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The Relationship Between Bone Morphotype, Bone Density, and Apical Root Resorption of Posterior Teeth Induced by Orthodontic Forces

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ABSTRACT

Background: Modern orthodontic treatment reliably achieves optimal functional and aesthetic outcomes; however, complications such as internal or external tooth root resorption remain a concern. Orthodontic forces are a primary factor contributing to the development of root resorption. Extensive research has been conducted to elucidate the etiology of root resorption, which may arise from various factors, including the mechanics employed during orthodontic treatment, the type and magnitude of forces applied, and other treatment-related parameters, such as the nature of tooth movement and the specific type of malocclusion. The clinical relevance of root resorption is closely tied to its detectability. Literature indicates that the relationship between root resorption, bone morphotype, and bone density is clinically important in dentistry but has not been extensively explored.

Objectives: This study aimed to evaluate the extent of apical root resorption in the posterior region of the dentition following fixed and removable orthodontic appliance therapy and to investigate the association between bone morphotype, bone density, and tooth root resorption induced by orthodontic treatment.

Methods: To address the study's objectives, patients from the research and control groups underwent cone beam computed tomography (CBCT) examinations.

Results: The findings of this study did not reveal a significant correlation between bone morphotype, bone density, and the rate of root resorption associated with orthodontic treatment. However, a notable correlation was observed between gender and age. Apical root resorption in the posterior teeth was predominantly identified in females, specifically in study group B, who were treated with fixed orthodontic appliances.

Conclusions: Given the clinical significance of root resorption, further research is warranted to elucidate the relationship between orthodontic force-induced root resorption, the shape of the apex, and root length.

Keywords: External Apical root resorption (EAAR); bone mineral density (BMD); bone morphotype; cone beam computed tomography (CBCT); orthodontic tooth movement (OTM).

BACKGROUND

External Apical Root Resorption (EARR) is an inevitable pathological outcome of orthodontic tooth movement. It is characterized as an iatrogenic condition that occurs unpredictably after orthodontic treatment. In this process, the resorbed portion of the apical root is replaced by normal bone. EARR represents a sterile inflammatory process of significant complexity, involving interactions among mechanical forces, tooth and bone structures, cellular activity, the extracellular matrix, and specific biological messengers.[1]

The potential adverse effects of modern orthodontic treatment, particularly on dentition and hard tissues, have been extensively studied over recent decades, yet the available data remains inconclusive. Research indicates root resorption is most frequently observed in maxillary anterior teeth, followed by mandibular anterior teeth, first molars, canines, and premolars.[2]

Bone remodeling, a critical process during orthodontic treatment, occurs as teeth shift positions, resulting in modifications to tissue dimensions. However, uncontrolled tooth movements beyond the original boundaries of the bone forces can lead to significant bone dehiscences, increasing the risk of tooth gingival recession. The development of dehiscences during the orthodontic treatment is multifactorial, influenced by the direction, intensity, and duration of orthodontic forces, alveolar bone morphotype, occlusal trauma, bone density, oral habits, and biological responses to orthodontic forces. These factors must be carefully managed, as apical root resorption (ARR) can result in an altered crown-to-root ratio, potentially leading to tooth loss in severe cases and negatively affecting both the patient's quality of life and the overall success of orthodontic treatment.

Limited research exists regarding EARR associated with clear aligners, with conclusions varying among studies. Most evidence suggests that EARR incidence and severity are lower with clear aligners than fixed appliances; however, some studies report no significant differences in root resorption rates between these treatment modalities.[3]

Orthodontic tooth movement (OTM) is facilitated by bone resorption and apposition, driven by forces applied to the dental crown. A critical factor in this process is adequate alveolar bone thickness surrounding the tooth root.[4] Bone density is pivotal in OTM, as reduced bone density can significantly accelerate tooth movement. However, localized density changes may increase the risk of adverse outcomes, such as EARR.[5]

The relationship between alveolar bone density and root resorption remains contentious. Some studies indicate that denser alveolar bone correlates with increased root resorption during orthodontic treatment. Reitan's research demonstrates that strong continuous forces on less dense bone result in similar root resorption levels as mild continuous forces on denser bone. Additionally, resorbing bundle bone under orthodontic pressure is more challenging than other bone types. Wainwright, however, argues that while bone density influences the rate of tooth movement, it does not correlate with the extent of root resorption.[6]

The gingival phenotype, defined by gingival thickness and keratinized tissue width, and bisone morphotype, characterized by bone thickness and morphology, are essential in classifying periodontal phenotype. Most studies investigating periodontal phenotype's influence on gingival recession (GR) in orthodontic patients have focused on soft tissues. Given the vulnerability of thin alveolar bone, analyzing hard tissues is recommended for assessing prospective orthodontic candidates.[7]

Fixed appliances have traditionally been the standard for orthodontic treatment. However, clear aligners like the Invisalign system have become increasingly popular due to their enhanced aesthetics and greater comfort than fixed appliances.[8]

Research has demonstrated that the type of fixed appliances used in orthodontic treatment is associated with the incidence of apical root resorption (ARR).[9,10] The prevalence of ARR in patients treated with clear aligners remains a topic of debate.[11] For instance, a study evaluating clear aligners analyzed the upper and lower anterior teeth and the first molars using panoramic radiographs. The findings revealed that 46% of the teeth exhibited measurable root reduction during treatment with clear aligners. This apical root resorption (ARR) prevalence appears to be similar to or lower than that observed with fixed appliances.[12,13]

According to Baumrind's research data, the prevalence of ARR ranges from 20% to 100% among orthodontic patients.[14] Severe ARR, characterized by resorption exceeding 5 mm or one-fourth of the root length, is rare, with an incidence between 1% and 5%.[15]

The literature indicates that maxillary first molars are the teeth most affected by radicular resorption, with volume losses ranging from 83.12 mm³ to 37.4 mm³. First and second premolars are also affected, with radicular volume losses ranging from 40.86 mm³ to 13.12 mm³ and 37.64 mm³ to 13.93 mm³, respectively.[16-18] Sharpe et al. observed that molars exhibited the second-highest incidence of EARR after maxillary central incisors.[19]

This study aimed to assess the extent of apical root resorption in the posterior region of the dentition following fixed and removable orthodontic appliance therapy and to evaluate the relationship between bone morphotype, bone density, and orthodontically induced tooth root resorption. The objective was to quantitatively analyze the alveolar bone density at the sites of the premolars and molars in the lower jaw.

METHODS

A systematic search was conducted for patient archives from the previous study at the Grigol Robakidze University Dental Center "Gruniverse." A trained professional team collected the necessary information utilizing the center's database and record-keeping system. The search was based on specific criteria, including the study's timeframe starting from June 2022.

The Exclusion Criteria were patients with systemic diseases or the use of any prescription drugs that might impact bone metabolism processes and patients with odontogenic acute or chronic apical periodontitis.

This study comprised 80 patients, including 40 patients with non-removable orthodontic appliances of different age groups: 20 patients from Group A (12 to 17 years old) and 20 patients from Group B (18 to 35 years old), as well as 40 patients with removable orthodontic appliances of different age groups: 20 patients from Group A1 (12 to 17 years old) and 20 patients from Group B1 (18 to 35 years old). Regarding the gender distribution, there were 20 males and 20 females in Groups A and A1 (50%/50%), and the same pattern was observed in Groups B and B1.

To achieve the study's objective, patients from the research and control groups underwent CBCT examinations. Subsequently, statistical analysis and comparative evaluation of the obtained results were performed. The HR-CBCT images were taken using a KAVO Dental Excellence OP 3D device (Finland).

Bone morphotype resulted in a mean buccal bone thickness of 0.343 (±0.135) mm for the thin biotype and 0.754 (±0.128) mm for the thick/average biotype. Bone morphotypes were radiographically measured with cone-beam computed tomography (CBCT).[20] Prior to measurement, all scans were aligned with a standardized protocol.[21]

The evaluation of 1,280 posterior teeth, first and second premolars (P), and first and second molars (M) from all four quadrants was performed. The images were obtained from high-resolution cone-beam computed tomography. Posterior teeth with EAAR were identified, and root tissue loss was measured (Fig.1 and Fig.2). Then, the thickness of the buccal alveolar bone plate of teeth was measured at three levels. Each image was positioned along the main axis of the tooth, passing the sagittal plane over the root's longest buccal-lingual diameter. The thickness of the alveolar bone was measured in the mandible at three levels on the buccal surfaces: (i) Cervical level (CeL), at the level of a line perpendicular to the tooth's main axis, traced at 1 mm from the CEJ; (ii) Apical level (ApL), at the level of a line perpendicular to the tooth's main axis,

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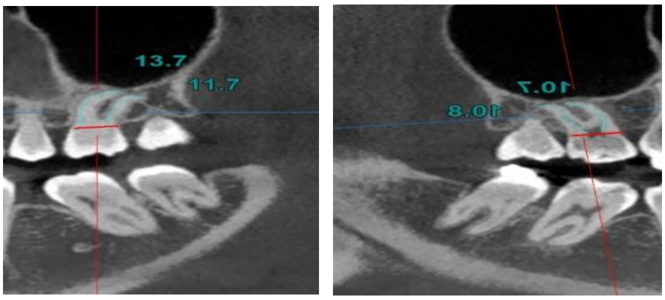
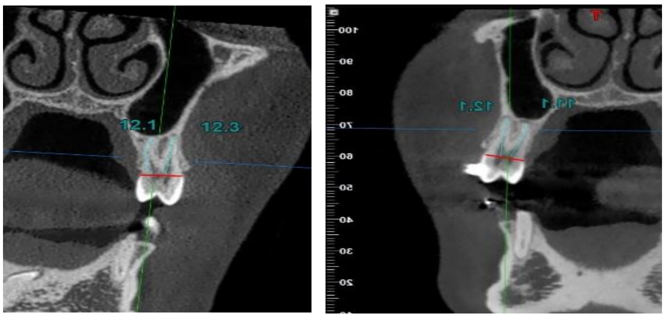
passing through the root apex; and (iii) Middle level (MiL), at the midpoint between the previous two.

FIGURE 1. Measure the root length before orthodontic treatment (A) and after 1 year (B) by CBCT scan (tooth #1.6 with EARR)



A B

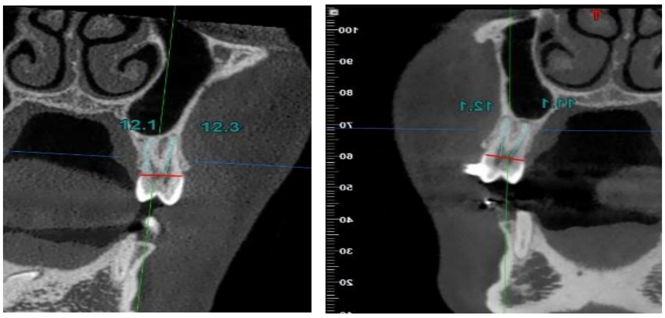
FIGURE 2. Measure the root length before orthodontic treatment (A) and after 1 year (B) by CBCT scan (tooth #2.5 with EARR)



A B

Eighty sets of computed tomography (CT) images were selected, and bone density measurements were taken (Fig.3).

FIGURE 3. Measure the bone morphotype and density in the site of premolars (A: tooth #2.5) and molars (B: tooth #4.6) before treatment



A B

The bone morphotype and bone density were analyzed across all four patient groups to establish statistical evidence of a correlation between bone morphotype, bone density, and tooth root resorption.

RESULTS

The study results were processed statistically. First, the extent of tooth root resorption in the study groups was analyzed to determine whether it was statistically significantly higher. The relative risk (RR), its standard error, and 95% confidence interval (CI) were calculated according to Altman (Altman DG, 1991).

A statistically significant difference was observed between the study and control groups regarding the risk of tooth root resorption as a complication of orthodontic treatment. Bone morphotype and bone density were assessed in all four patient groups to establish statistical evidence of a correlation between bone morphotype, bone density, and tooth root resorption. Predictors and standard deviations for this analysis were determined.

The relationship between tooth root resorption and different tooth morphotypes was assessed using a t-test after calculating the morphotype data's mean values and standard deviations in groups with and without resorption (Tab.1).

TABLE 1. Comparison of bone morphotype between patients with and without root resorption

Root Resorption	The bone morphotype Mean ±SD	P-value
With root resorption (n=12)	1.12±0.017	0.105
Without root resorption (n=1280)	1.11±0.98	

Comparing measurements at three points—cervical level (CeL), middle level (MiL), and apical level (ApL)—on the posterior teeth of the upper and lower jaws revealed the following: At CeL, bone thickness was less than 1 mm in 43% of cases for both jaws. At ApL, bone thickness exceeded 1 mm in 100% of cases for both the maxilla and mandible. At MiL, bone thickness was less than 1 mm in 24% of cases and greater than 1 mm in 76% in the upper jaw. In the lower jaw, bone thickness was less than 1 mm in 16% of cases and more than 1 mm in 84%.

From the 80 patients in the posterior tooth region, the thick bone morphotype was observed in 57 patients, while 23 patients had the thin morphotype. Tooth root resorption due to orthodontic forces was identified in only five patients in Group B (18 to 35 years old) with fixed appliances.

When examining the bone morphotype of patients with external apical root resorption (EAAR) by sex, the following distribution was noted:

- Thin morphotype: three females;
- Thick morphotype: one female and one male

The maxilla's average bone thickness was greater at CeL; similarly, the mandible's bone exhibited significantly thicker bone at the same point.

The mean cortical bone thickness (CBT) for maxillary premolars and molars was 1.4 mm (range: 1.4–1.6 mm) and 2.4 mm (range: 0.7–1.8 mm), respectively. For mandibular premolars and molars, the mean CBT was 1.9 mm (range: 0.92–1.91 mm) and 4.3 mm (range: 0.78–1.88 mm), respectively. No statistically significant differences were found

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when comparing bone morphotypes between patients with and without tooth root resorption.

In general, bone density in the posterior region of the mandible was higher than that in the posterior region of the maxilla. This difference is primarily attributed to anatomical and functional variations. The mandible, more compact and subjected to greater functional loads during activities such as chewing, typically exhibits denser bone in the posterior region. Conversely, the maxilla has a more trabecular structure, particularly in the posterior areas, resulting in lower bone density. Age, sex, genetics, and oral health may also influence bone density.

The bone density of the maxilla ranged between 548 and 1470 Hounsfield units (HU), while that of the mandible ranged between 744 and 1648 HU.

This study did not demonstrate any significant correlation between bone morphotype, bone density, and the rate of root resorption associated with orthodontic treatment (Tab.2). Although bone morphotypes and densities were similar, apical root resorption was predominantly observed in females.

In contrast to previous studies on anterior tooth root resorption, posterior tooth root resorption was observed exclusively in study group B (18 to 35 years old) with fixed orthodontic appliances.[22]

TABLE 2. Comparison of bone morphotype between patients with and without root resorption

Tooth number	Number of cases	Bone morphotype (mm)	Bone density	Gender
1.5	1	1.1	D1	Female
1.4	1	1.2	D1	Female
2.4	1	1.31	D1	Female
2.5	2	1.1-1.4	D2	Female
3.4	1	1.4	D2	Female
1.6	3	1.9-2.1	D2	Female
2.6	1	1.9	D2	Female
3.6	1	4.3	D1	Male
4.6	1	3.9	D2	Female

DISCUSSION

According to the literature, maxillary first molars are the teeth most affected by radicular resorption, with volumes ranging from 83.12 mm^3 to 37.4 mm^3. First and second premolars are also affected, with radicular volume losses ranging from 40.86 mm^3 to 13.12 mm^3 and 37.64 mm^3 to 13.93 mm^3, respectively.23,24 Sharpe et al. observed that molars had the second-highest incidence of external apical root resorption (EARR) after maxillary central incisors.[22]

Our research indicates similar findings: maxillary first molars are typically the most affected during orthodontic treatment, followed by second molars and premolars.

Certain studies suggest that increased alveolar bone density is associated with a higher risk of root resorption during orthodontic treatment. According to Reitan, applying strong continuous force on less dense alveolar bone results in the same degree of root resorption as the mild continuous force applied to the denser bone. Additionally, it is more challenging to resorb bundle bone under orthodontic pressure than other types of bone. Wainwright has argued that although bone density influences the rate of tooth movement, it does not appear to correlate with the extent of root resorption.[25]

Our study did not demonstrate any significant correlation between bone morphotype, bone density, and the rate of root resorption associated with orthodontic treatment. However, some correlation was observed concerning gender and age. Apical root resorption of posterior teeth was predominantly found in females within study group B (ages 18 to 35) treated with fixed orthodontic appliances.

CONCLUSIONS

Despite the same bone morphotype and density, apical root resorption of posterior teeth was predominantly observed in females in study group B (ages 18 to 35) with fixed orthodontic appliances. Among 80 patients with posterior teeth, 57 exhibited a thick bone morphotype, while 23 had a thin morphotype. The average bone thickness was more significant in the upper maxilla at the ApL point, and similarly, the bone was significantly thicker at the same point in the mandible.

In patients with apical root resorption, a tendency for cortical bone thinning was observed in the areas surrounding the resorbed teeth. However, this thinning was not evident in regions associated with healthy teeth.

According to our study's results, no significant correlation was found between the occurrence of apical root resorption of posterior teeth due to orthodontic treatment and the bone morphotype or density of the patients. However, some correlation was found concerning gender and age. Apical root resorption of posterior teeth was predominantly observed in females, specifically in study group B (ages 18 to 35) with fixed orthodontic appliances.

Given the issue's relevance, further research is needed to explore the relationship between root hard tissue resorption caused by orthodontic forces, the shape of the apex, and the length of the root. Considering patients' characteristics and selecting the appropriate orthodontic appliance could help prevent complications associated with orthodontics. Further detailed studies will significantly simplify treatment planning. In addition to making treatment outcomes more predictable,

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these studies will also contribute to the stability and safety of the treatment.

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REFERENCES

1. Akyalcin S, Alexander SP, Silva RM, English JD. Evaluation of three-dimensional root surface changes and resorption following rapid maxillary expansion: A cone beam computed tomography investigation. Orthod Craniofac Res. 2015;18(2):117-126.
2. Baysal A, Karadede I, Hekimoglu S, et al. Evaluation of root resorption following rapid maxillary expansion using cone-beam computed tomography. Angle Orthod. 2012;82(3):488-494.
3. Iglesias-Linares A, Morford LA, Hartsfield JK Jr. Bone density and dental external apical root resorption. Curr Osteoporos Rep. 2016;14(6):292-309.
4. Almeida MR, Marcal ASB, Fernandes TMF, Vasconcelos JB, de Almeida RR, Nanda R. A comparative study of the effect of the intrusion arch and straight wire mechanics on incisor root resorption: A randomized controlled trial. Angle Orthod. 2018;88(1):20-26.
5. Baumrind S, Korn EL, Boyd RL. Apical root resorption in orthodontically treated adults. Am J Orthod Dentofacial Orthop. 1996;110(3):311-320.
6. Brezniak N, Wasserstein A. Orthodontically induced inflammatory root resorption. Part I: The basic science aspects. Angle Orthod. 2002;72(2):175-179.
7. Brezniak N. Root resorption after orthodontic treatment. Part II. Literature review. Am J Orthod Dentofacial Orthop. 1993;103(2):138-146.
8. Ramanathan C, Hofman Z. Root resorption in relation to orthodontic tooth movement. Acta Medica (Hradec Kralove). 2006;49(2):91-95.
9. Castro IO, Alencar AH, Valladares-Neto J, Estrela C. Apical root resorption due to orthodontic treatment detected by cone beam computed tomography. Angle Orthod. 2013;83(2):196-203.
10. Battistutta D, Taverne A, Symons AL. External apical root resorption following orthodontic treatment. Angle Orthod. 2000;70(3):227-232.
11. Dindaroğlu F, Doğan S. Evaluation and comparison of root resorption between tooth-borne and tooth-tissue borne rapid maxillary expansion appliances: A CBCT study. Angle Orthod. 2016;86(1):46-52.
12. Fujiyama K, Honjo T, Suzuki M, Matsuoka S, Deguchi T. Analysis of pain level in cases treated with Invisalign aligner: Comparison with fixed edgewise appliance therapy. Prog Orthod. 2014;15:64.
13. Iwasaki LR, Haack JE, Nickel JC, Morton J. Human tooth movement in response to continuous stress of low magnitude. Am J Orthod Dentofacial Orthop. 2000;117(2):175-183.
14. Jacques JA, Balbontin-Ayala FA, Gambetta-Tessini KF, et al. Alveolar bone morphotype in orthodontic patients. Arch Orofac Sci. 2021;16(2):127-140.
15. Krieger E, Drechsler T, Schmidtmann I, Jacobs C, Haag S, Wehrbein H. Apical root resorption during orthodontic treatment with aligners? A retrospective radiometric study. Head Face Med. 2013;9:21.
16. Mavragani M, Vergari A, Selliseth NJ, Boe OE, Wisth PL. A radiographic comparison of apical root resorption after orthodontic treatment with a standard edgewise and a straight-wire edgewise technique. Eur J Orthod. 2000;22(6):665-674.
17. Frost NA, Mealey BL, Jones AA, Huynh-Ba G. Periodontal biotype: Gingival thickness as it relates to probe visibility and buccal plate thickness. J Periodontol. 2015;86(10):1141-1149.
18. Cortellini P, Bissada NF. Mucogingival conditions in the natural dentition: Narrative review, case definitions, and diagnostic considerations. J Periodontol. 2018;89(Suppl 1):S204-S213.
19. Preoteasa CT, Ionescu E, Preoteasa E, et al. Orthodontically induced root resorption correlated with morphological characteristics. Rom J Morphol Embryol. 2009;50(2):257-262.
20. Butsabul P, Kanpittaya P, Nantanee R. Root resorption in clear aligner treatment detected by CBCT: A systematic review and meta-analysis. Int Dent J. 2024;74(6):1326-1336.
21. Kawashima-Ichinomiya R, Yamaguchi M, Tanimoto Y, et al. External apical root resorption and the release of interleukin-6 in the gingival crevicular fluid induced by a self-ligating system. Open J Stomatol. 2012;2(3):116-121.
22. Sharpe W, Reed B, Subtelny JD, Poison AP. Orthodontic relapse, apical root resorption, and crestal alveolar bone levels. Am J Orthod. 1987;91(3):252-258.
23. Tsilosani N, Natsvlishvili N, Mirvelashvili E, Zerekidze T. The correlation between bone morphotype and density and root apical resorption of the anterior teeth due to orthodontic forces. Eur Sci J. 2024;20(37):12th Eurasian Multidisciplinary Forum, EMF, 21-22 September 2023.
24. Walton DK, Fields HW, Johnston WM, et al. Orthodontic appliance preferences of children and adolescents. Am J Orthod Dentofacial Orthop. 2010;138(6):698.e1-12.
25. Lopatiene K, Dumbravaite A. Risk factors of root resorption after orthodontic treatment. Stomatologija. 2008;10(3):89-94..

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