Evaluation Of Changes in Alveolar Bone Width, Alveolar Bone Height, Root Length and Inclination of Maxillary Central Incisors in High Anchorage Cases Treated with Extraction of Maxillary First Premolars: A Cone Beam Computed Tomography Study

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ABSTRACT

Background and Aim: Orthodontic treatment involving premolar extraction is a commonly employed strategy for correction of dentoalveolar protrusion. The extent to which anterior retraction influences alveolar bone architecture, root length, and incisor inclination remains under active investigation. The aim of this study was to evaluate changes in alveolar bone width, alveolar bone height, root length, and inclination of maxillary central incisors in high anchorage cases treated with extraction of maxillary first premolars using Cone Beam Computed Tomography (CBCT).

Materials and Methodology: A prospective observational study was conducted on 34 patients (age range: 12–30 years) with Angle's Class I malocclusion and bimaxillary protrusion. All patients underwent maxillary first premolar extractions and were treated with a pre-adjusted edgewise appliance (MBT prescription, 0.022″ × 0.028″ slot) under maximum anchorage mechanics. CBCT scans were obtained before (pre-retraction) and after(post-retraction) anterior retraction using CS 3D Imaging Software (90 kV, 6.3 mA, 15 sec; voxel: 150 μm; slice:1.1 mm). Six parameters were measured and compared using the Student's paired t-test (significance: $p \leq 0.05$).

Results: Palatal alveolar bone height showed a non-significant increase (3.36 ± 0.70 mm → 3.58 ± 0.75 mm; p =0.23). Labial bone height showed a non-significant decrease (3.17 ± 0.86 mm → 3.09 ± 0.72 mm; p = 0.68). Alveolar bone width showed a non-significant reduction (6.82 ± 0.54 mm → 6.69 ± 0.48 mm; p = 0.30). Root length demonstrated a non-significant decrease (11.72 ± 1.07 mm → 11.60 ± 1.10 mm; p = 0.65). Root inclination showed a highly significant reduction (112.79° ± 5.87 → 106.91° ± 5.32; $p < 0.001$), indicating controlled lingual tipping of the maxillary central incisors.

Conclusion: Orthodontic retraction in high-anchorage extraction cases produced no statistically significant changes in alveolar bone height, width, or root length, indicating biological tolerance of the alveolar housing. A highly significant reduction in root inclination confirmed predominantly tipping-type mechanics, underscoring the importance of torque control and careful force application during space closure. CBCT proved valuable in accurately detecting these subtle three-dimensional dentoalveolar changes.

Keywords: Alveolar bone; CBCT; Maxillary central incisors; Premolar extraction; Root inclination; Root resorption; Orthodontic retraction; High anchorage; MBT prescription; Bimaxillary protrusion.

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INTRODUCTION

Orthodontic treatment plays a crucial role in influencing alveolar bone and periodontal structures, both of which are key determinants of treatment success and long-term oral health. A foundational concept in orthodontics is that controlled tooth movement induces bone remodeling, characterized by resorption on the pressure side and apposition on the tension side.[1] However, this "with-the-bone" model does not always predict outcomes accurately, particularly in specific movements such as anterior tooth retraction or extrusion.[2] In such cases, unintended consequences—including alveolar bone loss, dehiscence, and fenestration—can arise, potentially compromising periodontal integrity and treatment outcomes.

Historically, bone changes during orthodontic treatment were assessed using two- dimensional (2D) imaging techniques such as lateral cephalograms and panoramic radiographs. While these methods have been widely used, they suffer from significant limitations, including image distortion, magnification errors, and overlapping anatomical structures. These drawbacks hinder the accurate evaluation of complex three- dimensional (3D) structures, especially in the anterior region.[3]

The introduction of cone-beam computed tomography (CBCT) marked a significant advancement in diagnostic imaging. CBCT offers high-resolution, three-dimensional visualization of craniofacial structures, enabling clinicians to evaluate alveolar bone morphology, root positioning, and periodontal health with greater precision.[4,5] It has become particularly useful in assessing treatment-induced bone remodeling and in planning complex procedures such as anterior retraction.

The ability of CBCT to provide both qualitative and quantitative assessments has enhanced understanding of bone responses to orthodontic forces. Recent research has focused on voxel size and its influence on measurement accuracy.[6] Additionally, CBCT enables the assessment of root length and marginal bone levels during orthodontic treatment.[7] It also demonstrates high accuracy and reliability in evaluating alveolar bone height and thickness.[8]

As orthodontic tooth movements often lead to complex bone changes across all three spatial dimensions, understanding the relationship between tooth displacement and alveolar remodeling is essential. CBCT serves as a critical tool in bridging this knowledge gap, offering clinicians a more reliable foundation for evidence-based treatment planning and risk management.

AIM AND OBJECTIVES

Aim:

The aim of this study is to evaluate the changes in alveolar bone width, alveolar bone height, root length and inclination of maxillary incisors in high anchorage cases treated with first premolars extraction.

Objectives:

1. To determine the alveolar bone width of maxillary central incisors on pre- retraction and post-retraction CBCT.
2. To determine the alveolar bone height of maxillary central incisors on pre- retraction and post-retraction CBCT.
3. To determine the root length of maxillary central incisors on pre-retraction and post-retraction CBCT.
4. To determine the inclination of maxillary central incisors on pre and post- retraction CBCT.
5. To determine the changes observed in above mentioned parameters before and after retraction of maxillary central incisors.

MATERIALS AND METHODOLOGY

This study was conducted as a prospective observational study. A total of 34 pre-retraction and 34 post-retraction Cone Beam Computed Tomography (CBCT) scans of patients diagnosed with Angle's Class I malocclusion with dentoalveolar bimaxillary protrusion were included in the study. All patients were selected from those undergoing orthodontic treatment at the Department of Orthodontics and Dentofacial Orthopedics, Geetanjali Dental and Research Institute, Udaipur, Rajasthan.

Each patient required extraction of the maxillary and mandibular first premolars as part of the orthodontic treatment plan to facilitate retraction of the anterior teeth. Treatment was carried out using a pre-adjusted edgewise appliance system with MBT prescription and a bracket slot dimension of 0.022″ × 0.028″. Maximum anchorage mechanics was employed in all cases to achieve controlled anterior retraction while minimizing undesirable mesial movement of the posterior dentition.

The study sample was selected in accordance with predefined inclusion and exclusion
criteria to ensure homogeneity and standardization of the study population.

The Primary Inclusion Criteria were:-
• Patients treated with extraction of maxillary first premolar.
• Patients between 12- 30 years of age.
• Patients with high anchorage consideration.
• All permanent teeth should be present (third molar may or may not be present)
• No history of orthodontic treatment.

The Exclusion Criteria were:-
• Patients with severe craniofacial dysplasia / syndrome.
• Patients with missing teeth.
• Moderate and low anchorage cases.

For each CBCT 6 landmarks were identified & sequential 1.1mm slice thickness CT scans were obtained for upper incisors as shown in Figure 1a and Figure 1b.
A- Alveolar crest on the palatal side.
B- Alveolar crest on labial side.
C- Root Length.
D- Alveolar bone height on palatal side.
E- Alveolar bone height on labial side.
F- Inclination of maxillary central incisors.

Figure 1a

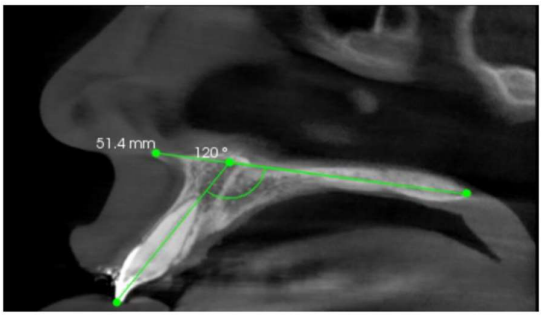


Figure 1b

The alveolar bone width, alveolar bone height, root length and inclination of maxillary incisors were measured using CBCT imaging and the differences was evaluated.
The following software was used for the present study:-
The CS 3D imaging software with exposure parameters set at 90 kV, 6.3 mA, and 15 seconds. The voxel size was 150 µm × 150 µm × 150 µm, and the slice thickness was 1.1 mm. The measured values were recorded and tabulated, and the differences between them were subsequently evaluated using statistical analysis.

RESULTS

The present study evaluated the changes in alveolar bone width, alveolar bone height, root length, and root inclination of the maxillary central incisors in patients with Class I malocclusion treated with maxillary first premolar extractions under maximum anchorage using a preadjusted edgewise appliance with MBT prescription. These parameters were assessed using cone-beam computed tomography (CBCT).
All measurements obtained from the CBCT images were subjected to statistical analysis using the Student's t-test, and the level of statistical significance was predetermined at $p \leq 0.05$.
The individual patient data used for statistical analysis, including demographic details and CBCT measurements recorded at pre-retraction and post-retraction stages, are presented in Table 1.
Descriptive statistics were calculated to summarize the pre-retraction and post-retraction measurements. The mean and standard deviation were determined for alveolar bone height (palatal and labial), alveolar bone width, root length, and root inclination of the maxillary central incisors. These descriptive statistics provide an overview of the distribution of the measured variables before and after orthodontic retraction. The results of the descriptive analysis are presented in Table 2 and illustrated in Figures 3 and 4. Subsequently, a comparative analysis was performed to evaluate the changes between the pre-retraction and post-retraction

measurements. For each parameter, the mean, standard deviation, mean difference, and corresponding p-value were calculated to determine the statistical significance of the observed changes. The results of these comparisons are presented in Tables 3–6 and Figures 5–8.

Table 1. Individual patient data used for statistical analysis, including age, sex, treatment duration, and CBCT measurements recorded at pre-retraction and post-retraction stages.

S.No.	AGE (Yrs)	SEX (M/F)	Duration of Procedure (days)	Pre-retraction					Post-retraction				
				Alveolar Bone height (mm)		Alveolar Bone Width (mm)	Root Length	Root Inclination	Alveolar Bone height (mm)		Alveolar Bone Width (mm)	Root Length	Root Inclination
				Palatal side	Labial side				Palatal side	Labial side			
1	19	F	149	4.4	3.1	9	14.7	114	5.1	3.1	8.2	14.6	94
2	21	M	164	3.7	3.3	6.5	12.7	105	3.6	2.8	6.2	11.9	101
3	18	M	137	2.8	2.2	7.1	11	108	5.2	2.3	6.9	9.6	110
4	22	F	171	3.4	2.8	6.1	11.3	105	3.6	3	5.9	11.2	103
5	21	F	180	2.3	6	6.9	11.5	123	3.5	4.9	6.5	12.6	113
6	19	M	162	2.7	2.3	6.8	11	111	2.9	2.2	6.4	10.8	103
7	23	F	169	1.9	2	6.9	12.4	110	2	1.7	6.7	12.5	108
8	24	M	175	3.6	3.2	6.8	11.2	117	3.8	3.7	6.7	11.7	113
9	18	M	184	2.3	3.2	6.3	12.9	119	1.8	2.7	7	12.6	117
10	19	M	165	4.6	3.4	6.5	13.5	126	4.4	3.6	6.8	13.2	121
11	25	F	151	2.7	2.4	6.9	11.2	109	2.9	2.3	6.6	11	106
12	26	F	157	2.8	2.5	6.8	11.1	110	3	2.4	6.6	10.9	107
13	21	M	167	3.2	2.7	6.9	10.9	108	3.3	2.5	6.7	11.1	106
14	22	M	177	3.3	2.9	7	11.1	112	3.5	2.7	6.8	10.9	109
15	21	F	146	3.1	4.2	6.6	12.1	121	3.4	4	6.4	11.9	112
16	19	F	158	3.4	2.8	6.1	11.3	105	3.6	3	5.9	11.2	103
17	18	M	148	3.4	2.9	6.2	11.4	107	3.6	3.1	6	11.1	102
18	24	F	152	4.6	3.4	6.5	13.5	126	4.4	3.6	6.8	13.2	116
19	25	M	165	2.4	6	6.8	11.6	119	2.9	4.8	6.4	11.2	109
20	20	F	156	3.6	3.2	6.8	11.2	117	3.8	3.7	6.7	11.5	106
21	19	M	158	2.8	2.5	6.8	11.1	110	3	2.4	6.6	10.9	107
22	22	F	170	3.2	2.7	6.9	10.9	108	3.3	2.5	6.7	11.1	106
23	28	F	172	2.7	2.4	6.9	11.2	110	2.9	2.3	6.6	11	105
24	24	F	165	3.3	2.9	7	11.1	112	3.5	2.7	6.8	10.9	108
25	26	M	166	4.4	3.1	8	14.5	133	5.1	3.1	8.2	14.6	98
26	25	M	178	3.6	3.4	6.7	11.1	108	3.9	3.7	6.9	11.2	108
27	20	F	164	3.3	2.8	6.8	11.2	113	3.4	2.9	6.7	11	103
28	18	F	186	3.6	3.2	6.8	11	118	3.8	3.7	6.6	10.9	107
29	19	F	176	4.6	3.4	6.5	13.5	120	4.4	3.6	6.8	13.2	111
30	21	F	166	3.6	3	5.9	11	106	3.4	2.9	6	11.1	102
31	25	M	155	3.2	2.9	7.1	11.2	109	3.3	2.7	7	11.1	105
32	26	F	154	3.6	3.2	7.2	10.9	113	3.4	3	6.9	10.8	107
33	24	F	164	4.1	3.8	6.8	11	112	3.9	3.6	6.6	10.9	104
34	22	M	166	4.2	3.9	6.9	11.2	111	4	3.8	6.8	11	105

Table 2. Mean and standard deviation of pre-retraction and post-retraction alveolar bone height, alveolar bone width, root length, and root inclination.
(NS – Not significant; HS – Highly significant)

	Pre-Retraction		Post-Retraction			
	Mean	SD	Mean	SD	p value between pre and Post	Significance
Alveolar Bone height (mm) Palatal side	3.36	0.70	3.58	0.75	0.23	NS
Labial side	3.17	0.86	3.09	0.72	0.68	NS
Alveolar Bone Width (mm)	6.82	0.54	6.69	0.48	0.30	NS
Root Length (mm)	11.72	1.07	11.60	1.10	0.65	NS
Root Inclination (degrees)	112.79	5.87	106.91	5.32	0.00	<0.001 (HS)

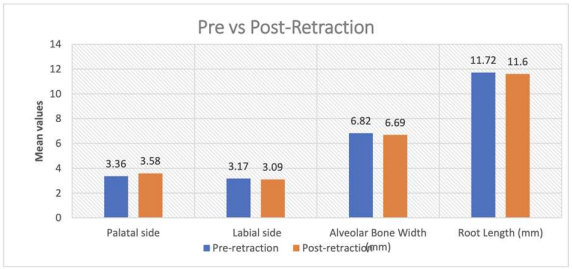


Figure 3. Evaluation of Pre-retraction and Post retraction alveolar bone height, alveolar bone width and root length.

Figure 4. Evaluation of Pre-retraction and Post retraction root inclination.

Table 3. Comparison of Pre-retraction and Post-retraction labial alveolar bone height and palatal alveolar bone height

	Pre-Retraction		Post-Retraction			
	Mean	SD	Mean	SD	p value between pre and Post	Significance
Alveolar Bone height (mm) Palatal side	3.36	0.70	3.58	0.75	0.23	NS
Labial side	3.17	0.86	3.09	0.72	0.68	NS

Student's t-test; * indicates a significant difference at $p \leq 0.05$

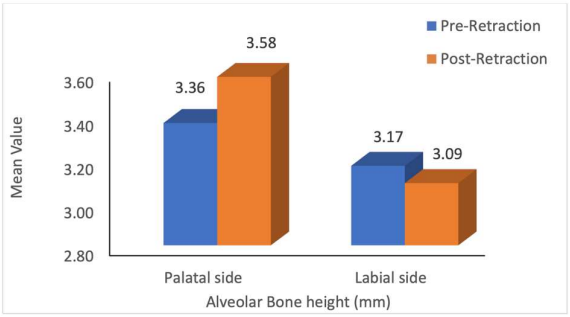


Figure 5. Comparison of Pre-retraction and Post-retraction labial alveolar bone height and palatal alveolar bone height.

No statistically significant difference was observed between pre-retraction and post-
retraction alveolar bone height on the palatal and labial sides ($p > 0.05$).

Table 4. Comparison of Pre-retraction and Post-retraction alveolar bone width

	Pre-Retraction		Post-Retraction			
	Mean	SD	Mean	SD	p value between pre and Post	Significance
Alveolar Bone Width (mm)	6.82	0.54	6.69	0.48	0.30	NS

Student's t-test ; * indicates a significant difference at p≤0.05.

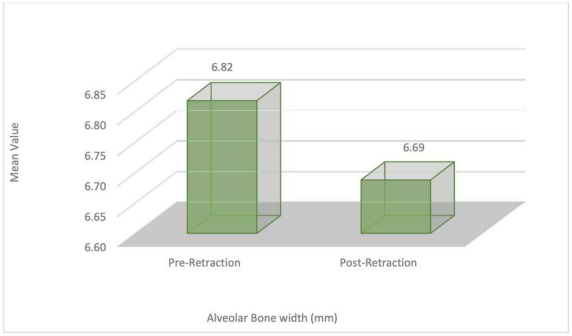


Figure 6. Comparison of Pre-retraction and Post-retraction alveolar bone width

No statistically significant difference was observed in alveolar bone width between pre-retraction and post-retraction measurements (p > 0.05).

Table 5. Comparison of Pre-retraction and Post-retraction root length

	Pre-Retraction		Post-Retraction			
	Mean	SD	Mean	SD	p value between pre and Post	Significance
Root Length (mm)	11.72	1.07	11.60	1.10	0.65	NS

Student's t-test ; * indicates a significant difference at p≤0.05.

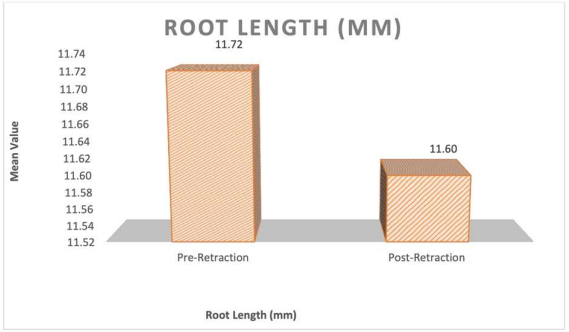


Figure 7. Comparison of Pre-retraction and Post-retraction root length

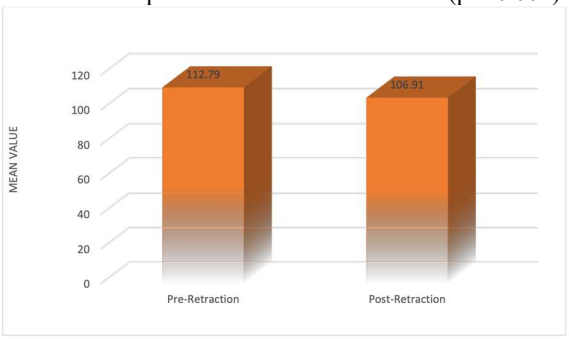
No statistically significant difference was observed in root length between pre-retraction and post-retraction measurements (p > 0.05).

Table 6. Comparison of Pre-retraction and Post-retraction root inclination

	Pre-Retraction		Post-Retraction			
	Mean	SD	Mean	SD	P value	Significance
Root Inclination (degrees)	112.79	5.87	106.91	5.32	0.00	<0.001* (HS)

Student's t-test ; * indicated a significant difference at p≤0.05

A highly statistically significant reduction in root inclination was observed between pre-retraction and post-retraction measurements (p < 0.001).



DISCUSSION

Orthodontic treatment involving premolar extraction is commonly employed for the correction of dentoalveolar protrusion and improvement of facial esthetics. Retraction of anterior teeth following premolar extraction facilitates reduction of lip prominence and establishment of a more harmonious facial profile. However, extensive orthodontic tooth movement may influence the surrounding periodontal structures, particularly the alveolar bone and root morphology. Orthodontic tooth movement occurs through a process of bone remodeling characterized by bone resorption on the pressure side and bone apposition on the tension side. Nevertheless, several investigators, including Garib et al.[5] and Vardimon et al.[2], have reported that alveolar bone remodeling does not always occur proportionally with the magnitude of tooth movement, particularly when movement approaches the anatomical limits of the alveolar housing. Under such circumstances, undesirable consequences such as alveolar bone loss, dehiscence, fenestration, and root resorption may occur. Fuhrmann[10] and Garib et al.[5] have also emphasized these risks. These observations are further supported by Wehrbein et al.[43] ,who demonstrated histologically that orthodontic tooth movement beyond cortical boundaries may result in reduced periodontal support and cortical bone limitations. This discrepancy between tooth movement and alveolar bone remodeling highlights the importance

of three-dimensional imaging in accurately assessing treatment-induced changes.

In the present study, cone-beam computed tomography (CBCT) was used to evaluate changes in alveolar bone height, alveolar bone width, root length, and root inclination of the maxillary central incisors before and after orthodontic retraction in patients with Class I malocclusion treated with maxillary first premolar extraction and high anchorage mechanics. CBCT imaging was selected because it provides reliable three-dimensional visualization of dentoalveolar structures and reduces the limitations associated with conventional two-dimensional radiographic techniques such as magnification errors, distortion, and superimposition of anatomical structures. Li et al.[26], Menezes et al.[6],Leung et al.[8], and Timock et al.[44] support the use of CBCT for such assessment.

The reliability of CBCT for evaluating alveolar bone morphology has been well established. Li et al.[26] demonstrated that CBCT measurements of alveolar bone height and thickness were highly comparable with direct anatomical measurements, confirming its validity as a diagnostic tool in orthodontic research and clinical practice. Similarly, Menezes et al.[6] reported that CBCT enables accurate evaluation of alveolar bone morphology and buccolingual bone dimensions that cannot be reliably assessed using conventional radiography. Patcas et al.[45] further confirmed that CBCT provides reproducible and clinically reliable measurements of alveolar bone dimensions.

Alveolar Bone Height

Evaluation of alveolar bone height is important for assessing the periodontal response to
orthodontic tooth movement during anterior tooth retraction.

In the present study, palatal alveolar bone height demonstrated a minimal increase from pre-retraction (3.36 ± 0.70 mm) to post-retraction (3.58 ± 0.75 mm), whereas labial alveolar bone height showed a marginal reduction from pre-retraction (3.17 ± 0.86 mm) to post-retraction (3.09 ± 0.72 mm). However, these changes were not statistically significant. This finding suggests that controlled orthodontic retraction may permit adaptive alveolar bone remodeling without producing significant vertical bone loss. Similar observations were reported by Lund et al.[7], who observed minimal changes in alveolar bone height following orthodontic treatment. Likewise, Pop et al.[37] reported that although orthodontic treatment may result in measurable root resorption, significant reductions in alveolar bone height were not consistently observed. These findings are also in agreement with Melsen[46] , who emphasized that periodontal tissues can adapt to orthodontic forces when maintained within biological limits.

Conversely, other investigators have reported more pronounced vertical alveolar bone changes. Guo et al.[28] concluded that orthodontic tooth movement may be associated with measurable vertical alveolar bone loss, while Tuladhar et al.[30] and Wang et al.[29] reported reductions in alveolar bone height following orthodontic treatment. Similarly, Zhang et al.[3] demonstrated decrease in marginal alveolar bone height following anterior retraction with premolar extraction. Comparable findings were reported by Li et al.[26] and Sun et al.[47], who also observed significant alveolar bone changes following orthodontic incisor retraction.

The differences between the present findings and previous studies may be attributed to variations in treatment mechanics, magnitude and direction of incisor movement, and individual alveolar housing limitations. Controlled retraction within the biological limits of the alveolar bone may allow adaptive remodeling without significant vertical bone loss, whereas excessive or uncontrolled movements may predispose to periodontal compromise.

Alveolar Bone Width

Assessment of alveolar bone width provides insight into transverse alveolar bone
remodeling associated with orthodontic tooth movement.

In the present study, alveolar bone width demonstrated a minimal reduction from pre- retraction (6.82 ± 0.54 mm) to post-retraction (6.69 ± 0.48 mm); however, the change was not statistically significant. This suggests that orthodontic retraction performed with controlled biomechanics may preserve the transverse dimension of the alveolar housing surrounding the incisors.

Comparable findings were reported by Sarikaya et al.[12], who observed that although palatal bone thickness decreased following incisor retraction, labial alveolar bone thickness remained relatively stable. Similarly, Liu et al.[35] demonstrated localized alveolar bone remodeling with increased labial bone thickness and decreased palatal bone thickness following incisor retraction. Yodthong et al.[17] further reported that alveolar bone thickness changes are closely associated with alterations in incisor inclination. Similar findings were reported by Evangelista et al.[48], who identified the presence of alveolar bone defects such as dehiscence and fenestration associated with orthodontic tooth positioning.

In contrast, other investigators have reported significant reductions in alveolar bone thickness following orthodontic treatment. Ahn et al.[16] and Chen et al.[21] observed
decreases in palatal alveolar bone thickness following anterior retraction. Similarly, Zhang et al.[3] demonstrated thinning of the lingual cortical plate after orthodontic treatment involving premolar extraction. These findings further support the concept that orthodontic tooth movement is constrained by the dimensions of the alveolar envelope, beyond which undesirable bone remodeling may occur.

Root Length

Evaluation of root length is essential for identifying external apical root resorption associated with orthodontic tooth movement.

In the present study, root length demonstrated a minimal reduction from pre-retraction (11.72 ± 1.07 mm) to post-retraction (11.60 ± 1.10 mm); however, this reduction was not statistically significant. This reduction may represent mild external apical root resorption that commonly accompanies orthodontic tooth movement.

Root resorption is a recognized adverse effect of orthodontic treatment. Mohandesan et al.[14] reported mild external apical root resorption during orthodontic treatment, while Pop et al.[37] demonstrated that CBCT imaging allows accurate detection of root length changes following orthodontic therapy. These findings are consistent with those of Apajalahti and Peltola[49], who reported that root resorption is a common and clinically relevant finding associated with orthodontic treatment.

However, Zhang et al.[3] and Ma et al.[25] reported greater degrees of root-related changes associated with orthodontic treatment involving anterior retraction. Similarly, Gao et al.[32] reported reductions in root length and root volume following orthodontic treatment assessed using CBCT imaging. Clinically, this suggests that controlled force application and careful monitoring are essential to minimize the risk of clinically significant root resorption during orthodontic treatment.

Root Inclination

Changes in incisor inclination represent an important biomechanical outcome of orthodontic anterior retraction. In the present study, a highly significant reduction in root inclination was observed from pre-retraction (112.79°) to post-retraction (106.91°), indicating lingual tipping of the maxillary central incisors during orthodontic retraction. This finding suggests that the mechanics used in the present study resulted primarily in controlled tipping rather than bodily movement of the incisors. This pattern of movement is consistent with mechanics involving sliding techniques under high anchorage conditions. Similar findings have been reported by Yodthong et al.[17], who demonstrated that alveolar bone thickness changes during incisor retraction are closely associated with alterations in incisor inclination. Likewise, Vardimon et al.[2] reported that excessive tipping movements may increase the risk of periodontal complications due to disproportionate cortical bone remodeling. Similar biomechanical behaviour during anterior retraction has also been reported by Upadhyay et al.[50], who demonstrated that anterior retraction mechanics often result in controlled tipping depending on anchorage control and force application.

When interpreted alongside previous literature, the findings of the present study suggest that orthodontic retraction of maxillary central incisors performed with controlled biomechanics may not produce significant alterations in alveolar bone height, width, or root length, although changes in incisor inclination are evident. While several studies have reported significant alveolar bone remodeling following orthodontic treatment, the present findings indicate that such changes may be minimized when tooth movement is maintained within the biological limits of the alveolar housing. Therefore, careful treatment planning, appropriate force application, and consideration of individual anatomical boundaries are essential to achieve optimal outcomes while minimizing iatrogenic effects.

CONCLUSION

This study was undertaken to evaluate the changes in alveolar bone width, alveolar bone height, root length, and root inclination of maxillary central incisors in Class I malocclusion cases treated with first premolar extractions using a preadjusted edgewise appliance with MBT prescription, assessed through cone beam computed tomography (CBCT).

A total of 34 pre-retraction and 34 post-retraction CBCT records of patients with Angle's Class I malocclusion with bimaxillary protrusion were analyzed using CS 3D imaging software.

The following conclusions were drawn:

• Palatal alveolar bone height exhibited a slight increase in post retraction CBCT, while labial alveolar bone height showed a mild reduction in post retraction CBCT, indicating minimal overall vertical changes in the alveolar bone and suggesting that alveolar remodeling was adaptive but not necessarily synchronous with the magnitude or direction of tooth movement.

• Alveolar bone width demonstrated a minor decrease in post retraction CBCT, indicating a limited transverse alteration of the supporting bone and suggesting that these changes remained within the confines of the alveolar envelope.

• Root length revealed a slight reduction in post retraction CBCT, indicating absence of clinically significant root resorption and suggesting that orthodontic retraction was biologically well tolerated without compromising periodontal support.

• Root inclination showed a marked reduction in post retraction CBCT, indicating lingual tipping of the maxillary incisors and suggesting that retraction was predominantly achieved through tipping mechanics rather than bodily movement, thereby emphasizing the importance of torque control and appropriate root positioning during orthodontic space closure.

Overall, the findings of the present study indicated that orthodontic retraction of maxillary incisors in extraction cases was biologically well tolerated with respect to alveolar bone dimensions and root integrity, without significant compromise to periodontal support. The results further suggested that alveolar bone remodeling was adaptive in nature, although not always synchronous with the magnitude or direction of tooth movement, and was influenced by biomechanical factors as well as individual anatomical variability.

From a clinical perspective, these observations highlighted that anterior retraction could be performed

safely within the limits of the alveolar envelope, provided that precise force application and appropriate biomechanical control were maintained to ensure physiologic tooth movement and to minimize potential periodontal risks. The use of CBCT as a three-dimensional diagnostic modality proved valuable in accurately assessing subtle dentoalveolar changes and served as an important adjunct in both treatment planning and outcome evaluation.

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