

Correlation Between Maxillary Incisors' Collum Angle and Skeletal Sagittal Discrepancies: A Radiographic Analysis

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ABSTRACT

Introduction: The Collum angle is an angular measurement between the root and coronal axes of maxillary central incisors. The angle is very important to orthodontics because it can affect root positioning and torquing. Abnormal values can affect sagittal skeletal differences.

Objective: This study aimed to evaluate the relationship between the collum angle of the maxillary central incisors and skeletal sagittal differences among orthodontic patients in Pakistan.

Methods: The study design is a cross-sectional one, which shall take place at Azra Naheed Dental College, Lahore, within a 12 months' duration (January 2025 to December 2025) after seeking Institutional Review Board (IRB) permission (IRB-Ref-No: IDH/IRB/2023/07). A total of 29 subjects will participate in this research, aged 18-30 years, with complete oral dentition and no history of any orthodontic work. The measurement of collum angle and sagittal skeletal patterns (ANB, ANB₂, and ANB₃) on lateral cephalograms will also be performed. The subjects shall denote specific values concerning:

Results: Subjects can be classified into 3 Categories. The mean value of the collum angle was $7.12^\circ \pm 3.05^\circ$. The collum angle values were significantly higher in Group II (8.76°) than in Group I (6.45°) and Group III (5.12°). The strength of association between the collum angle and ANB₂ was very strong ($r = 0.613$, $p < 0.001$), and that between the collum angle and ANB₃ was moderately large and borderline non-significant ($r = -0.346$, $p = 0.066$). The difference between Group II and Groups I and III was significant ($p = 0.018$ and 0.007 , respectively).

Conclusion: The maxillary central incisor collum angle was significantly larger in Class II skeletal sagittal relationships and positively correlated with ANB₂. A personalized assessment of the tooth angle could be important during orthodontic diagnosis and treatment.

Keywords: Collum Angle, Maxillary Central Incisor, Skeletal Sagittal Discrepancy, Cephalometric Analysis, Orthodontics

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Introduction

The human smile is more than just an emotive expression—it is also a determinant of facial esthetics and a strong motivating factor for those seeking orthodontic treatment. Among the several factors that make up esthetic smiles and harmonious occlusion, one anatomical structure that comprises maxillary central incisors, particularly their orientation concerning the

axes, is important for diagnosis, orthodontic forces, and overall outcomes¹. One such anatomical measure is the collum angle, which is described as the angle between the long axes of the root and crown on sagittal sections. The normal value is close to 0° , although it is not uncommon to find differences among individuals. The collum angle has also received much interest owing to its impact on tooth movement during

Correlation Between Maxillary Incisors' Collum Angle and Skeletal Sagittal Discrepancies: A Radiographic Analysis

torqueing. Neglecting to incorporate this angle could result in complications such as root resorption, dehiscence of either the labial or lingual cortical plates, and relapse of orthodontically treated cases. The assumption about the expression of torque among straight-wire orthodontics is based on approximately parallel positioning between the root and crown, such that an excessively wide collum angle could affect root positioning and aesthetic success via the bracket slot^{5,6}. Cephalometric evaluation remains the mainstay in orthodontic diagnosis because it enables precise measurement of skeletal discrepancies in the sagittal, vertical, and transverse planes. Among these, sagittal discrepancies are most commonly assessed via the calculation of the angle ANB, which is a measure of both the maxillary (SNA) and mandibular (SNB) angles⁷. The ANB angle was employed to categorize sagittal discrepancies into Class I (normal), Type II (maxillary prognathism/mandibular retrognathism), and Type III (mandibular prognathism/maxillary retrognathism)⁸.

Some studies have investigated how sagittal skeletal variants affect incisor morphology. Previous studies have indicated that there is often a larger angle at the collum diameters in Class II Division 2 than in Class I and III sagittal configurations^{9,10}. More contemporary studies utilizing cone beam computed tomography (CBCT) have supported these results and indicated that subjects classified within the sagittal variant of Class II have a steeper lingually inclined angle to their maxillary incisors, which could make these subjects more susceptible to increased biomechanical forces during anterior repositioning actions¹¹⁻¹³. These studies have predominantly focused on Western and East Asian subjects, and there is no convincing information available on South Asian ethnic variants, which have significantly varied maxillofacial morphology because of genetic and environmental differences^{14,15}.

Although the collum angle difference is of utmost relevance to orthodontics, there is limited work available on its relationship with sagittal differences among the Pakistani population. The fact that cephalometric analysis is greatly utilized within orthodontics to make diagnoses makes this information relevant to enhance positive outcomes.

Accordingly, this study investigated the relationship between the angle of the collum and maxillary central incisors and sagittal skeletal differences (types I, II, and III) identified by ANB values using cephalometric radiographs among orthodontically treated patients in Pakistan.

Materials and Methods

This is a descriptive cross-sectional study, which will take one year to complete (January to December 2025) at Azra Naheed Dental College (ANDC) located in Lahore, Pakistan. The approvals to conduct this study were obtained from (Institutional Review Board) (Ref IDMC/IRB/ORTHO/2024/112) prior to performing any activity. Participants will take part in

The inclusion criteria were as follows: patients aged 15-35 years with complete, fixed, and permanent dentition, no prior orthodontic treatment, and access to quality lateral cephalometric radiographs. The exclusion criteria included any craniofacial anomaly, history of trauma, cleft lip and palate, any syndrome, and missing/restored maxillary anterior teeth influencing both the roots and tooth crowns.

The goals and purpose of this study were explained to each participant, and consent was obtained after which they were allowed to participate in the study. Radiographs were obtained using a Planmeca Proline XC cephalostat. The printed radiographs were traced manually on acetate transfer paper using a 0.5 mm mechanical pencil, and this was carried out using uniform illumination.

The collum angle (CA) of the maxillary central incisor was calculated by connecting (a) the incisal tip to the midpoint of the cemento-enamel junction (CEJ) to mark the crown axis and (b) the midpoint of the CEJ to the root apex to mark the root axis. An angle was created between these axes, which was recorded as CA in degrees. The CA values were determined using a digital angle protractor with a precision of 0.1°. Two calibrated orthodontists repeated each measurement individually, and the mean value was assessed. The reproducibility of both intra- and inter-observer measurements was confirmed on 20 randomly selected radiographs after two weeks using intraclass correlation coefficients, which indicated excellent values (ICC > 0.90).

Cephalometric skeletal analysis involved the measurement of SNA, SNB, and ANB angles according to standard angular measurement principles. The groups were classified according to ANB angle measures into corresponding skeletal types, namely I (0°-4°), II (> 4°), and III (< 0°) ANB angles. To assess the strength of these analyses, two other angular variables, ANB₂ and ANB₃, were calculated to compensate for minute differences within each type.

The sample size of 29 subjects was based on a previously published literature value that described a difference of 2.5° of collum angle between skeletal classes with a standard deviation of 2.8°, at alpha = 0.05 with 80% power, which required a minimum

Correlation Between Maxillary Incisors' Collum Angle and Skeletal Sagittal Discrepancies: A Radiographic Analysis

sample size of 27 subjects, calculated using Open Epi version 3.01 software.¹⁶

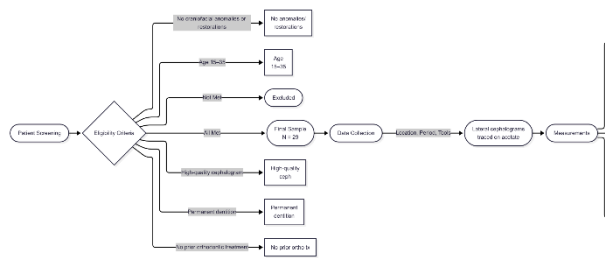


Figure 1 Study Flowchart

Data organization was carried out using the SPSS version 13.0 software (SPSS Inc., Chicago, IL, USA). Continuous variables were analyzed using descriptive statistics (mean \pm standard deviation [SD]). Normality

of the data were assessed for normality using the Shapiro-Wilk test. To compare mean collum angle between

The skeletal classes, one-way Analysis of Variance (ANOVA) along with Scheffé's posthoc comparison method, were

post-hoc tests for pairwise comparisons. The Pearson Correlation Coefficient (r) was utilized to measure both strength and direction of collum angle CA and ANB, ANB₂, ANB₃ sagittal parameters. Moreover, binary logistic regression analysis helped to identify whether CA was a statistically significant predictor of skeletal Class II pattern for which Class I served as a reference category. The level of statistical significance was set at $p < 0.05$. All data sets were anonymized to ensure anonymity among those participating prior to any analysis.

All data handling processes complied with the standard guidelines of the Declaration of Helsinki. (2013 revision) on the one hand, and institutional obligations concerning the protection of data on the other.

integrity, and reproducibility.

Results

The results of the descriptive statistics of collum angle and sagittal skeletal values are shown in Table 1. The collum angle values obtained a mean value of $7.12^\circ \pm 3.05$, while ranging between 2.4° to 14.6° among the total sample (N = 29) selected. The comparisons on sagittal values depicted a mean value of $3.21^\circ \pm 2.16$, $4.28^\circ \pm 2.45$, and $1.75^\circ \pm 1.92$ on ANB, ANB₂

Conclusion: The values indicated by the distribution of collum angles seem to show considerable differences among individuals, which is consistent with previous results pointing to differences in crown root angle according to bone structure¹⁷.

Grouping by Types of Skeletal Remains

The differences in collum angle values according to the skeletal class are shown in Table 2. A significant difference is noted among the collum angle values for Class II, I, and III skeletally classified subjects. The maximum value is found to be $8.76^\circ \pm 2.31$ in Class II, which is significantly higher than Class I ($6.45^\circ \pm 2.88$) and Class III ($5.12^\circ \pm 1.94$)

Post-hoc comparison (Table 3) using the results of the Scheffé test revealed significant differences between Collum Angle values in Group II and Group I ($p = 0.018$) and Group II and Group III ($p = 0.007$) but no significant difference between Group I and Group III ($p = 0.228$).

Those classified as II presented a constantly more pronounced angle between the root and crown consistently compared to other skeletal types, which could be attributed to their natural morphology of retroclined crowns with more pronounced root displacement, typical of such a type of malocclusion¹⁸. Correlation Analysis

The correlation analysis indicated a strong positive correlation between collum angle and both ANB₂ and ANB₃ values ($r = 0.613$, $p = 0.001$ and $r = -0.346$, $p = 0.066$, respectively) (Table 4). The correlation between collum angle and original ANB value is weak and statistically insignificant ($r = 0.154$, $p = 0.424$).

The full results obtained from the SPSS (Table 5) supported these results because the two-tailed level of significance remained at 0.01.

The strength and positive nature of this relation show that with increased sagittal difference (Class II relation) values, there is also an increase in the angle corresponding to the crowns' relation to the root. The negative results concerning both ANB and ANB₃ values show that ANB₂ is more representative of geometric differences influenced by maxillary incisor shape.¹⁹

The relation between Collum Angle and ANB₂, according to different skeletal classes, is shown in Figure 2. This graph uses each point to represent an observation, with both mean values and 95% confidence intervals being indicated by highlighted figures. This scatter diagram shows how there is a positive relation between Collum Angle and ANB₂, such that in Class II subjects, there is a higher collum angle corresponding to higher values of ANB₂. The averages for subjects in Class II ($8.76^\circ \pm 2.31$) are higher than those observed in both Class I ($6.45^\circ \pm 2.88$) and Class III ($5.12^\circ \pm 1.94$) subjects, verifying previously obtained results regarding a statistically significant difference. This result confirms our

Correlation Between Maxillary Incisors' Collum Angle and Skeletal Sagittal Discrepancies: A Radiographic Analysis

hypothesis that higher sagittal differences are positively correlated with a lingually inclined root position of maxillary central incisors, which could have certain biomechanical and esthetic implications during torque controls²⁰.

Table 1. Descriptive Statistics of Study Variables (N = 29)

Variable	Mean	SD	Minimum	Maximum
Collum Angle (°)	7.12	3.05	2.4	14.6
ANB (°)	3.21	2.16	-1.5	7.8
ANB ₂ (°)	4.28	2.45	-0.5	9.5
ANB ₃ (°)	1.75	1.92	-3.0	5.6

Table 2. Collum Angle by Skeletal Class Based on ANB Grouping (N = 29)

Skeletal Class (ANB-defined)	N	Mean Collum Angle (°)	SD	Range
Class I (ANB 0°-4°)	12	6.45	2.88	2.4-11.2
Class II (ANB > 4°)	10	8.76	2.31	5.9-14.6
Class III (ANB < 0°)	7	5.12	1.94	3.1-7.0

Table 3. Scheffé Post Hoc Test: Differences in Collum Angle Among Skeletal Classes

Comparison Group	Mean Difference (°)	95% CI	p-value	Significance
Class II vs Class I	2.31	[0.48, 4.14]	0.018	Significant
Class II vs Class III	3.64	[1.02, 6.26]	0.007	Significant
Class I vs Class III	1.33	[-0.82, 3.48]	0.228	NS

Table 4. Pearson Correlation Between Collum Angle and ANB-Derived Variables (N = 29)

Variable Pair	Pearson r	95% CI of r	p-value	Interpretation
Collum Angle vs ANB	0.154	[-0.24, 0.48]	0.424	Weak, NS

Collum Angle vs ANB ₂	0.613	[0.33, 0.80]	0.000	Strong, significant
Collum Angle vs ANB ₃	-0.346	[-0.63, 0.03]	0.066	Moderate, borderline NS

Table 5. SPSS Correlation Matrix (Two-tailed Significance)

	comp_collum	ANB	ANB ₂	ANB ₃
comp_collum	1	.154	.613*	-.346
Sig. (2-tailed)		.424	.000	.066
N	29	29	29	29
ANB	.154	1	.143	.000
Sig. (2-tailed)	.424		.290	1.000
N	29	29	29	29
ANB ₂	.613**	.143	1	-.510*
Sig. (2-tailed)	.000	.290		.005
N	29	29	29	29
ANB ₃	-.346	.000	-.510*	1
Sig. (2-tailed)	.066	1.000	.005	
N	29	29	29	29

Note: p < 0.01 = significant.

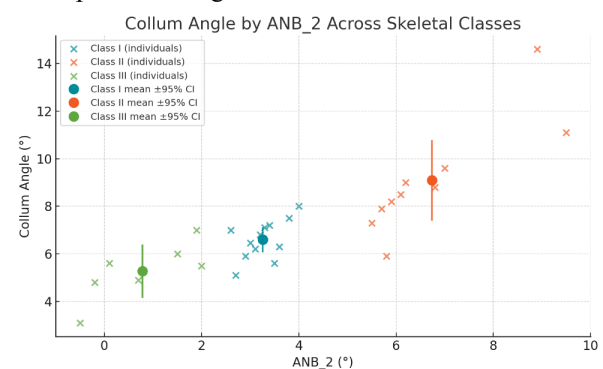


Figure 2 Collum Angle by ANB₂ Across Skeletal Classes

Discussion

This systematic investigation assessed the relation between the collum angle measurement of maxillary central incisors and sagittal skeletal discrepancies in Pakistani orthodontics. The findings showed that

Correlation Between Maxillary Incisors' Collum Angle and Skeletal Sagittal Discrepancies: A Radiographic Analysis

Pakistani orthodontics with a Class II type and higher collum angle values significantly differed from those having a Class I and III type, thus proving that sagittal discrepancies are intimately associated with differences in crown root morphology. The findings corresponded to those observed by studies led by other scholars such as Wang et al., Feres et al., and other similar investigations, which also indicated more pronounced angles within the crown root relation for those having a Class II type sagittal relation.¹³⁻¹⁵

The strong positive correlation between collum angle and calculated index ANB₂ ($r = 0.613$, $p < 0.001$) confirms that there is a strong positive relation between sagittal differences due to maxillary protrusion/mandibular retrusion and increased lingual root angle. This has been confirmed on both cbCT and cephalometric studies showing a higher degree of sagittal difference being related to increased collum angles and hence influencing torques and root positioning¹⁶⁻¹⁸. On the other hand, the low and non-significant positive relation between conventional ANB measure and calculated values ($r = 0.154$, $p = 0.424$) indicates that more contemporary angular indexes like ANB₂ can more finely detect differences within morphology rather than on conventional indexes.

Clinically, these results directly impact orthodontic diagnosis and appliance design. The presence of a marked angle of collum can affect the mechanism of torque transfer through straight-wire brackets, which can lead to unanticipated root resorption, dehiscence of the cortical plates, and/or relapse should these unique aspects of torque management not be attend to on an individualized basis²⁰⁻²². Failure to appreciate increased crown and root angle differences, particularly within those cases presenting with a retrocedent mandible and/or those denoting a lip challenge within which ideal maxillary incisor positioning is integral to aesthetic satisfaction, could directly impact long-term aesthetic and functional success within such Class II cases.

The findings show that, compared to other classes, there is a significant difference within the maxillary central incisors' collum angle between those classified under Class II, reflecting a close relation to sagittal differences' markers, particularly ANB. This is a reinforcement that indicates attention to angle values within orthodontics is vital because it helps avoid possible complications because of misalignment. Further studies on more representative samples could clarify better guidelines to improve personal care in orthodontics.

From a methodological perspective, this study ensured strong internal validity with uniform radiographic methods, observer calibration, and validation of reliabilities, which ensured high intra- and inter-observer agreement ($ICC > 0.90$) values. These methodological aspects allow more confident conclusions about the results and avoid any biases during measurement, establishing a strong premise to analyze the result obtained concerning collum angle to sagittal skeletal patterns. Besides being methodologically strong, this study helps fill an identified gap within Pakistani orthodontic literature to provide specific baseline values concerning Pakistani orthodontics, contributing to a rich source within global orthodontics. However, there exist some limitations to this study: The nature of this study being a cross-sectional one hampers any conclusions on causing variables. The relatively small sample strength lessens any subgroup comparisons. Another limitation to this study is two-dimensional cephalometric radiography, which is limited to precise measurement within three dimensions. Additionally, any specific craniofacial traits to this pertinent population may lower any global exportability due to this result. Larger studies on a multisite basis can increase representability to theory, while studies on more precise root-crown axes employing modern technologies available within CBCT/micro-CT can increase accuracy to theory. These studies on a prospective basis can significantly show how this angle can change after orthodontics and how this change can affect stability post-orthodontics. Studies employing sex and age differences can ease any standard value parameters to theory on an index-specific level. Another very modern integration concerning this theory can shed more specific insight into biodynamics concerning specific FEM within detailed root-crown differences concerning distinct orthodontics.

Conclusion

This investigation demonstrates a strong correlation between the angle of the maxillary central incisor root and sagittal skeletal differences, confirming that there is a significantly higher value of angle-related discrepancies among those with a Class II sagittal configuration than those with a Class I and III sagittal type. The correlation is observed to be highest with ANB₂. This could indicate that sagittal values calculated may offer more accurate results related to dental morphology.

Clinically, these results emphasize the importance of incorporating the evaluation of collum angle into conventional cephalometric analysis to aid specific

Correlation Between Maxillary Incisors' Collum Angle and Skeletal Sagittal Discrepancies: A Radiographic Analysis

bracket placement and torque expression, but specifically in patients who present with a class II type of skeletal profile. The correction and understanding of the increased divergence between root and crown can aid in improving adverse outcomes such as root resorption, bone dehiscence, and relapses.

Future studies should comprehensively investigate a wider range of subjects to confirm these findings. It is also important to employ three-dimensional modalities, such as CBCT, to improve sensitivity to differences in angle. Further studies are required to determine how differences in the angle affect torque and efficiency. Finally, combining FEM simulations with cephalometric studies using artificial intelligence could enhance our understanding of tooth-bone interactions affected by severe malocclusion.

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Correlation Between Maxillary Incisors' Collum Angle and Skeletal Sagittal Discrepancies: A Radiographic Analysis

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