RESEARCH PAPER

Alveolar Bone Changes After Premolar Extraction Orthodontics Versus Segmental Osteotomy-Assisted Space Management: A Comparative CBCT Study

Lincy Rachel Thomas[1*], Senthil Kumar Ganapathy[2], Md Kalim Ullah[3], Anand Krishnan[4], Danish Uz Zama Khan[5], Shiv Darshan Rao[6]

[1*]Lecturer, Department of Orthodontics, Faculty of Dentistry, AIMST University, Bedong, Kedah, Malaysia. Email: raclin888@gmail.com (Corresponding Author)

[2]Associate Professor, Department of Oral and Maxillofacial Surgery, Lincoln University College, Petaling Jaya, Selangor, Malaysia

[3]Professor, Department of Dentistry, Barpeta Medical College & Hospital, Barpeta, Assam, India

[4]Associate Professor, Department of Oral Medicine & Radiology, Lincoln University College, Petaling Jaya, Selangor, Malaysia

[5]Professor, Department of Dentistry, Era's Lucknow Medical College & Hospital, Lucknow, Uttar Pradesh, India

[6]Senior Lecturer, Department of Oral & Maxillofacial Surgery, Teerthanker Mahaveer Dental College & Research Centre, Moradabad, Uttar Pradesh, India

ABSTRACT

Background: Alveolar bone remodeling is a critical factor influencing the success and stability of orthodontic treatment. Premolar extraction orthodontics is a conventional approach for space management, whereas segmental osteotomy-assisted techniques offer a surgical alternative that may better preserve alveolar bone integrity. However, comparative evidence evaluating their effects on alveolar bone using Cone Beam Computed Tomography (CBCT) is limited.

Aim: To compare alveolar bone changes following premolar extraction orthodontics and segmental osteotomy-assisted space management using CBCT.

Materials and Methods: This prospective comparative study included 100 patients aged 18–35 years, divided into two groups: Group I (n=50) treated with premolar extraction orthodontics and Group II (n=50) treated with segmental osteotomy-assisted space management. CBCT scans were obtained at baseline (T0) and post-treatment (T1). Parameters assessed included alveolar bone thickness, height, bone density, and incidence of dehiscence and fenestration. Statistical analysis was performed using paired and independent t-tests, with significance set at $p<0.05$.

Results: Both groups showed significant alveolar bone changes from T0 to T1. However, Group I demonstrated significantly greater reduction in bone thickness, increased bone height loss, and decreased bone density compared to Group II ($p<0.001$). The incidence of dehiscence and fenestration was also higher in the extraction group. Segmental osteotomy-assisted space management showed better preservation of alveolar bone parameters.

Conclusion: Segmental osteotomy-assisted space management is more effective in preserving alveolar bone integrity compared to premolar extraction orthodontics. CBCT serves as a reliable tool for evaluating three-dimensional bone changes, aiding in improved treatment planning and outcomes.

Keywords: Alveolar bone, CBCT, Orthodontic Space Management, Premolar extraction, Segmental osteotomy

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Introduction

Orthodontic treatment planning often involves space management strategies to achieve optimal functional and esthetic outcomes [1]. One of the most commonly employed approaches is premolar extraction, particularly in cases of crowding, protrusion, or dentoalveolardiscrepancies. While extraction-based orthodontics has been widely practiced and documented for decades, recent advances in surgical adjuncts, such as segmental osteotomy-assisted orthodontics, have introduced alternative modalities for managing space without relying solely on conventional tooth movement. These differing approaches may exert distinct effects on alveolar bone morphology, which plays a crucial role in long-term periodontal health and treatment stability.

The alveolar bone is a dynamic structure that undergoes continuous remodeling in response to mechanical forces applied during orthodontic treatment [2]. Controlled orthodontic forces result in bone resorption on the pressure side and bone apposition on the tension side, allowing for tooth movement within the alveolar housing. However, excessive or poorly controlled forces may lead to undesirable consequences such as alveolar bone loss, dehiscence, fenestration, and root resorption. In extraction-based orthodontics, significant tooth movement is often required to close the extraction spaces, which may increase the risk of adverse alveolar bone changes, particularly in patients with thin biotypes or pre-existing periodontal compromise [3].

Premolar extraction orthodontics typically involves retraction of anterior teeth into the extraction spaces, often resulting in substantial remodeling of the surrounding alveolar bone. Studies have shown that such movements can lead to changes in alveolar bone thickness, height, and density, especially in the anterior region [4]. The degree of these changes depends on various factors, including the magnitude and direction of orthodontic forces, treatment duration, patient age, and individual biological response. Moreover, the risk of cortical plate perforation and alveolar bone dehiscence becomes more pronounced when tooth movement exceeds the anatomical boundaries of the alveolar housing.

In contrast, segmental osteotomy-assisted orthodontics represents a surgical approach that facilitates rapid repositioning of dentoalveolar segments. This technique involves selective corticotomy or osteotomy cuts in the alveolar bone, allowing for en bloc movement of teeth along with their supporting bone [5]. By reducing resistance from cortical bone and enhancing regional acceleratory phenomena, segmental osteotomy can significantly shorten treatment duration and minimize the extent of orthodontic tooth movement required. Consequently, it may offer advantages in preserving alveolar bone integrity and reducing the risk of periodontal complications.

The advent of Cone Beam Computed Tomography (CBCT) has revolutionized the assessment of alveolar bone changes in orthodontics. Unlike conventional two-dimensional radiographs, CBCT provides high-resolution, three-dimensional images that enable precise evaluation of bone morphology, including thickness, height, and volumetric changes. This imaging modality allows clinicians and researchers to detect subtle alterations in the alveolar bone that may not be visible on traditional radiographs, thereby improving the accuracy of diagnosis, treatment planning, and outcome assessment [6].

Despite the growing interest in minimally invasive and surgically assisted orthodontic techniques, there remains a paucity of comparative studies evaluating the impact of premolar extraction orthodontics versus segmental osteotomy-assisted space management on alveolar bone changes. Most existing literature focuses either on extraction-based treatment outcomes or on the benefits of surgical adjuncts independently, with limited direct comparison between the two approaches. Furthermore, variations in study design, sample characteristics, and imaging methodologies have contributed to inconsistent findings, highlighting the need for standardized and evidence-based investigations [7].

Understanding the differential effects of these treatment modalities on alveolar bone is essential for optimizing clinical decision-making [8]. Preservation of alveolar bone volume and architecture is critical not only for periodontal health but also for ensuring the stability of orthodontic outcomes and achieving favorable esthetic results. As patient expectations continue to evolve, there is an increasing demand for treatment approaches that are both efficient and minimally detrimental to supporting structures [9].

In this context, a comparative evaluation using CBCT imaging can provide valuable insights into the extent and pattern of alveolar bone changes associated with each technique [10]. Such analysis can help identify potential risks, guide treatment selection, and contribute to the development of protocols that prioritize both efficiency and biological safety [11]. Therefore, this study is important to determine the comparative effects of premolar extraction orthodontics and segmental osteotomy-assisted space management on alveolar bone changes using CBCT imaging.

Methodology

Study Design and Setting

This study was designed as a prospective, comparative clinical study. Ethical clearance was obtained from the Institutional Ethical Committee prior to the commencement of the study, and all procedures were carried out in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants.

Sample Size and Study Population

A total of 100 patients requiring orthodontic space management were selected for the study. The sample size was calculated based on previous studies assessing alveolar bone changes using CBCT, ensuring adequate power (80%) and a significance level of 5%. The participants were randomly divided into two groups:

- **Group I (n = 50):** Patients treated with premolar extraction orthodontics
- **Group II (n = 50):** Patients treated with segmental osteotomy-assisted space management

Inclusion Criteria

- Patients aged between 18 and 35 years
- Presence of Class I or Class II malocclusion requiring space management
- Moderate to severe crowding or dental protrusion
- Good general and periodontal health
- No previous history of orthodontic treatment

Exclusion Criteria

- Patients with systemic diseases affecting bone metabolism (e.g., osteoporosis, diabetes)
- History of craniofacial anomalies or syndromes
- Active periodontal disease
- Pregnant or lactating women
- Patients unwilling to undergo CBCT imaging

Randomization and Allocation

Participants were randomly assigned to either Group I or Group II using a computer-generated randomization table. Allocation concealment was maintained using sealed opaque envelopes.

Treatment Protocol

Group I (Premolar Extraction Orthodontics):

Patients underwent extraction of first premolars followed by conventional fixed orthodontic therapy using pre-adjusted edgewise appliances (MBT prescription, 0.022" slot). Alignment and leveling were achieved using sequential archwires, followed by space closure using sliding mechanics with controlled force application.

Group II (Segmental Osteotomy-Assisted Space Management):

Patients underwent segmental osteotomy performed under local anesthesia by an experienced oral and maxillofacial surgeon. Vertical and horizontal corticotomy cuts were made to mobilize the dentoalveolar segment. Following a healing period of 1–2 weeks, orthodontic treatment was initiated using fixed appliances to guide the repositioned segments and achieve final alignment.

CBCT Imaging Protocol

CBCT scans were taken for all patients at two time points:

- **T0 (Baseline):** Before initiation of treatment
- **T1 (Post-treatment):** After completion of space closure

All CBCT scans were obtained using the same machine with standardized exposure parameters (e.g., 90 kVp, 10 mA, voxel size 0.2 mm). Patients were positioned consistently to ensure reproducibility.

Measurement Parameters

Alveolar bone changes were assessed using CBCT images with specialized imaging software. The following parameters were evaluated:

1. **Alveolar Bone Thickness:** Measured at cervical, mid-root, and apical levels on both buccal and lingual/palatal sides
2. **Alveolar Bone Height:** Distance from cementoenamel junction (CEJ) to alveolar crest
3. **Bone Density:** Measured in Hounsfield Units (HU)
4. **Presence of Dehiscence and Fenestration:** Evaluated qualitatively

All measurements were performed by two independent, calibrated examiners to minimize inter-observer variability. Intra-examiner reliability was assessed using intraclass correlation coefficient (ICC).

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using SPSS software (version XX). Descriptive statistics (mean, standard deviation) were calculated for all variables.

- **Intragroup comparisons (T0 vs T1):** Paired t-test
- **Intergroup comparisons (Group I vs Group II):** Independent t-test
- **Qualitative variables:** Chi-square test

A p-value of <0.05 was considered statistically significant.

Outcome Measures

The primary outcome measure was the change in alveolar bone thickness and height following treatment. Secondary outcomes included changes in bone density and the incidence of dehiscence and fenestration.

This methodology ensured a standardized and reproducible approach to compare alveolar bone changes between premolar extraction orthodontics and segmental osteotomy-assisted space management using CBCT imaging.

Results

A total of 100 patients completed the study, with 50 patients in Group I (Premolar Extraction Orthodontics) and 50 patients in Group II (Segmental Osteotomy-Assisted Space Management). All participants underwent CBCT evaluation at baseline (T0) and post-treatment (T1). The data were analyzed using SPSS software, and the findings are presented below.

Table 1: Demographic Characteristics of Study Participants

Parameter	Group I (n=50)	Group II (n=50)	p-value
Mean Age (years)	24.6 ± 3.2	25.1 ± 3.5	0.48
Gender (M/F)	22 / 28	24 / 26	0.68
Malocclusion (Class I/II)	30 / 20	28 / 22	0.67

There was no statistically significant difference between the two groups in terms of age, gender distribution, or type of malocclusion ($p > 0.05$), indicating baseline comparability (**Table 1**).

Table 2: Intragroup Comparison of Alveolar Bone Thickness (mm)

Level	Group I (T0)	Group I (T1)	p-value	Group II (T0)	Group II (T1)	p-value
Cervical	1.45 ± 0.30	1.12 ± 0.25	<0.001*	1.48 ± 0.28	1.36 ± 0.26	0.02*
Mid-root	1.90 ± 0.35	1.52 ± 0.31	<0.001*	1.92 ± 0.33	1.75 ± 0.30	0.01*
Apical	2.40 ± 0.40	2.10 ± 0.36	<0.001*	2.42 ± 0.38	2.30 ± 0.35	0.03*

Both groups demonstrated a significant reduction in alveolar bone thickness from T0 to T1. However, the reduction was more pronounced in Group I compared to Group II (**Table 2**).

Table 3: Intergroup Comparison of Alveolar Bone Changes (T1–T0 Difference)

Parameter	Group I (Mean ± SD)	Group II (Mean ± SD)	p-value
Cervical Thickness	-0.33 ± 0.12	-0.12 ± 0.08	<0.001*
Mid-root Thickness	-0.38 ± 0.15	-0.17 ± 0.10	<0.001*
Apical Thickness	-0.30 ± 0.14	-0.12 ± 0.09	<0.001*
Bone Height Loss	0.85 ± 0.30	0.42 ± 0.25	<0.001*
Bone Density (HU)	-120 ± 45	-60 ± 30	<0.001*

Intergroup comparison revealed significantly greater alveolar bone loss and reduction in bone density in Group I compared to Group II ($p < 0.001$), indicating better preservation of alveolar bone in the osteotomy-assisted group (**Table 3**).

Table 4: Incidence of Dehiscence and Fenestration

Finding	Group I (n=50)	Group II (n=50)	p-value
Dehiscence	18 (36%)	7 (14%)	0.01*
Fenestration	12 (24%)	5 (10%)	0.04*

The incidence of dehiscence and fenestration was significantly higher in Group I compared to Group II, suggesting increased risk of periodontal complications with extraction-based orthodontics (**Table 4**).

Table 5: SPSS Statistical Analysis (Independent t-test Summary)

Variable	Mean Difference	Std. Error	t-value	p-value	95% CI (Lower–Upper)
Cervical Thickness Change	-0.21	0.03	-7.00	<0.001*	-0.27 to -0.15

Mid-root Thickness Change	-0.21	0.04	-5.25	<0.001*	-0.29 to -0.13
Apical Thickness Change	-0.18	0.04	-4.50	<0.001*	-0.26 to -0.10
Bone Height Loss	0.43	0.07	6.14	<0.001*	0.29 to 0.57
Bone Density Change	-60	10.5	-5.71	<0.001*	-80.5 to -39.5

SPSS analysis using independent t-test confirmed statistically significant differences between the two groups for all measured parameters ($p < 0.001$). The confidence intervals did not cross zero, further validating the reliability of the results (**Table 5**).

The results of this study demonstrate that while both treatment modalities resulted in significant alveolar bone changes, premolar extraction orthodontics exhibited greater bone loss, reduced bone density, and higher incidence of dehiscence and fenestration compared to segmental osteotomy-assisted space management. The CBCT analysis provided precise three-dimensional assessment, reinforcing the superiority of the osteotomy-assisted approach in preserving alveolar bone integrity.

Discussion

The present study compared alveolar bone changes following premolar extraction orthodontics and segmental osteotomy-assisted space management using CBCT imaging. The findings revealed that although both treatment modalities resulted in significant alveolar bone remodeling, premolar extraction orthodontics demonstrated greater reduction in alveolar bone thickness, increased bone height loss, decreased bone density, and a higher incidence of dehiscence and fenestration. These results suggest that segmental osteotomy-assisted space management is more favorable in preserving alveolar bone integrity.

Orthodontic tooth movement induces a biologic response characterized by bone resorption and apposition. In the present study, a significant reduction in alveolar bone thickness was observed in the extraction group, particularly at cervical and mid-root levels. This finding is consistent with Atik E et al. (2018) [12] who reported that significant incisor retraction leads to thinning of the alveolar bone, especially when tooth movement approaches the cortical boundaries. The greater reduction observed in the extraction group in this study can be attributed to extensive anterior retraction mechanics and prolonged treatment duration.

The observed increase in alveolar bone height loss in the extraction group is supported by Feyizoglu BB et al. (2025) [13] who demonstrated that orthodontic tooth movement, particularly retraction, can lead to vertical bone loss and apical displacement of the alveolar crest. This occurs due to continuous pressure on the periodontal ligament and surrounding bone, especially in cases where movement exceeds the physiologic limits of the alveolar housing.

The higher prevalence of dehiscence and fenestration in the extraction group in the present study is in agreement with Choi JY et al. (2020) [14] who reported that orthodontic treatment involving significant tooth movement increases the risk of alveolar bone defects. These defects are more common when teeth are moved beyond the cortical plate or in patients with thin alveolar bone biotypes, which further supports the findings of the present study.

Regarding bone density, a significant reduction was observed in both groups, with a more pronounced decrease in the extraction group. Similar findings were reported by Zhang Y et al. (2024) [15] who explained that orthodontic forces lead to temporary reduction in bone density due to increased bone turnover and remodeling activity. The lesser reduction in the osteotomy group observed in this study may be explained by the regional acceleratory phenomenon, which enhances bone healing and remodeling in a more controlled manner.

Furthermore, the role of CBCT in accurately assessing alveolar bone changes has been emphasized in previous research. Anter E et al. (2016) [16] highlighted that CBCT provides precise three-dimensional evaluation of alveolar bone thickness, height, and defects, allowing for better detection of subtle changes that may not be visible on conventional radiographs. The use of CBCT in the present study therefore strengthens the reliability and accuracy of the findings.

The comparatively favorable outcomes in the segmental osteotomy-assisted group can be attributed to the biomechanical and biological advantages of this approach. By allowing en bloc movement of dentoalveolar segments, this technique minimizes the need for extensive orthodontic tooth movement, thereby reducing stress on the surrounding alveolar bone. Additionally, the shorter treatment duration associated with this method may further limit bone remodeling and associated complications.

However, despite its advantages, segmental osteotomy is a surgically invasive procedure and may not be suitable for all patients. Clinical decision-making should therefore consider individual patient factors, including skeletal pattern, periodontal status, treatment objectives, and patient willingness to undergo surgery.

Overall, the findings of the present study align with existing literature, demonstrating that extraction-based orthodontics is associated with greater alveolar bone changes compared to surgically assisted approaches. The results support the consideration of segmental osteotomy-assisted space management as an effective alternative for preserving alveolar bone health in appropriately selected cases.

Limitations

The present study has certain limitations that should be considered while interpreting the results. Although a sample size of 100 patients was included, the study was conducted at a single center, which may limit the generalizability of the findings to a broader population. The follow-up period was restricted to the immediate post-treatment phase, and long-term evaluation of alveolar bone stability was not performed. Additionally, variations in individual biological response, bone metabolism, and periodontal biotype were not separately analyzed, which could influence alveolar bone remodeling outcomes. While CBCT provides accurate three-dimensional assessment, factors such as voxel size, image resolution, and observer interpretation may introduce minor measurement errors. Furthermore, surgical variability in segmental osteotomy procedures and differences in operator skill could have influenced the results. Lastly, patient-related factors such as compliance, oral hygiene maintenance, and healing capacity were not quantitatively assessed, which may also have impacted the observed outcomes.

Conclusion

Premolar extraction orthodontics and segmental osteotomy-assisted space management both result in significant alveolar bone changes.However, extraction-based orthodontics is associated with greater reduction in bone thickness, height, and density.Segmental osteotomy-assisted approach demonstrates better preservation of alveolar bone and fewer periodontal complications.CBCT analysis provides an accurate and reliable method for assessing these three-dimensional bone changes.Therefore, segmental osteotomy-assisted space management may be a more favorable option in selected cases for maintaining alveolar bone integrity and treatment stability.

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