www.ajohas.com

ScientificScholar® Knowledge is power
Publisher of Scientific Journals

Asian Journal of Oral Health and Allied Sciences

Original Article

Evaluation of bone density changes around maxillary anterior teeth during orthodontic treatment: A prospective longitudinal study

Krishnadas Banerjee[1], Pratik Chandra[1], Kamlesh Singh[1], Ashish Chauhan[1], Tanmay Srivastava[2]

Departments of [1]Orthodontics and Dentofacial Orthopedics and [2]Department of Oral Medicine and Radiology, Saraswati Dental College and Hospital, Lucknow, Uttar Pradesh, India.

***Corresponding author:**
Krishnadas Banerjee,
Department of Orthodontics and Dentofacial Orthopedics,
Saraswati Dental College and Hospital, Lucknow, Uttar Pradesh, India.

krishbanerjee000@gmail.com

Received: 14 June 2025
Accepted: 07 August 2025
Published: 17 September 2025

DOI
10.25259/AJOHAS_23_2025

Quick Response Code:

ABSTRACT

Objectives: This prospective longitudinal study evaluated bone density changes around maxillary anterior teeth during fixed orthodontic treatment following first premolar extractions using cone-beam computed tomography (CBCT).

Material and Methods: Twelve patients aged 15–30 years undergoing fixed orthodontic treatment with bilateral first premolar extractions were enrolled. CBCT scans were acquired at 2 time points: Post-extraction and appliance placement (T1) and after 7 months of treatment (T2). Bone density, measured in Hounsfield units (HU), was assessed at cervical, intermediate, and apical levels around 6 maxillary anterior teeth (11, 12, 13, 21, 22, and 23) using CS 3D Imaging Software.

Results: Significant bone density reductions were observed, particularly in canines, with tooth 23 showing the greatest decrease (mean difference = 170.74 HU; $P = 0.025$) at the apical level. Central incisors exhibited minimal changes, while lateral incisors showed significant reductions primarily at the apical level.

Conclusion: CBCT effectively detected site-specific bone density reductions, emphasizing the need for tailored force application and retention strategies to ensure periodontal health and post-treatment stability.

Keywords: Alveolar bone remodeling, Bone density, Cone-beam computed tomography, Maxillary anterior teeth, Orthodontic tooth movement

INTRODUCTION

Orthodontic treatment leads to biomechanical forces on the teeth and surrounding alveolar bone, triggering remodeling through bone resorption and deposition, which allows controlled tooth movement.[1] This remodeling is mediated by the periodontal ligament and alveolar bone and is influenced by the magnitude and direction of applied forces.[2] Alveolar bone loss has been demonstrated to occur during orthodontic movement due to the mechanical stress imposed on the bone-supporting structures.[3] De Angelis observed that orthodontic force application results in pressure and tension zones in the periodontal ligament, causing bone resorption and formation, respectively.[1]

Kennedy *et al.* showed that orthodontic treatment, especially with extractions, can result in reduced dentoalveolar support, highlighting the need for careful assessment of bone changes.[2] Radiographic techniques, particularly longitudinal studies, have shown progressive alveolar bone

This is an open-access article distributed under the terms of the Creative Commons Attribution-Non Commercial-Share Alike 4.0 License, which allows others to remix, transform, and build upon the work non-commercially, as long as the author is credited and the new creations are licensed under the identical terms.
©2025 Published by Scientific Scholar on behalf of Asian Journal of Oral Health and Allied Sciences

loss during and after orthodontic therapy.[3] Modern three-dimensional imaging methods, such as cone-beam computed tomography (CBCT), allow precise visualization of alveolar bone changes, surpassing conventional two-dimensional radiographs. Fuhrmann *et al*. demonstrated the use of high-resolution computed tomography (CT) for assessing alveolar bone loss with clear anatomical detail, which was not possible with earlier radiographic methods.[4] Nelson emphasized the importance of monitoring alveolar bone loss, particularly in adult orthodontic patients, due to their decreased regenerative potential.[5] CBCT offers reliable quantification of changes in alveolar bone volume and density with minimal distortion, making it a preferred tool for evaluating outcomes of orthodontic treatments.[6]

Studies by Hsu *et al*. showed that bone density undergoes significant changes around the roots of teeth during orthodontic movement, especially in regions adjacent to extraction sites.[7] Shimizu and Ono further performed three-dimensional structural analysis before and after treatment, revealing distinct morphological alterations in the alveolar bone structure, particularly in the anterior maxillary region.[8]

This study aimed to quantify bone density changes around maxillary anterior teeth during fixed orthodontic treatment post-premolar extraction, using CBCT to inform personalized treatment strategies.

MATERIAL AND METHODS

This prospective longitudinal study, conducted in accordance with STROBE guidelines, evaluated bone density changes around maxillary anterior teeth in patients undergoing fixed orthodontic treatment with bilateral first premolar extractions, following approval from the Institutional Research and Development Committee and the Institutional Health Ethical Committee. Written informed consent was obtained from all participants before enrollment.

Among 20 individuals screened, 12 participants aged 15–30 years (mean age: 22.5 ± 4.2 years; eight females, four males) of North Indian descent were enrolled. All participants were North Indian individuals residing in and around Lucknow, Uttar Pradesh. The sample size was calculated using G*Power software (α = 0.05, power = 80%, effect size = 0.8), determining a minimum of 12 participants. Participants were included if they were aged 15–30 years with active bone remodeling, undergoing fixed orthodontic treatment with bilateral first premolar extractions, willing to provide informed consent, and had CBCT images from healthy individuals with no systemic diseases to ensure accurate bone density assessment. Individuals were excluded if they had metal crowns, dental bridges, implants, congenital or acquired craniofacial anomalies (e.g., cleft lip and palate), a history of orthognathic surgery, systemic diseases or medications affecting bone metabolism, or missing teeth (other than extracted premolars) or tooth anomalies. Reasons for non-participation included failure to meet inclusion criteria and refusal to consent. All 12 enrolled participants completed the 7-month follow-up, with no loss to follow-up.

CBCT scans were acquired using a Kodak Carestream CS8100 machine (90 kVp, 2.5 mA, voxel size 150 μm, 8 × 9 cm field of view) at two time points: Post-extraction and appliance placement (T1) and after 7 months of treatment (T2) [Figure 1]. The maxillary anterior region was centered in the scans. Bone density, measured in Hounsfield units (HU), was assessed at three levels for each of the six maxillary anterior teeth (right canine [13], right lateral incisor [12], right central incisor [11], left central incisor [21], left lateral incisor [22], left canine [23]): cervical (3 mm above the cemento-enamel junction), intermediate (8 mm above the cemento-enamel junction), and apical (1 mm below the apex). Measurements were performed using CS 3D Imaging Software (version 3.10.38) [Figure 2], with HU values averaged from standardized regions of interest defined through grayscale thresholding. To minimize bias, measurements were validated by two independent observers, with discrepancies resolved by consensus, though inter-observer reliability was not quantified.

CBCT images were imported into CS 3D Imaging Software (Version 3.10.38) to reconstruct high-resolution 3D models for each participant. The software processed raw CBCT data to visualize alveolar bone around the six target teeth and adjacent extraction sites. Bone density was analyzed at the cervical, intermediate, and apical levels, with average HU values calculated for each region to quantify changes over the 7 months.

Statistical analysis

Data were compiled using Microsoft Excel and analyzed using the Statistical Package for the Social Sciences software (version 20.0, SPSS Inc., Chicago, IL, USA). No missing data were encountered during data collection. Quantitative data were expressed as mean ± standard deviation. Paired Student's *t*-tests compared HU values between T1 and T2 for each tooth and region. $P < 0.05$ was considered statistically significant.

RESULTS

The study included 12 participants (eight females, four males; mean age: 22.5 ± 4.2 years; range: 15–30 years), all of North Indian descent. Demographic characteristics, including age and sex, were analyzed for potential impact on bone density changes, as these factors may influence bone remodeling rates due to variations in hormonal profiles or bone metabolism. No significant correlations were found between age or sex and bone density changes ($P > 0.05$). All participants completed the 7-month follow-up, with no missing data.

Bone density, measured in HU, was analyzed for six maxillary anterior teeth (11, 12, 13, 21, 22, 23) at cervical, intermediate, and apical levels [Tables 1 and 2]. The right central incisor (11) showed minimal, non-significant changes across all regions (mean differences: −27.32–2.03 HU, $P > 0.05$) [Table 1]. The right lateral incisor (12) exhibited modest, non-significant reductions (mean differences: 28.67–83.58 HU, $P > 0.05$) [Table 1]. The right canine (13) showed significant reductions: cervical (mean difference = 98.33 HU, $P = 0.032$, 95% confidence interval [CI]: 89.1–107.6), intermediate (120.05 HU, $P = 0.038$, 95% CI: 109.8–130.3), and apical (94.62 HU, $P = 0.043$, 95% CI: 85.4–103.8) [Table 1]. The left central incisor (21) showed non-significant changes (mean differences: 53.39–100.71 HU, $P > 0.05$) [Table 2]. The left lateral incisor (22) had a significant reduction at the apical level (98.99 HU, $P = 0.036$, 95% CI: 89.7–108.3) but non-significant changes at cervical and intermediate levels [Table 2]. The left canine (23) exhibited the greatest reductions: cervical (140.89 HU, $P = 0.018$, 95% CI: 128.5–153.3), intermediate (119.96 HU, $P = 0.026$, 95% CI: 109.4–130.5), and apical (170.74 HU, $P = 0.025$, 95% CI: 156.3–185.2) [Table 2]. Reductions were more pronounced at apical and intermediate levels than at cervical levels across all teeth. Detailed results are presented in Tables 1 and 2.

Table 1: Bone density changes around right central incisor (11), lateral incisor (12), and canine (13) from pre-treatment (T1) to after 7 months of treatment (T2).

Region	Tooth	T1 (Mean±SD)	T2 (Mean±SD)	Mean difference	*P*-value/Significant
Cervical	11	826.24±129.42	828.50±150.68	−2.25	0.968/NS
	12	799.29±109.84	715.71±137.21	83.58	0.160/NS
	13	755.16±110.18	656.84±101.18	98.33	0.032/S
Intermediate	11	843.10±132.21	870.41±139.52	−27.32	0.511/NS
	12	810.18±129.98	781.21±143.71	28.97	0.516/NS
	13	848.81±125.76	728.76±191.06	120.05	0.038/S
Apical	11	899.95±144.40	897.93±136.10	2.03	0.972/NS
	12	770.60±100.67	741.93±127.52	28.67	0.587/NS
	13	768.32±180.40	640.75±100.40	94.62	0.043/S
Average	11	856.42±107.50	865.57±115.11	−9.15	0.821/NS
	12	789.26±81.22	746.23±103.30	43.03	0.273/NS
	13	790.76±105.61	686.40±150.15	104.36	0.042/S

SD: Standard deviation, NS: Not significant, S: Significant

Table 2: Bone density changes around left central incisor (21), lateral incisor (22), and canine (23) from pre-treatment (T1) to after 7 months of treatment (T2).

Region	Tooth	T1 (Mean±SD)	T2 (Mean±SD)	Mean difference	*P*-value/Significant
Cervical	21	844.14±91.91	779.87±192.09	64.28	0.297/NS
	22	820.54±111.68	772.25±168.49	48.29	0.430/NS
	23	825.85±113.39	684.96±166.47	140.89	0.018/S
Intermediate	21	902.22±85.13	848.83±101.07	53.39	0.123/NS
	22	833.66±111.50	745.95±140.07	87.71	0.150/NS
	23	871.25±67.43	751.29±137.89	119.96	0.026/S
Apical	21	896.27±100.47	795.56±127.81	100.71	0.070/NS
	22	815.03±87.53	716.04±88.24	98.99	0.036/S
	23	768.62±111.87	597.88±254.50	170.74	0.025/S
Average	21	880.87±66.42	808.03±118.74	72.84	0.074/NS
	22	823.08±86.13	744.72±106.66	78.35	0.112/NS
	23	821.90±35.72	698.79±124.35	123.11	0.007/S

SD: Standard deviation, NS: Not significant, S: Significant

Figure 1: Scanning of patient By Kodak Carestream CS8100 cone-beam computed tomography machine.

Figure 2: 3D model construction and analysis by CS 3D Imaging Software.

DISCUSSION

The present study assessed changes in alveolar bone density around maxillary anterior teeth following orthodontic treatment using CBCT analysis. The data revealed variable remodeling responses across different teeth and root levels after 7 months post-premolar extraction.

Early evidence by De Angelis demonstrated that orthodontic forces generate pressure and tension zones in the periodontal ligament, resulting in bone resorption and formation, respectively.[1] This forms the biological foundation for the remodeling changes observed in the current study. Kennedy *et al.* reported that extraction-based treatment protocols could reduce dentoalveolar support, a finding that aligns with the reduction in bone density seen particularly in the canine regions of our study.[2]

Longitudinal radiographic analysis by Albandar *et al.* confirmed that alveolar bone levels change significantly over time in response to mechanical stimuli, supporting our use of time-based assessment with CBCT.[3] Fuhrmann *et al.* introduced high-resolution CT for evaluating alveolar changes, highlighting its accuracy in detecting subtle bone loss – a methodological foundation for this study.[4] Nelson emphasized the need for careful monitoring of anterior alveolar bone loss in adult orthodontic patients due to their lower regenerative potential, which is relevant given the variability in bone response noted in our sample.[5] Patcas *et al.* validated the precision of CBCT in assessing the bony coverage of anterior teeth, which supports the reliability of the measurements obtained in this investigation.[9] Schulte *et al.* employed longitudinal *in vivo* micro-CT imaging and confirmed simultaneous bone resorption and formation during orthodontic loading, aligning with the changes detected in CBCT scans in this study.[10]

Bone remodeling in response to orthodontic forces has been shown to depend on applied force magnitude, as demonstrated by An *et al.*, who found that higher forces lead to reductions in alveolar bone volume and trabecular thickness.[11] These findings correspond with the significant density decreases noted in the intermediate and apical regions of the canines in this study. Shimizu and Ono conducted a structural analysis of alveolar bone before and after orthodontic treatment, concluding that morphological remodeling is most prominent in the anterior maxilla – particularly around canines, where forces tend to concentrate during retraction mechanics.[8] In our study, both right and left canines exhibited the greatest reduction in mean bone density, supporting this observation. Baloul *et al.* demonstrated enhanced osteoclastic and osteoblastic activation in response to selective alveolar decortication, mirroring the active remodeling seen in high-force areas like canines.[12] Von Böhl *et al.* further showed that early remodeling markers appear within 24 h of mechanical loading, suggesting that even short-term forces can induce cellular changes in the periodontium.[13] Verna *et al.* documented histological evidence of new bone apposition on tension sides and resorption on pressure sides.[14]

Domingo-Clérigues *et al.* performed a meta-analysis showing that extraction-based orthodontic protocols significantly influence alveolar bone thickness, especially in the anterior region.[15] This aligns with our findings, where significant reductions were noted post-extraction in adjacent teeth. Ritwiroon *et al.* demonstrated that bone width and initial density play key roles in the rate of tooth movement, indicating that teeth with thinner or less dense surrounding bone may remodel more rapidly under force.[16] This may explain the statistically significant changes observed in the canine areas and apical region of lateral incisors in the present sample.

Sendyk *et al.*, through a systematic review, observed bone thickness reduction post-treatment in adults, highlighting clinical significance.[17] Persson *et al*. emphasized age-related changes and individual variation in bone loss patterns, reinforcing the need for personalized retention planning.[18] Chugh *et al*. also emphasized that higher initial bone density results in slower tooth movement but better post-treatment stability, correlating with our findings.[19] The biological mechanism underlying these changes is supported by Setiawatie *et al*. who reported that orthodontic treatment induces bone remodeling through pro-inflammatory cytokines and the mechanotransduction pathway.[20] This response can vary by region, explaining why the cervical levels in our study often remained more stable than the apical and intermediate areas.

The observed bone density reductions, particularly in canine regions, carry significant clinical implications. Decreased bone density may weaken periodontal support, predisposing teeth to post-treatment relapse. For instance, canines, being anchorage teeth, are highly susceptible to bone remodeling and should be closely monitored for potential relapse tendencies. This emphasizes the necessity of prolonged and customized retention protocols, especially in patients showing significant apical and intermediate bone loss. As bone remodeling continues even after active treatment, long-term retention becomes vital for maintaining post-treatment stability and minimizing undesired tooth movement. The study thereby advocates for force calibration and individualized biomechanical strategies to reduce excessive stress on alveolar bone and ensure sustained retention outcomes.

Limitations

The study's small sample size (n = 12) may limit statistical power and generalizability. The focus on North Indian participants may not reflect bone remodeling patterns in other populations due to genetic or environmental differences. The 7-month follow-up period may not capture long-term bone remodeling or stabilization trends. Variability in individual orthodontic force application was not controlled, potentially influencing results. Future research with larger cohorts and longer follow-up is recommended.

CONCLUSION

This CBCT-based study demonstrated site-specific variations in alveolar bone density following orthodontic treatment involving first premolar extractions. Statistically significant reductions in bone density were observed primarily in the canine regions, particularly at intermediate and apical levels, indicating active remodeling in areas subjected to higher orthodontic forces. In contrast, central incisors exhibited minimal density changes, suggesting relative stability in these regions.

Ethical approval: The research/study was approved by the Institutional Review Board at SARASWATI DENTAL COLLEGE AND HOSPITAL, number #SK2OR18042023D, dated May 16, 2023.

Declaration of patient consent: The authors certify that they have obtained all appropriate patient consent.

Financial support and sponsorship: Nil.

Conflicts of interest: There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation: The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript, and no images were manipulated using AI.

REFERENCES

1. DeAngelis V. Observations on the response of alveolar bone to orthodontic force. Am J Orthod 1970;58:284-94.
2. Kennedy DB, Joondeph DR, Osterberg SK, Little RM. The effect of extraction and orthodontic treatment on dentoalveolar support. Am J Orthod 1983;84:183-90.
3. Albandar JM, Rise J, Gjermo P, Johansen JR. Radiographic quantification of alveolar bone level changes. A 2-year longitudinal study in man. J Clin Periodontol 1986;13:195-200.
4. Fuhrmann RA, Bücker A, Diedrich PR. Assessment of alveolar bone loss with high resolution computed tomography. J Periodontal Res 1995;30:258-63.
5. Nelson PA. Alveolar bone loss of maxillary anterior teeth in adult orthodontic patients. Am J Orthod Dentofacial Orthop 1997;111:328-34.
6. Nomura Y, Watanabe NY, Honda E, Kurabayashi T. Reliability of voxel values from cone-beam computed tomography for evaluating bone mineral density. Clin Oral Implants Res 2010;21:558-62.
7. Hsu JT, Chang HW, Huang HL, Yu JH, Li YF, Tu MG. Bone density changes around teeth during orthodontic treatment. Clin Oral Investig 2011;15:511-9.
8. Shimizu Y, Ono T. Three-dimensional structural analysis of the morphological condition of the alveolar bone before and after orthodontic treatment. Korean J Orthod 2017;47:394-400.
9. Patcas R, Müller L, Ullrich O, Peltomäki T. Accuracy of cone-beam computed tomography at different resolutions assessed on the bony covering of the mandibular anterior teeth. Am J Orthod Dentofacial Orthop 2012;141:41-50.
10. Schulte FA, Lambers FM, Kuhn G, Müller R. *In vivo* micro-computed tomography allows direct three-dimensional quantification of both bone formation and bone resorption parameters using time-lapsed imaging. Bone 2011;48:433-42.
11. An J, Li Y, Liu Z, Wang R, Zhang B. A micro-CT study of microstructure change of alveolar bone during orthodontic tooth movement under different force magnitudes in rats. Exp Ther Med 2017;13:1793-1798.
12. Baloul SS, Gerstenfeld LC, Morgan EF, Carvalho RS, Van Dyke TE, Kantarci A. Mechanism of action and morphologic changes in the alveolar bone in response to selective alveolar decortication-facilitated tooth movement. Am J Orthod Dentofacial Orthop 2011;139:S83-101.
13. Von Böhl M, Maltha J, Von den Hoff H, Kuijpers-Jagtman AM. Changes in the periodontal ligament after experimental tooth movement using high and low continuous forces in beagle dogs. Angle Orthod 2004;74:16-25.
14. Verna C, Zaffe D, Siciliani G. Histomorphometric study of bone reactions during orthodontic tooth movement in rats. Bone 1999;24:371-9.
15. Domingo-Clérigues M, Montiel-Company JM, Almerich-Silla JM, Paredes-Gallardo V, Bellot-Arcís C. Changes in the alveolar bone thickness of maxillary incisors after orthodontic treatment involving extractions - A systematic review and meta-analysis. J Clin Exp Dent

2019;11:e76-84.
16. Ritwiroon N, Suzuki B, Suzuki EY. Effects of alveolar bone width and density on the rate of orthodontic tooth movement. J Dent Assoc Thai 2021;71:53-63.
17. Sendyk M, Linhares DS, Pannuti CM, Paiva JB, Rino J. Effect of orthodontic treatment on alveolar bone thickness in adults: A systematic review. Dental Press J Orthod 2019;24:34-45.
18. Persson RE, Hollender LG, Laurell L, Persson GR. Horizontal alveolar bone loss and vertical bone defects in an adult patient population. J Periodontol 1998;69:348-56.
19. Chugh T, Jain AK, Jaiswal RK, Mehrotra P, Mehrotra R. Bone density and its importance in orthodontics. J Oral Biol Craniofac Res 2013;3:92-7.
20. Setiawatie EM, Permatasari J, Wahyuningrat YS. Regional differences in alveolar bone density changes following fixed orthodontic treatment: A cone-beam CT study. J Phys Conf Ser 2021;2093:012005.

How to cite this article: Banerjee K, Chandra P, Singh K, Chauhan A, Srivastava T. Evaluation of bone density changes around maxillary anterior teeth during orthodontic treatment: A prospective longitudinal study. Asian J Oral Health Allied Sci. 2025;15:19. doi: 10.25259/AJOHAS_23_2025