to Class III. As shown in Table 1, the mean length was  $66.20 \pm 2.59$  mm in Class I,  $66.60 \pm 3.87$  mm in Class II, and  $67.13 \pm 4.56$  mm in Class III. The highest mean was observed in Class III, whereas the lowest was observed in Class I. The mean differences were relatively small, measuring 0.40 mm between Classes I and II, 0.93 mm between Classes I and III, and 0.53 mm between Classes II and III. The observed ranges were 61–70 mm, 58–74 mm, and 59–76 mm, respectively. The wider range and greater standard deviation in Class III indicated greater variability in anterior cranial base length within this group.

**Table 1. Descriptive statistics of anterior cranial base length among skeletal malocclusion groups**

| Skeletal group | n  | Mean $\pm$ SD (mm) | Minimum (mm) | Maximum (mm) |
|----------------|----|--------------------|--------------|--------------|
| Class I        | 30 | $66.20 \pm 2.59$   | 61           | 70           |
| Class II       | 30 | $66.60 \pm 3.87$   | 58           | 74           |
| Class III      | 30 | $67.13 \pm 4.56$   | 59           | 76           |

The Shapiro–Wilk test showed no statistically significant departure from normality in Class I ( $p = 0.082$ ), Class II ( $p = 0.109$ ), or Class III ( $p = 0.153$ ), as presented in Figure 1. These findings supported the normality assumption for the group distributions, although they did

not independently establish that the data were normally distributed.

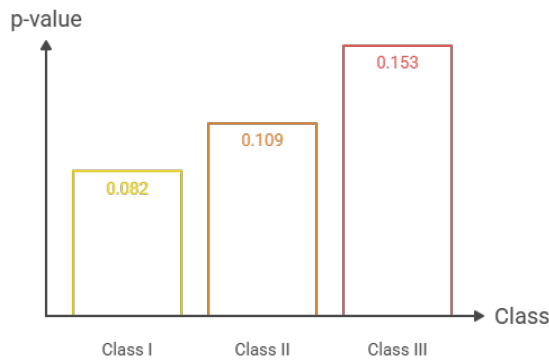


**Figure 1.** Shapiro-Wilk Test p-values for Class Distributions

Levene's test demonstrated a statistically significant difference in group variances (Levene statistic = 6.738,  $df = 2, 87$ ;  $p = 0.002$ ), indicating that the homogeneity-of-variance assumption was violated (Table 2). The variability observed in Class III was consistent with its comparatively larger standard deviation, although the group-specific variances require further assessment to determine their contribution to the significant Levene's test.

**Table 2. Levene's test for homogeneity of variances**

| Levene statistic | df1 | df2 | p-value |
|------------------|-----|-----|---------|
| 6.738            | 2   | 87  | 0.002   |

The conventional one-way ANOVA revealed no statistically significant difference in mean anterior cranial base length among the three skeletal malocclusion groups ( $F = 0.465$ ,  $p = 0.630$ ), as shown in Table 3. The estimated effect size was small ( $\eta^2 \approx 0.011$ ), indicating that approximately 1.1% of the observed sample variation was associated with group membership under the conventional ANOVA model. Thus, despite the slight increase in mean S–N length from Class I to Class III, the observed differences were not statistically significant. Because the homogeneity-of-variance assumption was violated, confirmation using Welch's ANOVA is recommended before drawing a definitive inferential conclusion.

**Table 3. Comparison of anterior cranial base length among skeletal malocclusion groups**

| Test          | F-statistic | p-value | Effect size ( $\eta^2$ ) |
|---------------|-------------|---------|--------------------------|
| One-way ANOVA | 0.465       | 0.630   | 0.011                    |

## DISCUSSION

In the present study, the mean anterior cranial base length (S–N) was  $66.20 \pm 2.59$  mm in skeletal Class I,  $66.60 \pm 3.87$  mm in Class II, and  $67.13 \pm 4.56$  mm in Class III subjects. Although the mean length increased progressively across the three groups, the difference was not statistically significant ( $F = 0.465$ ,  $p = 0.630$ ). The highest mean was observed in Class III, whereas the lowest was recorded in Class I. However, the small differences between group means do not provide sufficient evidence of a significant association between anterior cranial base length and sagittal skeletal classification in the study population.

An important distinction exists between anterior cranial base length and sagittal skeletal indicators. The S–N distance represents a linear measurement of cranial base length, whereas parameters such as the ANB, Beta, and Yen angles assess sagittal skeletal relationships using angular measurements. Previous studies have investigated the variability and diagnostic performance of these indicators, demonstrating that their interpretation may depend on anatomical reference points and underlying craniofacial characteristics.<sup>[10–12]</sup> Population-specific variation is another important consideration in orthodontic diagnosis. Studies conducted in different Indian populations, including South Indian, Eastern Indian, and Gulbarga populations, have investigated regional differences in craniofacial measurements and sagittal skeletal indicators.<sup>[13,14]</sup> Such research underscores the importance of considering population characteristics when interpreting cephalometric findings. Nevertheless, results concerning angular indicators cannot be directly extrapolated to linear cranial base measurements. The present study contributes population-specific data on anterior cranial base length in a North Indian sample, although further investigations are required to establish the generalizability of these findings.<sup>[15–18]</sup>

The absence of a statistically significant difference in the present study suggests that anterior cranial base length alone may have limited value in distinguishing the three skeletal malocclusion groups within this sample. Sagittal skeletal relationships reflect the combined morphology and positioning of the cranial base, maxilla, and mandible. Previous work on anteroposterior dysplasia and the Wits appraisal has emphasized the importance of evaluating skeletal discrepancies through multiple anatomical relationships.<sup>[7,9]</sup> Furthermore, the interpretation of cephalometric measurements may be affected by mandibular rotation, growth direction, and reference-plane orientation.<sup>[10]</sup> Therefore, anterior cranial base length should be considered alongside other

craniofacial measurements when assessing sagittal skeletal patterns.

**Limitation:** The present study has several limitations. Its retrospective design, purposive sampling, single-centre setting, and relatively small sample size may limit the generalizability of the findings. Additionally, the study included only individuals aged 18–25 years and assessed a single linear cranial base measurement. Other potentially relevant factors, including sex, individual craniofacial variation, and additional skeletal measurements, should be considered in future investigations. Multicentre studies involving larger samples, standardized measurement protocols, and comprehensive assessment of cranial base morphology and sagittal skeletal indicators may provide a more detailed understanding of these relationships.

## CONCLUSION

The present study observed small differences in mean anterior cranial base length among skeletal Class I, Class II, and Class III subjects, with no statistically significant difference detected by conventional one-way ANOVA. These findings do not establish a significant association between S–N length and sagittal skeletal classification in the studied North Indian population. Further research using variance-robust statistical methods and multiple cephalometric parameters is warranted to clarify the relationship between cranial base morphology and sagittal skeletal patterns.

## DECLARATIONS

**Ethical Approval:** Ethical approval should be obtained from the relevant Institutional Ethics Committee before submission, and the approval number should be provided where applicable.

**Consent to Participate:** Not Required.

**Funding:** NA

**Conflict of Interest:** NA

**Data Availability:** The data supporting the findings of this study are available from the corresponding author upon reasonable request, subject to institutional and ethical requirements.

**Author Contributions:** All authors contributed to the study design, data collection, analysis, interpretation, and manuscript preparation, and approved the final version.

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