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Original Article

Dentistry Section

Risk of Root Resorption between Clear Aligners and Fixed Orthodontic Appliances: A Retrospective Cohort Study

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ABSTRACT

Introduction: External Root Resorption (ERR) is a recognised complication of orthodontic treatment, and its severity may vary with appliance type. Clear aligners are often perceived as a more biologically gentle alternative to conventional fixed appliances; however, evidence directly comparing ERR between these modalities remains limited. Most studies focus on specific teeth or use small, heterogeneous samples, making it difficult to draw definitive clinical conclusions. The present study addresses this gap by comprehensively evaluating ERR patterns at the patient level, including severity, distribution, and tooth-specific involvement, in a single Institutional cohort.

Aim: To evaluate and compare the prevalence and severity of ERR in patients treated with clear aligners and conventional fixed orthodontic appliances.

Materials and Methods: A retrospective cohort study was conducted at King Abdulaziz University Dental Hospital, Jeddah, Saudi Arabia between November 2022 and September 2025 on 100 patients. The sample comprised 57 patients treated with fixed appliances and 43 patients treated with clear aligners. Pretreatment and post-treatment panoramic radiographs were extracted from the Radiology Department archive and reviewed to assess ERR. Parameters evaluated included the prevalence of ERR, its severity, number of teeth affected, unilateral or bilateral involvement, tooth-specific involvement, and treatment duration. Mann-Whitney U test, Chisquare test, Fisher's-exact test were used for statistical analysis.

Results: Of 100 patients, 57.0% were treated with fixed appliances and 43.0% with clear aligners. The aligner group was older (26.8±19.5 years, $p<0.001$) and included more females {35 (81.4%) vs 29 (50.9%), $p=0.003$}, while malocclusion type did not differ ($p=0.215$). Extractions were significantly more frequent with fixed appliances ($p<0.001$), and treatment duration was longer ($p=0.005$). ERR prevalence ($p=0.002$), severity ($p<0.001$), bilateral involvement ($p=0.008$), and multi-tooth involvement ($p=0.033$) were all higher in the fixed appliance group. Multivariable regression confirmed fixed appliance therapy as the significant predictor of ERR ($p=0.034$).

Conclusion: Although both fixed appliances and clear aligners are associated with a risk of ERR, fixed appliances demonstrated significantly higher prevalence, greater severity, and wider distribution of resorption. Clear aligners showed a biological advantage in limiting ERR, particularly in maxillary incisors, though careful radiographic monitoring remains essential with both modalities.

Keywords: Aesthetics, Brackets and arch wires, External root resorption, Invisible teeth braces, Malocclusion

INTRODUCTION

Orthodontic treatment is a cornerstone of modern dentistry. However, there are few treatment-related complications including ERR [1,2]. ERR is characterised by an irreversible loss of cementum and dentin, which may compromise tooth integrity if severe [3,4]. Its pathogenesis is multifactorial, with reported risk factors including prolonged treatment duration, magnitude and direction of orthodontic force, malocclusion type, and individual susceptibility [5,6]. At the cellular level, ERR results from a remodelling imbalance, where orthodontic forces stimulate clastic cell activity, leading to resorption defects on root surfaces [7-9].

Over the past two decades, orthodontic therapy has undergone major advances. Fixed appliances remain the gold standard, especially in moderate to severe malocclusions, where they provide continuous force application through brackets and arch wires [9]. In contrast, clear aligners have become increasingly popular due to their esthetic appeal, removability, and ease of maintaining oral hygiene [10]. The biomechanics of these systems differ substantially: fixed appliances generate constant, localised forces at bracket sites, while aligners apply intermittent and more distributed forces via sequential trays and attachments [11]. These biomechanical distinctions are thought to influence the incidence and severity of ERR [4].

Krieger E et al., reported that although aligners may be associated with a higher frequency of root changes, the extent of resorption is generally less severe than with fixed appliances [11]. Yi J et al., and Li Y et al., using Cone Beam Computed Tomography (CBCT), observed differences in ERR prevalence and severity between modalities, though results were inconclusive [10,12]. Patel A et al., noted accurate detection of ERR relies on radiographic monitoring [13]. CBCT has the highest diagnostic precision and allows early detection of subtle apical changes [14]. However, its use in routine follow-up is limited by higher cost and radiation exposure. Panoramic radiographs, though less sensitive to minor root resorption, remain the standard in many orthodontic Institutions due to their broad coverage and relatively low radiation dose. This raises the concern that panoramic-based assessments may underestimate the true prevalence of ERR [15].

With the increasing adoption of clear aligner therapy and ongoing debate regarding its biological safety compared with fixed appliances, there remains a pressing need for studies that directly compare ERR outcomes between these treatment modalities. By addressing these elements, the study seeks to provide clinically relevant insights into ERR risk and support orthodontists in making evidence-based

treatment decisions that balance aesthetic demands with biological safety and minimise adverse outcomes. Thus, the present study was undertaken to evaluate and compare the risk of root resorption between clear aligner and fixed orthodontic appliances.

MATERIALS AND METHODS

This retrospective cohort study was conducted at King Abdulaziz University Dental Hospital, Jeddah, Saudi Arabia, between November 2022 and September 2025 in accordance with the Declaration of Helsinki and approved by the Research Ethics Committee of the Faculty of Dentistry, King Abdulaziz University (Approval No. 161-12-20).

Inclusion criteria: The patients between 15 and 45 years of age at the initiation of treatment, those who had completed orthodontic treatment with either fixed appliances or clear aligners for simple to moderate malocclusion (Class-I, II, or III) and possessed both pre-treatment and post-treatment panoramic radiographs were included in the study.

Exclusion criteria: Radiographs of the patients suffering from systemic conditions or bone diseases that are likely to affect root morphology, and those who had incomplete or ongoing orthodontic treatment. Also, the radiographs of the patients having a history of endodontic treatment, impacted canines causing adjacent root resorption, the use of adjunctive appliances such as headgear, facemasks, or mini-screws, previous jaw surgery, maxillofacial trauma, or radiographs compromised by superimposition or blurring were excluded.

Study Procedure

A total of 249 patient records were reviewed (173 fixed appliances, 76 clear aligners), with 100 cases deemed eligible after applying inclusion and exclusion criteria: 57 in the fixed appliance group and 43 in the clear aligner group. Baseline demographic and treatment characteristics (age, gender, malocclusion class, treatment duration, and extraction history) were documented for both groups. For fixed appliances, treatment involved conventional pre-adjusted edgewise brackets, while clear aligners utilised commercially available systems with digitally generated treatment plans. Radiographic evaluations were conducted by two Oral and Maxillofacial Radiologists. Pre- and post-treatment panoramic radiographs were analysed, measuring ERR as the difference in root length from cementoenamel junction to the root apex. ERR was defined as at least one tooth with root resorption greater than 1 mm, with severity categorised as none (0 mm), mild (1 mm), moderate (2 mm), or severe (≥3 mm) [16]. For each patient, data on ERR presence, number of affected teeth, laterality, and specific tooth involvement were recorded and categorised by tooth type, number of affected teeth, and laterality.

STATISTICAL ANALYSIS

Data were analysed using Statistical Package for Social Sciences (SPSS) version 27.0 (IBM Corp., Armonk, NY, USA) and GraphPad Prism version 7.0 (GraphPad Software, San Diego, CA, USA). Descriptive statistics were calculated for all demographic and clinical variables. Mann-Whitney U test, Chi-square test, Fisher's-exact test were used for statistical analysis. For the binary logistic regression model, calibration was assessed using the Hosmer–Lemeshow goodness-of-fit test. For the ordinal logistic regression model, the proportional odds assumption was evaluated using the test of parallel lines. A p-value <0.05 was considered statistically significant.

RESULTS

Of 100 patients, 57 were treated with fixed appliances and 43 with clear aligners. The aligner group was older (p<0.001) and included more females (p=0.003), while malocclusion type did not differ (p=0.215). Extractions were more frequent with fixed appliances, 34 (59.6%), vs 1 (2.3%) with (p<0.001). Treatment duration was longer for fixed appliances (p=0.005), with 62.8% of aligner patients completing therapy within 20 months [Table/Fig-1].

Variables	Fixed appliance (n=57)	Clear aligner (n=43)	Statistical test
Age (years), Mean±SD (Range)	19.54±5.76 (15-45)	26.80±9.21 (15-43)[a]	U=671.5, p<0.001*
Gender	Male: 28 (49.1%) Female: 29 (50.9%)	Male: 8 (18.6%) Female: 35 (81.4%)	χ^2=8.63, p=0.003*
Malocclusion	Class-I: 25 (43.9%) Class-II: 8 (14.0%) Class-III: 24 (42.1%)	Class-I: 23 (53.5%) Class-II: 9 (20.9%) Class-III: 11 (25.6%)	χ^2=3.07, p=0.215
Treatment type	Extraction: 34 (59.6%) Non-extraction: 23 (40.4%)	Extraction: 1 (2.3%) Non-extraction: 42 (97.7%)	χ^2=32.93, p<0.001*
Treatment duration (months), Mean±SD (Range)	25.51±10.32 (7-56)	20.32±12.61 (5-58)	U=1632.0, p=0.005*

[Table/Fig-1]: Baseline demographic and treatment characteristics of patients treated with fixed appliances versus clear aligners.
*Statistically significant at p<0.05. Chi-square (χ^2) test for categorical variables (gender, malocclusion class, treatment type) and the Mann-Whitney U test for continuous variables (age, treatment duration).

The ERR prevalence was significantly higher with fixed appliances (p=0.002). Moderate-to-severe ERR occurred in 21 (36.8%) fixed appliance patients while only 2 (4.7%) of aligner patients (p<0.001). Bilateral involvement was more common with fixed appliances (p=0.008), and involvement of 4-7 teeth was more frequent (p=0.033). Maxillary central incisors were most frequently affected in both groups [Table/Fig-2].

Variables	Fixed appliance (n=57)	Clear aligner (n=43)	Statistical test
Presence of ERR	49 (84.5%)	24 (55.8%)	χ^2=9.83, p=0.002*
Severity (mm resorbed)	None: 8 (14.0%) 1 mm: 11 (19.3%) 2 mm: 17 (29.8%) ≥3 mm: 21 (36.8%)	None: 20 (46.5%) 1 mm: 12 (27.9%) 2 mm: 9 (20.9%) ≥3 mm: 2 (4.7%)	χ^2=21.81, p<0.001*
Number of teeth affected	0-3: 43 (75.4%) 4-7: 11 (19.3%) 8-11: 3 (5.3%)	0-3: 40 (93.0%) 4-7: 1 (2.3%) 8-11: 2 (4.7%)	χ^2=6.82, p=0.033*
Presence of sides	Unilateral: 20 (35.1%) Bilateral: 28 (49.1%) None: 9 (15.8%)	Unilateral: 14 (32.6%) Bilateral: 11 (25.6%) None: 18 (41.9%)	χ^2=9.70, p=0.008*
Most affected teeth	Maxillary central > lateral incisors	Predominantly central incisors	-

[Table/Fig-2]: ERR characteristics by treatment type.
*Statistically significant (p<0.05)

Multivariable logistic regression identified treatment with fixed appliances as a significant predictor of ERR compared with clear aligners (OR=5.08, 95% CI: 1.13–22.83, p=0.034). Age, gender, malocclusion class, extraction therapy, and treatment duration were not statistically significant predictors in the adjusted model [Table/Fig-3].

Treatment with fixed appliances showed a non significant trend toward higher odds of greater ERR severity compared with clear aligners (OR=2.83, 95% CI: 0.81-9.92, p=0.104). Extraction therapy

Variables	β	SE	Adjusted OR	95% CI	p-value
Fixed appliances (ref: clear aligners)	1.626	0.766	5.08	1.13-22.83	0.034*
Age (years)	-0.027	0.031	0.97	0.92-1.04	0.394
Male (ref: female)	-1.130	0.622	0.32	0.10-1.09	0.069
Treatment duration (months)	0.017	0.022	1.02	0.97-1.06	0.458
Class -II (ref: Class-I)	-0.410	0.697	0.66	0.17-2.60	0.556
Class-III (ref: Class-I)	-0.796	0.597	0.45	0.14-1.45	0.183
Extraction (yes vs no)	0.502	0.757	1.65	0.37-7.29	0.508

[Table/Fig-3]: Multivariable binary logistic regression analysis for predictors of External Root Resorption (ERR).
Statistically significant at p<0.05

(OR=2.55, 95% CI: 0.84-7.76, p=0.100) and treatment duration (OR=1.01, 95% CI: 0.96-1.05, p=0.780) were also not significant predictors. Age, gender, and malocclusion class similarly showed no significant associations [Table/Fig-4].

Variables	β	SE	Proportional OR	95% CI	p-value
Fixed appliances (ref: clear aligners)	1.040	0.640	2.83	0.81-9.92	0.104
Age (years)	-0.004	0.031	1.00	0.94-1.06	0.903
Male (ref: female)	-0.519	0.515	0.59	0.22-1.63	0.313
Treatment duration (months)	0.006	0.021	1.01	0.96-1.05	0.780
Class-II (ref: Class-I)	0.033	0.625	1.03	0.30-3.52	0.958
Class-III (ref: Class-I)	-0.117	0.557	0.89	0.30-2.65	0.833
Extraction (yes vs no)	0.935	0.568	2.55	0.84-7.76	0.100

[Table/Fig-4]: Ordinal logistic regression analysis of factors associated with External Root Resorption (ERR) severity.

DISCUSSION

The ERR is a well-recognised adverse consequence of orthodontic treatment arising from mechanical forces interacting with individual biological susceptibility. The principal finding is that ERR was significantly more frequent and extensive among patients treated with fixed appliances compared with clear aligners. Fixed appliances demonstrated five times higher odds of ERR occurrence and affected significantly more teeth per patient. However, among patients who developed ERR, no significant difference in severity was observed between treatment modalities. The 5.08-fold increased odds corroborate systematic reviews identifying ERR as a common complication of orthodontic tooth movement [3]. The finding that multiple teeth were affected supports reports by Brin I et al., showing that ERR typically involves multiple teeth, especially anteriorly [2]. The observed prevalence of 84.5% in fixed appliance patients versus 55.8% in aligner patients represents one of the first direct comparisons using panoramic radiography in a mixed-age cohort. These findings parallel CBCT-based investigations by Yi J et al., and Li Y et al., who reported higher resorption prevalence in fixed appliance groups [10,12]. Krieger E et al., also observed ERR in over half of aligner patients, though extent was generally mild [11].

Moderate-to-severe ERR (≥3 mm) occurred in 22.8% of resorption instances in fixed appliance cases compared with only 5.2% in aligner cases, suggesting clear aligners may offer protective effects against clinically significant root shortening. This mirrors findings by Li Y et al., who reported greater root shortening in fixed appliance patients, supporting the view that while aligners reduce ERR severity, they do not eliminate risk [12].

Fixed appliances affected more teeth per patient, with over three teeth involved in 28.6% of cases compared with 12.5% in the aligner group. This broader multi-tooth involvement is clinically important, as it may have greater long-term functional consequences. While most previous reports focused primarily on single-tooth severity [10-13,17], our results highlight the cumulative burden of ERR across the dentition, which has not been extensively documented in aligner literature. Continuous forces from fixed appliances may predispose multiple teeth to resorption simultaneously.

Bilateral involvement was more common in the fixed group, indicating a more symmetrical and widespread resorption pattern. This may reflect biomechanical differences between modalities: fixed appliances deliver sustained forces through archwires, whereas aligners apply intermittent forces removed during eating and oral hygiene. Few previous studies have explicitly reported side distribution, but our findings support the principle that resorption extent and distribution depend strongly on appliance biomechanics [3,10-14].

Maxillary lateral and central incisors were most frequently affected in the fixed appliance group. Brin I et al., and Mirabella AD and Årtun J attributed maxillary incisor vulnerability to root morphology, frequent involvement in torque and retraction, and high stress concentrations [2,9]. Conversely, molars and premolars demonstrated minimal changes in both groups (7.6% in fixed, 11.9% in aligners), consistent with previous reviews [3,12].

Treatment duration was significantly longer in the fixed appliance group (mean: 25.5 months) compared with the aligner group (mean: 20.3 months; p=0.026). Extended treatment time is a recognised risk factor for ERR. Sameshima GT and Sinclair PM demonstrated that treatment exceeding two years was strongly associated with greater resorption, while Segal GR et al., highlighted the cumulative effect of prolonged force application [5,6]. The current study findings suggest that typically shorter treatment duration with aligners may contribute to their relatively lower ERR severity.

Although gender distribution differed between groups, ERR prevalence and severity were not significantly influenced by gender, consistent with several reports [8], though some studies suggest higher female susceptibility due to hormonal or genetic factors [7]. Age also showed no significant association with ERR in our cohort, contrasting with findings by Segal GR et al., suggesting older patients may be at higher risk [5]. This discrepancy may reflect our relatively narrow age range or the protective effect of aligners in the older cohort.

Limitation(s)

Study limitations include the retrospective design and reliance on panoramic radiography, which may underestimate ERR compared with CBCT. However, panoramic radiographs remain the standard clinical tool for ERR screening due to lower radiation exposure and cost-effectiveness. Future prospective studies using CBCT and standardised force protocols would provide more precise quantification of ERR progression.

CONCLUSION(S)

The present study revealed that ERR occurred with both fixed appliances and clear aligners, but the fixed appliance group experienced higher rates and severity, particularly affecting maxillary incisors. Clear aligners resulted in less frequent and severe resorption. Despite these differences, root resorption remains a clinical concern, necessitating careful case selection, individualised treatment, and regular monitoring. Future research should focus on controlled trials with standardised imaging, matched treatment durations, and exploration of patient-specific risk factors and biomechanical parameters to refine treatment strategies and reduce the risk of ERR in orthodontics.

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