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Original Article

ANALYSIS OF MEAN ANTERIOR ALVEOLAR BONE THICKNESS AMONG THE PATIENTS PRESENTING WITH MALALIGNED TEETH AT TERTIARY CARE HOSPITAL

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ABSTRACT

Objectives: *To analyze the mean anterior alveolar bone thickness among patients presenting with malaligned teeth.*

Materials and Methods: *This cross-sectional study was conducted in the "Department of Orthodontics, Altamash Institute of Dental Medicine", Karachi, Pakistan from 1st Dec 2024 to 31st May 2025. A total of 100 patients with malaligned teeth, full permanent dentition, and clear lateral cephalograms were included. Malocclusion was classified using Angle's criteria, and lateral cephalograms were hand-traced by a single examiner. Alveolar bone thickness was measured. Continuous variables were reported as mean ± SD, categorical variables as frequency and percentage. Chi-square or Fisher's exact test, one-way ANOVA, and independent t-test were applied, with $p < 0.05$ considered statistically significant.*

Results: *The mean age was 19.78 ± 6.20 years, with 53% females. Maxillary alveolar bone thickness averaged 10.02 ± 1.55 mm with no significant differences among malocclusion groups ($p = 0.121$). Mandibular thickness varied significantly ($p = 0.003$), highest in Class III (12.00 ± 3.32 mm). Maxillary labial bone was thinner in Class II (4.62 ± 1.41 mm) than Class I (5.58 ± 1.57 mm; $p = 0.008$), and mandibular lingual bone was thicker in Class III (5.75 ± 1.19 mm; $p = 0.0005$). No significant gender differences were observe.*

Conclusion: *Alveolar bone thickness varies with malocclusion type. Thinner maxillary labial bone in Class II and thicker mandibular bone in Class III emphasize the importance of individualized orthodontic planning to safeguard periodontal health.*

Key words: *DMalaligned teeth, Alveolar bone thickness, Malocclusion, Cephalometric analysis, Lateral cephalogram, Dental malocclusion, Orthodontic*

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INTRODUCTION

Diagnosis of the position of the central incisor teeth involves routine lateral cephalometric analysis in orthodontics. It is relatively easy to obtain an idea of the inclination of the central incisor teeth and their association to the alveolar bone surrounding them, and which are based on the movements, anterior, posterior, and vertical, that are desirable in treatment in relation to the anterior teeth. It is the bone tissue which circumscribes the limits of allowable movements in the teeth, and an attempt to transgress these limits may bring about disagreeable collateral effects on the periodontal structures. The tooth movement which is especially important in orthodontic is that of widening the dental arch and the buccal-lingual movements of the incisor teeth. It is this dental manipulation that has a tendency to displace the teeth

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from within the limits of their alveolar bony envelope, which may result in dehiscence of bone covering the roots, fenestration, and gingival recession, depending entirely on the morphology of the alveolar bone, as well as the amount of tooth movement. The fact that a root of a maxillary incisor may come in contact with one or the other hard tissue structures, such as the plates covering the labial or palatal bone, and incisive canal cortices, is a predisposing cause for apical root resorption in this tooth, and is one of the iatrogenic effects of orthodontic treatment. The genesis of safe anatomic repositions for incisor root motion in each jaw can be utilized in determining the desirability of treatment in the light of minimizing such iatrogenic effects[1,2].

Crowded arches are subject to ectopic erruption of teeth which may affect the observable thickness of the alveolar bone surrounding the roots. Malocclusions are also subject to various accidents in adaptive dental growth, or para-functional habit, or other environmental influences which may adversely affect observable dental position of the incisors in the alveolar processes. On the other hand, the study of a sample of teeth in normal, naturally occurring occlusions, might bring out anatomical relationships existing between roots and alveolar process of bone worthy of emulation[3].

Andrews et al[3] observed that maxillary incisor roots are positioned closer to the labial than the palatal surface in about a 2:1 ratio, while mandibular incisor apices remain centered between labial and lingual cortices. Matsumoto et al[4] reported that alveolar bone dimensions in Class II cases restrict mandibular incisor advancement, highlighting periodontal limits. Uesugi et al[5] emphasized the importance of CBCT-based diagnosis for assessing root–bone relationships in protrusive profiles. Pan and Chen[6] noted that proximity between the incisive canal and maxillary incisors can lead to root resorption following retraction with mini-implants

Malaligned teeth are common worldwide and are frequently associated with oral hygiene difficulties, periodontal inflammation, and an increased risk of anterior alveolar bone loss. Assessment of anterior alveolar bone thickness is therefore critical for safe orthodontic tooth movement, as insufficient bone support can lead to dehiscence, fenestration, prolonged treatment time, and compromised long-term stability. Despite the rising demand for orthodontic care in Pakistan, particularly in Karachi, there is a lack of population-specific data on anterior alveolar bone thickness in patients with malaligned teeth. This study provides valuable baseline anatomical information for the local population, enabling more accurate diagnosis, individualized treatment planning, prediction and prevention of treatment-related complications, and improved orthodontic outcomes. By contributing evidence for clinical training and strengthening the scientific basis for orthodontic practice, this study holds public health significance and may benefit the substantial proportion of adolescents and young adults, estimated at 20–40% who present with malalignment and may require orthodontic evaluation or treatment in Pakistan.

MATERIALS AND METHODS

This cross-sectional study was conducted in the "Department of Orthodontics, Altamash Institute of Dental Medicine", Karachi, Pakistan from 1st Dec 2024 to 31st May 2025. Non probability consecutive sampling method was used to get the sample population. The hospital ethics committee granted ethical permission, [ERC: AIDM/ERC/07/2024/01] and before any patient could participate, their signed informed consent was acquired . Confidentiality of demographic and clinical data was assured.

Patients were enrolled according to strict inclusion and exclusion criteria. Confirmed cases of malaligned teeth, with a full set of erupted permanent teeth (with or without third molars), with clear lateral cephalograms were included. Both male and female with 13 to 40 years of age were eligible. Patients with a previous history of orthodontic treatment, well-aligned dentition not requiring treatment, traumatic occlusion, maxillary or mandibular bony exostosis, or craniofacial syndromes were excluded. Each subject underwent a clinical examination by the investigator to verify the presence of malocclusion, classification of incisor relation, and overjet according to the operational definitions used in this study. Malocclusion was defined as a misalignment or incorrect relationship between the teeth of the two dental arches when the jaws are closed. Angle's classification was applied, whereby Class I was identified when the lower incisor occluded with or lay immediately below the cingulum plateau of the upper incisor, Class II when the lower incisor lay posterior to the cingulum plateau, and Class III when the mandibular incisor lay anterior to the cingulum plateau of the upper incisors. An overjet of 5 mm or more was taken as indicative of Angle's Class II malocclusion.

Lateral cephalograms of all patients were obtained in the Department of Orthodontics and manually traced on acetate sheets using a standardized protocol. All tracings and radiographic measurements were performed by a single trained examiner to reduce inter-observer variability and ensure consistent data collection. Intra-rater reliability was assessed by repeating measurements on a subset of radiographs at two different time points. Although multiple examiners could enhance generalizability, the additional time, resources, and calibration required were not feasible within the study design; therefore, utilizing one well-trained examiner ensured higher internal validity and minimized measurement error.

The cephalometric tracings included the maxilla, mandible, inner and outer cortices of the mandibular symphysis, first molars, and central incisors. Key landmarks such as the occlusal plane, incisal edges, root apices, long axes of incisors, and cementoenamel junctions (CEJ) were identified. For the maxillary central incisors, perpendicular distances from the midpoint of the root (located between the CEJ and apex along the long axis) to the labial (U1-lab) and palatal (U1-pal) cortical plates were measured. For the mandibular central incisors, the incisal edges, root apices, and CEJs were traced, and distances from the root apex to the labial (L1-lab) and lingual (L1-ling) cortical plates were recorded.

The primary objective of this study was to analyze the mean anterior alveolar bone thickness among patients presenting with malaligned teeth. The sample size was calculated using a previously reported mean mandibular alveolar bone thickness of 5.32 ± 1.41 mm (Andrews et al., 2022). A 99% confidence level (Z = 2.57) and a margin of error (E) of 0.36 mm were applied. The minimum required sample size was determined using the formula: n= (Z□σ/E)2

Where σ=1.41, Z=2.57 and E=0.36. Based on this calculation, the study required a minimum of 100 patient

Data were analyzed using SPSS version 22.0. Qualitative variables such as gender, occupation, and residence were summarized as frequencies and percentages. Quantitative variables such as age and alveolar bone thickness were expressed as mean and standard deviation or median values. "Chi-square or fisher exact test" was used for categorical difference among the three classes of malocclusion. One-way "ANOVA" were applied for mean age and anterior alveolar bone thickness among the three classes of malocclusion groups and for multiple comparison Bonferroni test was used. "Independent sample t test" was used to compare anterior alveolar bone thickness between genders according to malocclusion status. A p-value ≤0.05 was significant threshold.

RESULT

The average age of the patients was 19.78 ± 6.20 years, with no significant variation across malocclusion groups (p = 0.472). The largest proportion of participants (62%) belonged to the 13–20 years age group, indicating that younger individuals were more commonly represented in this sample. Gender distribution showed a slight female predominance (53%), though the no significant difference was observed (p = 0.845). A majority of participants were from urban areas (94%). Regarding occupation, no statistically significant differences were observed among groups (p = 0.728); however, students (43%) and individuals in private jobs (45%) made up the majority of the sample, while government employees accounted for only 12%. (Table 1)

The overall mean maxillary alveolar bone thickness was 10.02 ± 1.55 mm, with no statistically significant differences across malocclusion groups (Class I: 10.39 ± 1.21 mm, Class II: 9.70 ± 1.73 mm, Class III: 10.11 ± 1.55 mm; p = 0.121). By contrast, mandibular alveolar bone thickness showed significant variation (p = 0.003), being greatest in Class III patients (12.00 ± 3.32 mm) compared to Class I (9.98 ± 1.34 mm) and Class II (10.01 ± 1.94 mm).

For the maxillary central incisor labial bone (U1-Lab), Class II patients had significantly reduced thickness (4.62 ± 1.41 mm) compared to Class I (5.58 ± 1.57 mm; p = 0.008). No significant difference was observed in palatal bone thickness (U1-Pal), which ranged from 4.81 ± 1.22 mm to 5.46 ± 1.01 mm across groups (p = 0.217). The mandibular central incisor labial bone (L1-Lab) showed no significant difference among groups (overall mean: 5.60 ±

1.75 mm; p = 0.251). However, mandibular lingual bone (L1-Ling) was significantly thicker in Class III patients (5.75 ± 1.19 mm) compared to Class I (4.74 ± 0.85 mm) and Class II (4.39 ± 1.10 mm; p = 0.0005). (Table 2)

In Class I malocclusion, males had a slightly higher mandibular alveolar bone thickness (10.41 ± 1.44 mm) compared to females (9.64 ± 1.19 mm), though this was not statistically significant (p=0.09). Similarly, labial bone thickness at the lower incisors (L1-Lab) was greater in males (5.90 ± 1.66 mm) than females (4.78 ± 1.69 mm), showing a borderline difference (p=0.052). In Class II patients, mean values for maxillary and mandibular alveolar bone as well as U1-Lab, U1-Pal, and L1 measures were comparable between males and females, with no significant differences observed (p>0.05). In Class III cases, females exhibited slightly higher mandibular alveolar bone thickness (12.42 ± 3.63 mm) than males (11.57 ± 3.19 mm) along with higher lingual bone thickness in male than female (6.07 ± 1.13 mm vs. 5.42 ± 1.24 mm), but none reached statistical significance. (Table 3)

DISCUSSION

The present study evaluated anterior alveolar bone thickness (ABT) among patients with

Table 1: Demographic according to malocclusion Status (n=100)

Variables	Overall n=100	Malocclusion Status			P-Value
		Class –I n=37	Class-II n=49	Class-III n=14	
Age (Years), Mean ± SD	19.78±6.20	19.83±6.29	20.29±6.48	17.97±4.3	0.472
Age Groups (Years)					
13-20	62(62%)	25(67.6%)	28(57.1%)	9(64.3%)	0.216
21-25	19(19%)	4(10.8%)	11(22.4%)	4(28.6%)	
26-30	10(10%)	2(5.4%)	7(14.3%)	1(7.1%)	
>30	9(9%)	6(16.2%)	3(6.1%)	0	
Gender					
Male	47(47%)	16(43.2%)	24(49%)	7(50%)	0.845
Female	53(53%)	21(56.8%)	25(51%)	7(50%)	
Residence					
Urban	94(94%)	32(86.5%)	49(100%)	13(92.9%)	0.032
Rural	6(6%)	5(13.5%)	0	1(7.1%)	
Occupation					
Student	43(43%)	15(40.5)	20(40.8%)	8(57.1%)	0.728
Private Job	45(45%)	17(45.9%)	24(49%)	4(28.6%)	
Govt. Job	12(12%)	5(13.5%)	5(10.2%)	2(14.3%)	

Table 2: Comparison of mean anterior alveolar bone thickness among patients with malaligned teeth among malocclusion Status.

Cephalometric analysis of central incisor	Overall n=100	Malocclusion Status			P-Value
		Class –I n=37	Class-II n=49	Class-III n=14	
Maxillary - Alveolar bone	10.02±1.55	10.39±1.21	9.70±1.73	10.11±1.55	0.121
Mandibular- Alveolar bone	10.28±2.10	9.98±1.34	10.01±1.94	12±3.32‡¥	0.003*
U1-Lab	4.98±1.52	5.58±1.57	4.62±1.41†	4.64±1.32	0.008*
U1- Pal	5.04±1.22	4.81±1.22	5.08±1.26	5.46±1.01	0.217
L1-Lab	5.60±1.75	5.27±1.75	5.68±1.52	6.14±2.37	0.251
L1- Ling	4.71±1.11	4.74±0.85	4.39±1.10	5.75±1.19‡¥	0.0005*

U1-Lab= alveolar bone on the labial side; U1- Pal= alveolar bone on the palatal side
L1-Lab= alveolar bone on the labial side; L1-Ling alveolar bone on the lingual side
*P<0.01
† Class-I VS. Class II
‡ Class-I VS. Class III
¥ Class II VS. Class III

Table 3: Comparison of mean anterior alveolar bone thickness among patients with maligned teeth between genders stratified by malocclusion status.

Cephalometric analysis of central incisor	Class –I			Class –II			Class –III		
	Male n=16	Female n=21	P-Value	Male n=24	Female n=25	P-Value	Male n=7	Female n=7	P-Value
Maxillary - Alveolar bone	10.34 ±1.31	10.42 ±1.15	0.83	9.92 ±1.55	9.50 ±1.89	0.41	10.15 ±1.99	10.07 ±1.09	0.93
Mandibular- Alveolar bone	10.41 ±1.44	9.64 ±1.19	0.09	9.92 ±1.79	10.10 ±2.09	0.74	11.57 ±3.19	12.42 ±3.63	0.65
U1-Lab	5.12 ±1.33	5.93 ±1.67	0.12	4.93 ±1.56	4.31 ±1.19	0.12	4.93 ±1.88	4.35 ±0.24	0.44
U1- Pal	5.22 ±1.29	45.0 ±1.08	0.07	4.97 ±0.87	5.18 ±1.54	0.58	5.21 ±0.81	5.71 ±1.18	0.37
L1-Lab	5.90 ±1.66	4.78 ±1.69	0.052	5.47 ±1.47	5.88 ±1.56	0.36	5.42 ±2.44	6.85 ±2.25	0.27
L1- Ling	4.63 ±0.72	4.83 ±0.94	0.46	4.43 ±1.09	4.34 ±1.12	0.76	6.07 ±1.13	5.42 ±1.24	0.33

malaligned teeth across different malocclusion classes. Our results revealed that maxillary alveolar bone thickness remained relatively similar across malocclusion types, while mandibular alveolar bone was significantly thicker in Class III patients. Moreover, maxillary labial bone (U1-Lab) was thinner in Class II cases, and mandibular lingual bone (L1-Ling) was greatest in Class III. These findings provide meaningful insights into orthodontic diagnosis and treatment planning, particularly in populations with a high prevalence of malocclusion.

Our findings showed that mandibular alveolar bone thickness was significantly greater in Class III patients (12.00 ± 3.32 mm), particularly on the lingual side, compared to Class I and Class II. This contrasts with the results of Chen Y (2024)[8], who reported that mandibular incisor alveolar bone in Class III malocclusion was thinner and narrower than in Class II, especially near the labial and lingual attachment levels. The discrepancy between our results and theirs may be attributed to methodological differences, including our reliance on cephalometric tracing versus their CBCT-based three-dimensional evaluation, as well as variations in population characteristics. Nevertheless, both studies emphasize that skeletal discrepancies play a crucial role in determining alveolar bone morphology and should be carefully considered when planning orthodontic tooth movement. The classical findings of Andrews et al[3] in optimal occlusions showed that maxillary incisor roots are positioned closer to the labial surface in a ~2:1 ratio, while mandibular incisors are more centrally positioned. Our Class I results mirrored these trends, with relatively balanced alveolar bone thickness. However, skeletal discrepancies in Class II and III showed departures from this pattern, consistent with Matsumoto et al[4] who demonstrated that Class II patient's exhibit altered alveolar dimensions and limited tolerance for mandibular incisor advancement. Similarly, Uesugi et al[5] emphasized that CBCT-based assessment of Class II and III patients reveals important variations in root–bone relationships, particularly in protrusive profiles. In terms of risk for iatrogenic outcomes, Pan and Chen[6] demonstrated that contact between maxillary incisors and the incisive canal can cause resorption during retraction using skeletal anchorage. Although our study did not evaluate the incisive canal, the finding of reduced labial thickness in Class II highlights the potential risk of such resorptive complications if orthodontic mechanics push incisors beyond alveolar boundaries.

Recent studies further advanced this knowledge. Lu et al. examined skeletal Class III low-angle patients and found greater alveolar bone support with increased labial inclination of mandibular incisors[9]. This resonates with our finding that Class III patients had significantly greater mandibular lingual bone thickness, supporting the notion that skeletal Class III offers increased alveolar support in the anterior region. Liu et al. reported significant morphological changes in alveolar bone following retraction of maxillary incisors in Class II patients[10]. While our cross-sectional study, the thinner labial bone observed in Class II cases supports their findings that these patients may be at greater risk of alveolar remodeling and periodontal compromise. Other studies have emphasized population-based variation. Aljabr et al. found that maxillary labial bone is generally thin among Saudi patients[11], which matches our observation of thin labial bone in Class II cases. Tang et al. demonstrated that deep overbite cases, often associated with Class II Division 2, exhibit reduced labial alveolar thickness[12]. More recently, Yaseen et al investigated vertical facial types and found that hyperdivergent patients had thinner anterior alveolar bone compared with hypodivergent types[13]. Although our study did not stratify patients by vertical skeletal pattern, this factor may partially explain the variability in bone thickness observed in our sample. Elangovan B et al. examined collum angle, tooth dimensions, and alveolar bone thickness, concluding that tooth morphology also plays a role in alveolar bone support[14]. Since our study focused only on central incisors, the contribution of crown-root morphology could not be assessed, but our findings are consistent with the overall variations they reported among different incisor groups. Bhatnagar D[15] also shows variation by skeletal pattern; their samples show similar ranges for labial and palatal bone in maxilla and variation in mandibular lingual bone. Wang et al[16] confirmed that skeletal pattern and tooth inclination directly affect alveolar bone thickness. Another CBCT investigation established a correlation between central incisor inclination and bone thickness across skeletal Class I and II malocclusions with different vertical skeletal patterns[17]; Rawaqa et al[18] reported consistent dentoalveolar variations, including collum angle and alveolar thickness differences, among different anteroposterior skeletal relationships; and Zhang et al[19] demonstrated that tooth proclination and labial movement lead to significant changes in alveolar bone morphology.

Overall, our study confirms that Class II patients have reduced maxillary labial bone thickness, increasing their susceptibility to dehiscence and fenestration during orthodontic retraction. Conversely, Class III patients had thicker mandibular alveolar bone, particularly on the lingual side, which may provide a relative advantage in terms of alveolar support. These findings align with multiple CBCT-based studies across different populations and support the importance of individualized treatment planning. The absence of significant gender differences in our results is consistent with meta-regression revealed no specific association between gender and bone thickness[20].

The clinical implications of these findings are important. In Class II patients, orthodontic treatment must be carefully planned to prevent iatrogenic periodontal damage, especially when significant incisor retraction is considered. In Class III patients, although thicker alveolar bone may provide greater tolerance, caution is still warranted during decompensation or lingual tooth movement. Taken together, our findings underscore the role of thorough radiographic evaluation, preferably with CBCT where available, in determining safe treatment limits.

Despite providing valuable insights, our study has some limitations. We did not stratify patients according to vertical facial pattern or incisor inclination, factors known to influence alveolar bone morphology. Moreover, the relatively smaller number of Class III patients may limit generalizability. This study employed a nonprobability consecutive sampling technique to enroll participants. While this method is practical in busy clinical settings and ensures steady recruitment, it inherently limits the generalizability of the findings. The sample may not fully represent the broader population of Karachi or Pakistan, as patients presenting to a tertiary care hospital may differ from individuals in community settings or rural areas. This limitation should be considered when interpreting the results, and future studies using probabilistic sampling methods are recommended to improve external validity. Finally, being cross-sectional in design, our study could not evaluate dynamic bone changes during treatment. Moreover, environmental and functional factors (e.g., tongue posture, habits) that may affect alveolar bone were not evaluated. Future longitudinal studies, ideally using CBCT, are recommended to confirm and expand upon these observations.

CONCLUSION

In conclusion, our study adds to the growing body of evidence that alveolar bone morphology varies significantly with malocclusion type. The finding of thinner maxillary labial bone in Class II and thicker mandibular bone in Class III is consistent with international literature and highlights the need for individualized orthodontic planning to protect periodontal health. No significant association were observed between gender and anterior alveolar bone dimensions.

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CONFLICT OF INTEREST
Authors declare no conflict of interest.
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AUTHORS' CONTRIBUTION

The following authors have made substantial contributions to the manuscript as under:

Conception or Design:	M, HS, AAE, MM
Acquisition, Analysis or Interpretation of Data:	M, HS, AAE, MM
Manuscript Writing & Approval:	M, HS, AAE, MM

All the authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.