Comparative Evaluation of External Apical Root Resorption Following En-Masse Retraction Using Conventional Anchorage and Temporary Anchorage Devices: A CBCT Study

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Abstract
Background: External apical root resorption (EARR) is a common iatrogenic consequence of orthodontic tooth movement and is frequently associated with extraction-based treatment involving anterior retraction. Temporary anchorage devices (TADs) have become widely used for maximum anchorage control during en-masse retraction; however, their influence on root resorption remains unclear. **Objective:** To compare external apical root resorption in maxillary teeth following en-masse retraction using conventional anchorage and temporary anchorage devices (TADs) through cone-beam computed tomography (CBCT) evaluation. **Materials and Methods:** This prospective, in vivo, comparative clinical study included 30 patients requiring bilateral maxillary first premolar extractions for orthodontic treatment. Patients were allocated into two groups: conventional anchorage group (n = 15) and TAD group (n = 15). All subjects were treated using 0.022-inch MBT prescription appliances. En-masse retraction was performed using elastomeric chains delivering 150 g of force per side. CBCT scans were obtained before initiation of anterior retraction and after complete extraction space closure. Root lengths of maxillary incisors, canines, second premolars, and first molars were measured using Rainbow™ 3D Viewer software. External apical root resorption was calculated as the difference between pre-retraction and post-retraction root lengths. Intergroup comparisons were performed using independent t-tests, with statistical significance set at $p < 0.05$. **Results:** Root resorption was observed in all evaluated teeth in both groups. The TAD group demonstrated significantly greater root resorption than the conventional anchorage group in most teeth. The mean root resorption in the anterior region was significantly higher in the TAD group (0.65 ± 0.06 mm) compared with the conventional anchorage group (0.36 ± 0.08 mm) ($p < 0.001$). Similarly, posterior teeth exhibited significantly greater root resorption in the TAD group (0.53 ± 0.19 mm) than in the conventional group (0.32 ± 0.08 mm) ($p < 0.001$). The overall mean root resorption was 0.58 ± 0.12 mm in the TAD group and 0.33 ± 0.07 mm in the conventional anchorage group ($p < 0.001$). Maxillary canines and incisors exhibited the greatest degree of root shortening. **Conclusions:** External apical root resorption occurred following orthodontic space closure irrespective of the anchorage system used. However, TAD-supported en-masse retraction was associated with significantly greater root resorption than conventional anchorage. Despite these differences, the magnitude of root shortening remained less than 1 mm and within clinically acceptable limits. CBCT proved to be a reliable method for three-dimensional assessment of orthodontically induced root resorption.

Keywords: External apical root resorption; Cone-beam computed tomography; Temporary anchorage devices; Mini-implants; En-masse retraction.

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INTRODUCTION:

Orthodontics is a specialized branch of dentistry that deals with the diagnosis, prevention, interception, and correction of malocclusions to improve oral health, function, and dentofacial aesthetics. Although orthodontic treatment is highly effective, it may be associated with certain complications, one of the most significant being external apical root resorption (EARR).[1]

EARR is characterized by the shortening of tooth roots resulting from the irreversible loss of cementum and dentin from the root apex and is recognized as one of the most common iatrogenic consequences of orthodontic tooth movement.[2]

While mild root resorption is frequently observed and often considered clinically insignificant, excessive root shortening may adversely affect the crown-root ratio, compromise periodontal support, and potentially influence the long-term prognosis of the affected teeth.[3,4]

The etiology of EARR is multifactorial and involves a complex interaction between biological and mechanical factors. Biological determinants such as genetic predisposition, age, sex, systemic health, root morphology, and alveolar bone characteristics may influence an individual's susceptibility to root resorption. Mechanical factors including treatment duration, force magnitude, extraction therapy, appliance design, and the type of tooth movement have also been implicated.[5]Excessive or prolonged force application can generate localized pressure zones around the periodontal ligament, triggering inflammatory responses that lead to resorption.[6]Different types of orthodontic tooth movement may also affect the severity of resorption, with intrusive and tipping movements generally demonstrating a greater chance for apical root resorption than controlled bodily movement because of increased stress concentration in the apical region.[7]

Susceptibility to EARR may vary among different teeth within the dental arch. Previous studies have consistently reported a higher prevalence and severity of root resorption in the maxillary anterior teeth, particularly the incisors, which are frequently subjected to substantial orthodontic forces during retraction procedures.The morphology of these teeth, combined with the magnitude and direction of orthodontic forces applied during space closure, may contribute to their increased vulnerability to resorptive changes. In contrast, posterior teeth generally exhibit lower levels of resorption, although they may also be affected depending on the treatment mechanics employed.[8] Understanding these variations in tooth-specific susceptibility is essential for optimizing orthodontic force systems and minimizing the risk of clinically significant root resorption.

Extraction-based orthodontic treatment often necessitates en-masse retraction of the anterior teeth to correct dentoalveolar protrusion and achieve optimal facial esthetics. Successful en-masse retraction requires effective anchorage control to minimize unwanted mesial movement of the posterior teeth and maximize utilization of extraction spaces. While conventional anchorage methods have traditionally been used for this purpose, temporary anchorage devices (TADs), particularly mini-implantssupported mechanics facilitate efficient anterior retraction with minimal anchorage loss and have therefore become an integral component of contemporary orthodontic treatment, especially in cases requiring maximum anchorage.[9]

Despite the biomechanical advantages offered by mini-implant anchorage, concerns remain regarding its influence on root resorption. Enhanced anchorage may permit greater amounts of anterior tooth movement and alter force distribution within the periodontal ligament, potentially affecting the degree of apical root resorption.However, the available evidence regarding the influence of different anchorage systems on root resorption remains limited and inconclusive, highlighting the need for further investigation.

Accurate assessment of root resorption is essential for understanding the biological effects of orthodontic treatment and optimizing treatment protocols. Cone-beam computed tomography (CBCT) has emerged as a reliable three-dimensional imaging modality that enables accurate visualization and quantitative assessment of root length changes without superimposition.[10]

This study aimed to compare root length changes in the anterior and posterior segments of the maxillary arch before and after en-masse retraction withconventional molar anchorage and temporary anchorage devicesusing cone-beam computed tomography.

Materials And Methods:

Study design and setting

This prospective, in vivo, comparative clinical study was conducted in the Department of Orthodontics and Dentofacial Orthopaedics after obtaining approval from the Institutional Ethical Committee. Written informed consent was obtained from all participants before commencement of the study.

Sample Size Calculation

The sample size was calculated based on data reported by **Kabi S et al.** [Egyptian Dental Journal. 2019;65:881-894]. [11] Assuming a significance level of 5% and a study power of 80%, the estimated sample size was 15 subjects per group. Accordingly, a total of 30 patients were included in the study.

Study Method

Patients who presented to the Department of Orthodontics were screened for eligibility. The inclusion criteria were patients aged >18 years with Complete root apex formation, Mild to moderate crowding and requiring Bilateral maxillary first premolar extraction for orthodontic treatment.Exclusion Criteria includedPrevious orthodontic treatment, history of facial or dental trauma, medically compromised or syndromic patients, Severe facial or dental asymmetry, periodontal disease, presence of periapical or periradicular pathology.The 30 enrolled patients were selectedusing a convenience sampling method and allocated into two groups according to the anchorage system used during space closure:

- **Group 1 (Conventional Anchorage Group):** 15 patients treated with conventional anchorage-supported space closure. (n=15)

- **Group 2 (TAD Group):** 15 patients treated with temporary anchorage devices-supported space closure. (n=15)

Orthodontic Procedure

All patients were treated using a pre-adjusted edgewise appliance system with 0.022-inch slot MBT prescription metal brackets. A standardized archwire sequence was followed for all participants. Following leveling and alignment, 0.019 × 0.025-inch stainless steel archwires were placed and maintained for a minimum of one month before initiation of space closure.

En-masse retraction of the maxillary anterior teeth was performed using elastomeric chains attached to crimpable hooks positioned bilaterally between the lateral incisors and canines. A retraction force of 150 g per side was applied and verified using a Dontrix force gauge. In the conventional anchorage group, elastomeric chains were extended from the anterior hooks to the maxillary first molar tube hooks and in the TAD group, bilateral mini-implants were placed in the posterior maxillary region between roots of second premolars and first molars close to the mucogingival junction and the elastomeric chains were attached directly from the anterior hooks to the mini-implants as shown in **Figure 1.**

Patients were reviewed at four-week intervals. At each appointment, the elastomeric chains were replaced and the retraction force was re-evaluated to ensure consistent force delivery throughout treatment. Retraction was continued until complete extraction space closure was achieved.

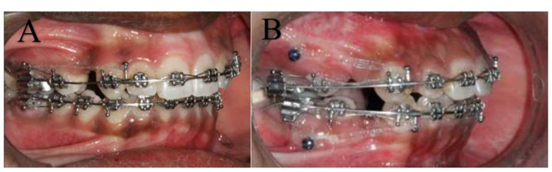

FIGURE 1: Maxillary en masse retraction using (A) conventional anchorage method (B) Temporary Anchorage Device (mini-implants)
(This figure represents study patients, included with appropriate informed consent.)

CBCT Acquisition and Root Length Assessment

Cone-beam computed tomography (CBCT) scans were obtained before initiation of en masse retraction and after complete extraction space closure to measure the baseline root lengths of all the bonded teeth (incisors to first molars) in the maxillary arch. All scans were acquired using a Dentium CBCT unit and exported as Digital Imaging and Communications in Medicine (DICOM) files for analysis using Rainbow™ 3D Viewer software.The imaging parameters included an axial slice thickness of 0.150 mm, tube voltage of 94 kV, tube current of 8 mA, field of view of 16 × 10 cm, exposure time of 20 seconds, and voxel size of 300 µm. Image translucency and segmentation settings were standardized and maintained throughout the analysis to ensure optimal visualization.

CBCT reconstructions were oriented such that the axial plane was perpendicular to the long axis of each tooth, allowing accurate visualization in the axial, coronal, and sagittal planes. Root length was measured as the perpendicular distance between a reference line connecting the buccal and palatal cementoenamel junctions and a parallel line passing through the root apex. For multi-rooted teeth, each root was evaluated separately. Post-treatment measurements were performed at the same slice level as the pretreatment measurements to ensure reproducibility.

Measurement Reliability

All measurements were performed by a single investigator. To assess measurement reliability, a subset of CBCT scans from both groups was independently re-evaluated by a second examiner.

Outcome Variable

The primary outcome variable was external apical root resorption (EARR), calculated as the difference between pre-retraction and post-retraction root lengths using the following formula:

EARR (mm) = Pre-retraction root length − Post-retraction root length

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using SPSS software version 25.0 (IBM Corp., Armonk, NY, USA).Normality of data distribution was assessed using the Shapiro-Wilk test. Descriptive statistics were expressed as mean and standard deviation.Intragroup comparisons between pre- and post-retraction root lengths were performed using paired t-tests , Intergroup comparisons of root length changes between the conventional anchorage and TAD groups were performed using independent t-tests. Statistical significance was established at $p < 0.05$.

RESULTS

A total of 30 patients were included in the study, with 15 patients each in the conventional anchorage and temporary anchorage device (TAD) groups. Root length changes were evaluated using CBCT before initiation of en-masse retraction and after complete extraction space closure.

Tooth	Conventional		TAD		Difference	t-value	p-value
	Mean	SD	Mean	SD			
Right Central Incisor (11)	0.41	0.19	0.61	0.20	-0.20	-2.767	0.010*
Right Lateral Incisor (12)	0.39	0.15	0.64	0.17	-0.26	-4.388	<0.001*
Right Canine (13)	0.33	0.06	0.70	0.12	-0.37	-10.142	<0.001*
Right Second Premolar (15)	0.27	0.15	0.50	0.16	-0.24	-4.128	<0.001*
Mesiobuccal Root of Right First Molar (16MB)	0.28	0.09	0.48	0.16	-0.20	-4.143	<0.001*
Palatal Root of Right First Molar (16P)	0.30	0.07	0.65	0.69	-0.35	-1.954	0.061
Distobuccal Root of Right First Molar (16DB)	0.28	0.08	0.46	0.15	-0.18	-4.259	<0.001*
Left Central Incisor (21)	0.31	0.08	0.65	0.18	-0.34	-6.618	<0.001*
Left Lateral Incisor (22)	0.35	0.16	0.58	0.19	-0.23	-3.651	0.001*
Left Canine (23)	0.35	0.14	0.73	0.26	-0.38	-4.992	<0.001*
Left Second Premolar (25)	0.36	0.22	0.46	0.35	-0.10	-0.922	0.364
Mesiobuccal Root of Left First Molar (26MB)	0.32	0.10	0.56	0.23	-0.24	-3.775	0.001*
Palatal Root of Left First Molar (26P)	0.33	0.10	0.50	0.16	-0.18	-3.519	0.002*
Distobuccal Root of Left First Molar (26DB)	0.40	0.16	0.65	0.46	-0.25	-1.941	0.062

Table1:Comparisonofmeanrootresorption(inmm)ineachtooth between the Conventional method and Temporary Anchorage Device group.

Table 1 presents the intergroup comparison of external apical root resorption between the conventional anchorage and TAD groups. The TAD group exhibited significantly greater root resorption than the conventional anchorage group in most of the evaluated teeth. The greatest difference was observed in the maxillary left canine, followed by the right canine and central incisors. Among the posterior teeth, significantly greater root resorption was observed in the mesiobuccal and distobuccal roots of the first molars in the TAD group. However, no statistically significant differences were found for the palatal root of the right first molar (16P), the left second premolar (25), and the distobuccal root of the left first molar (26DB) ($p > 0.05$). Overall, the findings indicate that TAD-supported en-masse retraction was associated with greater external apical root resorption compared with conventional anchorage mechanics.

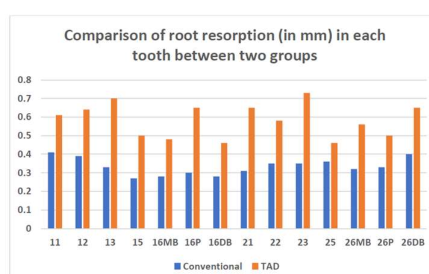

Figure 2: Comparisonofmeanrootresorption(inmm)ineach tooth between the Conventional method and

Temporary Anchorage Device (TAD) group. This figure is derived from the data of the study.

Root resorption site	Conventional (Mean ± SD)	TAD (Mean ± SD)	Mean Difference	t-value	p-value
Anterior teeth	0.36 ± 0.08	0.65 ± 0.06	-0.29	-11.442	<0.001*
Posterior teeth	0.32 ± 0.08	0.53 ± 0.19	-0.21	-4.066	<0.001*
Overall	0.33 ± 0.07	0.58 ± 0.12	-0.25	-6.923	<0.001*

Table 2: Regional Comparison of External Apical Root Resorption Betweenthe Conventional method and Temporary Anchorage Device (TAD) group.

Regional comparison of root resorption is presented in **Table 2**. The mean root resorption in the anterior region was significantly greater in the TAD group (0.65 ± 0.06 mm) than in the conventional anchorage group (0.36 ± 0.08 mm), with a mean difference of 0.29 mm ($t = -11.442$, $p < 0.001$). Similarly, the posterior region demonstrated significantly greater root resorption in the TAD group (0.53 ± 0.19 mm) compared with the conventional anchorage group (0.32 ± 0.08 mm), with a mean difference of 0.21 mm ($t = -4.066$, $p < 0.001$). The overall mean root resorption was also significantly higher in the TAD group (0.58 ± 0.12 mm) than in the conventional anchorage group (0.33 ± 0.07 mm), with a mean difference of 0.25 mm ($t = -6.923$, $p < 0.001$).

Overall, root resorption occurred in all evaluated teeth following orthodontic space closure. The magnitude of root resorption was significantly greater in patients treated with TAD-supported anchorage than in those treated with conventional anchorage. Furthermore, anterior teeth demonstrated greater susceptibility to root resorption than posterior teeth, with the maxillary canines and incisors exhibiting the highest degree of root length reduction.

DISCUSSION:

The present study evaluated CBCT-based root length changes following extraction space closure using conventional anchorage and temporary anchorage devices (TADs). The findings demonstrated that root resorption occurred in all evaluated teeth irrespective of the anchorage system employed. However, significantly greater root resorption was observed in the TAD group compared with the conventional anchorage group.

External apical root resorption (EARR) is one of the most common undesirable sequelae associated with orthodontic tooth movement and is considered an unavoidable consequence of the biological response of the periodontal ligament and surrounding alveolar bone to orthodontic forces.[3]The presence of root resorption in all evaluated teeth in both groups is consistent with previous literature reporting that mild to moderate root resorption is a common finding following fixed orthodontic therapy. **Brezniak and Wasserstein**[3] described orthodontically induced inflammatory root resorption as a biological response to hyalinization and sterile inflammation in the periodontal ligament, leading to cementoclastic activity at the root apex. Similarly, **Levander and Malmgren**[12] emphasized that most patients undergoing comprehensive orthodontic treatment experience some degree of root shortening, although it is usually clinically insignificant.

A key finding of the present study was the significantly greater root resorption observed in the TAD group compared with the conventional anchorage group. This is in agreement with **Gomaa and Elmarhoumy**[11], who reported increased apical root resorption in patients undergoing en-masse retraction with skeletal anchorage compared with conventional anchorage mechanics, attributing this to increased efficiency of space closure and greater magnitude of tooth displacement.

The increased root resorption in the TAD group may be explained by biomechanical differences between anchorage systems. TADs provide absolute anchorage, eliminating posterior anchorage loss and allowing complete utilization of extraction spaces. This results in greater anterior tooth displacement and potentially increased apical stress. **Proffit et al.**[13]highlighted that magnitude, duration, and type of orthodontic force are critical determinants of root resorption risk, with intrusive and high-displacement movements increasing susceptibility. Similarly, **Weltman et al.**[14] in a systematic review, concluded that greater treatment duration, extraction therapy, and increased tooth movement are associated with higher levels of EARR.

Another important finding was the greater susceptibility of anterior teeth to root resorption compared with posterior teeth. This is in agreement with **Lupi et al.,**[15] who reported that maxillary incisors are the most frequently affected teeth in orthodontic patients. The increased vulnerability of anterior teeth can be attributed to their root morphology, proximity to cortical bone, and the magnitude of retraction forces applied during extraction space closure. Additionally,studies demonstrated that stress concentration is significantly higher in the apical region of incisors during retraction mechanics, which may explain the higher incidence of resorption.

Interestingly, the maxillary canines exhibited the highest root resorption values in the present study. This finding differs from several previous studies that identified maxillary incisors as the teeth most susceptible to orthodontically induced root resorption. The greater resorption observed in canines may be attributed to the extensive tooth movement required during extraction space closure and the prolonged application of orthodontic forces. The use of CBCT in the present study provides a methodological advantage in accurately assessing root length changes. Conventional two-dimensional radiography is limited by magnification, distortion, and superimposition errors, which may underestimate true resorption.**Castro et al.**[16] utilized CBCT to assess orthodontically induced root resorption and emphasized its value in detecting apical changes that may not be readily identified on conventional two-dimensional radiographs.**Dudic et al**.[17] demonstrated that CBCT is significantly more sensitive than periapical and panoramic radiographs in detecting orthodontically induced root resorption. Previous studies have highlighted the superiority of cone-beam computed tomography (CBCT) in providing a three-dimensional evaluation of root morphology and apical changes, making it a highly reliable imaging modality and the preferred standard for research involving root resorption assessment.[18]

Although statistically significant differences were observed between groups, the magnitude of root resorption in both groups remained less than 1 mm, which is considered clinically acceptable. **Weltman et al.**[14] reported that most orthodontically induced root resorption remains mild and does not compromise long-term tooth prognosis in the majority of cases. Nevertheless, careful monitoring is essential, especially in cases involving extraction therapy and extensive anterior retraction.

The present study had certain limitations. The sample size was relatively small and was derived from a single institution. The influence of treatment duration, amount of anterior retraction, root morphology, and individual biological susceptibility was not evaluated. Additionally, long-term follow-up was not performed to assess the clinical significance of the observed root length changes.Also, CBCT involves radiation exposure, raising ethical concerns regarding its routine application, especially in younger patients.

CONCLUSION:

The present study concluded that external apical root resorption occurred in all evaluated maxillary teeth following orthodontic space closure, irrespective of the anchorage system used. However, significantly greater root resorption was observed in patients treated with temporary anchorage devices (mini-implants) compared with those treated using conventional anchorage. Root resorption was more pronounced in the anterior region than in the posterior region, with the maxillary canines and incisors exhibiting the highest degree of root length reduction. Despite these statistically significant differences, the magnitude of root shortening remained less than 1 mm in both groups and was within clinically acceptable limits. Furthermore, CBCT proved to be a reliable and effective imaging modality for the three-dimensional assessment of root length changes and orthodontically induced root resorption.

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