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Determination of Alveolar Bone Thickness and Inclination of Upper and Lower Incisors: An Analogy of Diverse Untreated Age Groups Using Lateral Cephalogram

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Abstract

Introduction: This study highlights the crucial role of biomechanics and bone morphology in orthodontics, focusing on how anatomical changes impact tooth movement. It stresses the need to evaluate the relationship between teeth and alveolar bone, noting potential complications.

Aim: Determination of alveolar bone thickness in upper and lower incisor region, a comparative analysis of various untreated age groups using lateral cephalogram.

Materials and Methods: The study involves 120 samples (30 per group, evenly split by gender) divided into four age groups: Group 1 (8 -16),Group 2 (17-30) ,Group 3 (31-45) ,Group 4 (above 45). Lateral cephalograms were manually traced to measure distances from the root centers of upper and lower incisors to the outer cortical surfaces, assessing alveolar bone thickness. The study also measures the inclination of upper and lower central incisors to analyze tooth positions and bone thickness in relation to incisor angles.

Results: The study found non-significant differences in incisor inclination and maxillary alveolar bone thickness among age groups. Group 2 had the highest upper incisor inclination, and Groups 3 and 4 had the highest lower incisor inclinations. Group 1 had the highest maxillary alveolar bone thickness.

Conclusion: The study concludes that with increase in age of the patient there is no change in alveolar bone thickness.

Keywords: Alveolar bone thickness, incisor inclination, lateral cephalogram

Introduction

In orthodontic diagnosis, a lateral cephalogram is key for assessing the central incisor position. Treatment decisions for anterior-posterior (AP) incisor movements hinge on their inclination and relation to the surrounding alveolar bone. Diagnosis and planning are guided by three factors:

1. Dental crowding severity
2. Lower incisor positioning
3. Facial development pattern.[1]

Orthodontic tooth movement relies on bone remodeling (resorption and apposition) in the alveolar process, where the roots of the teeth are housed.[2] Bone resorption follows tooth movement direction, with apposition on the opposite side. Reduced alveolar bone volume on the resorption side can complicate orthodontic treatment.[3]

In orthodontic treatment, movements in the alveolar bone include labial and palatal/lingual shifts, but the cortical surfaces act as limits. Beyond these limits, fenestration or dehiscence may occur. [3-12]Contact between the cortical bone and the roots can lead to external root resorption. [13-15] Contact between cortical bone and roots can lead to external root resorption, while the increased distance from the alveolar crest to the cementoenamel junction is termed bone dehiscences.[6] Before, animal tests were the main focus of research into how tooth movement affects the buccal and lingual bone plates.[16]

Alveolar bone fenestrations, revealing small root areas, are discontinuities on the buccal or lingual sides. The incisive canal (IC) can also limit root movement, potentially causing apical root resorption during orthodontic tooth movement.[17-20] Hence It's crucial to identify these anatomical boundaries to prevent potential complications.

Contemporary orthodontics emphasizes both smile aesthetics and facial harmony. The patient's initial periodontal morphology is poised to be added to the existing considerations of dental arch expansion and incisor buccal-lingual movement as key factors in future orthodontic practices.[4]

Various studies have examined incisor positions in different malocclusions, [11, 21-24] yet establishing precise guidelines for root positioning remains challenging. In cases of crowding, teeth may erupt ectopically, affecting observable alveolar bone thickness around the root. It's more feasible to study the anatomic limits of alveolar bone and roots in naturally occurring optimal occlusions (NOOS), and static occlusions without the need for orthodontic intervention.

To date, no studies have compared alveolar bone thickness across age groups in Angle's Class I malocclusion. This study seeks to determine the inclination and alveolar bone thickness in the upper and lower incisal regions. By analyzing untreated age groups using lateral cephalograms, the aim is to define safe anatomic boundaries for incisor root movements. This analysis will inform treatment decisions, aiming to prevent inadvertent complications and establish clear guidelines for root positioning.

Materials and Method

An institutional ethical committee approval (SSDCRI/IEC/2021-22/9/3) was obtained.

Sample Size-

Four groups were involved and each group had 30 samples (15 male and 15 female). The four groups are divided based on age which are

Group 1 (8 -16 years)

Group 2 (17-30 years)

Group 3 (31-45years)

Group 4 (above 45 years)

The sample calculation was performed using G * Power v3.1 (Heinrich Heine, University of Düsseldorf) with alpha error set at 0.05, beta power at 0.95, and an N2/N1 ratio of 1. The test showed 30 samples for each group as the ideal size for the study.

Naturally occurring optimal occlusions (NOOs) Lateral cephalometric images of individuals with NOOs were acquired from patients coming to college for treatment.

Inclusion Criteria

1. No history of orthodontic treatment
2. Angles class I malocclusion
3. A full complement of erupted permanent teeth till 7's (with or without third molars and exemption for group 1)

Exclusion Criteria

1. History of previous orthodontic treatment
2. Class II and Class III malocclusion
3. Missing tooth

Cephalometric Tracing

Lateral Cephalogram will be hand-traced by the examiner with a 0.5mm 3h led pencil on acetate paper. Structures to be traced include the maxillary, mandibular, medial, and lateral cortical surfaces of the mandibular symphysis, first molars, and central incisors (left and right averages). The occlusal surface, incisor margin, root tip, vertical axis of the incisor, cementum-enamel junction of the maxillary incisor, and root center of the maxillary incisor (midpoint between CEJ and apex along the long axis of the tooth) are also identified and traced. (Fig 1)

Maxillary Central Incisor Root Position (Fig 2)

The distance (in millimeters) from the center of the root to the outer cortical surface of the alveolar process on the labial (U1lab) and palatal (U1pal) sides will be measured perpendicular to the long axis of the tooth.

Maxillary Alveolar Process Thickness (Fig 2)

The total thickness of the maxillary alveolar process (MxAlv) was calculated by adding the distances U1lab and U1pal.

Mandibular Central Incisor Root Position (Fig 2)

Both labial (L1lab) and lingual (L1ling) distances (in millimeters) from the apex of the root to the lateral cortical surface of the alveolar process were measured parallel to the occlusal plane.

Mandibular Alveolar Process Thickness (Fig 2)

The total thickness of the mandibular alveolar process (MdAlv) was calculated by adding the distances L1lab and L1ling.

Incisor Inclination (Fig 2)

The inclination of the upper (U1incl) and lower (L1incl) central incisors was measured by the acute angle formed between the vertical axis of the tooth and the line perpendicular to the occlusal plane

AP Jaw Relationship (Fig 2)

The Wits appraisal (Wits) was used to assess AP jaw relationships. All measurements are performed by one examiner using venire calipers, for linear measurements and a manual protractor for angular measurements.

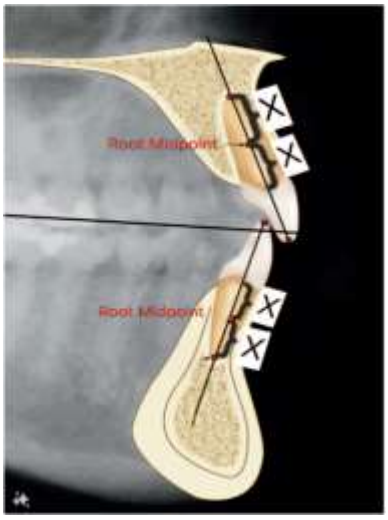


Figure 1: The occlusal plane, incisal edges, root apices, long axes of the teeth, maxillary incisor cementoenamel junction (CEJ), and maxillary incisor root midpoint are among the reference points and lines drawn.

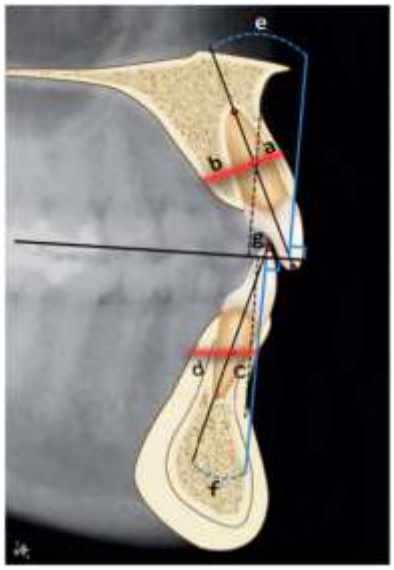


Figure 2: Measurements included (a) U1-lab, (b) U1-pal, (aþb) MxAlv, (c) L1-lab, (d) L1-ling, (cþd) Md-Alv, (e) U1-incl, (f) L1-incl, and (g) Wits.

Results

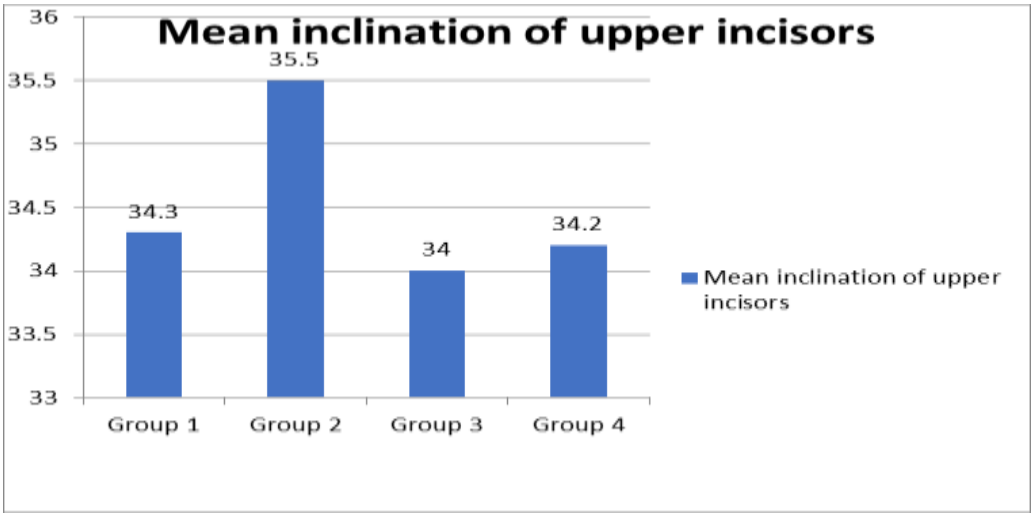
Intergroup comparative analysis of upper incisor inclination across the four age groups is presented in Table 1,Graph 1. While a slight difference was observed, no statistically significant variance was found (P= .73). Notably, Group 2 subjects exhibited the highest mean inclination of the upper incisor at 35.5 ± 5.7, followed closely by Group 1 at 34.4 ± 5.9.

Table 1: Comparative analysis of Inclination of upper incisors between the age groups

Variable	Groups	N	Mean	Std Deviation	Std Error	Upper Bound (95%Ci)	Upper Bound (95%Ci)	F value	p-value
U1 Inclination	1	30	34.3	5.9	1.08	32.09	36.51	0.42	0.73
	2	30	35.5	5.7	1.05	33.30	37.63		
	3	30	34	5.3	.97	32.01	35.99		
	4	30	34.2	5.3	.96	32.22	36.18		
Total		120	34.5	5.5	.50	33.49	35.50		

One-way ANOVA test, p<0.05 is statistically significant

Graph 1: Mean inclination of upper incisors between the age groups



In Table 2,graph 2, intergroup comparative data of lower incisor inclination among the diverse age groups is detailed. Similarly, a minor difference was noted with no statistically significant variance (P= .67). Subjects in Groups 3 and 4 displayed the highest mean inclination of the lower incisor, measuring 26 ± 4.1 and 26 ± 4.2, respectively, followed by Group 1 at 25.1 ± 4.6.

Table 2: Comparative analysis of Inclination of lower incisors between the age groups.

Variable	Groups	N	Mean	Std Deviation	Std Error	Upper Bound (95%Ci)	Upper Bound (95%Ci)	F value	p-value
L1 Inclination	1	30	25.1	4.6	.85	23.39	26.87	0.521	0.669
	2	30	24.9	3.9	.72	23.38	26.34		
	3	30	26	4.1	.74	24.40	27.46		
	4	30	26	4.2	.76	24.39	27.54		
Total		120	26	4.2	.38	24.71	26.23		

One-way ANOVA test, $p<0.05$ is statistically significant

Graph 2: Mean inclination of lower incisors between the age groups

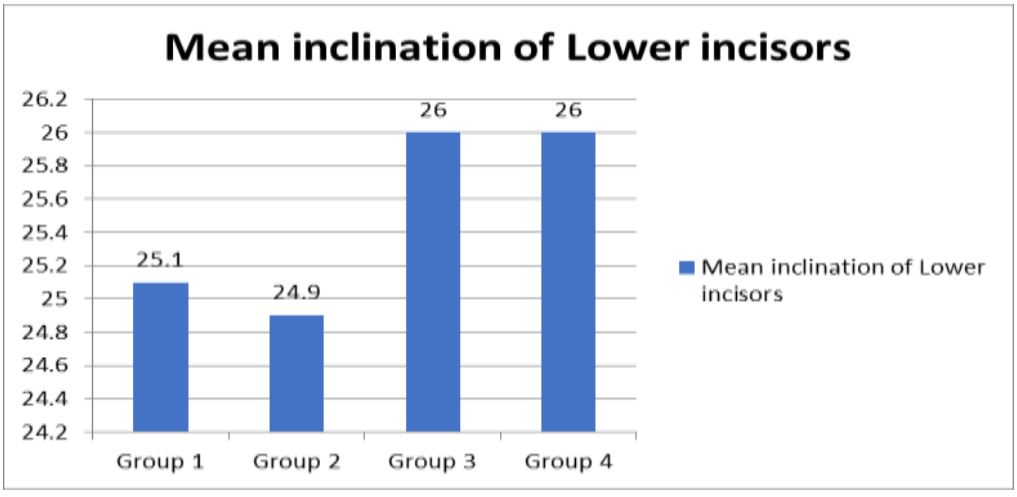


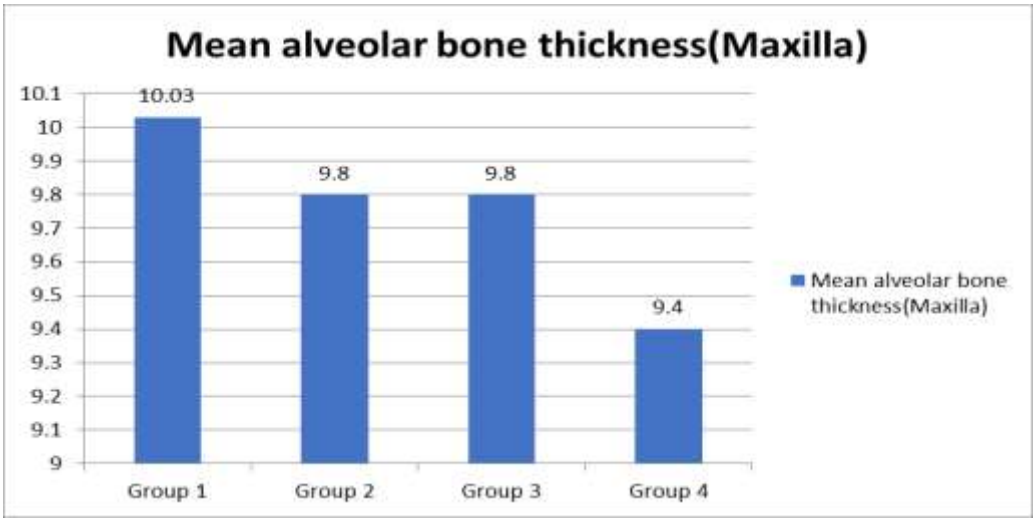
Table 3, Graph 3 delves into the intergroup comparative data of maxillary alveolar bone thickness across the four age groups. Although a small variation was observed, no statistically significant difference was detected (P= .26). Noteworthy is that Group 1 participants exhibited the highest mean alveolar thickness at 10.3 ± 9.8, with Groups 2 and 3 following closely at 9.8 ± 1.1 and 9.8 ± 1.3, respectively.

Table 3: Comparative analysis of Maxillary alveolar bone thickness between the age groups

Variable	Groups	N	Mean	Std Deviation	Std Error	Upper Bound (95%Ci)	Upper Bound (95%Ci)	F value	p-value
Maxillary Thickness	1	30	10.03	1.27	.23	9.55	10.51	1.35	0.26
	2	30	9.8	1.1	.20	9.38	10.21		
	3	30	9.8	1.3	.24	9.32	10.34		
	4	30	9.4	1.0	.19	9.01	9.81		
Total		120	9.7	1.2	.11	9.55	9.99		

One-way ANOVA test, p<0.05 is statistically significant

Graph 3: Mean Alveolar bone thickness in maxilla between the age groups



Lastly, Table 4, graph 4 presents intergroup comparative data of mandibular alveolar bone thickness among the diverse age groups. Here, a slight difference was observed with no statistically significant variance (P= .77). Participants in Groups 1 and 3 showcased the highest mean alveolar thickness at 7.8 ± 1.1 and 7.8 ± 0.76, respectively, while Groups 2 and 4 followed closely at 7.7 ± 0.97 and 7.7 ± 1.03, respectively.

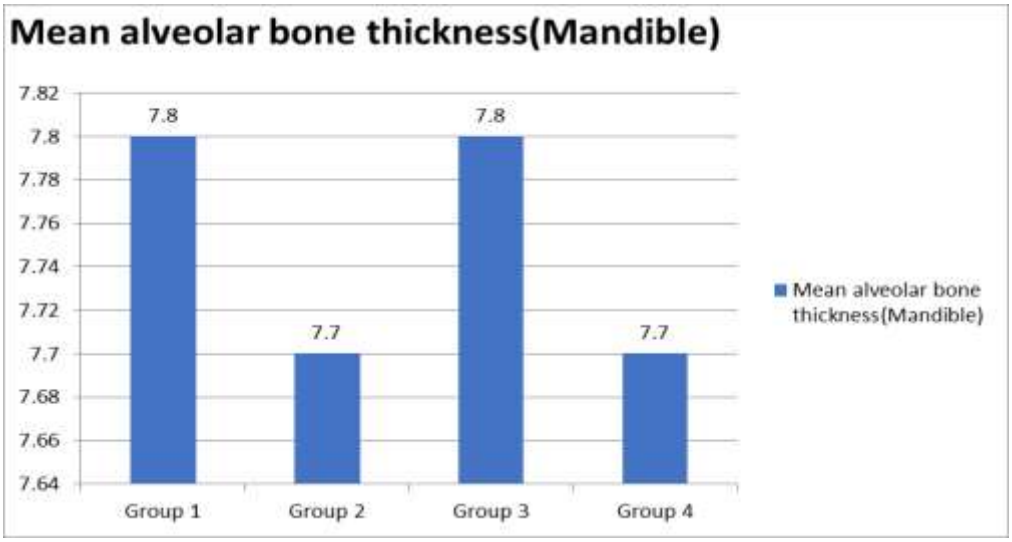
Table 4: Comparative analysis of Mandibular alveolar bone thickness between the age groups

Variable	Groups	N	Mean	Std Deviation	Std Error	Upper Bound (95%Ci)	Upper Bound (95%Ci)	F value	p-value
	1	30	7.2	1.04	.24	7.39	8.45		
	2	30	7.5	.92	.19	7.35	8.36		

Mandibular Thickness	3	30	7.4	.70	.18	7.58	8.27	0.28	0.764
	4	30	7.8	1.12	.26	7.92	8.12		
Total		120	7.5	.95	.21	7.56	8.30		

One-way ANOVA test. $p<0.05$ is statistically significant

Graph 4: Mean Alveolar bone thickness in mandible between the age groups



Discussion

Andrews's six keys of occlusion, including mesiodistal and labiolingual crown inclinations, are crucial in orthodontic therapy. [25] Alveolar housing around teeth also affects root positioning. [26] Although crown positions are well-documented,[11,21-24] there's a gap in understanding root inclination and alveolar housing changes across age groups, warranting further research.

Central incisor inclination significantly impacts orthodontic treatment decisions, especially in addressing anterior-posterior movements. Evaluating incisor inclination and its relation to alveolar bone is crucial for achieving functional, aesthetic, and long-term oral health goals in orthodontic therapy. [25]

Orthodontic tooth movement is limited by cortical surfaces in the alveolar bone to prevent issues like fenestration or dehiscence. [3-12] The incisive canal in the maxillary arch can lead to external root resorption, especially in class III malocclusions(James Kaley 1991).[15] Careful treatment planning and monitoring are crucial to avoid periodontal consequences and ensure forces stay within bone adaptability limits.[3-15] Understanding anatomical limitations, particularly of the alveolar bone, is key for successful and stable orthodontic outcomes while maintaining overall oral health.

Understanding anatomical boundaries enables orthodontists to customize treatment approaches, reducing the risk of iatrogenic issues like external root resorption. [17-20] Recognizing the risks linked to contact between incisor roots, alveolar cortical bone, and the incisive canal is essential for effective orthodontic treatment planning.

Assessing root positions across age groups in untreated samples is vital for grasping natural variations. Establishing guidelines from these evaluations helps create reliable benchmarks in orthodontic practice,

assisting in treatment planning and achieving optimal patient outcomes.[25]

Studies comparing alveolar bone thickness in different malocclusions often show thinner alveolar widths lingual to maxillary incisors in class II cases compared to class I groups.[3]

Among class II groups, individuals with high mandibular plane angle were found to have less alveolar bone thickness. [3, 21, 27] Class III patients typically exhibit reduced apical and alveolar bone thickness compared to class I and class II cases.[28,29]

Despite extensive studies [11, 21-24] on malocclusions, there's a gap in comparing alveolar bone thickness across age groups in Class I malocclusions. This study aimed to fill this gap by analyzing incisor inclination and alveolar bone thickness in the upper and lower incisal regions across various age groups using lateral cephalograms.

This study included 120 lateral cephalograms of Angle's class I malocclusion, divided into four age groups: 8-16 years, 17-30 years, 31-45 years, and 45 years and above. Each age group had 30 samples with an equal gender distribution to avoid gender-related biases. The images were sourced from patients at Sree Sai Dental College and Research Institute, categorized based on facial feature changes with aging according to Dipali Bhat et al.[30]

The analysis across four age groups showed that Group 2 (17-30 years) had the highest mean inclination of upper incisors at 35.5° ± 5.7°, followed by Group 1 (8-16 years) at 34.3° ± 5.9°. However, the differences between these groups, as well as Groups 3 (31-45 years) and 4 (above 45 years), were not statistically significant ($p = 0.73$). This lack of significant difference was consistent across the 120 subjects, indicated by the p-value of 0.73 from the ANOVA test.

In a similar study by Nameer Al-Taai et al., [31] analyzing incisor inclination across age groups from 13 to 60 years, no significant difference was found. Choosing a sample with similar incisal inclination in a class I occlusion helped eliminate biases related to alveolar bone thickness variations due to proclination or retroclination.

Earlier studies by Yy-lou Tian et al. noted reduced bone support in retroclined incisors, highlighting the importance of considering incisor inclination in orthodontic planning. [23] Raphaelli also emphasized variations in bone tissue based on incisor inclination. [32]

Nameer Al-Taai et al[31] study highlighted stable incisor inclination patterns from early adolescence to early adulthood, with significant retrusion and retroclination observed in late adulthood (above 60 years). Other studies also noted retroclination of incisors. [33,34] During late adulthood, upper incisors retrocline by approximately 4° due to the incisor apex moving forward, while lower incisors retrocline due to posterior mandibular rotation, not a change in axial inclination. This study did not observe such changes as the adult subjects were mostly below 50 years of age.[31]

The comparative analysis of maxillary alveolar bone thickness across four age groups showed a slight decrease with increasing age, with Group 1 having the highest mean thickness at 10.03 ± 1.27, followed by Groups 2 and 3 at 9.8 ± 1.1 and 9.8 ± 1.3, respectively. Group 4 had a slightly lower mean thickness of 9.4 ± 1.0. However, the differences were not statistically significant ($p = 0.26$), indicating stability of maxillary alveolar bone thickness within the examined population despite age-related variations.

Lingual bone thickness decreases significantly after incisor retraction,[7] but this study, conducted before orthodontic treatment, did not observe such changes.

The mandible shows a smaller width in subjects aged 10 to 19 years, with thickness peaking around 40 to 49 years and decreasing after 49 years.[37] A similar trend was observed in this study, with Group 3 showing slightly more alveolar bone thickness that later reduces, though not statistically significant. This reflects ongoing alveolar bone changes in response to masticatory load, influenced by periodontal conditions worsening with age.

Sathapana et al.[35] investigated the correlation between alveolar bone cortical thickness (ABCT) and age in the maxillae and mandible among individuals aged 10 to 50. They found a statistically significant correlation between ABCT and age but noted relatively minor actual changes in ABCT with age.

Ichiki et al.[36] studied age-related changes in alveolar bone height and width using CT scans in individuals undergoing dental implant treatment. They categorized participants into age groups (20-64 and 65-85 years) and observed decreased alveolar bone thickness in patients who lost teeth. Similarly, in this study, alveolar bone thickness remained constant in the age group between 20-64 years.

The present study showed similar age-related changes to prior studies, suggesting that alveolar bone thickness is not age-dependent but influenced by factors like malocclusion type, growth pattern, and incisor inclination. In class I malocclusions, alveolar bone thickness remains relatively constant unless affected by periodontal or pathological factors.

Conclusion

The study exhibits a balanced gender distribution, with an equal representation of males and females across all study groups.

The intergroup comparison of upper incisor inclination across four age groups reveals small differences, but none are statistically significant. Group 2 demonstrates the highest mean inclination of upper incisors, followed closely by Group 1.

The intergroup comparison of lower incisor inclination among the four age groups reveals minor differences, but none are statistically significant. Notably, Groups 3 & 4 exhibit the highest mean inclination of lower incisors, respectively, followed by Groups 1&2

The intergroup comparison of maxillary alveolar bone thickness across the four age groups indicates a small difference but without statistical significance. Group 1 stands out with the highest mean alveolar thickness, followed closely by Group 2&3.

The intergroup comparison of maxillary alveolar bone thickness among the four age groups indicates a small, non-statistically significant difference. Notably, Groups 1&3 exhibit the highest mean alveolar thickness, followed by Groups 2&4, suggesting subtle variations across the diverse age categories.

Abbreviations:

ABT	Alveolar Bone Thickness
NOOs	Naturally occurring optimal occlusions
EARR	External apical root resorbtion
Mx-Alv	Maxillary alveolar bone thickness
Md-Alv	Mandibular alveolar bone thickness
U1-incl	Maxillary central incisor inclination
L1-incl	Mandibular central incisor inclination

References

1. Ricketts RM. Orthodontic Diagnosis and Planning:-- Their roles in preventive and rehabilitative dentistry. Rocky Mountain/Orthodontics; 1982.
2. Reitan K. Biomechanical principles and reaction. Orthodontics current principles and techniques. 1985:101-92.

3. Handelman CS. The anterior alveolus: its importance in limiting orthodontic treatment and its influence on the occurrence of iatrogenic sequelae. The Angle Orthodontist. 1996 Apr 1;66(2):95-110.
4. Garib DG, Yatabe MS, Ozawa TO, da Silva Filho OG. Alveolar bone morphology under the perspective of the computed tomography: defining the biological limits of tooth movement. Dental Press J Orthod. 2010;15:192–205.
5. Lund H, Grondahl K, Grondahl H-G. Cone beam computed tomography evaluations of marginal alveolar bone before and after orthodontic treatment combined with premolar extractions. Eur J Oral Sci. 2012;120:201–211.
6. Evangelista K, Vasconcelos K, Bumann A, Hirsch E, Nitka M, Silva MAG. Dehiscence and fenestration in patients with Class I and Class II Division 1 malocclusion assessed with cone-beam computed tomography. Am J Orthod Dentofacial Orthop. 2010;138:133–135.
7. Sarikaya S, Haydar B, Ciger S, Ariyurek M. Changes in alveolar bone thickness due to retraction of anterior teeth. Am J Orthod Dentofacial Orthop. 2002;122:15–26.
8. Wehrbein H, Bauer W, Diedrich P. Mandibular incisors, alveolar bone, and symphysis after orthodontic treatment. A retrospective study. Am J Orthod Dentofacial Orthop. 1996; 110:239–246.
9. Yagci A, Veli I, Uysal T, Ucar FI, Ozer T, Enhos S. Dehiscence and fenestration in skeletal Class I, II, and III malocclusions assessed with cone-beam computed tomography. Angle Orthod. 2012;82:67–74.
10. Yared KFG, Zenobio EC, Pacheco W. Periodontal status of mandibular central incisors after orthodontic proclination in adults. Am J Orthod Dentofacial Orthop. 2006;130:6.e1– 6.e8.
11. Nauert K, Berg R. Evaluation of labio-lingual bony support of lower incisors in orthodontically untreated adults with the help of computed tomography. J Orthofac Orthop. 1999;60: 321–334
12. Matsumoto K, Sherrill-Mix S, Boucher N, Tanna N. A conebeam computed tomographic evaluation of alveolar bone dimensional changes and the periodontal limits of mandibular incisor advancement in skeletal Class II patients. Angle Orthod. 2020;90:330–338.
13. Ten Hoeve A, Mulie RM. The effect of antero-posterior incisor repositioning on the palatal cortex as studied with laminography. J Clin Orthod. 1976;10:804–822.
14. Horiuchi A, Hotokezaka H, Kobayashi K. Correlation between cortical plate proximity and apical root resorption. Am J Orthod Dentofacial Orthop. 1998;114:311–318.
15. Kaley J, Phillips C. Factors related to root resorption in edgewise practice. Angle Orthod. 1991; 61:125–132.
16. Kalajzic Z, Peluso EB, Utreja A, Dyment N, Nihara J, Xu M, Chen J, Uribe F, Wadhwa S. Effect of cyclical forces on the periodontal ligament and alveolar bone remodeling during orthodontic tooth movement. The Angle Orthodontist. 2014 Mar 1;84(2):297-303.
17. Chung CJ, Choi YJ, Kim KH. Approximation and contact of the maxillary central incisor roots with the incisive canal after maximum retraction with temporary anchorage devices: report of 2 patients. Am J Orthod Dentofacial Orthop. 2015;148:493–502.

18. Matsumura T, Ishida Y, Kawabe A, Ono T. Quantitative analysis of the relationship between maxillary incisors and the incisive canal by cone-beam computed tomography in an adult Japanese population. Prog Orthod. 2017;18:24. doi:10.1186/s40510-017-0181-1
19. Uesugi S, Imamura T, Kokai S, Ono T. Cone-beam computed tomography-based diagnosis and treatment simulation for a patient with a protrusive profile and a gummy smile. Korean J Orthod. 2018;48:189–199.
20. Pan Y, Chen S. Contact of the incisive canal and upper central incisors causing root resorption after retraction with orthodontic mini-implants: A CBCT study. Angle Orthod. 2019;89:200–205.
21. Gracco A, Lombardo L, Mancuso G, Gravina V, Siciliani G. Upper incisor position and bony support in untreated patients as seen on CBCT. Angle Orthod. 2009;79:692–702.
22. Nahas-Scocate ACR, Brandao AS, Patel MP, LipiecXiminez ME, Chilvarquer I, Valle-Corotti KM. Bone tissue amount related to upper incisors inclination. Angle Orthod. 2014;84:279–285.
23. Tian Y, Liu F, Sun H, et al. Alveolar bone thickness around maxillary central incisors of different inclination assessed with cone-beam computed tomography. Korean J Orthod. 2015;45:245–252.
24. Yamada C, Kitai N, Kakimoto S, Furukawa S, Takada K. Spatial relationships between the mandibular central incisor and associated alveolar bone in adults with mandibular prognathism. Angle Orthod. 2007;77:766–772.
25. Andrews LF. The six keys to normal (optimal) occlusion. Am J Orthod. 1972;62:296–309.
26. Andrews WA, Abdulrazzaq WS, Hunt JE, Mendes LM, Hallman LA. Incisor position and alveolar bone thickness: A comparative analysis of two untreated samples using lateral cephalograms. The Angle Orthodontist. 2022 Jan 1;92(1):3-10.
27. Horner KA, Behrents RG, Kim KB, Buschang PH. Cortical bone and ridge thickness of hyperdivergent and hypodivergent adults. American journal of orthodontics and dentofacial orthopedics. 2012 Aug 1;142(2):170-8.
28. Al-Masri MM, Ajaj MA, Hajeer MY, Al-Eed MS. Evaluation of bone thickness and density in the lower incisors' region in adults with different types of skeletal malocclusion using cone-beam computed tomography. J Contemp Dent Pract. 2015 Aug 1;16(8):630-7.
29. Kook YA, Kim G, Kim Y. Comparison of alveolar bone loss around incisors in normal occlusion samples and surgical skeletal class III patients. The Angle Orthodontist. 2012 Jul 1;82(4):645-52.
30. Bhat D, Patil VK. Human Age Estimation Based on Facial Aging Patterns. International Research Journal of Engineering and Technology (IRJET). 2016;3(7):124-8.
31. Al-Taai N, Persson M, Ransjö M, Levring Jäghagen E, Fors R, Westerlund A. Craniofacial changes from 13 to 62 years of age. European Journal of Orthodontics. 2022 Oct 1;44(5):556-65.
32. Nahás-Scocate AC, de Siqueira Brandão A, Patel MP, Lipiec-Ximenez ME, Chilvarquer I, do Valle-Corotti KM. Bone tissue amount related to upper incisors inclination. The Angle Orthodontist. 2014 Mar 1;84(2):279-85.
33. Behrents RG. Growth in the aging craniofacial skeleton. 1985.
34. Bondevik O. Dentofacial changes in adults. Journal of Orofacial Orthopedics/Fortschritte der Kieferorthopadie. 2012 Aug 1;73(4).

35. Sathapana S, Forrest A, Monsour P, Naser-ud-Din S. Age-related changes in maxillary and mandibular cortical bone thickness in relation to temporary anchorage device placement. Australian dental journal. 2013 Mar;58(1):67-74.
36. Ichiki S, Muraoka H, Hirahara N, Ito K, Okada H, Kaneda T. Age Affects Alveolar Bone Height and Width in Patients Undergoing Dental Implant Treatment: Findings from Computed Tomography Imaging. Journal of Hard Tissue Biology. 2021;30(4):383-8.
37. Swasty D, Lee JS, Huang JC, Maki K, Gansky SA, Hatcher D, Miller AJ. Anthropometric analysis of the human mandibular cortical bone as assessed by cone-beam computed tomography. Journal of oral and maxillofacial surgery. 2009 Mar 1;67(3):491-500.