Evaluation of alveolar bone width, alveolar bone height and vertical changes in maxillary first molar in high anchorage cases treated with extraction of maxillary first premolars: A cone beam computed tomography study

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ABSTRACT

Introduction: Orthodontic space closure after premolar extraction may influence alveolar bone morphology and molar position. Cone beam computed tomography (CBCT) provides accurate three-dimensional assessment of these changes. The present study evaluated alveolar bone width, alveolar bone height, and vertical changes in maxillary first molars following orthodontic retraction in high anchorage extraction cases.

Materials and methods: A retrospective CBCT study was conducted using 34 pre-retraction and 34 post-retraction scans of patients treated with extraction of maxillary first premolars under maximum anchorage mechanics. Labial and palatal alveolar bone height, alveolar bone width, and vertical position of the maxillary first molar were measured using CS 3D software. Comparisons between pre- and post-retraction measurements were performed using Student's t-test with significance set at $p \leq 0.05$.

Results: Mean labial alveolar bone height increased from 2.69±0.51 mm to 2.88±0.50 mm ($p=0.11$). Palatal alveolar bone height decreased from 3.01±0.50 mm to 2.94±0.66 mm ($p=0.62$). Alveolar bone width reduced from 13.41±1.01 mm to 13.06±1.00 mm ($p=0.17$). Vertical measurements increased from 19.15±0.86 mm to 19.35±0.89 mm ($p=0.35$). None of the changes were statistically significant.

Conclusion: Orthodontic retraction in high anchorage extraction cases resulted in minimal and statistically non-significant changes in alveolar bone height, alveolar bone width, and vertical position of maxillary first molars. These findings suggest that controlled orthodontic mechanics preserve periodontal support during space closure.

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 aims to provide a balance between teeth and facial structures. Many factors, especially individual characteristics, play a role in ensuring this balance. In addition to the causes of anomalies, factors such as the technique used in orthodontic treatment, the forces applied, the duration of treatment, and the structural features of teeth and bone may pose a risk to the success of orthodontic treatment.[1]

Extraction of premolars, as a routine orthodontic treatment for reducing protrusion or crowding of dental arch, has been widely used in the correction of severe tooth arch discrepancy. Measuring three-dimensional objects using two-dimensional images routinely leads to inevitable errors. CBCT is promised to establish a uniform and all sided measurement system thus improving the reliability and comparability of the results.[2]

Anchorage control plays a pivotal role in the effective management of orthodontic patients for obtaining both structural and facial esthetics.[3]

The tissue response to orthodontic forces enables teeth to be moved in the alveolar bone. CBCT measurements of alveolar bone height could be good to excellent interrater and interrater repeatability.[4]

Owing to the limitations of two-dimensional images, technical shortcomings such as magnification, geometric distortion and overlap of the structures restricted the reliability of their results.[5]

CBCT has obvious advantages in the linear measurement of alveolar bone and the precision, reproducibility and accuracy of the alveolar bone measurements were good for a 0.3mm voxel size.

Changes in spatial position of the teeth causes resultant changes in height and width of the alveolar bone adjacent to respective teeth.

These changes can be evaluated by various radiographic methods like lateral cephalogram and cone-beam computed tomography.

Various studies have been conducted to evaluate changes in anchor molar position using lateral cephalogram. However, CBCT studies conducted to evaluate changes in the alveolar bone adjacent to each tooth in cases treated with first premolar extractions are scarce.

The purpose of the study was to evaluate the alveolar bone width, alveolar bone height and vertical changes in maxillary first molar in high anchorage cases treated with extraction of maxillary first premolars using Cone beam computed tomography.

AIM AND OBJECTIVES

The present study evaluated the alveolar bone width, alveolar bone height and vertical changes in maxillary first molar in high anchorage cases treated with extraction of maxillary first premolars using Cone beam computed tomography.

Sample collection -

34 Pre-retraction CBCT and 34 post-retraction CBCT of patients requiring premolars extraction were collected from the Department of Orthodontics and Dentofacial Orthopedics, Geetanjali Dental and Research Institute, Udaipur, Rajasthan.

All the patients were treated with the first premolars extraction to evaluate alveolar bone width, alveolar bone height, and vertical changes in maxillary first molar in high anchorage cases using an appliance with MBT prescription, and maximum anchorage mechanics was planned.

The samples were collected as per the inclusion and exclusion criteria mentioned below -

INCLUSION CRITERIA:

-Patient within age group of 12-30 years.

-Full complement of permanent teeth (with or without third molars).

-Patients indicated for extraction of maxillary first premolar.

-High anchorage cases.

-No history of orthodontic treatment.

EXCLUSION CRITERIA:

-Craniofacial or skeletal anomalies affecting the craniofacial region.

-Moderate and low anchorage cases.

The following measurements were taken on CS 3D software are mentioned in the Table 1 below-

Table 1. Measurement of Alveolar bone width, Alveolar bone height and vertical changes

A - B	Alveolar bone height(buccal)	CEJ to alveolar crest(buccal side)
C - D	Alveolar bone height(palatal)	CEJ to alveolar crest(palatal side)

E - F	Alveolar bone width	Widest point of the labiolingual root (alveolar crest to alveolar crest on either side)
G - H	Vertical changes	Mesiobuccal cusp tip to inferior cortical border of maxillary alveolar process

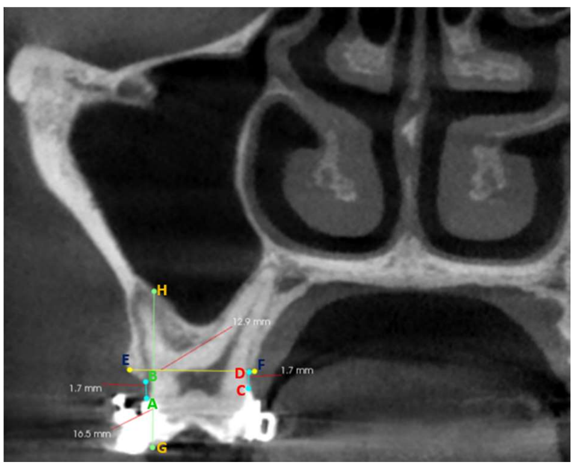


Figure1(a)- Pre-retraction CBCT measurement of alveolar bone height,width and vertical changes

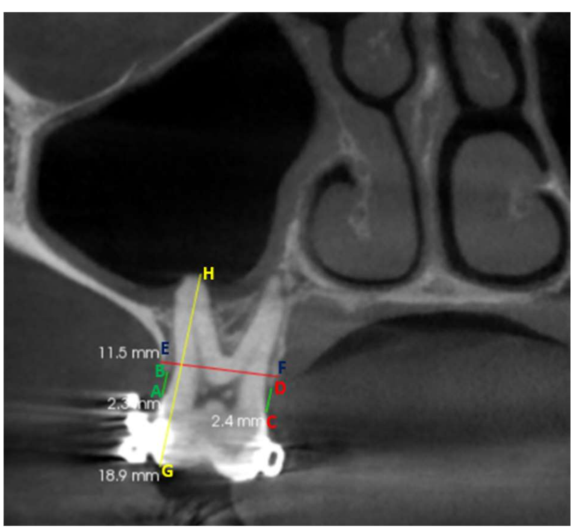


Figure1(b)-Post-retraction CBCT measurement of alveolar bone height,width and vertical changes

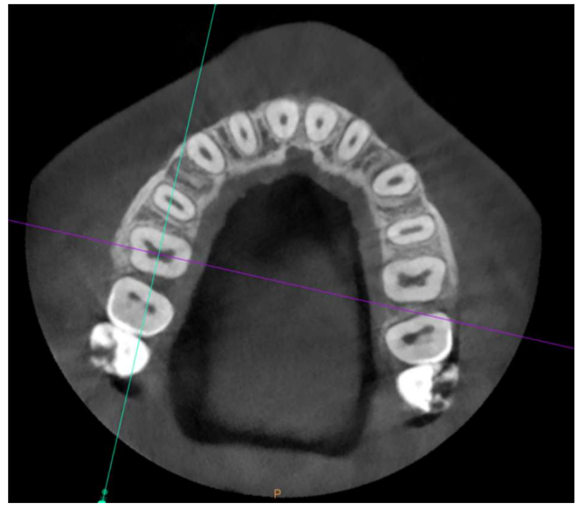


Figure1(c)- All the measurements are taken at the long axis

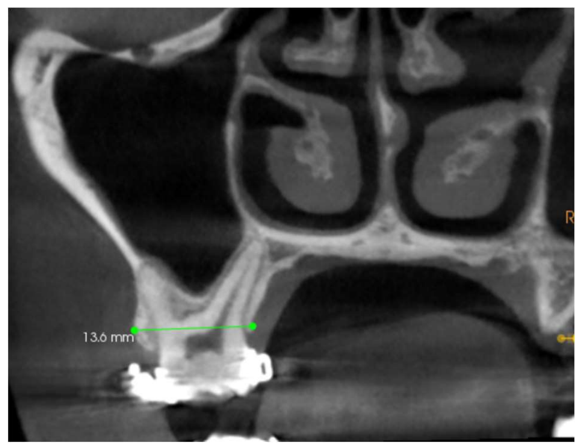


Figure1(d)- The measurements for alveolar bone width is taken at the widest point of labiolingual root

The following software specifications were used in the study-
Software
CS 3D Software, exposure 90KV 6.3mA 15s
Voxel size – 150µmx150µmx150µm
Slice thickness 1.1mm
The measured values obtained were tabulated, and the differences were evaluated with
statistical analysis.

RESULTS

The present study evaluated the changes in alveolar bone width, alveolar bone height, and vertical changes of the maxillary first molar in high-anchorage cases treated with extraction of the maxillary first premolars, using cone beam computed tomography (CBCT).

The 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 pre-retraction and the post-retraction measurements of the alveolar bone height (labial and palatal), alveolar bone width and vertical changes of the maxillary first molar are tabulated in Table 2

Subsequently, a comparative analysis between the pre-retraction and post-retraction measurements of alveolar bone height, alveolar bone width, and vertical changes were performed. The mean differences, standard deviations, and corresponding p-values obtained from this comparison are summarized in Tables 3–6 and Figures 2-5.

Table 2- Evaluation of the Pre-retraction and Post-retraction measurements of alveolar bone height, alveolar bone width and vertical changes of maxillary first molar.

	Preretraction				Postretraction			
S. No	Alveolar bone height(mm)		Alveolar bone width(mm)	Vertical changes (mm)	Alveolar bone height(mm)		Alveolar bone width(mm)	Vertical changes(mm)
	Labial	Palatal			Labial	Palatal		
1	2.6	2.8	11.8	20.4	2.4	4	11.2	18.9
2	3.3	3.8	15.4	19.4	2.6	2.3	14	20.4
3	2.9	3.6	12.9	19.6	3.8	3.5	12.5	20.1
4	2.5	2.6	11.9	18.7	2.3	2.4	11.5	18.9
5	1.9	3.4	13.4	17.8	2.9	4.7	12.3	19.2
6	2.9	2.5	12.2	19.3	3.1	2.3	12	20.1
7	2.6	2.7	15.7	17.1	2.8	2.4	15.5	17.3
8	3.3	4	13.3	19.6	3.1	4	13	18.9
9	3	3.1	14.3	19.4	3.5	3.6	14.3	18.8
10	2.9	3.1	13.5	19.1	3	3.4	13.3	18.8
11	3.4	1.7	12.3	20	3.1	1.6	12.1	20.1
12	1.8	2.5	12.7	19.6	2.1	2.7	12.3	19.9
13	2.1	3.4	14.7	20.1	2.4	3.1	14.3	20.5
14	2.6	2.9	13.6	18.6	2.9	2.4	13.1	19.1
15	3.1	2.7	12.6	19.4	3.5	2.7	12.2	20.1
16	2	3.1	13.2	18.8	2.3	2.9	13	19.2
17	2.6	3.4	12.9	18.9	2.9	3.1	12.5	19.1
18	3.1	2.5	13.1	19.3	3.4	2.3	12.9	20.1
19	2.3	2.9	13.3	20.1	2.7	2.5	13	20.3
20	2.7	3.1	14	19.6	2.5	3.3	13.7	20
21	2.1	3.3	12.1	20.1	2.5	3.1	11.8	20.4
22	3.6	3.1	13.3	19.3	3.9	2.9	13	19.6
23	3.2	2.6	12.6	18.7	3	2.8	12.3	18.3
24	1.9	2.5	14.1	19.1	2.3	2.2	14	19.5
25	2.7	3.3	15.1	17.6	3.1	3.3	14.8	17.9
26	3.4	2.9	13.3	18.3	3.7	2.7	13.1	18.1
27	2.1	2.9	12.9	19.4	2.3	2.6	12.5	19.6
28	2.3	3.2	14.2	20.1	2.3	3.3	14.1	20.3
29	2.6	3.4	15.1	17.1	2.9	3.3	14.8	17.5
30	1.9	2.1	13.1	18.3	2.1	1.9	12.9	18.1
31	3.1	3.3	12.6	18.9	3.3	3.1	12.3	19.1
32	2.9	4	14.3	20.1	3.1	4	14.1	20.3

33	2.5	3.1	13..3	19.1			2.7	3	13.1	19.3
34	3.4	2.7	12.9	20.3			3.5	2.4	12.6	20.2

Table 3- Comparison of Pre-retraction and Post-retraction alveolar bone height, alveolar bone width and vertical changes

	Pre-Retraction		Post-Retraction			
	Mean	SD	Mean	SD	p value	Significance
Alveolar bone height(mm) Labial	2.69	0.51	2.88	0.50	0.11	NS
Palatal	3.01	0.50	2.94	0.66	0.62	NS
Alveolar bone width(mm)	13.41	1.01	13.06	1.00	0.17	NS
Vertical changes(mm)	19.15	0.86	19.35	0.89	0.35	NS

Student t test indicated a significant difference at p≤0.05

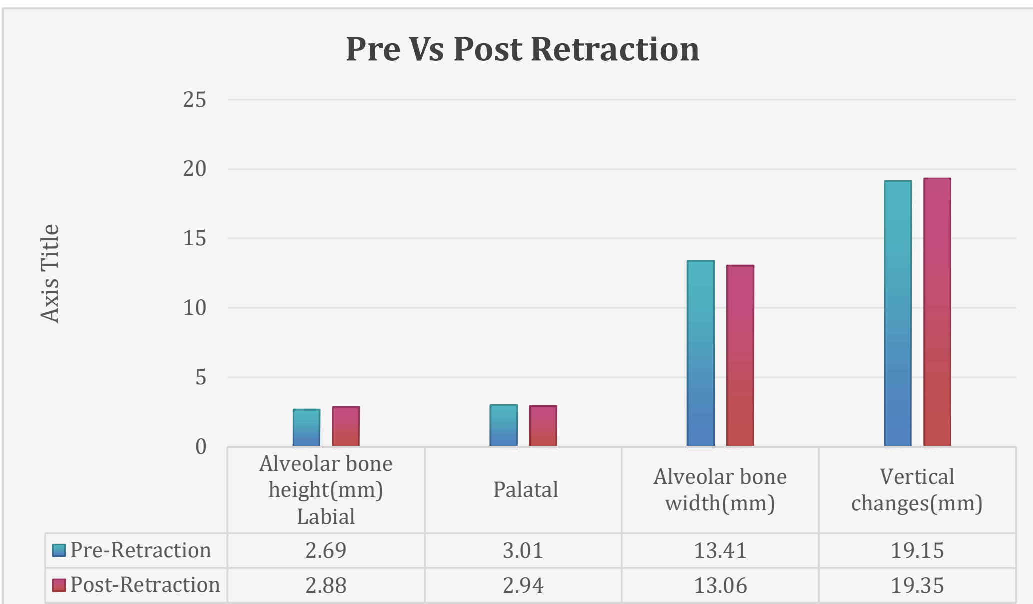


Figure 2- Comparison of Pre-retraction and Post-retraction alveolar bone height, alveolar bone width, and vertical changes

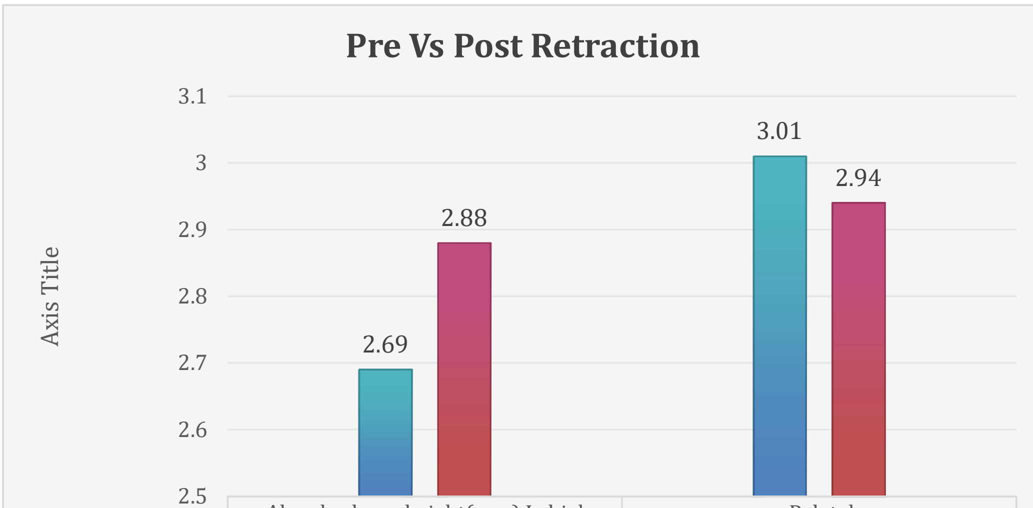
Non significant results were found at p >0.05

This detailed table and graph allowed for the evaluation of baseline pre-retraction and post-retraction values for alveolar bone height, width, and vertical changes of the teeth, providing a foundation for analysing the changes induced by orthodontic treatment in subsequent sections.

Table 4. Comparison of Pre-retraction and Post-retraction labial and palatal alveolar bone height

Student t test indicated a significant difference at p≤0.05

	Pre-Retraction		Post-Retraction			
	Mean	SD	Mean	SD	p value	Significance
Alveolar bone height(mm) Labial	2.69	0.51	2.88	0.50	0.11	NS
Palatal	3.01	0.50	2.94	0.66	0.62	NS



	Alveolar bone height(mm) Labial	Palatal
Pre-Retraction	2.69	3.01
Post-Retraction	2.88	2.94

Figure 3. Comparison of Pre-retraction and Post-retraction labial and palatal alveolar bone height
Non significant results were found at p >0.05

Table 5. Comparison of Pre-retraction and Post-retraction alveolar bone width

	Pre-Retraction		Post-Retraction			
	Mean	SD	Mean	SD	p value	Significance
Alveolar bone width(mm)	13.41	1.01	13.06	1.00	0.17	NS

Student t test indicated a significant difference at p≤0.05

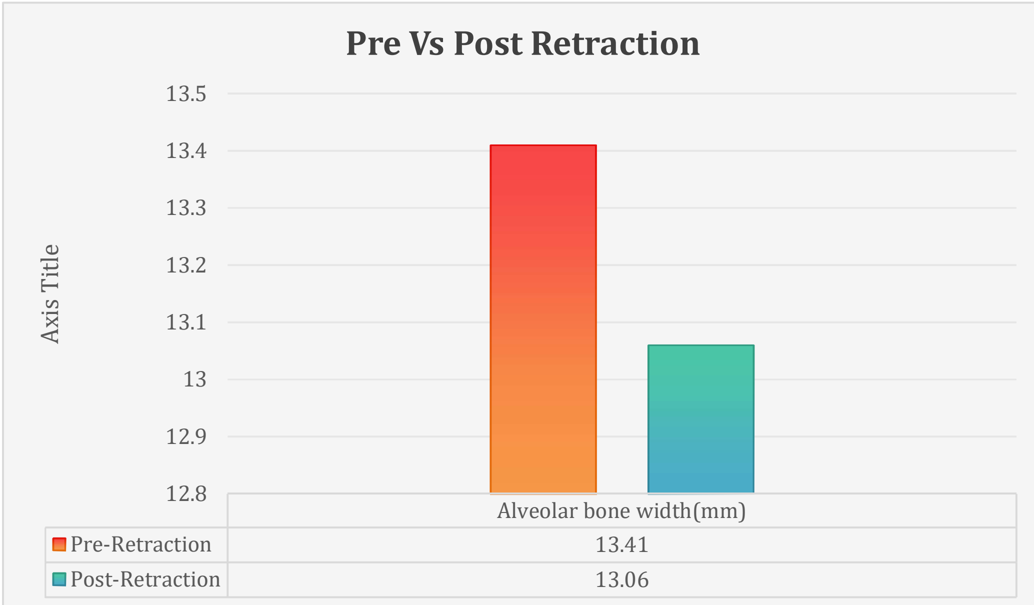


Figure 4. Comparison of Pre-retraction and Post-retraction alveolar bone width
Non significant results were found at p >0.05

Table 6. Comparison of Pre-retraction and Post-retraction vertical changes

	Pre-Retraction		Post-Retraction			
	Mean	SD	Mean	SD	p value	Significance
Vertical changes(mm)	19.15	0.86	19.35	0.89	0.35	NS

Student t test indicated a significant difference at p≤0.05

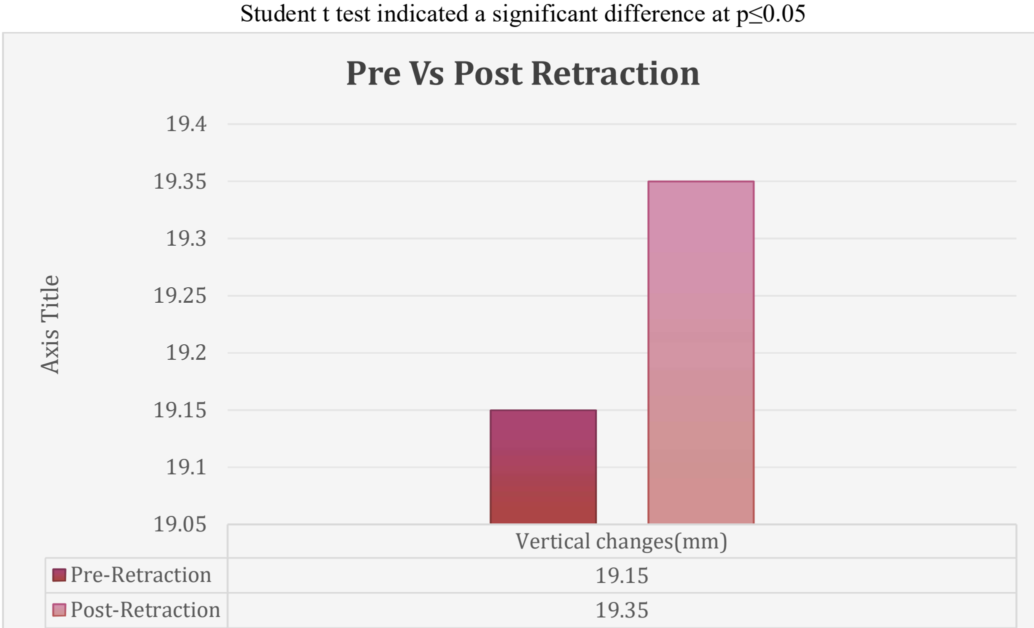


Figure 5. Comparison of Pre-retraction and Post-retraction vertical changes
Non significant results were found at p >0.05

DISCUSSION

The classical theory of orthodontic tooth movement is ‘with-the bone’, meaning that as long as the orthodontic force is appropriate, bone resorption will occur on the compression side of the alveolar bone, with bone apposition on the tension side, and the cortical plate will be compensated accordingly to maintain the thickness of the alveolar bone around the teeth.[25]

The tissue response to orthodontic forces enables teeth to be moved in the alveolar bone but could also result in adverse side effects.

CBCT can be used to investigate marginal alterations in bone during the course of orthodontic treatment because it offers the possibility of evaluating more tooth surfaces than conventional radiography.[4]

Bone remodelling secondary to tooth movement is fundamental for orthodontic treatment. Bone remodelling is dominantly influenced by the morphology of alveolar bone and orthodontic procedures.

It is widely accepted that orthodontic movement should allow the tooth to remain within the bone. Once tooth movement exceeds the alveolar bone boundary, dehiscence and fenestration occur.

Due to the limitations of conventional two-dimensional radiographs, lateral cephalograms and panoramic radiographs cannot accurately assess alveolar bone loss. Cone-beam computed tomography (CBCT) visualizes the morphology of the tooth root and alveolar bone in three dimensions thus, CBCT has become more mainstream in diagnostics and orthodontic treatment planning. [23]

This study was conducted to evaluate the changes in alveolar bone width, alveolar bone height and vertical changes in maxillary first molar in high anchorage cases treated with extraction of maxillary first premolars using cone beam computed tomography (CBCT).

This study was conducted on 34 pre-retraction and 34 post-retraction CBCT of patients with maxillary first premolars extraction.

The pre-retraction CBCT and post-retraction CBCT values were compared, and the findings were observed for the following parameters:

Labial Alveolar bone height-

The labial alveolar bone height demonstrated a slight increase from 2.69 ± 0.51 mm pre-retraction to 2.88 ± 0.50 mm post retraction; however, this change was not statistically significant, indicating that orthodontic retraction had a minimal effect on labial alveolar bone height.

Similar observations were reported in the study conducted by Pop et al. , in which a reduction in alveolar bone height, most prominently on the buccal (labial) aspect of the teeth was observed. This reduction was attributed to bone remodelling during orthodontic tooth movement, wherein resorption occurs on the pressure side of the tooth.[33] Correspondingly, Lund, Grondahl K, and Grondahl HG also reported minor changes in alveolar bone height following orthodontic treatment, with a slight reduction in marginal bone height post-treatment, suggestive of mild bone resorption associated with space closure mechanics.[4]

The present findings are also in agreement with those of Liu et al., in which alveolar bone changes following retraction was observed; however, it was demonstrated that a significant reduction in alveolar bone height which was indicative of marginal bone resorption associated with orthodontic tooth movement, particularly in extraction cases.[29]

In contrast, the results of the present study do not support the findings of Zhi-Gui Ma et al., in which adaptive bone deposition at the alveolar crest following orthodontic treatment was reported. It was observed that an increase in alveolar bone height, which was attributed to bone apposition on the tension side during orthodontic tooth movement.[19]

Overall, the variation in findings among different studies may be attributed to differences in sample characteristics, treatment mechanics, force application, and imaging modalities, which could influence the pattern and extent of alveolar bone remodelling during orthodontic tooth movement.

Palatal alveolar bone height-

In the present study, the palatal alveolar bone height showed a small decrease from pre- retraction 3.01 ± 0.50 mm to post- retraction 2.94 ± 0.66 mm, however these changes were not statistically significant. This indicated that the palatal alveolar bone crest was positioned slightly more coronally than the buccal alveolar crest.

Comparable findings were reported by Al-Worafi et al. in which alveolar bone changes around maxillary first molars following orthodontic treatment where bone deposition on the palatal surface of maxillary first molars was observed.[27] Similarly, Wang et al. , showed an increase in alveolar bone dimensions in the posterior regions following orthodontic treatment.[25]

However, in contrast, these findings are not in accordance with the study conducted by Ebadi et al. and Pop et al. in which significant reduction in alveolar bone height around molars was observed which was attributed to bone resorption associated with orthodontic tooth movement and loading patterns. [36,33]

Likewise, in the study conducted by Liu et al. it was observed that there was an increase in the alveolar bone height after orthodontic treatment, indicating a resorption on palatal side.[29]

Overall, the discrepancies observed among various studies may be attributed to differences in sample characteristics, treatment protocols, magnitude and direction of orthodontic forces, duration of retraction, and imaging modalities.

Alveolar bone width-

In the present study, the alveolar bone width was reduced marginally from 13.41 ± 1.01 mm in the pre-retraction stage to 13.06 ± 1.00 mm following retraction but these changes were not statistically significant, indicating minimal impact of orthodontic retraction. This suggested that the alveolar bone width remained relatively stable, with no clinically significant bone loss during treatment. Similar observations were reported by Al-Warafi et al. in which significant reductions in alveolar bone dimensions around molars following orthodontic movement was observed, indicating alveolar bone resorption associated with tooth movement.[27] Collectively, both studies suggested that the alveolar bone width may decrease following orthodontic retraction, reflecting adaptive remodelling of the supporting bone, within physiological limits in most cases

Likewise, Ebadi et al. observed a reduction in alveolar bone thickness around molars following orthodontic treatment indicating alveolar bone resorption associated with tooth movement.[36] Morais et al. further reported alveolar bone resorption associated with orthodontic tooth movement which revealed a reduction in alveolar bone dimensions, particularly in areas subjected to active tooth movement.[17]

However, the findings were not in accordance with the results obtained from the study conducted by Ma J et al. in which maintenance or slight increase in alveolar bone dimensions following orthodontic treatment was observed suggesting of adaptive bone deposition at the alveolar crest.[19]

The discrepancies observed among these studies may be attributed to variations in treatment mechanics, magnitude and direction of orthodontic forces, duration of force application, and the use of different anchorage systems. Additionally, differences in patient-related factors such as age, bone density, and biological response to tooth movement may influence the pattern of alveolar bone remodelling

Vertical changes-

The vertical measurement of the maxillary first molar showed a slight increase from 19.15 ± 0.86 mm pre-retraction to 19.35 ± 0.89 mm post-retraction, suggesting a mild extrusion of the molar. However, this change was minimal and was not statistically significant, indicating that vertical positioning of the maxillary first molar remained relatively stable during orthodontic retraction.

Similar findings were reported by Chandra et al., in which mild molar extrusion of the maxillary first molars during space closure was observed. This extrusion was primarily attributed to the biomechanics of retraction, wherein the line of force application often passes below the center of resistance of the posterior teeth, thereby generating an extrusive component.[3]

Likewise, AlShazly R.M et al. , also observed slight extrusion of the maxillary molars during orthodontic space closure, suggesting that posterior teeth may undergo minor vertical displacement during retraction mechanics in which they demonstrated a minor increase in the vertical position of maxillary molars, indicating extrusion during the course of treatment.[37]

However, Liu J et al. observed intrusion of molars instead of extrusion during space closure was observed, which was attributed to the use of controlled biomechanics. [38]

Overall, these variations may be attributed to differences in force application, mechanics of space closure, anchorage control, and treatment protocols, all of which influence the vertical behavior of posterior teeth during orthodontic retraction.

The findings of the present study indicate that orthodontic retraction results in minimal and non-significant changes in alveolar bone height, width, and vertical position of the maxillary first molars, suggesting that the observed alterations are largely within physiological limits. A slight increase in labial alveolar bone height and marginal reduction in palatal bone height and alveolar bone width was noted, reflecting the dynamic nature of alveolar bone remodeling during orthodontic tooth movement. Similarly, the mild extrusion of maxillary first molars observed in this study indicated that minor vertical changes may occur during space closure, likely influenced by the applied biomechanics and anchorage control.

CONCLUSION

This study aimed to evaluate the changes in alveolar bone width, alveolar bone height, and vertical changes in maxillary first molar in high anchorage cases treated with extraction of maxillary first premolars using cone beam computed tomography(CBCT).

34 pre-retraction and 34 post-retraction CBCT patients requiring premolar extractions were collected, and measurement was performed using CS 3D software.

Through the study, it was concluded that -

Orthodontic space closure following extraction of maxillary first premolars in high anchorage cases results in significant alterations in alveolar bone dimensions and molar position, indicating active and site-specific bone remodeling in response to orthodontic forces.

- Labial alveolar bone height shows a significant increase after retraction, which indicates bone resorption on the labial side, leading to an apparent increase in measured height as the alveolar crest moves apically.
- Palatal alveolar bone height demonstrates a significant decrease post-retraction, indicating bone deposition on the palatal side, which reduces the measured height due to coronal apposition of bone.
- A significant reduction in alveolar bone width is observed post-retraction, indicating bone resorption within the alveolar housing, as teeth are moved into the extraction space and the surrounding bone remodels to adapt to the new tooth position.
- Vertical changes show a significant increase, indicating extrusion of the maxillary first molars during space closure, despite the use of high anchorage mechanics.

Overall, these findings indicate that orthodontic retraction is associated with coordinated bone resorption and deposition in different regions, along with minor vertical tooth movement. This highlights the dynamic nature of alveolar bone remodeling and emphasizes the importance of controlled biomechanics to minimize unwanted effects and preserve periodontal support.

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