



## Comparative evaluation of crown–root angle and labial surface angle of mandibular central incisors in class i and class ii malocclusions: A cross-sectional CBCT study

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DOI: <https://doi.org/10.66856/ijds.2026.8.2.8052>

### Abstract

Variations in crown–root morphology, particularly Collum Angle (CA) and Labial Surface Angle (LSA), influence orthodontic biomechanics, torque expression, and bracket positioning. This retrospective cross-sectional CBCT study was conducted on 45 patient records selected from the archives of the Department of Orthodontics and Dentofacial Orthopaedics. The subjects were equally divided into three groups based on skeletal malocclusion: Class I, Class II Division 1, and Class II Division 2, with 15 subjects in each group. Sagittal CBCT sections of mandibular central incisors were analyzed to measure Collum Angle and Labial Surface Angle using standardized anatomical landmarks and reference axes. The results demonstrated statistically significant differences in Collum Angle among the three groups, with the highest mean values observed in Class II Division 2 malocclusion, followed by Class II Division 1, while Class I malocclusion exhibited the lowest values. Labial Surface Angle also showed significant intergroup variation. Indicating that increased crown–root angulation was associated with altered labial surface morphology.

**Keywords:** To evaluate and compare the Collum Angle and Labial Surface Angle of mandibular central incisors among skeletal Class I, Class II div 1 & Class II div 2 malocclusion groups using CBCT

### Introduction

Modern orthodontics relies heavily on pre-adjusted edgewise appliances, introduced by Andrews, which assume ideal crown–root relationships. However, this assumption does not account for natural anatomical variability, particularly in crown–root angulation. Collum Angle (CA), defined as the angle between the long axes of crown and root, plays a critical role in determining root positioning during orthodontic movement. Variations in CA can significantly affect torque expression and may predispose teeth to complications such as root resorption or cortical plate perforation. Andrews<sup>[1]</sup> in 1968 The limitations of the straight-wire appliance become apparent however, when one considers the variability inherent in natural crown forms, as well as the variability of root position in relation to the clinical crown. In study discussed by Bryant *et al*<sup>[2]</sup> have shown that root translation or torquing into the palatal cortex significantly increases the odds of root resorption. Baumrind *et al*<sup>[3]</sup>, have shown that errors in landmark identification are too great to be ignored, and that the amount of error depends on the landmark identified on cephalogram tracing. Lee *et al*<sup>[4]</sup> conducted a three-dimensional evaluation of crown–root angulation in maxillary anterior teeth across different skeletal malocclusions using CBCT. Evaluated both mesiodistal and labiolingual components, thereby providing a more comprehensive assessment of tooth morphology. Their findings demonstrated that while mesiodistal crown–root angulation did not show significant variation among skeletal malocclusion groups, the labiolingual crown–root angulation of maxillary central incisors was significantly reduced in skeletal Class III. Wang *et al*<sup>[5]</sup>, provided a more precise assess of crown–root morphology by evaluating both Collum

Angle and labial surface angle across different skeletal malocclusions. Similarly, Labial Surface Angle (LSA) reflects the curvature and inclination of the labial surface and directly influences bracket positioning and effective force transmission. Despite its clinical importance, LSA remains underexplored in orthodontic literature. With the advent of Cone Beam Computed Tomography (CBCT), three-dimensional assessment of dental morphology has become more accurate and reliable compared to conventional cephalometric methods, which are prone to landmark identification errors. Previous studies have primarily focused on maxillary incisors or evaluated CA independently. There is gap in literature regarding combined evaluation of CA and LSA in mandibular incisors across different malocclusions. Therefore, this study was undertaken to provide a comprehensive CBCT-based analysis of these parameters.

Aim of study was to evaluate and compare crown root angle and labial surface angle of mandibular central incisor in Class I, Class II div.1 and Class II div. 2 malocclusions.

### Objectives of the Study

- To evaluate and compare Crown root angle in mandibular central incisor of Class I, Class II Div 1 and Class II div 2 malocclusion.
- To evaluate and compare Labial surface angle in mandibular central incisor of Class I, Class II Div 1 and Class II div 2 malocclusion.

### Materials and Methods

The retrospective cross-sectional CBCT study was done to evaluate and compare Crown Root Angle and Labial Surface Angle of mandibular left central incisor in Class I,

Class II div. 1 and Class II div. 2 malocclusions. The current study was carried out by using records from archives records from Pacific Dental College, Udaipur

**Sample Size**

The study consists of 45 patients which was calculated using G power software (version 3.1.9.4, Franz Faul, Universita

Kiel, Kiel, Germany) 15 each group, effect size (0, 92) based on a original research conducted by Wang *et al* [5].

**Ethical approval**

This study was approved by the Institutional ethical committee prior to the research. Annexure 1 – STU/IEC/2024/406

Inclusion Criteria	Exclusion Criteria
1. Patients with age group between 14-24 years.	1. Patients with Rotations, fractured crown and abrasion.
2. Patients who had not undergone orthodontic treatment.	2. Patients with Caries, restoration history and periodontitis in anterior teeth.
3. Patients with Left mandibular central incisor without root Resorption.	3. Patients with impacted/ ankylosed mandibular central incisor.
4. Patients with Root formed completely.	4. Patients with severe crowding in mandibular incisors.
5. Patients with Skeletal Class I, Class II div.1, and Class II, div. 2 malocclusion.	5. Patients with Skeletal Class III malocclusion.

**Equipments**

Carestream 9000 3D Extraoral imaging System (Carestream Health [TM], Rochester, New York) Software. (Fig. 1)

**Total: 45 patients**

- Groups:
- Group 1 -Class I skeletal malocclusion
- Group 2 - Class II Division 1 skeletal malocclusion
- Group 3 - Class II Division 2 skeletal malocclusion

45 Patients with full filling inclusion criteria were included in study. Lateral cephalogram and CBCT Records of selected patients was obtained and evaluated. Lateral cephalogram tracing was done manually to evaluate skeletal malocclusion of Class I, Class II by ANB Angle and Wits appraisal followed by upper incisor to SN angle and upper incisor to NA that elaborate types of malocclusion among Class II Div 1 and Class II Div 2 malocclusion The 45 samples were divided into three groups according to ANB angle and Wits appraisal. (Table 1)

**Table 1:** Parameters used to Classification of Skeletal malocclusion

Parameter	Group I Skeletal Class I	Group 2 Skeletal Class II Div 1	Group 3 Skeletal Class II Div 2
ANB Angle	0 ± 2 °	> 4 °	> 4 °
Wits appraisal	Males: -1 mm to +1 mm Females: 0 mm	> +2 mm	> +2 mm

Then subdivision was done among Class II Div 1 and Class II Div 2 according to upper incisor to SN angle and upper incisor to NA by Lateral Cephalogram tracings. (Table 2)

**Table 2:** Parameters used to classification of Class II div 1 and Class II Div 2 skeletal malocclusion

Parameter	Group 2 Skeletal Class II Div 1	Group 3 Skeletal Class II Div 2
U1-SN Angle	more than 108°	less than 100°
U1-NA Angle	more than 28°	less than 20°

- CBCT DICOM record of mandible was interpreted in sagittal section to evaluate crown root angle and labial surface angle using CARE STREAM 3D Imaging software version 3.8.7.

- CBCT records of mandible with area of interest incisor and lateral cephalogram were collected. CBCT records of mandible with FOV of 5 × 5 cm, 200 micron voxel size, setting of tube current 5.0 ma, voltage of 80 kvp and exposure time of 8 seconds.
- In axial section at midline of left mandibular central incisor was divided in equal sections by split slicing for interpretation in CS 3D Imaging software version 3.8.7. At integration of 300µm /500 µm. and 7<sup>th</sup> no of slice was used for evaluation and readings noted in MS office Excel 2013 spreadsheet.

**Measurements steps for sagittal plane selection**

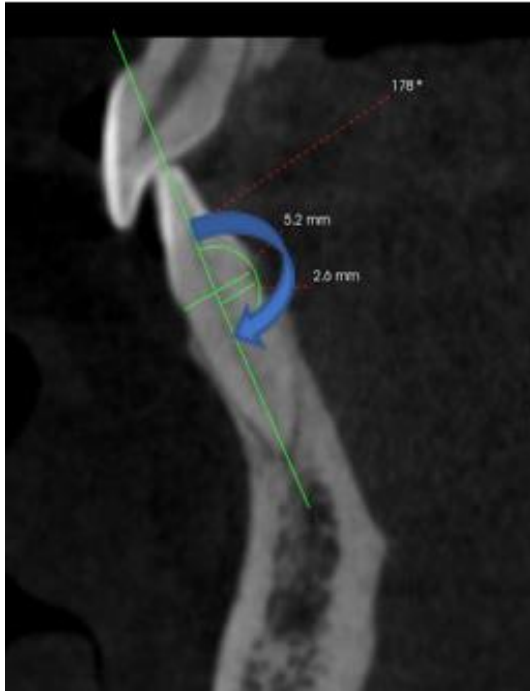
- In axial section mesio-distal width of left mandibular central incisor at incisal edge was measured then half of that value noted, then on that slice in axial plane showing sagittal plane is used for make measurements in axial section (in mm) (Fig. 1)



**Fig 1:** At midline of sagittal section, CS 3d software depicting integration Of 1.5 mm and 7<sup>th</sup> no of slice for interpretation at mesio-distal centre of mandibular central incisor

**Crown Root Angle**

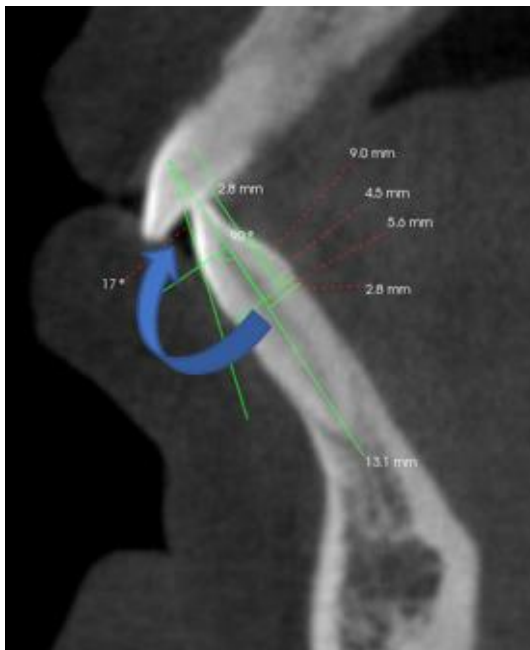
- In selected sagittal plane slice labio-lingual width was measured at CEJ by drawing a line and divided into equal half.
- Longitudinal axis of crown was passed through Incisal edge and mid centre of labiaoligual width at CEJ.
- Then from mid centre of labiaoligual width at CEJ to the root apex Longitudinal axis was passed followed by measuring formed angle between these long axes (Fig. 2).



**Fig 2:** In sagittal section, depicting labio-lingual width measured at CEJ by drawing a line and divided into equal half and longitudinal axis of crown with measuring angle between long axes.

### Labial Surface Angle

- In sagittal section total length of crown was measured from incisal edge to mid centre of CEJ.
- Then it is divided in equal halves from that point a line was passed perpendicular from most countered labial surface of crown to intersecting at longitudinal axis of crown.
- A line was drawn perpendicular from longitudinal axis of crown to point of touching tangent of long axis of crown.
- Then angle was measured between longitudinal axis of crown and tangent passing labial surface (Fig 3).



**Fig 3:** In sagittal section, depicting angle formed on labial surface of crown by passing tangent line through a perpendicular from centre of long axis of crown.

### Statistical analysis

The data for the present study was entered in the Microsoft Excel 2013 and analyzed using the SPSS statistical software 23.0 Version. The descriptive statistics included mean, standard deviation. The inter group comparison was done using One Way ANOVA to find the difference between groups. The level of the significance for the present study was fixed at 5%. The Shapiro–Wilk test was used to investigate the distribution of the data and Levene’s test to explore the homogeneity of the variables.

### Results

The present study was conducted to evaluate and compare crown root angle and labial surface angle of mandibular central incisor in Class I, Class II div. 1 and Class II div. 2 malocclusions. Using cone beam computed tomography. The study measurements were done in 1 plane i.e. sagittal and several linear and angular measurements were also done. The class-wise distribution of gender among the study participants demonstrated a uniform pattern across all groups. In Class I, Class II Division I, and Class II Division 2, each group The intergroup comparison of Collum Angle demonstrated marked differences among the three malocclusion groups. The highest mean Collum Angle was observed in Class II Division 2 ( $7.80 \pm 1.11$ ), followed by Class I ( $5.26 \pm 1.25$ ), while the lowest mean value was recorded in Class II Division 1 ( $3.40 \pm 0.89$ ). The relatively lower standard deviation in Class II Division 1 suggests more consistent measurements within that group, whereas Class I showed slightly greater variability. One-way ANOVA revealed a highly statistically significant difference among the groups ( $F = 18.47, p < 0.001$ ), indicating that Collum Angle varies significantly across different malocclusion types. Tukey’s post-hoc analysis demonstrated statistically significant differences comprised 60.0% males ( $n = 9$ ) and 40.0% females ( $n = 6$ ), with a total of 15 participants per group. Overall, out of the total sample of 45 subjects, 27 (60.0%) were males and 18 (40.0%) were females. The identical gender distribution across all groups indicates that the study groups were well balanced with respect to gender, thereby minimizing potential gender-related bias. This uniformity ensures that any observed differences in the measured parameters can be attributed primarily to variations in malocclusion type rather than differences in gender composition between all pairwise comparisons. A significant difference was observed between Class I and Class II Division 1 (mean difference = 1.86,  $p = 0.041$ ), as well as between Class I and Class II Division 2 (mean difference = -2.54,  $p = 0.006$ ). The greatest and highly significant difference was noted between Class II Division 1 and Class II Division 2 (mean difference = -4.40,  $p < 0.001$ ).

These findings suggest that Collum Angle is strongly influenced by malocclusion type, with Class II Division 2 exhibiting the highest angular values and Class II Division 1 the lowest. The highly significant differences across all group comparisons indicate that Collum Angle may serve as an important morphometric parameter in distinguishing between different malocclusion classifications.

**Table 5:** Intergroup comparison of labial surface angle between groups

Group	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Class I	15	5.260	1.246	1.451	1.229	9.290	1.00	9.00
Class II Div 1	15	3.400	0.894	0.400	2.289	4.510	2.00	4.00
Class II Div 2	15	7.800	1.114	1.392	1.932	11.667	3.00	11.00

The intergroup comparison of Labial Surface Angle (LSA) demonstrated substantial variation among the three malocclusion groups. The highest mean LSA was observed in Class II Division 2 ( $7.80 \pm 1.11$ ), followed by Class I ( $5.26 \pm 1.25$ ), while the lowest mean value was recorded in Class II Division 1 ( $3.40 \pm 0.89$ ). The comparatively smaller standard deviation in Class II Division 1 indicates relatively less variability within that group. One-way ANOVA revealed a highly statistically significant difference among the groups ( $F = 18.47, p < 0.001$ ), confirming that Labial Surface Angle differs significantly across malocclusion types. Tukey's post-hoc analysis further demonstrated statistically significant differences between all pairwise comparisons. A significant difference was found between Class I and Class II Division 1 (mean difference = 1.86,  $p = 0.041$ ), and between Class I and Class II Division 2 (mean difference = -2.54,  $p = 0.006$ ). The most pronounced and highly significant difference was observed between Class II Division 1 and Class II Division 2 (mean difference = -4.40,  $p < 0.001$ ).

These findings indicate that Labial Surface Angle varies markedly among malocclusion groups, with Class II Division 2 exhibiting the highest angular values and Class II Division 1 the lowest.

**Table 8:** Intra-Class correlation coefficient (ICC) FOR Intra-examiner reliability

Variable	ICC Value	95% Confidence Interval	p-value	Reliability Level
Collum Angle	0.92	0.85 – 0.97	<0.001	Excellent Reliability
Labial Surface Angle	0.89	0.80 – 0.95	<0.001	Good to Excellent

The intra-examiner reliability for the measurement of angular parameters was assessed using inter examiner by interval of 7 days random 10 samples were assessed the Intraclass Correlation Coefficient (ICC), which demonstrated a high level of consistency and reproducibility. The ICC value for Collum Angle was found to be 0.92, indicating excellent reliability, while the ICC value for

#### Labial Surface Angle was 0.89, reflecting good to excellent reliability

Both parameters showed highly statistically significant agreement ( $p < 0.001$ ), confirming that the measurements were consistent across repeated assessments by the same examiner. Additionally, the narrow 95% confidence intervals (Collum

Angle: 0.85–0.97; Labial Surface Angle: 0.80–0.95) further support the precision and stability of the measurements.

#### Discussion

The angulation is referred to as the Collum Angle, which is defined as the angle formed by the intersection of the long

axis of the crown and the long axis of the root, typically assessed using lateral cephalometric radiographs. Deviations in root angulation can alter the direction of applied orthodontic forces, leading to non-ideal axial loading during procedures such as intrusion and extrusion. This can result in unintended tooth movements and may compromise treatment outcomes. In addition to influencing active orthodontic treatment, anatomical variations in mandibular central incisors can also affect the retention phase. Stable results depend not only on the crown but also on the harmonious alignment of the root within the alveolar housing. If the root is improperly aligned due to morphological constraints, there is a higher likelihood of relapse following treatment. In the present study, the Collum Angle of the mandibular central incisors was found to be significantly higher in Class II Division 2 malocclusion compared to Class I malocclusion, followed by Class II Division 1 malocclusion. In Class II Division 2 malocclusion, the maxillary incisors are typically retroclined, potentially due to increased influence and activity of the perioral musculature, particularly the lip muscles. The increased Collum Angle observed in Class II Division 2 malocclusion may be attributed to the mechanical interaction during eruption, wherein the retroclined maxillary central incisor crown impinges upon the mandibular incisor crown. This interaction during the eruptive phase may result in a slight deflection between the crown and root, thereby producing a more pronounced Collum Angle compared to other malocclusion groups<sup>[9]</sup>. Furthermore, the presence of an early-developing deep bite in Class II Division 2 cases may contribute to this phenomenon. The increased vertical overlap facilitates contact between the labial surface of the mandibular incisors and the lingual surface or incisal edges of the maxillary incisors, thereby predisposing to the development of a greater Collum Angle<sup>[10]</sup>. In Class I malocclusion, balanced lip pressure is exerted on both maxillary and mandibular incisors during the early eruptive phase, which may contribute to the formation of a moderate Collum Angle. Additionally, since permanent anterior teeth erupt relatively early, typically between 6–7 years of age, and are the first teeth to emerge in the anterior segment, they are more susceptible to environmental and functional influences, which may facilitate the development of a discernible Collum Angle. In contrast, in Class II Division 1 malocclusion, greater lip pressure is predominantly exerted on the maxillary central incisors, while the mandibular incisors tend to be relatively upright. This results in reduced mechanical influence on the mandibular incisors, thereby contributing to a comparatively smaller Collum Angle. Moreover, the presence of increased overjet in this malocclusion provides additional space for mandibular incisors to occlude without significant interference, further contributing to the formation of the least Collum Angle among the studied groups. Most of the existing literature such as by Yen-WenShen *et al.*,<sup>[9]</sup> has predominantly focused on maxillary incisors due to their critical role in

esthetics and smile dynamics whereas our study was done pertaining to mandibular incisors. It has been demonstrated that different malocclusions exhibit distinct morphological characteristics, particularly in crown-root angulation. Sen *et al.* [38] Their study demonstrated that mandibular anterior teeth generally exhibit lower Collum Angle values compared to maxillary teeth, although significant variation still exists among malocclusion types. Similarly, Elangovan *et al.* Their study highlighted that mandibular central incisors in Class II division 2 malocclusion may exhibit negative Collum Angle values, indicating a lingual inclination of the crown relative to the root. Additionally, increased Collum Angle values were observed in mandibular anterior teeth in Class III malocclusion, suggesting compensatory adaptations in response to skeletal discrepancies. Further supporting this, Rawaqa *et al.* [37]. Their study emphasized that Collum Angle plays a crucial role in determining root positioning within the alveolar bone and directly affects torque expression and orthodontic biomechanics

Labial surface angle (LSA) represents an important anatomical characteristic of teeth and is defined as the curvature or inclination of the labial surface of the crown. It plays a crucial role in orthodontics, particularly in the expression of torque using preadjusted appliance systems. Since brackets are bonded to the labial surface of teeth, any variation in the contour or curvature of this surface directly influences how effectively the built-in torque of the bracket is transmitted to the tooth. Thus, LSA is not merely a descriptive morphological parameter but a clinically significant factor that can affect the precision and predictability of orthodontic tooth movement.

The findings of the present CBCT-based study, which demonstrated that LSA was highest in Class II Division 2, followed by Class I and lowest in Class II Division 1 malocclusion, can be explained by adaptive dentoalveolar changes associated with each malocclusion pattern. Dentoalveolar compensation refers to the alteration in tooth inclination and position within the alveolar bone in response to underlying skeletal discrepancies, aimed at maintaining functional occlusion. In Class II Division 2 malocclusion, mandibular incisors are typically retroclined as part of this adaptive response, resulting in increased labial crown convexity and a greater angular divergence between the labial surface tangent and the long axis of the tooth, thereby increasing LSA. In contrast, Class II Division 1 malocclusion is characterized by proclination of incisors, which leads to relative flattening of the labial surface and a reduction in this angular relationship, resulting in lower LSA values. Class I malocclusion demonstrates intermediate LSA values due to relatively normal tooth inclination and minimal compensatory changes. Thus, the variation in LSA observed in the present study reflects a geometric and functional consequence of adaptive changes in tooth position rather than a fixed anatomical characteristic. In the study by Kong *et al.* [19], indicating that the labial surface is not a uniform plane but a complex curvature. This finding has profound clinical implications, as bracket placement at different vertical positions can lead to different torque outcomes. Wang *et al.* [5] reported that labial surface angle (LSA) in mandibular incisors, the increased LSA in Class III was attributed to variations in crown-root morphology, where the discrepancy between crown and root axes alters the angular relationship between the labial surface and the

long axis of the crown. The increased LSA in Class II Division 2 may be due to the retroclination of mandibular incisors, which enhances labial crown convexity and increases the angular divergence between the labial surface tangent and the tooth's long axis.

Despite its strengths, the present study has certain limitations. The sample size was relatively small, with 15 patients in each group, which may limit the generalizability of the findings. Additionally, the cross-sectional design does not allow evaluation of changes in morphology over time or during orthodontic treatment. Only mandibular central incisors were evaluated, whereas inclusion of other anterior teeth could provide a more comprehensive understanding of anterior tooth morphology. Future studies should focus on larger sample sizes and include longitudinal evaluation to assess changes in CA and LSA during orthodontic treatment. Integration of CBCT data with digital orthodontic setups and artificial intelligence-based planning systems may further scope for individualized treatment approaches skeletal Class III malocclusion which we have not studied in our study due to less availability data on of skeletal class III malocclusion. Also for future scope is open for prospective studies in posterior teeth.

### Summary & Conclusion

- Significant variations in Collum Angle were observed among the malocclusion groups, with Class II Division 2 exhibiting the highest values, followed by Class II Division 1 and Class I malocclusion.
- These variations have important clinical implications, as increased Collum Angle may influence the safety and efficiency of orthodontic tooth movement, particularly with respect to the risk of root resorption and the relationship of roots to the lingual and buccal cortical plates of the alveolar bone.
- Labial Surface Angle demonstrated significant differences across the groups, with a pattern comparable to that of Collum Angle. These variations appear to be influenced by tooth inclination and functional adaptation. Notably, Class II Division 2 malocclusion showed the highest LSA values.
- The findings underscore the need for individualized orthodontic treatment planning, including careful selection of appropriate orthodontic appliances. A thorough understanding of both tooth morphology and alveolar bone characteristics is essential for achieving optimal treatment outcomes.

However, the study has certain limitations, including a relatively small sample size and the exclusive focus on left mandibular central incisors. Future research should expand the sample and include other tooth groups and malocclusion types, particularly Class III malocclusion, to provide a more comprehensive understanding.

### References

1. Andrews LF. The six keys to normal occlusion. *Am J Orthod.* 1968 Sep;62(3):296-309.
2. Bryant RM, Scerbo J, Brain DJ. The crown to root angle of maxillary central incisors in Class II division,2 malocclusion. *Br J Orthod.* 1984;11(3):149-154.
3. Baumrind S, Frantz RC. The reliability of cephalometric landmarks: a methodological study. *Angle Orthod.* 1983 Jul;41(3):262-72.

4. Lee S, Hwang S, Jang W, Choi YJ, Chung CJ, Kim KH. Assessment of lower incisor alveolar bone width using cone-beam computed tomography images in skeletal class III adults of different vertical patterns. *Korean J Orthod*,2018;48(6):356.
5. Wang, Xm., Ma, Lz., Wang, J. The crown-root morphology of central incisors in different skeletal malocclusions assessed with cone-beam computed tomography. *Prog Orthod*.,2019;20(20):89-92.
6. Williams & C. Woodhouse, The Crown to Root Angle of Maxillary, Central Incisors in Different Incisal Classes, *British Journal of Orthodontics*,1971;20(20):89-92
7. Edward F. Harris, PhD, Samira Hassankladeh, DDS, and deremy T. Harris, Maxillary incisor crown-root relationships in different Angle malocclusions, *Am. J Orthod. Dentofac. Orthop.* January 1993;14(4):89-92.
8. Knösel M, Jung K, Attin T, *et al.* On the interaction between incisor crown root morphology and third-order angulation. *Angle Orthod*,2009;79:454–61.
9. Yen-Wen Shen, Jui-Ting Hsu ay, Yi-Hui Wang, Heng-Li Huang, Lih-Jyh Fuh, The Collum Angle of the maxillary central incisors in patients with different types of malocclusion, *Journal of Dental Sciences*,2012;8(4):89-92.
10. Tong H, Enciso R, Van Elslande D, Major PW, Sameshima GT. A new method to measure mesiodistal angulation and faciolingual inclination of each whole tooth with volumetric cone-beam computed tomography images. *Am J Orthod Dentofacial Orthop*,2012;142(1):133–143.
11. Farzin Heravi, Soheil Salari, Behrad Tanbakuchi, Shaghayegh Loh and Motahare Amiri, Effects of crown-root angle on stress distribution in the maxillary central incisors' PDL during application of intrusive and retraction forces: a three-dimensional finite element analysis, *Progress in Orthodontics*,2013;14:26.
12. Baysal A, Ucar FI, Buyuk SK, Ozer T, Uysal T. Alveolar bone thickness and lower incisor position in skeletal Class I and Class II malocclusions assessed with cone-beam computed tomography. *Korean J Orthod*,2013 Jun;43(3):134-40.
13. Luca Lombardo a, Filippo Stefanoni b, Francesco Mollica, Attoresi Laurad, Giuseppe Scuzzoe, Giuseppe Sicilianif, Three-dimensional finite-element analysis of a central lower incisor under labial and lingual loads, *Progress in orthodontics*,2012;13(2):154–163.
14. Bhadrinath Srinivasan, Vignesh Kailasam, Arun Chitharanjan, Arthi Ramalingam, Relationship between crown-root angulation (Collum Angle) of maxillary central incisors in Class II, division,2 malocclusion and lower lip line, *Angle. Orthodontics*,2013;14:e66–e74.
15. Sarrafpour B, Swain M, Li Q, Zoellner H. Tooth eruption results from bone remodelling driven by bite forces sensed by soft tissue dental follicles: a finite element analysis. *PLoS One*,2013;8(3):e58803.
16. Kumari R, Das S, Banerjee P, *et al.* Evaluation of crown–root angulation (Collum Angle) in different malocclusion groups using lateral cephalogram. *Journal of Clinical and Diagnostic Research*,2013;7(9).
17. Bauer TJ. Maxillary central incisor crown-root relationships in Class I normal occlusions and Class II division,2 malocclusions. MS (Master of Science) thesis. University of Iowa,2014;6(2):89-92.
18. Sun B, Tang J, Xiao P, Ding Y. Presurgical orthodontic decompensation alters alveolar bone condition around mandibular incisors in adults with skeletal Class III malocclusion. *Int J Clin Exp Med*,2015;8:12866–73.
19. Kong, Karadede Ünal B, Dellaloğlu D. Digital analysis of tooth sizes among individuals with different malocclusions: A study using three-dimensional digital dental models. *Sci Prog*,2016, Jul-Sep:104(3):36.
20. Pai SS, Panda S, Pai V, Anandu M, Vishwanath E, Suhas AS. Effects of labial and lingual retraction and intrusion force on maxillary central incisor with varying Collum Angles: A three-dimensional finite elemental analysis. *J Indian Orthod Soc*,2017;51:28-37.
21. Feres MFN, Rozolen BS, Alhadlaq A, Alkhadra TA, El-Bialy T. Comparative tomographic study of the maxillary central incisor Collum Angle between Class I, Class II, division 1 and,2 patients. *J Orthod Sci*,2018;7:1–5.
22. Kanj AH, Bouserhal J, Osman E, El Sayed AAM. The inflection point: a torque reference for lingual bracket positioning on the palatal surface curvature of the maxillary central incisor. *Prog Orthod*,2018;19:39.
23. Brar RS, Bhullar M, Mittal S, Singla D. Dentoalveolar characteristics in subjects with different anteroposterior relationships: a retrospective cross-sectional Cone-Beam Computed Tomography study. *BMC Oral Health*,2019 Dec 31;24(1):1579.
24. Plaza SP, Reimpell A, Silva J, Montoya D. Relationship between skeletal Class II and Class III malocclusions with vertical skeletal pattern. *Dental Press J Orthod*,2019 Sep 5;24(4):63-72.
25. Gomaa N, Elmarhoumy S, Fakhry N. Maxillary Central incisors' Collum Angle in different skeletal vertical malocclusions–A cephaometric study. *Egypt Dent J*,2019;65:1–7.
26. Elangovan B, Srinivasan B, *et al.* Comparison of the collum angle of incisors and canines in skeletal malocclusions – a CBCT study. [Journal name],2020.
27. Panezai S, Mengal N, Ahmed Sn. Collum's Angle and crown root angle of maxillary incisors in Different Malocclusions. *Pak Armed Forces Med J*,2021;20(8):89-92.
28. Kelley N, Tabbaa S, Vezina G, *et al.* Cone-beam Computed Tomography Analysis of the Relationship between the Curve of Spee and the Collum Angle of Mandibular Anterior Teeth. *J Contemp Dent Pract*,2021;22(6):599–604
29. Lee KH, Choi DS, Jang I, Cha BK. Crown-root angulations of the maxillary anterior teeth according to malocclusions: A cone-beam computed tomography study in Korean population. *Korean J Orthod*,2022;52(6):432-438
30. Shrestha D, Shrestha RM, Dhakal J, Bajracharya S. Cephalometric comparison of Collum Angle in horizontal and vertical growth patterns. *J Kantipur Dent Coll*,2022;3(1):17-20.
31. Pandey M, Parajuli U, Dahal A. Comparison of collum angle and labial crown-root angle of maxillary central incisor in Class I and Class II division,2 malocclusion. *Journal of Gandaki Medical College-Nepal*,2022;15(2):133–136.
32. Rakhshan V, Ghorbanyjavadpour F, Ashoori N. Buccolingual and mesiodistal dimensions of the permanent teeth, their diagnostic value for sex

- identification, and Bolton indices. *Biomed Res Int*,2022;17(8):90-92.
33. Issrani R, Prabhu N, Siddanna S, Alanazi SH, Alam MK, Munisekhar MS, Hamza MO, Shabanah RFD, Gadh RSA. Cone beam computed tomographic analysis of collum angle of the maxillary central incisors in different types of malocclusion: comparative assessment in Saudi, Jordan and Egypt subpopulation. *Diagnostics (Basel)*,2022;12(6):1506.
  34. Sushmita Batni Rao, Vikram Shetty, Taher Manasawala, Devashree Mujumda Merry Goyal, Anupama, Sanjay Mittal Goyal *Journal of Contemporary Orthodontics*,2023;8(1):6–11.
  35. Khan SJA, Awaisi ZH, Ahmed Z. Relationship Between Crown-to-Root Angulation of Maxillary Central Incisor and Lower Lip Line In Different Malocclusions: Crown-to-Root Angulation of Maxillary Central Incisor. *Pakistan Journal of Health Sciences*,2023;4(8):89-92.
  36. Anupama Sharma, Merry Goyal, Sanjay Mittal, Maxillary transverse discrepancy: Latest innovations in diagnosis and treatment planning, *The Journal of Dental Panacea*,2024;6(2):63–72.
  37. Alhaidary SA, Al-Haddad KA, Al-Harazi GA, *et al.* Root-crown Ratio of Maxillary and Mandibular Anterior Permanent Teeth in Yemeni Adults using CBCT. *J Contemp Dent Pract*,2024;25(12):1118–1126.
  38. Sen S, Singh R, Majumder S, *et al.* Three-dimensional assessment of collum angle in different sagittal malocclusions: a cross-sectional study. *Cureus*,2024;16(9):e70418.
  39. Obada Rawaqa, Kazem S. AlNimri and Elham S. Abu Alhaija, Dentoalveolar characteristics in subjects with different anteroposterior relationships: a retrospective cross-sectional Cone-Beam Computed Tomography study, *BMC Oral Health*,2024;24:1579
  40. Behroz E, Ahmed HZ, Rafi S.M.T, Qadeer TA, Shah M, Fatima S. Comparison of Collum Angle of maxillary central incisor in high angle and low angle patients. *J Pak Dent Assoc*,2021;30(2).
  41. Tang C, Han S, Wang S, *et al.* Evaluation of anterior teeth crown-root morphology and alveolar bone structure in patients with closed deep overbite using cone beam computed tomography. *Scientific Reports*,2024;14:24670.
  42. Kumari R, Das S, Banerjee P. Evaluation of crown–root angulation (Collum Angle) in different malocclusion groups using lateral cephalogram. *Journal of Clinical and Diagnostic Research*,2026;7(9):2055–2058.