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Comparative evaluation of mandibular incisor inclination and alveolar bone thickness in Angle's class I, class II division 1 and class II division 2 malocclusions: A CBCT study

Dr. Deepankar Soni[1], Dr. Kamlesh Garg[2], Dr. Bhavesh Kothari[3], Dr. Shlok Baldwa[1]
[1] Department of Orthodontics and Dentofacial Orthopaedics, Pacific Dental College and Hospital, Udaipur, Rajasthan, India
[2] Professor, Department of Orthodontics and Dentofacial Orthopaedics, Pacific Dental College and Hospital, Udaipur, Rajasthan, India
[3] Professor and Head, Department of Orthodontics and Dentofacial Orthopaedics, Pacific Dental College and Hospital, Udaipur, Rajasthan, India
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Abstract
Objective: To evaluate and compare mandibular incisor inclination and alveolar bone thickness among subjects with Angle's Class I, Class II Division 1, and Class II Division 2 malocclusions using cone-beam computed tomography (CBCT)
Materials and Methods: Forty-two untreated subjects aged 16–25 years were equally divided into three groups: Class I, Class II Division 1, and Class II Division 2 malocclusions (n=14 each). CBCT images were obtained using the Carestream 9000 3D imaging system. Mandibular incisor inclination was assessed using the Incisor Mandibular Plane Angle (IMPA). Alveolar bone thickness around the mandibular right central incisor was measured at eight sites. Intergroup comparisons were performed using one-way ANOVA and Tukey post hoc tests. Pearson correlation analysis was used to evaluate the relationship between IMPA and alveolar bone thickness.
Results: The mean IMPA differed significantly among the three groups ($p<0.001$). Class II Division 1 subjects exhibited the highest IMPA (105.21 ± 4.49°), whereas Class II Division 2 subjects demonstrated the lowest IMPA (88.85 ± 6.57°). Significant intergroup differences in alveolar bone thickness were observed at B1B2 ($p=0.004$) and C1C2 ($p<0.001$). Significant negative correlations between IMPA and A1A2 thickness were observed in Class I ($r=-0.589$, $p=0.027$) and Class II Division 2 subjects ($r=-0.534$, $p=0.049$). Class II Division 2 subjects also demonstrated a significant negative correlation between IMPA and E1E2 thickness ($r=-0.701$, $p=0.005$).
Conclusion: Mandibular incisor inclination is associated with site-specific variations in alveolar bone thickness. Class II Division 2 malocclusion demonstrated significant correlations between incisor inclination and alveolar bone morphology, highlighting the importance of evaluating alveolar boundaries before orthodontic tooth movement.

Keywords: CBCT, mandibular incisor inclination, alveolar bone thickness, IMPA, class II division 1 malocclusion, class II division 2 malocclusion

Introduction

The position of the mandibular incisors is a key determinant of facial esthetics, occlusal function, periodontal health, and long-term orthodontic stability. Consequently, accurate assessment of mandibular incisor position and the supporting alveolar bone is fundamental to orthodontic diagnosis and treatment planning. The extent to which mandibular incisors can be proclined or retroclined during treatment is largely dictated by the dimensions of the surrounding alveolar housing [1, 2] Orthodontic tooth movement beyond the biological limits of the alveolar process may result in undesirable sequelae such as alveolar bone dehiscence, fenestration, gingival recession, and root resorption [2, 3] Therefore, knowledge of alveolar bone morphology is essential when planning treatment strategies involving substantial changes in mandibular incisor inclination. The relationship between incisor inclination and alveolar bone morphology has been extensively investigated. Previous studies have demonstrated that proclined incisors tend to be associated with thinner alveolar bone support, whereas retroclined incisors are often located within a broader alveolar envelope [4, 8]. However, evidence comparing Angle's Class I, Class II Division 1, and Class II Division 2 malocclusions remains limited [9, 10] Conventional radiographic methods have inherent limitations in evaluating alveolar bone morphology because of image distortion, magnification errors, and superimposition of anatomical structures. Cone-beam computed tomography provides accurate three-dimensional visualization of the dentoalveolar complex and allows precise assessment of the relationship between tooth roots and surrounding cortical bone [11, 12] Consequently, CBCT has become a valuable diagnostic modality for evaluating the biological limits of orthodontic tooth movement.

Although several CBCT studies have assessed alveolar bone dimensions in different skeletal and dental malocclusions, limited information is available regarding the relationship between mandibular incisor inclination and alveolar bone thickness in Angle's Class I, Class II Division 1, and Class II Division 2 malocclusions [13, 14] Therefore, the present study was undertaken to evaluate and compare mandibular incisor inclination and alveolar bone thickness among subjects with Class I, Class II Division 1, and Class II Division 2 malocclusions using CBCT and to investigate the relationship between incisor inclination and alveolar bone thickness.

Materials and Methods

This cross-sectional study was conducted in the Department of Orthodontics and Dentofacial Orthopedics, Pacific Dental

College and Hospital, Udaipur, Rajasthan, India, after obtaining ethical clearance from the Institutional Ethical Committee prior to research - STU/IEC/2024/429. Sample size was determined using G Power software (Neu-Isenburg, Germany) with 80% power and margin of error at 5%. The study sample consisted of 42 untreated subjects aged between 16 and 25 years. Subjects were divided into three groups on the basis of their malocclusion:

- Group I: Class I malocclusion (n=14)
- Group II: Class II Division 1 malocclusion (n=14)
- Group III: Class II Division 2 malocclusion (n=14)

Inclusion Criteria

- Age between 16 and 25 years
- Permanent dentition excluding third molars
- No previous orthodontic treatment
- High-quality CBCT scans

Exclusion Criteria

- Craniofacial syndromes or anomalies
- Previous orthodontic treatment
- Periodontal disease
- Missing mandibular incisors
- Poor-quality CBCT images

CBCT scans were acquired using the Carestream 9000 3D imaging system (Figure 1) under standardized conditions. Images were reconstructed and analyzed using the manufacturer's software.

Fig 1: Carestream 9000 3D Imaging Software

Mandibular incisor inclination was evaluated by drawing a line passing through long axis of the central incisor L1 (tip of crown) intersecting Go-Me (mandibular plane) at L2 (Figure 2).

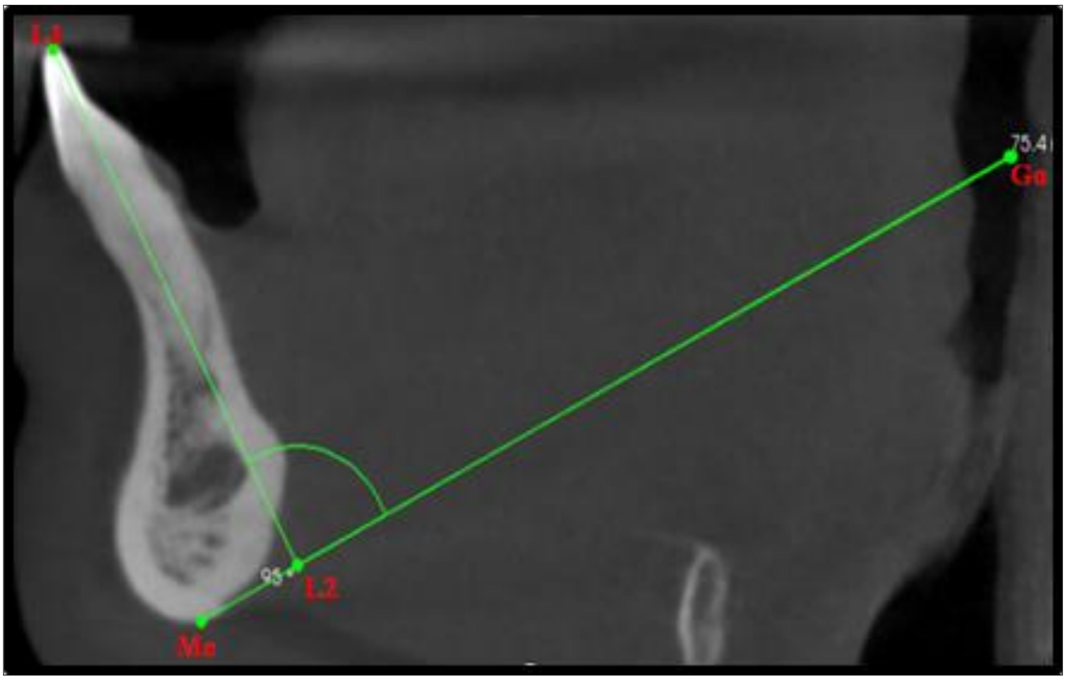

Fig 2: Incisor Mandibular Plane Angle (IMPA)

Alveolar bone thickness around the mandibular right central incisor was measured at eight sites (Figure 3). A line was drawn at the level of CEJ passing through Point A and Point B which are defined as most anterior point (Point A) and most posterior point (Point B) on mandibular alveolar bone at the level of CEJ the buccal (A1A2) and lingual (B1B2) alveolar bone thickness was measured along this line, similarly the measurements was carried out at 3 mm below CEJ, at centre of rotation (COR) & at the level of the root apex.

- A1A2 at CEJ buccal
- B1B2 at CEJ lingual
- C1C2 3mm apical to CEJ buccal
- D1D2 3mm apical to CEJ lingual
- E1E2 at Centre of rotation buccal
- F1F2 at Centre of rotation lingual
- G1G2 at root apex buccal
- H1H2 at root apex lingual

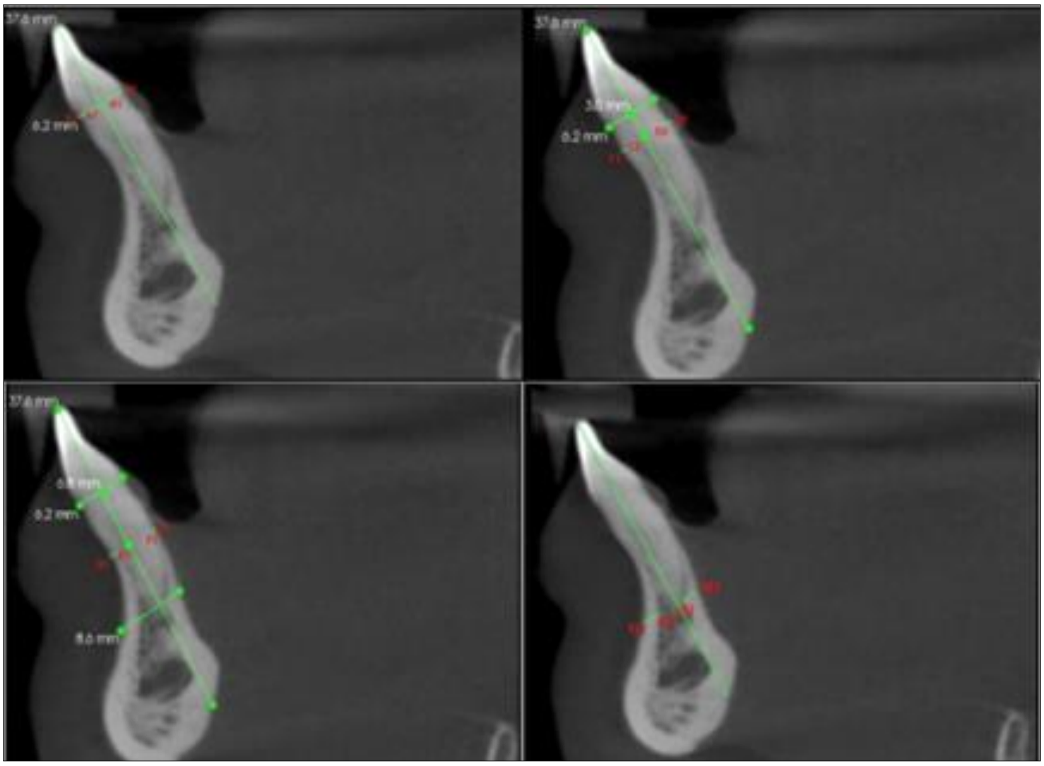

Fig 3: Buccal and lingual alveolar bone thickness at various sites

Statistical Analysis

Data were analyzed using SPSS version 25.0 (IBM Corp, Armonk, NY, USA). Descriptive statistics were calculated as mean and standard deviation. Intergroup comparisons were performed using one-way analysis of variance (ANOVA), followed by Tukey post hoc testing. Pearson correlation analysis was used to evaluate associations between IMPA and alveolar bone thickness. A p-value < 0.05 was considered statistically significant.

Results

Comparison of the mean IMPA differed significantly among the three groups (p<0.001). Class II Division 1 subjects exhibited the greatest mandibular incisor proclination 105.21± 4.49, whereas Class II Division 2 subjects demonstrated the greatest retroclination with the mean of 88.85 ± 6.57 SD (Table 1). Comparison of alveolar bone thickness among different groups revealed Significant differences at B1B2 and C1C2, indicating that bone thickness in these regions varies significantly among the three malocclusion groups, specifically, at C1C2 in group III showed the highest thickness, followed by group II and group I (Table 2).

Table 1: Evaluation of mean IMPA values among group I, group II and group III

Groups	Mean	SD	P value, Significance
Group I (Class I)	95.57	± 5.33	<0.001**
Group II (Class II Div1)	105.21	± 4.49	<0.001**
Group III (Class II Div 2)	88.85	± 6.57	<0.001**

*p<0.05 – significant difference **p<0.001 – highly significant difference

Comparison of alveolar bone thickness among different groups revealed Significant differences at B1B2 and C1C2, indicating that bone thickness in these regions varies significantly among the three malocclusion groups, specifically, at C1C2 in group III showed the highest thickness, followed by group II and group I (Table 2).

Table 2: Comparison of alveolar bone thickness among group I, group II and group III

Points	Group I (Class I)	Group II (Class II div 1)	Group II (Class II div 2)	p-value
A1A2	0.71 ± 0.1	0.67 ± 0.09	0.78 ± 0.1	0.240
B1B2	0.93 ± 0.2	0.77 ± 0.8	0.72 ± 0.1	0.004*
C1C2	0.6 ± 0.1	0.87 ± 0.2	1.03 ± 0.2	<0.001*
D1D2	1.36 ± 0.3	1.31 ± 0.1	1.3 ± 0.1	0.770
E1E2	1.13 ± 0.3	1.3 ± 0.3	1.32 ± 0.2	0.292
F1F2	1.54 ± 0.4	1.52 ± 0.2	1.61± 0.3	0.817
G1G2	1.81 ± 0.3	1.95 ± 0.4	1.80 ± 0.4	0.557
H1H2	2.22 ± 0.3	2.20 ± 0.2	2.31 ± 0.5	0.712

Pearson correlation analysis revealed a statistically significant negative correlation between IMPA and alveolar bone thickness at the A1A2 in Class I, at C1C2 in Class II div 1 and at A1A2, E1E2 in Class II div 2 malocclusion groups respectively (Table 3).

Table 3: Correlation between IMPA and alveolar bone thickness

Groups	Variable	r value	p-value
Class I	IMPA vs A1A2	-0.589	0.027*
Class II Div 1	IMPA vs C1C2	-0.526	0.021*
Class II Div 2	IMPA vs A1A2	-0.534	0.049*
Class II Div 2	IMPA vs E1E2	-0.701	0.005*

Discussion

The present study investigated the relationship between mandibular incisor inclination and alveolar bone thickness in subjects with Class I, Class II Division 1, and Class II Division 2 malocclusions using cone-beam computed tomography. Since mandibular incisors occupy a critical position within the dentoalveolar complex, understanding the anatomical limits imposed by the surrounding alveolar bone is essential for planning safe and stable orthodontic tooth movement [1, 2] A significant difference in mandibular incisor inclination was observed among the three malocclusion groups. Class II Division 1 subjects demonstrated the highest IMPA values, indicating marked proclination of the mandibular incisors, whereas Class II Division 2 subjects exhibited the lowest values, reflecting the characteristic retroclined incisor position associated with this malocclusion. These findings are consistent with previous reports describing dentoalveolar compensatory mechanisms in Class II malocclusions [4], [6] Evaluation of alveolar bone thickness revealed significant intergroup differences at the B1B2 and C1C2 levels. Class I subjects demonstrated greater cervical bone thickness, whereas Class II Division 2 subjects exhibited significantly greater thickness at the center-of-rotation level. Similar observations have been reported by Yu *et al*, Yamada *et al*, and Srebrzyńska-Witek *et al*, who demonstrated that alveolar bone morphology varies according to incisor inclination and skeletal pattern [5, 9, 18]

The greater bone thickness observed in Class II Division 2 subjects may be attributed to the retroclined position of the mandibular incisors. Retroclination tends to maintain the root within the confines of the alveolar process, preserving surrounding bone support. Conversely, proclination may position the root closer to the cortical boundaries, reducing the available alveolar housing. This interpretation supports the concept of the alveolar envelope proposed by Handelman [2]. An important finding of the present study was the significant negative correlation between IMPA and alveolar bone thickness in Class I and Class II Division 2 malocclusions. Increased proclination was associated with reduced alveolar bone thickness at specific sites. Similar findings have been reported in CBCT investigations evaluating the relationship between incisor inclination and supporting alveolar bone [7, 8, 11] The clinical significance of these findings lies in the potential periodontal consequences of excessive incisor proclination. Previous studies have demonstrated that movement beyond the biological limits of the alveolar process may increase the risk of dehiscence, fenestration, gingival recession, and root resorption [3, 15, 16] The present results reinforce the importance of assessing alveolar dimensions before planning substantial changes in mandibular incisor inclination.

Interestingly, no significant correlations were observed in Class II Division 1 subjects despite exhibiting the highest IMPA values. This may reflect individual variation in alveolar morphology, adaptive remodeling of the supporting bone, or the limited sample size of the present study. A major strength of this investigation was the use of CBCT, which allows accurate three-dimensional evaluation of tooth position and alveolar morphology without magnification or superimposition errors associated with conventional radiography [12, 17] Within the limitations of the present study, mandibular incisor inclination was found to be associated with site-specific variations in alveolar bone thickness. The observed correlations emphasize the importance of evaluating alveolar boundaries before orthodontic treatment and support the use of CBCT in assessing the biological limits of mandibular incisor movement.

Clinical Implications

The findings of this study highlight the importance of evaluating alveolar bone morphology before undertaking significant changes in mandibular incisor inclination. CBCT assessment may be particularly beneficial in patients requiring extensive incisor proclination, camouflage treatment of Class II malocclusions, or correction of retroclined incisors in Class II Division 2 cases. Knowledge of the available alveolar housing may help clinicians establish biologically acceptable treatment limits and minimize the risk of iatrogenic periodontal complications.

Conclusion

Mandibular incisor inclination exhibited significant variation among Class I, Class II Division 1, and Class II Division 2 malocclusions. Significant differences in alveolar bone thickness were observed at specific levels around the mandibular central incisors, indicating that alveolar morphology varies according to malocclusion type and tooth inclination. Negative correlations between incisor inclination and alveolar bone thickness in Class I and Class II Division 2 subjects suggest that increased proclination may be associated with reduced alveolar bone support. These findings emphasize the importance of evaluating alveolar boundaries before orthodontic treatment and support the use of CBCT as a valuable tool for assessing the biological limits of mandibular incisor movement.

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