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Original Article

Dentistry Section

Comparison of Crown Root Morphology in Maxillary and Mandibular Anterior Teeth of Different Sagittal Skeletal Patterns in Bengali Population: A Retrospective CBCT Study

RUPAM KUMARI[1], SIDHARTHA DAS[2], PRASENJIT BANERJEE[3], ANUSREE PAUL[4], MITA MANDAL[5], MANISH JHA[6], SAMARENDRA RAY[7], ARUNAVO NANDY[8]

ABSTRACT

Introduction: Individual diversity is the cornerstone of human biology and this is also reflected in the crown and root morphology of teeth. The maxillary and mandibular anterior teeth can be differentiated based on their crown-root morphology, collum angle, Labial Surface Angle (LSA) and torque angle. In clinical orthodontic practice, the collum angle is often assumed to be zero, as seen in standardised cephalometric incisor tracing templates. This assumption overlooks the variations in collum angles observed in different malocclusions, leading to difficulties in achieving proper root angulation after treatment.

Aim: To evaluate and correlate the collum angle, LSA and torque angle in maxillary and mandibular anterior teeth across different skeletal patterns in the Bengali population.

Materials and Methods: This retrospective study was conducted at the Department of Orthodontics and Dentofacial Orthopaedics , Guru Nanak Institute of Dental Sciences and Research, Kolkata, West Bengal, India, from March 2022 to January 2024. It involved 90 Cone-Beam Computed Tomography (CBCT) scans of young adult patients aged 18–24 years, with no history of orthodontic treatment, cleft lip and palate, or oral habits. Participants were divided into three groups based on the angle between Point A, Point B and Nasion (ANB angle): skeletal Class-I (2°<ANB<4°), Class-II (ANB>4°) and Class-III (ANB<2°), with 30 subjects in each group. The collum angle, LSA and torque angle were measured for different malocclusions and compared using Pearson's correlation analysis and one-way Analysis of Variance (ANOVA) ($p<0.05$).

Results: A positive correlation ($p<0.05$) was found between the collum angle and LSA in all types of malocclusions. The smallest collum angle was observed in the lower left central incisor. The maxillary lateral incisor showed a larger crown-root angulation than the central incisor. The maxillary canine and mandibular central incisor exhibited the smallest collum angles in the maxillary and mandibular arches, respectively. An increase from 3.5 mm to 5 mm in the calculation of LSA resulted in a difference of 3.7° for maxillary incisors and 3.5° for mandibular incisors. In skeletal Class-I malocclusion, the maxillary lateral incisor showed the largest torque angle, while the mandibular lateral incisor had the smallest. In Class-II malocclusion, the maxillary central incisor had the largest torque angle, whereas the maxillary canine had the smallest. In Class-III malocclusion, the maxillary lateral incisor exhibited the highest torque angle, while the mandibular canine showed the smallest.

Conclusion: A statistically significant difference was observed in the crown-root morphology of maxillary and mandibular anterior teeth. Understanding the variations and correlations among the collum angle, torque angle and LSA across different sagittal skeletal malocclusions can help refine orthodontic treatment planning and improve post-treatment outcomes.

Keywords: Cone-beam computed tomography, Crown root anatomy, Malocclusion, Torque

INTRODUCTION

Multiple research studies have provided evidence that the shape and structure of teeth exhibit considerable variation [1-4]. Therefore, to help clinicians understand the morphological peculiarities of each patient, guidelines rather than strict rules are used in the evaluation of facial aesthetics.

The collum angle is defined as the angle between the long axis of the crown and that of the root, used to represent the angular difference between these two axes. Although the collum angle has been described in the literature, it is often assumed to be zero degrees (Bauer TJ, 2014) [5]. This assumption is deeply ingrained in cephalometric design, particularly in standard templates (Bryant RM et al., 1984) [6]. For instance, Björk described the long axis of the central incisor as a line drawn from the incisal edge to the root apex [7], with incisor inclination measured by comparing this longitudinal axis to various cephalometric reference lines.

The Labial Surface Angle (LSA) is determined by drawing a tangent from the axial view at the point of bracket placement on the labial surface and connecting it to the crown axis. A wide variation in LSA can significantly affect the accurate expression of torque. The crown inclination of a tooth plays a critical role in preventing anterior tooth supraeruption and in establishing proper proximal contact. Therefore, teeth with appropriate torque are essential for achieving optimal occlusion.

The morphology of the maxillary anterior teeth is also a major determinant of facial attractiveness. Researchers have shown that variations in crown anatomy can lead to differences in torque measurements. Additionally, several factors—including wire material, bracket type, slot play, method of ligation, bracket height and iatrogenic errors—can influence torque variation [2].

The role of Cone-Beam Computed Tomography (CBCT) is unparalleled in orthodontic diagnosis, as it allows detailed examination of anatomic features of the maxilla, mandible and dentition in all three planes. Conventional two-dimensional (2D) cephalometric evaluation often suffers from superimposition of multiple anatomical structures, potentially compromising diagnostic accuracy. Hence, CBCT is now preferred over 2D cephalometry for providing more precise and comprehensive information [8].

The aim of the present study was to evaluate and correlate the collum angle, LSA and torque angle in maxillary and mandibular anterior teeth across different skeletal patterns in the Bengali population using CBCT scans. The limited number of population-based studies on this topic served as the key rationale for the present research. The novelty of this study lies in it being conducted for the first time in the Bengali population group.

MATERIALS AND METHODS

The present retrospective study was conducted in the Department of Orthodontics and Dentofacial Orthopaedics, Guru Nanak Institute of Dental Sciences and Research (GNIDSR), Kolkata, India, from March 2022 to January 2024. Data were collected from March 2022 to March 2023, followed by analysis from April 2023 to January 2024 Ethical clearance for the study was obtained from the Institutional Ethics Committee (Approval No.: EC/NEW/INST/2021/WB/0041). The CBCT scans were retrieved from the departmental archive (2017–2022) for patients aged 18–24 years who reported for treatment.

Sample size calculation: The sample size was determined based on an alpha value of 0.05, power of 80% (β=0.2) and a 95% confidence level. A total of 90 samples were included, with a mean age of 22.45±4.33 years (range: 18–24 years). The standard normal deviate for $\alpha=Z\alpha=1.9600$. The standard normal deviate for $\beta=Z\beta=1.2816$ $C=0.5 * \ln \{(1+r) / (1 - r)\}=0.3316$

Total sample size=$N=\{(Z\alpha+Z\beta) / C\}^2+3=90$

The CBCT images were obtained using a Myray Blue Sky Machine (Conical, Variable-Field, H.R. Zoom, 90 kVp, 10 mA [max], Pulsed Emission) and analysed using MyRay's iRYS® software, which provides advanced tools for radiographic image analysis.

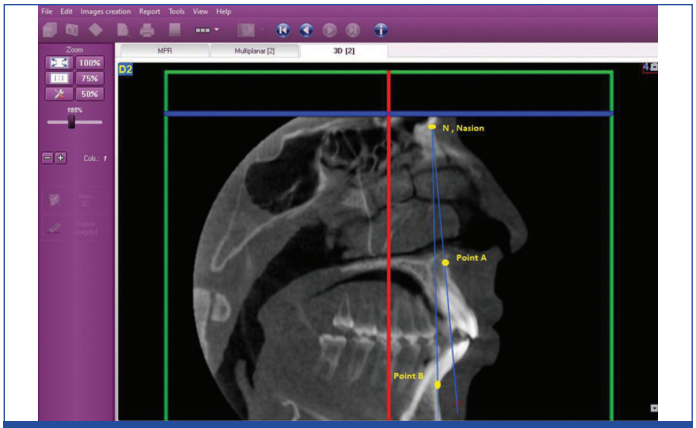
The samples were categorised into three groups based on the lateral cephalogram generated from the CBCT scans [Table/Fig-1] [9].

Groups	ANB Angle
Skeletal Class-I malocclusion (n=30)	2°≤ANB≤4°
Skeletal Class-II malocclusion (n=30)	ANB>4°
Skeletal Class-III malocclusion (n=30)	ANB<2°

[Table/Fig-1]: Classification of sagittal malocclusions according to ANB angle [9].

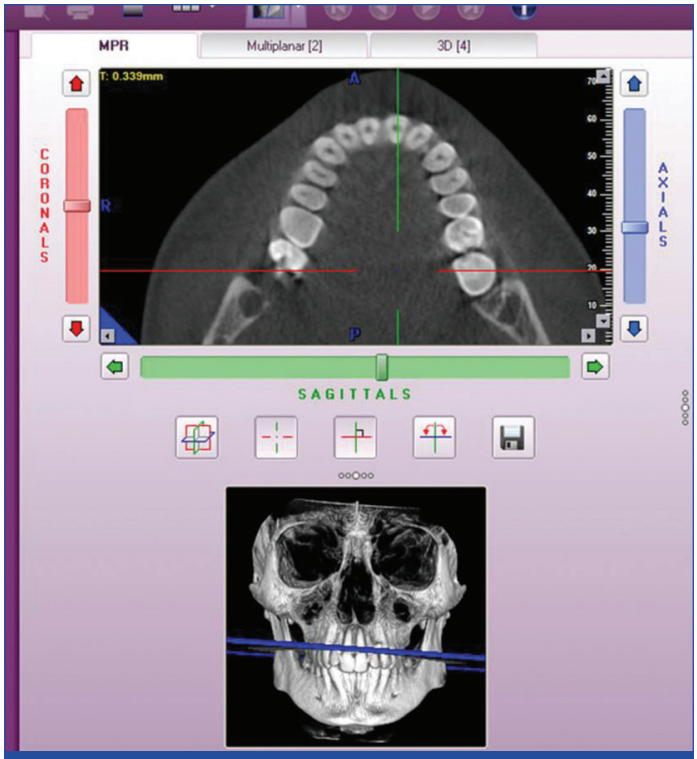
Study Procedure

Determination of ANB Angle: To calculate the ANB angle, a lateral cephalogram was derived from each CBCT scan. On the cephalogram, points Nasion (N), A and B were identified and joined as illustrated in [Table/Fig-2] to determine the ANB angle.



[Table/Fig-2]: Mid-sagittal section of CBCT scan illustrating measurement of ANB angle.

Obtaining Cross-Sectional Views: A cross-sectional view of the CBCT scan was obtained from the axial plane (blue) at the level of the Cementoenamel Junction (CEJ) of the tooth. A green reference line was drawn through the center of the tooth of interest to generate the mid-sagittal cross-sectional view [Table/Fig-3].



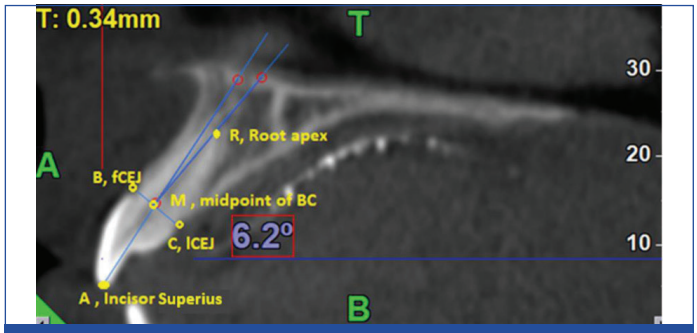
[Table/Fig-3]: Axial plane (blue line) placed at the position of cementoenamel junction of the central incisor of maxilla and sagittal plane (green line) passing through centre of the crown.

Measurement of Collum Angle [Table/Fig-4]: The mid-sagittal view was obtained with the axial plane positioned at the CEJ. Points B and C were identified to define the CEJ, where B represents the facial point (fCEJ) and C the lingual point (lCEJ).

The midpoint of the line segment BC was designated as point M.

The crown axis was defined by connecting point A (incisal edge) to point M.

The root axis was defined by connecting point M to point R (root apex) [Table/Fig-4].



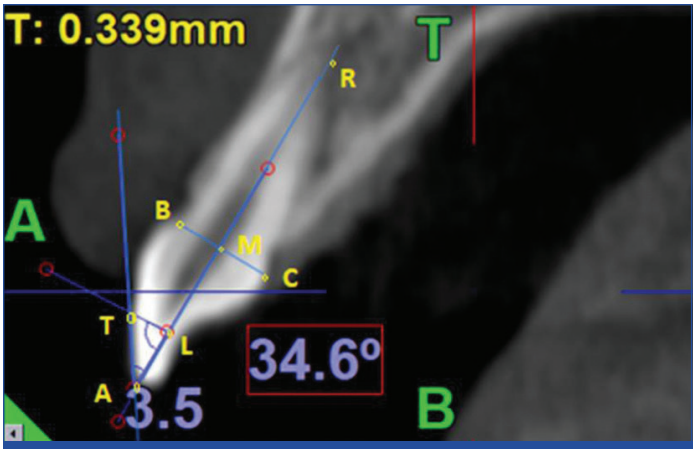
[Table/Fig-4]: Sagittal view of the central incisor of maxilla , measurement of the collum angle.

The collum angle was defined as the angle formed by the intersection of the crown and root axes. There are three possible variations of the collum angle:

1. Positive angle–when the longitudinal axis of the crown is ahead of the root,
2. Zero angle–when the axes of crown and root overlap and
3. Negative angle–when the crown axis lies behind the root axis [8].

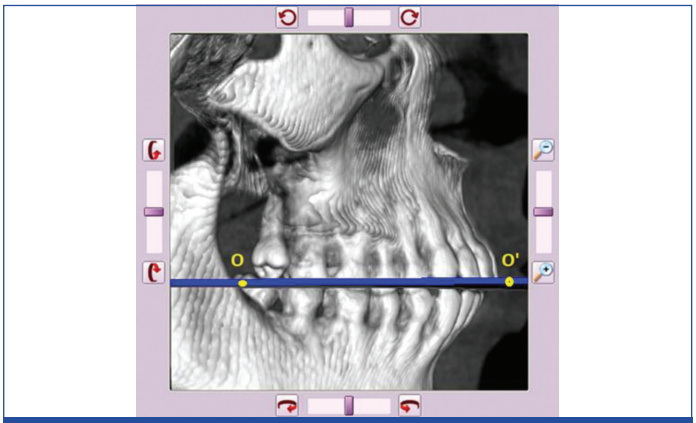
Measurement of Labial Surface Angle (LSA) [Table/Fig-5]: The mid-sagittal view of the tooth was obtained in the same manner as for the collum angle measurement. The longitudinal axis of the crown was drawn by connecting points A and M.

The LSA was measured at distances of 3.5 mm, 4.0 mm, 4.5 mm and 5.0 mm along the crown axis (AM) from point A [10]. For each measurement:

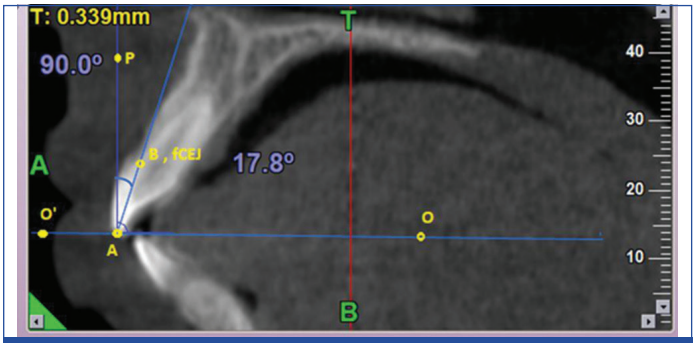


[Table/Fig-5]: Sagittal view of the maxillary incisor, measure of the LSA at the level of 3.5 mm from the incisor superius point on the crown axis.

The selected distance from A (e.g., AL=3.5 mm) was marked along the crown axis. From point L, a perpendicular was drawn to the labial surface of the tooth. The intersection point on the surface was marked as point T. A tangent was drawn at point T toward the longitudinal axis of the crown (AM). The angle (TAL) formed between the tangent and the crown axis represented the LSA at that specific distance from point A. Measurement of Torque Angle [Table/Fig-6,7].



[Table/Fig-6]: Occlusal plane (marked as blue line).



[Table/Fig-7]: Sagittal view of the maxillary central incisor, measurement of the torque.

The occlusal plane (as per Downs) [11] was drawn by connecting the midpoints of the occlusal surfaces of the maxillary and mandibular first molars posteriorly and the incisal edges of maxillary and mandibular incisors anteriorly (O–O').

A perpendicular line was dropped from point A (incisal edge) to the occlusal plane (O–O').

A line was then drawn joining point A to point B (facial point of CEJ).

A point P was marked on the perpendicular line from point A to the occlusal plane.

The torque angle was defined as the angle formed between points P, A and B [Table/Fig-7].

STATISTICAL ANALYSIS

Statistical analysis was performed using Jamovi version 2.3.21 software. Graphs and tables were prepared using Microsoft Office 2013. Pearson's correlation analysis was used to assess correlations among the collum angle, LSA, torque angle and ANB angle for each skeletal class. One-way ANOVA was applied to compare the different angular measurements across classes. The normality of data distribution was confirmed through visual inspection of Q–Q plots. Quantitative data were expressed as Mean±Standard Deviation (SD) and categorical data as percentages. A p-value<0.05 was considered statistically significant.

RESULTS

Statistically significant differences were observed among the collum angle, LSA and torque angle across teeth. As shown in [Table/Fig-8], in Class-I malocclusion, tooth 31 exhibited the smallest collum angle, while 42 had the largest. In Class-II malocclusion, tooth 12 showed the largest collum angle, whereas 41 had the smallest. Similarly, in Class-III malocclusion, tooth 41 had the smallest collum angle and 11 had the largest.

Among lateral incisors, the maxillary lateral incisor displayed the smallest collum angle in Class-I and Class-III malocclusions, but the opposite pattern was observed in Class-II malocclusion [Table/Fig-8]. The mandibular central incisor had the smallest collum angle among all central incisors [Table/Fig-8]. Regarding canines, the mandibular canine consistently had the smallest collum angle across all three malocclusion classes [Table/Fig-9].

Irrespective of skeletal malocclusion, a difference of 3.7° in LSA was observed in maxillary incisors and 3.5° in mandibular incisors, when

Class (tooth no. 11)	Collum Angle Mean±SD	F-statistics	p-value
Class-I	5.46±1.997	0.6506	0.549
Class-II	4.34±3.697		
Class-III	6.94±3.322		
Class (tooth no. 12)	**Collum Angle Mean±SD**	**F-statistics**	**p-value**
Class-I	5±1.918	0.377	0.698
Class-II	6.66±5.01		
Class-III	4.48±2.141		
Class (tooth no. 21)	**Collum Angle Mean±SD**	**F-statistics**	**p-value**
Class-I	5.08±2.039	0.62653	0.559
Class-II	4.74±3.183		
Class-III	6.56±2.548		
Class (tooth no. 22)	**Collum Angle Mean±SD**	**F-statistics**	**p-value**
Class-I	5±1.648	0.17	0.847
Class-II	6.16±4.03		
Class-III	5.04±1.673		
Class (tooth no. 31)	**Collum Angle Mean±SD**	**F-statistics**	**p-value**
Class-I	3.4±1.985	0.27383	0.768
Class-II	4.42±4.536		
Class-III	2.88±1.663		
Class (tooth no. 32)	**Collum Angle Mean±SD**	**F-statistics**	**p-value**
Class-I	6.62±4.599	1.264	0.342
Class-II	3.84±2.162		
Class-III	5.5±1.179		

Class (tooth no. 41)	Collum Angle Mean±SD	F-statistics	p-value
Class-I	3.82±2.244	0.24085	0.792
Class-II	3.3±3.501		
Class-III	2.74±2.474		
Class (tooth no. 42)	**Collum Angle Mean±SD**	**F-statistics**	**p-value**
Class-I	7.28±4.677	1.263	0.341
Class-II	4.02±1.914		
Class-III	5.28±1.188		

[Table/Fig-8]: Association between collum angle for different incisor teeth among Class-I, Class-II and Class-III malocclusions (N=30).
Test applied - One-way ANOVA, statistically significant p>0.05

Class (tooth no. 13)	Collum Angle Mean±SD	F- statistics	p-value
Class-I	5.42±2.16	0.521	0.614
Class-II	4.32±2.258		
Class-III	4.26±1.203		
Class (tooth no. 23)	**Collum Angle Mean±SD**	**F- statistics**	**p-value**
Class-I	5.54±1.767	0.6959	0.528
Class-II	4.72±2.018		
Class-III	4.38±1.148		
Class (tooth no. 33)	**Collum Angle Mean±SD**	**F- statistics**	**p-value**
Class-I	5.1±2.272	0.6519	0.553
Class-II	3.88±2.984		
Class-III	3.8±0.846		
Class (tooth no. 43)	**Collum Angle Mean±SD**	**F- statistics**	**p-value**
Class-I	5.02±2.34	1.9173	0.22
Class-II	3.8±2.059		
Class-III	2.86±0.865		

[Table/Fig-9]: Association between collum angle for canines among Class-I, Class-II and Class-III malocclusion (N=30).
Test applied- One-way ANOVA, statistically significant p<0.05

measured from 3.5 mm to 5 mm along the crown axis from the incisal edge. Similarly, in maxillary canines, a difference of 4.2° was noted and 3.5° in mandibular canines [Table/Fig-10].

Teeth	LSA at 3.5 mm	LSA at 4 mm	LSA at 4.5 mm	LSA at 5 mm
Maxillary incisors	24.7°	23.4°	22.1°	20.97°
Mandibular incisors	21.2°	20°	18.8°	17.7°
Maxillary canines	27.23°	25.77°	24.49°	23.08°
Mandibular canines	22.51°	21.2°	20.1°	19°

[Table/Fig-10]: Gradual changes in LSA with changes in height in anterior teeth.

In skeletal Class-I malocclusion, the maxillary lateral incisor exhibited the largest torque angle, while the mandibular lateral incisor had the smallest. In Class-II malocclusion, the maxillary central incisor had the largest torque angle and the maxillary canine had the smallest. In Class-III malocclusion, the maxillary lateral incisor had the highest torque angle and the mandibular canine the lowest.

Correlation analysis in Class-I malocclusion revealed a weak positive correlation between ANB angle and collum angle (r=0.201, p=0.124), which was not statistically significant. A weak negative correlation was observed between ANB angle and torque angle (r=-0.222, p=0.088), also not statistically significant. The collum angle and torque angle showed a very weak negative correlation (r=-0.037, p=0.778).

However, LSA at 4.5 mm exhibited a moderate positive correlation with torque angle (r=0.331, p=0.01), which was statistically significant (p<0.01). Similarly, LSA at 5 mm showed a moderate positive correlation with torque angle (r=0.312, p=0.015) and with collum angle (r=0.269, p=0.038), both statistically significant (p<0.05) [Table/Fig-11]. These results suggest that variations in labial surface angulation can influence root positions of anterior teeth in Class-I malocclusion, potentially affecting treatment outcomes if not considered during planning.

Correlation Matrix				
Variables		**ANB Angle**	**Collum angle**	**Torque angle**
ANB Angle	Pearson's r	-		
	p-value	-		
COLLUM Angle	Pearson's r	0.201	-	
	p-value	0.124	-	
Torque angle	Pearson's r	-0.222	-0.037	-
	p-value	0.088	0.778	-
LSA3.5	Pearson's r	-0.038	0.234	0.362**
	p-value	0.774	0.072	0.004
LSA4	Pearson's r	-0.016	0.263*	0.371**
	p-value	0.904	0.042	0.003
LSA4.5	Pearson's r	-0.001	0.247	0.331**
	p-value	0.995	0.057	0.01
LSA5	Pearson's r	0.032	0.269*	0.312*
	p-value	0.808	0.038	0.015

[Table/Fig-11]: Correlation between various dental angles in skeletal Class-I malocclusion.
Note: *p<0.05, **p<0.01 ***p<0.001

In Class-II malocclusion, ANB angle had a weak positive correlation with collum angle (r=0.205, p=0.115), which was not statistically significant. A strong negative correlation was observed between ANB angle and torque angle (r=-0.411, p=0.001) and a moderate positive correlation between collum angle and torque angle (r=0.342, p=0.008), both statistically significant at the 0.01 level. LSA measured from 3.5 mm to 5 mm showed weak positive correlations with ANB angle, collum angle and torque angle, but these were not statistically significant (p>0.05) [Table/Fig-12].

Correlation Matrix				
Variables		**ANB Angle**	**Collum angle**	**Torque angle**
ANB Angle	Pearson's r	-		
	p-value	-		
Collum angle	Pearson's r	0.205	-	
	p-value	0.115	-	
Torque angle	Pearson's r	-0.411**	0.342**	-
	p-value	0.001	0.008	-
LSA3.5	Pearson's r	0.17	0.144	-0.238
	p-value	0.193	0.273	0.067
LSA4	Pearson's r	0.185	0.133	-0.246
	p-value	0.157	0.309	0.058
LSA4.5	Pearson's r	0.177	0.128	-0.232
	p-value	0.175	0.328	0.074
LSA5	Pearson's r	0.164	0.139	-0.22
	p-value	0.212	0.288	0.091

[Table/Fig-12]: Correlation between various dental angles in skeletal Class-II malocclusion. Note: *p<0.05, **p<0.01, ***p<0.001

In Class-III malocclusion, LSA values from 3.5 mm to 5 mm demonstrated weak positive correlations with ANB angle, collum angle and torque angle, but none were statistically significant (p>0.05). Notably, LSA at 4 mm exhibited a statistically significant

negative correlation with torque angle (r=-0.27, p=0.037) and LSA at 4.5 mm also showed a significant negative correlation with torque angle (r=-0.265, p=0.041) [Table/Fig-13].

Correlation Matrix				
Variables		**ANB angle**	**Collum angle**	**Torque angle**
ANB angle	Pearson's r	-		
	p-value	-		
Collum angle	Pearson's r	0.071	-	
	p-value	0.589	-	
Torque angle	Pearson's r	-0.013	0.11	-
	p-value	0.924	0.401	-
LSA3.5	Pearson's r	0.097	0.132	-0.241
	p-value	0.462	0.314	0.064
LSA4	Pearson's r	0.121	0.11	-0.27*
	p-value	0.356	0.404	0.037
LSA4.5	Pearson's r	0.126	0.119	-0.265*
	p-value	0.337	0.365	0.041
LSA5	Pearson's r	0.11	0.111	-0.241
	p-value	0.401	0.398	0.063

[Table/Fig-13]: Correlation between various dental angles in skeletal Class-III malocclusion.
Note. *p<0.05, **p<0.01, ***p<0.001

DISCUSSION

A stable occlusal connection, a pleasing aesthetic outcome and a normal overjet and overbite all depend on the accurate expression of anterior torque. Straight-wire brackets present challenges in achieving optimal preadjusted torque due to variations in wire material, slot width, ligature choice, operator experience, tooth anatomy and alveolar bone morphology.

In a study by Wang XM et al., a positive correlation between collum angle and LSA was reported [8]. Similarly, in the present study, a positive correlation between collum angle and LSA was observed across all types of malocclusions. Wang XM et al., also reported significant crown-root angulation in mandibular incisors in Class-III malocclusion [8]. Consistent with this, the present study found that the lower left central incisor had the smallest crown-root angulation in Class-III malocclusion. Wang XM et al., also noted predominance of maxillary incisors in terms of crown-root angulation in Class-II malocclusions; however, our findings indicate that maxillary lateral incisors have greater crown-root angulation compared to maxillary central incisors in Class-II malocclusions.

Shailaja AM et al., reported significant differences in collum angles of Class-III maxillary central incisors compared with Class-I and Class-II malocclusions [12]. The present study supports this finding, demonstrating variations in collum angles of maxillary incisors across skeletal malocclusions. Ma ES reported that the maxillary canine has the smallest and the mandibular canine the greatest collum angle among all anterior teeth [13]. In contrast, the present study found that the maxillary canine exhibits the minimal collum angle in the maxilla and the mandibular central incisor has the smallest collum angle among anterior teeth.

Ma ES also concluded that maxillary lateral incisors exhibit relatively small collum angles compared to other lateral incisors, which aligns with the present results: maxillary lateral incisors had the smallest collum angle among lateral incisors in Class-I and Class-III malocclusions [13]. Harris EF et al., observed that Class-III subjects, particularly those with anterior crossbite of maxillary incisors, exhibit a higher average collum angle [14]. The present study corroborates this finding. Lee KH et al., reported that collum angles of maxillary incisors are significantly smaller in Class-III subjects compared to Class-I; however, in the present study, maxillary canines had greater crown-root angulation than maxillary central and lateral incisors in Class-III malocclusion [15].

Sino H et al., demonstrated that altering bracket position from 3.5 mm to 5.5 mm (maxillary central incisor) or 3 mm to 5 mm (mandibular incisor) changes the mean torque expression by 4.5° (maxillary incisor) and 3.2° (mandibular incisor) [16]. The present study findings are consistent, showing that moving from 3.5 mm to 5 mm from the incisal edge results in a 3.7° difference in LSA for maxillary incisors and 3.5° for mandibular incisors.

Limitation(s)

A notable limitation of the present study was the absence of a Class-I normal occlusion group, which would have served as a control for comparing all malocclusions. Patients with normal occlusion generally do not seek orthodontic treatment and records were retrieved from departmental archives at the study Institute Another constraint was the presence of artifacts in some CBCT scans. Although scans with suboptimal radiographic quality were excluded, some included scans still had noise that posed challenges. A "graining" effect may occur when image projections exhibit inconsistent attenuation values, affecting measurement accuracy.

CONCLUSION(S)

Modern orthodontics relies heavily on the preadjusted edge-wise appliance introduced by Andrews. However, the limitations of the straight-wire appliance become evident when considering natural variations in crown morphology and root position. While adjustments in wire or bracket position can compensate for crown form variations, root angulation is often overlooked in routine clinical practice. Orthodontists commonly assume zero-degree angulation between the crown and root, as reflected in standardised cephalometric incisor tracing templates. This assumption ignores the actual variation in crown-root angulation, known as the Collum Angle (CA), observed across different malocclusion types.

The results of the present study highlight the need for customised anterior brackets, as torque expression varies considerably among individual anterior teeth. Bracket positioning should also be adjusted accordingly. Future studies could further classify Class-II and Class-III malocclusions into subgroups to refine bracket selection and torque management.

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PARTICULARS OF CONTRIBUTORS:
1. Professor, Department of Orthodontics, Guru Nanak Institute of Dental Sciences and Research, Kolkata, West Bengal, India.
2. Postgraduate Trainee, Department of Orthodontics, Guru Nanak Institute of Dental Sciences and Research, Kolkata, West Bengal, India.
3. Professor, Department of Orthodontics, Guru Nanak Institute of Dental Sciences and Research, Kolkata, West Bengal, India.
4. Reader, Department of Orthodontics, Guru Nanak Institute of Dental Sciences and Research, Kolkata, West Bengal, India.
5. Reader, Department of Orthodontics, Guru Nanak Institute of Dental Sciences and Research, Kolkata, West Bengal, India.
6. Reader, Department of Orthodontics, Guru Nanak Institute of Dental Sciences and Research, Kolkata, West Bengal, India.
7. Professor, Department of Orthodontics, Guru Nanak Institute of Dental Sciences and Research, Kolkata, West Bengal, India.
8. Senior Lecturer, Department of Orthodontics, Guru Nanak Institute of Dental Sciences and Research, Kolkata, West Bengal, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Rupam Kumari,
Staff Quarter, Room No. 11, GNIDSR Campus, Panihathi,
Kolkata-700114, West Bengal, India.
E-mail: drkrupam2018@gmail.com

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