Research Article

Correlation of Alveolar Bone Thickness With Inclination of Mandibular Incisors And Depth of Overbite In Patients With Different Vertical Skeletal Patterns

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Abstract

Introduction: Alveolar bone thickness surrounding the mandibular incisors is an important factor influencing orthodontic tooth movement and periodontal stability. Variations in vertical skeletal pattern, incisor inclination, and overbite severity may affect alveolar bone morphology. CBCT enables accurate three-dimensional assessment of these structures.

Objective: To evaluate the association of mandibular incisor alveolar bone thickness with incisor inclination and overbite severity in different vertical skeletal patterns.

Materials and Methods: This retrospective cross-sectional study included pretreatment CBCT scans and lateral cephalograms of 48 untreated adults. Based on the SN-GoGn angle, subjects were categorized into high-angle, average-angle, and low-angle groups. Alveolar bone thickness was measured on the labial and lingual aspects of mandibular incisors at the crestal, mid-root, and apical levels. Incisor inclination was assessed using IMPA, and overbite severity was clinically categorized. Non-parametric tests were used for statistical analysis.

Results: Significant differences in alveolar bone thickness were observed at specific sites among skeletal patterns. Low-angle subjects exhibited greater labial alveolar bone thickness, whereas high-angle subjects showed comparatively thinner alveolar bone support. IMPA values did not differ significantly among groups. A strong negative correlation was observed between incisor inclination and lingual alveolar crest thickness in high-angle subjects ($r = -0.762$, $p = 0.001$). Associations between overbite severity and alveolar bone thickness were limited to specific regions in the high-angle group.

Conclusion: Mandibular incisor alveolar bone thickness varies according to vertical skeletal pattern. High-angle individuals exhibit thinner alveolar bone support and may be at greater risk of periodontal compromise during orthodontic treatment.

Keywords: Alveolar bone thickness; Mandibular incisors; Cone-beam computed tomography; Vertical skeletal pattern; Incisor inclination; Deep bite.

Introduction

Defining the limits of orthodontic tooth movement is essential before the onset of treatment to avoid iatrogenic side effects such as root resorption, dehiscence and fenestration and loss of periodontal support and for improved stability.[3] Evaluation of thickness of alveolar bone of incisors is particularly important in determining these limits.

The anterior mandible is an area that poses considerable diagnostic and therapeutic problems. This is due to relatively small dimensions of the teeth as well as the small distances between them, and these difficulties may be further intensified by frequent dental crowding. The vestibular cortical bone is prone to resorption during the course of periodontal bone disease as well as during orthodontic treatment.[5] Therefore the morphology and size of the mandibular alveolar bone play a critical role in planning orthodontic treatment.[2] With the introduction of cone beam computed tomography (CBCT) in the field of orthodontics high-definition images of teeth and surrounding bone can now be obtained at a far lower dose of radiation than that of other medical imaging techniques while being closer to the range of a standard dental film series. In conventional cephalometric radiographs, all structures overlap each other because of the divergent nature of the X-ray beam. High resolution CBCT images allow clinicians to visualize the shape and size of the alveolar bone without the

disadvantage of conventional radiographs. These images are free from distortion and superimposition thus CBCT imaging enables quantitative and qualitative evaluation of the relationship between teeth and bone. [6]
Previous studies have evaluated bone morphology with CBCT in different malocclusions and also the relationship between skeletal growth patterns, alveolar bone thickness and tooth inclination. These studies found differences in bone thickness and
density at buccal and lingual surfaces of the lower incisor roots between different skeletal patterns. Patients with a Class II/III malocclusion and high-angle pattern had thinner labial alveolar bone covering mandibular central incisors than those with a Class I malocclusion and normal or low-angle pattern.
In addition, the inclinations of the anterior teeth vary according to the skeletal typology and the corresponding alveolar bones do not always have the same thickness. Tian et al[8] found that patients with lingually inclined incisors have lower ABT values at the root apex of the maxillary central incisor than patients with normal and labial-inclined incisors, and they appear to be more vulnerable to bone defects.
The depth of overbite is related not only to the vertical skeletal pattern but also to the inclination of the anterior teeth. Beckmann et al[10] reported that the inclination of the maxillary central incisor seems to have an effect on the overbite. This study showed that in subjects with an open bite, the maxillary central incisor generally is protruded, whereas in subjects with deep bite, the maxillary central incisor generally is more steeply inclined. However, the relation between depth of overbite and inclination of the lower incisors to their alveolar housing is not clear.
Thus the aim of this retrospective CBCT study was to evaluate the correlation of alveolar bone thickness with inclination of mandibular incisors and depth of overbite in different vertical skeletal patterns.

Material and methods

This study was conducted in the Department of Orthodontics and Dentofacial Orthopedics, I.T.S Dental College, India.
Ethical consent: The study protocol was approved by the Institutional Ethics Committee. All procedures were performed in accordance with the ethical standards of the institutional committee and with the 1964 Helsinki Declaration and its later amendments.
The sample size was calculated assuming an expected correlation coefficient of 0.50, a two-sided significance level of 5% ($\alpha = 0.05$), and a statistical power of 95%. Based on these assumptions, the minimum required sample size was determined to be 46 participants.
Cephalometric x-rays and CBCT scans of the mandibular anterior arch taken for orthodontic evaluation were retrieved from the database of the department. All the scans had been done using the New Tom CBCT scanner VG10048S (Verona, Italy) with the following settings: voltage,90kV; scanning time,3.6s; voxel size,75 to 30um.
The patients were contacted and consent was taken to use their records in the present study. Inclusion criteria were patients aged >18 years, presence of complete permanent dentition up to second molars, crowding <4 mm in each arch and availability of pre-treatment diagnostic records including lateral cephalogram and CBCT scans of the lower mandibular anterior arch. Patients with history of previous orthodontic treatment or trauma, craniofacial or dental anomalies, congenitally missing or supernumerary teeth, skeletal asymmetry, periodontal disease and systemic conditions were excluded from the study.
The sample was divided into 3 groups of 16 each, according to the vertical skeletal pattern of the patients: Average angle (SN-GoGn 28˚-36˚), high angle (>36˚), and low angle (< 28˚). Sixteen patients of each type were selected so as to get a database of 48 patients (Table 1). Anterior overbite was evaluated and classified as: Normal, 3-5mm, Moderate, 5-7mm or Severe, >7mm. The inclination of the mandibular central incisor to the mandibular plane was assessed on lateral cephalograms.
The CBCT data was saved to DICOM files and exported to NNT (version 10.1) software to analyze the images using dedicated imaging software capable of multiplanar reconstruction (MPR). Localization of tooth of interest was done in all orthogonal planes (sagittal, coronal and axial planes) as per standardization protocol and alveolar bone thickness (ABT) was evaluated for the mandibular incisors. Root length of the incisors was determined as the distance from the cementoenamel junction (CEJ) to the root apex. The tooth length was segmented into three parts, with level 0 corresponding to the apical crest, level 2 corresponding to midpoint of distance between alveolar crest and apex of the tooth and level 3 representing the root apex. The alveolar plate thickness was assessed at these three levels. Bone thickness measurements were made at both the buccal and lingual sides for

all the lower incisors from their CBCT images in the sagittal plane.

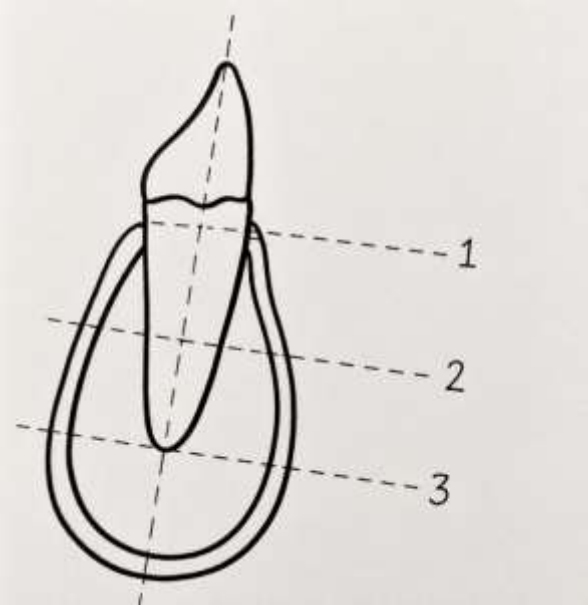


Figure 1: Measurement of the alveolar bone thickness (ABT) at alveolar crest, middle of the root and at the root apex.

1. Alveolar crest thickness
2. Thickness at midpoint between alveolar crest and root apex

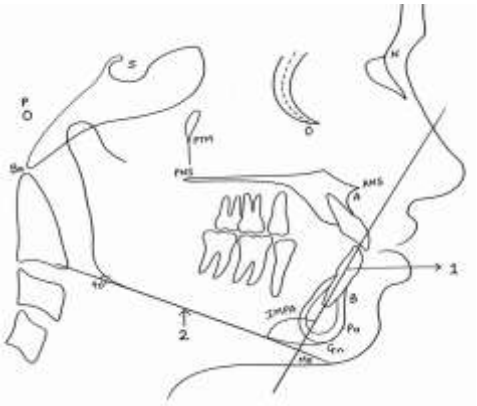


Figure 2: Measurement of the angle between the mandibular central incisor axis and the mandibular plane (IMPA) on the lateral cephalogram.

1. Lower incisor inclination
2. Mandibular plane

Result

Normality of the data distribution was assessed using the Shapiro–Wilk test. Non-parametric analyses were employed due to predominantly non-normal data distributions confirmed by Shapiro-Wilk testing. High intra-examiner reliability (ICC >0.88; Kappa=1.000) validated the measurements across all teeth (31, 32, 41, 42).

Table 1 shows alveolar bone measurements of the mandibular incisors showed limited differences among skeletal patterns. For tooth 31, a significant difference was observed only at the labial alveolar crest (p=0.035), with greater bone thickness in the low-angle group. For tooth 32, significant differences were found at the labial middle (p=0.004) and labial apex (p=0.044), with the high-angle group showing greater thickness at the labial middle region and the low-angle group at the labial apex. For tooth 41, a significant difference was noted only at the labial alveolar crest (p=0.002), where the low-angle group exhibited greater thickness than the average- and high-angle groups. For tooth 42, a significant difference was observed only at the lingual middle region (p=0.009), with greater bone thickness in the average-angle group compared with the high-angle group. No other regions demonstrated significant differences among skeletal patterns (p>0.05).

Table 1: Comparison of alveolar bone thickness between three skeletal patterns for tooth 31, 32, 41and 42

Tooth 31	Region	High angle (mean±SD)	Average angle (mean±SD)	Low angle (mean±SD)	p-value
Labial	Alveolar crest	0.11±0.14	0.17±0.26	0.33±0.27	0.035*
	Middle	0.60±0.68	0.74±0.72	0.61±0.43	0.757
	Apex	4.14±1.94	4.19±1.29	3.78±1.66	0.529
Lingual	Alveolar crest	0.53±0.39	0.52±0.38	0.48±0.34	0.979
	Middle	0.88±0.97	1.57±0.79	1.23±0.68	0.071
	Apex	3.26±0.94	3.51±1.32	3.66±0.98	0.576
Tooth 32					
Labial	Alveolar crest	0.83±1.07	0.43±0.40	0.62±0.39	0.344
	Middle	0.80±1.95	0.71±0.57	0.59±0.49	0.004*
	Apex	3.54±1.96	4.11±1.56	4.44±1.61	0.044*
Lingual	Alveolar crest	0.60±0.52	0.49±0.31	0.37±0.28	0.4
	Middle	1.58±1.15	1.55±0.63	1.14±0.82	0.262
	Apex	3.88±1.80	3.88±1.30	1.30±3.18	0.373
Tooth 41					
Labial	Alveolar crest	0.32±0.21	0.29±0.26	0.68±0.52	0.002*
	Middle	0.46±0.46	0.67±0.55	0.70±0.84	0.577
	Apex	3.69±1.86	1.86±4.13	4.39±1.70	0.265
Lingual	Alveolar crest	0.73±0.45	0.45±0.56	0.48±0.32	0.314
	Middle	1.24±0.90	0.90±1.60	1.25±0.65	0.125
	Apex	3.44±1.24	1.24±3.99	3.14±1.07	0.368
Tooth 42					
Labial	Alveolar crest	0.72±0.62	0.33±0.36	0.36±0.33	0.125
	Middle	0.79±0.94	0.79±0.72	0.63±0.49	0.811
	Apex	4.09±1.61	4.04±1.73	3.61±1.53	0.707
Lingual	Alveolar crest	0.44±0.35	0.42±0.34	0.47±0.32	0.946
	Middle	0.70±0.51	1.43±0.74	1.11±0.64	0.009*

	Apex	2.89±0.70	3.65±1.29	3.56±1.40	0.201

Table 2: Comparison of IMPA and deep bite between three skeletal patterns

Group	IMPA (mean±SD)	Deep bite n(%)		
		Normal	Moderate	Severe
High angle	97.48±4.21	6 (37.50%)	10 (62.5%)	0 (0%)
Average angle	102.37±9.87	8 (50%)	4 (25%)	4 (25%)
Low angle	102.52±6.64	4 (25%)	7 (43.8%)	7 (43.8%)
p-value	0.095	0.120		

Table 2 shows that IMPA and deep bite distribution did not differ significantly among the skeletal patterns (p>0.05).

Table 3: Correlation between alveolar bone thickness with IMPA and deep bite

Correlation between alveolar bone thickness and IMPA							
Side	Region	High angle		Average angle		Low angle	
		r-value	p-value	r-value	p-value	r-value	p-value
Labial	Alveolar crest	-0.148	0.583	-0.007	0.98	-0.111	0.682
	Middle	-0.201	0.455	-0.095	0.728	0.235	0.381
	Apex	-0.18	0.505	-0.114	0.674	0.271	0.311
Lingual	Alveolar crest	-0.762	0.001*	0.114	0.675	0.285	0.285
	Middle	-0.322	0.225	-0.065	0.81	0.28	0.293
	Apex	-0.187	0.489	-0.34	0.198	0.273	0.307
Correlation between alveolar bone thickness and deep bite							
Side	Region	High angle		Average angle		Low angle	
		r-value	p-value	r-value	p-value	r-value	p-value
Labial	Alveolar crest	0	1	0.016	0.952	0.47	0.066
	Middle	0.515	0.041*	0.209	0.438	0.163	0.545
	Apex	0.339	0.199	0.125	0.645	0.275	0.303
Lingual	Alveolar crest	0.257	0.336	0.32	0.227	-0.033	0.903
	Middle	0.341	0.196	0.208	0.439	0.069	0.8
	Apex	0.509	0.044*	0.282	0.29	0.175	0.516

In table 3 spearman correlation analysis revealed no significant association between alveolar bone thickness and IMPA at most labial and lingual regions of teeth 31 and 41 (p>0.05). A significant strong negative correlation was observed only at the lingual alveolar crest in the high-angle group (r = –0.762, p = 0.001), indicating that greater incisor proclination was associated with reduced lingual alveolar bone thickness.

Spearman correlation analysis demonstrated limited associations between deep bite severity and alveolar bone

thickness in teeth 31 and 41. Significant positive correlations were observed only in the high-angle group at the labial middle region (r = 0.515, p = 0.041) and lingual apex region (r = 0.509, p = 0.044), indicating increased bone thickness with greater deep bite severity. No significant correlations were found at the remaining labial or lingual regions or in the average- and low-angle groups (p>0.05).

Discussion

Periodontal health and the limitations imposed by the alveolar bone boundaries are critical factors in orthodontic treatment planning.[8] Uncontrolled orthodontic forces may lead to breakdown of the labiolingual alveolar bone, potentially leading to alveolar bone dehiscence and subsequent periodontal recession.[14]

In this study significant differences were found in alveolar bone thickness at the alveolar crest and middle regions in different vertical skeletal patterns. However no significant difference was found at the apex. For teeth 31 and 41, labial alveolar crest thickness was significantly greater in low-angle individuals compared to high- and average-angle groups. This observation aligns with the functional matrix theory and Wolff's law, which suggest that increased masticatory muscle activity and occlusal loading in low-angle individuals promote greater cortical bone apposition and a more robust mandibular morphology.

In this study high-angle individuals demonstrated thinner labial alveolar bone at the crestal region, particularly in the mandibular central incisors. This has important clinical implications, as reduced crestal bone thickness may increase susceptibility to gingival recession and alveolar bone loss during orthodontic proclination in hyperdivergent patients. Similar results were found according to Dalaie et al[3] in which thinner alveolar bone was found in the labial and lingual sides of the mandible and palatal sides of the maxilla with high angle compared with normal angle and low angle growth patterns in both Class I and Class II groups. According to Handelman[35], patients with high angle growth patterns had thinner labial and lingual alveolar bones. He stated that as facial height increases, the incisors tend to overerupt to reach normal overbites, and this overeruption is the cause of weak alveolar support. Eraydin et al[36] also reported thinner alveolar bone in patients with Class II malocclusion and high-angle growth patterns, which was in agreement with our findings. Hoang et al[37] evaluated the anterior mandible alveolus in different skeletal patterns and found that patients with high-angle growth patterns exhibited thinner alveolar housing, which was consistent with our findings. Their findings further demonstrated a greater incidence of external root resorption following orthodontic treatment in individuals with high-angle growth patterns compared to normal- and low-angle patterns, underscoring the clinical importance of evaluating alveolar bone support prior to treatment.

On the lingual aspect, significant differences were limited and inconsistent. For tooth 42, a significant increase in lingual middle alveolar bone thickness was observed in average-angle individuals compared to high-angle subjects. Overall, the limited lingual differences suggest that labial alveolar bone is more sensitive to variations in vertical skeletal pattern.

Appropriate torque management is crucial for achieving optimal occlusion, improving facial aesthetics, and ensuring long-term post-treatment stability.[39] Considering this, in this study we also aimed to evaluate the correlation between alveolar bone thickness and mandibular incisor inclination in different vertical skeletal patterns.

IMPA did not differ significantly among the three skeletal patterns, indicating that incisor inclination was comparable across groups. Despite this, correlation analysis revealed a strong and significant negative correlation between incisor inclination and lingual alveolar bone thickness at the alveolar crest in high-angle individuals. This suggests that increased mandibular incisor inclination is associated with reduced lingual crestal bone thickness specifically in hyperdivergent patients. At the labial surface, no statistically significant correlations were observed between alveolar bone thickness and IMPA at the alveolar crest, middle, or apex regions in any of the skeletal groups. The absence of significant correlations between incisor inclination and alveolar bone thickness in the average- and low-angle groups suggests that these skeletal patterns may better accommodate variations in incisor inclination, likely due to a more favorable alveolar bone morphology.

Similar results were found in the study by Dalaie et at[3] where a moderate negative correlation was found in the mandibular arch between ABT at 9mm distance from the crest and central incisor inclination among patients with Class II low angle and high angle. Eraydin et al[36] also reported thinner alveolar bone in patients with Class II malocclusion and high-angle growth patterns.[3] A systematic review by Gustavo d'Oliveira[39] reported a

significant association between incisor inclination and alveolar bone thickness. Greater labial inclination was associated with increased labial bone thickness, whereas reduced inclination was linked to increased lingual cortical bone thickness, particularly in mandibular incisors.

From a clinical perspective, these observations underscore the importance of careful incisor positioning in high-angle patients. In such individuals, excessive proclination should be avoided, as it may compromise lingual alveolar bone integrity and increase the risk of iatrogenic periodontal sequelae. This study also evaluated the correlation between alveolar bone thickness in mandible and deep bite in different vertical skeletal patterns. Although the distribution of deep bite severity did not differ significantly among skeletal patterns, correlation analysis revealed region-specific associations in high-angle individuals. At the labial surface, a significant positive correlation was observed in the high-angle group at the middle region ($r = 0.515$, $p = 0.041$), indicating increased alveolar bone thickness with increasing deep bite severity. On the lingual surface, a significant positive correlation was identified in the high-angle group at the apex region ($r = 0.509$, $p = 0.044$) suggesting that greater deep bite severity was associated with increased lingual alveolar bone thickness at the apex of mandibular incisors. Similar results were found in the study by Uengkajornkul et al[40] where skeletal deep bite patients had the thickest alveolar bone and those with skeletal open bite had the thinnest, particularly at the lingual mid-root and total apical levels. Thus, skeletal deep bite patients can tolerate more antero-posterior tooth movement in the mandibular incisor area. In contrast, skeletal open bite patients can tolerate limited movement of the mandibular incisor in antero-posterior direction, mainly at root apex level.

The findings of the present study carry significant clinical implications for orthodontic diagnosis and treatment planning. Individuals with a high-angle vertical skeletal pattern demonstrated comparatively thinner labial crestal alveolar bone and exhibited a negative association between mandibular incisor proclination and lingual crestal bone thickness, indicating an increased susceptibility to periodontal compromise. Conversely, low-angle individuals generally displayed greater labial alveolar bone thickness, suggesting the presence of a more favorable biological envelope that may accommodate orthodontic tooth movement with reduced risk to the supporting structures.

In this context, three-dimensional CBCT assessment of alveolar bone morphology may be considered particularly valuable in patients presenting with extreme vertical skeletal patterns prior to undertaking substantial incisor movements. Furthermore, the adoption of individualized biomechanical strategies tailored to the patient's alveolar anatomy is essential to reduce the likelihood of iatrogenic complications, including alveolar dehiscence, fenestration, and gingival recession, thereby promoting periodontal health and long-term treatment stability.

The present study has several limitations that should be considered. One of the primary constraints is the limited sample size. Additionally, the cross-sectional nature of the study only captures alveolar bone measurements at a single point in time, making it difficult to assess how growth patterns influence bone remodeling throughout orthodontic treatment. Another limitation is the lack of evaluation in different sagittal skeletal patterns. Additionally, while CBCT imaging was used to obtain detailed bone measurements, it has inherent limitations, including difficulty in detecting very thin cortical bone changes and potential artifacts or resolution issues that might affect precision.

Future studies with larger sample sizes, inclusion of sagittal skeletal patterns, and longitudinal evaluation of alveolar bone changes following orthodontic treatment would provide further insight into the complex relationship between skeletal pattern, incisor position, and alveolar bone morphology.

Conclusion

1. Mandibular incisor alveolar bone thickness varies according to the vertical skeletal pattern, with high-angle subjects exhibiting comparatively thinner alveolar bone support than low-angle subjects.
2. A significant negative correlation exists between mandibular incisor inclination and lingual alveolar bone thickness in high-angle individuals, suggesting greater vulnerability to periodontal compromise during incisor proclination.
3. The relationship between overbite severity and alveolar bone thickness is limited and appears to be confined to specific regions in high-angle subjects.

4. Vertical skeletal pattern should be considered an important factor when planning mandibular incisor movement, and CBCT assessment of alveolar bone morphology can aid in defining safe orthodontic treatment limits.

Patient's/Guardian's consent: The patients were contacted and consent was taken to use their records in the present study.

Ethical Approval: The study protocol was approved by the Institutional Ethics Committee of I.T.S. Centre for Dental Studies and Research, Ghaziabad under the protocol number ITSCDSR/IIEC/2023-26/ORTHO/05.

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Declaration of Interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Conflicts of Interest

The authors declare no conflicts of interest related to this work. No financial relationships with any organizations that might have an interest in the submitted work exist, and no other relationships or activities that could appear to have influenced it are present.

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Declaration of generative AI in scientific writing

1. During the preparation of this work the authors used ChatGPT in order to assist in summarizing the abstract and providing linguistic refinement. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.