Journal of Contemporary Orthodontics 2024;8(2):102–113

Content available at: https://www.ipinnovative.com/open-access-journals

Journal of Contemporary Orthodontics

Journal homepage: https://www.jco-ios.org/

Review Article

Root resorption in orthodontic treatment with clear aligners: A systematic review

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ARTICLE INFO

Article history:
Received 20-01-2024
Accepted 01-02-2024
Available online 15-05-2024

Keywords:
ERR
CAT
FAT

ABSTRACT

Background: The use of clear aligners in orthodontic treatment has grown in popularity because of its visual appeal and patient-friendly nature. In contrast to fixed appliance treatments (FAT), the relationship between external apical root resorption (ERR) and clear aligners is still unknown.
Objective: The objective of this systematic review was to evaluate the frequency and severity of root resorption in clear aligner orthodontic treatment, compare it to fixed multi-bracket appliances, and determine the factors that contribute to this phenomenon.
Materials and Methods: The review was conducted without regard to linguistic constraints, using PRISMA criteria and examining studies from 2000 to 2023. MEDLINE/PubMed, EMBASE, and the Cochrane Central Register of Controlled Trials were among the databases that were searched. MeSH words about root resorption, aligners, and orthodontics were utilized. Cohort studies, case-control studies, randomized clinical trials, and comparative clinical studies assessing root resorption during clear aligner orthodontic therapy.
Results: Out of the 116 studies that were first found, 11 studies were included in the final analysis. While several trials revealed equal results or no significant differences, six reported decreased incidence and severity of ERR in clear aligner therapies (CAT) compared to FAT. A meta-analysis revealed that CAT had less severe ERRs than FAT. In both treatments, ERR frequently affected the maxillary lateral incisors. Potential significant factors included the mechanical distinctions between CAT and FAT, length of therapy, tooth movement velocity, degree of malocclusion, and extraction instances.
Conclusion: The review indicates that there may be differences in the frequency and intensity of ERR between CAT and FAT. In multiple investigations, CAT demonstrated reduced ERR severity, although it did not completely eradicate its recurrence. Mechanical characteristics, length of therapy, degree of malocclusion, and number of extraction instances were factors affecting ERR. The included studies' quality assessment indicated a moderate to substantial risk of bias, highlighting the need for more thorough research using reliable measuring techniques, especially when utilizing CBCT imaging.

1. Introduction

The field of orthodontics has seen tremendous change recently due to an increase in demand from patients

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https://doi.org/10.18231/j.jco.2024.018

looking for discrete and aesthetically beautiful ways to have a perfect smile. The increasing inclination towards orthodontic treatments that prioritize comfort and aesthetics is ascribed to social and professional factors. The increasing acceptance of clear aligners among different systems is a prime example of this trend.[1]

The promise of clear aligners to maintain ideal dental hygiene while offering comfortable, discrete, and affordable solutions has attracted a lot of attention.[2] On the other hand, patients frequently have discomfort and aesthetic difficulties with standard fixed multi-bracket appliances, despite their effectiveness in accomplishing orthodontic adjustments. Furthermore, the orthodontic motions caused by these fixed appliances may apply excessive pressure at the root level, which could result in external apical root resorption (ERR).[3,4]

The incidence and severity of post-treatment root resorption linked to fixed multi-bracket appliances have been thoroughly reported by numerous research.[5] But even with the growing popularity of clear aligners, there is still a lack of knowledge on the connection between root resorption risk and aligner-based orthodontic therapy. While fixed appliances have been shown to have negative consequences in the past, it is still unclear how much aligners have caused root resorption. The progressive inflammatory response, or ERR, that arises during orthodontic treatments presents possible risks that could jeopardize the effectiveness of orthodontic procedures.[6,7]

The primary reason for the surge in popularity of clear aligner treatment (CAT) over Fixed Appliance Treatment (FAT) is its perceived benefits in terms of comfort and inconspicuousness.[3,4] ERR is significantly influenced by FAT, with more occurrences under stronger forces as contrasted to lighter forces.[8]

Different bonding methods and mechanical effects on teeth are two distinguishing aspects between CAT and FAT that raise the likelihood of varied degrees of root resorption associated with each treatment.[9] Regarding the superiority of CAT over FAT in alleviating ERR, however, the results of the trials that have been done so far show mixed results.[10–12] Due to inadequate sample numbers, a prior systematic review on CAT and ERR did not have tight inclusion criteria, which limited quantitative analysis.[11,12] Furthermore, the accuracy of the results may have been impacted by the fact that previous research mostly used panoramic radiographs for measurement, employing root-crown ratios (RCR) rather than precise measurements of the length of the tooth or roots.

Understanding the implications of external root resorption in orthodontic treatments is crucial, as it poses challenges that may compromise the success of these interventions.[11] While fixed appliances have been extensively studied and linked to ERR, the influence of clear aligners on this phenomenon remains less elucidated. The comparison between CAT and FAT in terms of their potential to induce or mitigate ERR is a critical aspect that demands further investigation.[12]

By employing advanced imaging techniques like CBCT and adopting a quantitative approach, this systematic review seeks to offer a comprehensive analysis that may shed light on the potential advantages of clear aligner treatments in reducing the incidence and severity of external apical root resorption compared to traditional fixed appliance treatments.

The primary objectives of this study are to assess whether orthodontic treatment using aligners is linked to an increased risk of root resorption. Additionally, the study aims to compare the occurrence and intensity of root resorption caused by aligners with that induced by fixed multi-bracket appliances. This systematic review seeks to address existing gaps in knowledge by investigating the frequency and severity of ERR in patients undergoing CAT in comparison to those undergoing FAT. The review also explores associated risk factors for each treatment method, utilizing state-of-the-art imaging techniques from recent research to enhance our understanding of the potential advantages of CAT in minimizing ERR in orthodontic practice.

2. Materials and Methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) standards were followed in this systematic review, guaranteeing a thorough and organized methodology. Before starting the review, methodologies were developed following the Cochrane Handbook for Systematic Reviews of Interventions' recommendations. A systematic and standardized procedure for the literature search, research selection, data extraction, and synthesis was ensured by this meticulous planning. Following PRISMA principles improved the approach, results, and conclusions of the review by facilitating transparency and completeness, which increased the review's credibility and dependability. The methodical methodology adhered to strict standards, enabling a comprehensive evaluation of the evidence about the study issue or subject being studied.

2.1. Focused question

"What is the incidence and severity of root resorption in orthodontic treatment utilizing clear aligners, and what are the contributing factors associated with this phenomenon?"

Table 1: Data extraction sheet

Sl No.	Study	Population	Type of Study	The age range of patients	Parameters checked	Intervention	Comparison	Outcome	Time period
1.	Aman C et al., 2018[13]	160 patients with clear aligner therapy.	Retrospective, experimental study	The mean age was 34 ± 16 years.	External apical root resorption (ERR) through CBCT images	Patients underwent comprehensive clear aligner therapy	Assessing changes in root length in patients with clear aligner therapy and traditional fixed appliance therapy.	Change in root length, specifically external apical root resorption,	2.5 years
2.	Cai et al., 2015[14]	23 patients undergoing orthodontic treatment	Retrospective study	The mean age was 31.7 ± 3.8 y	External apical root resorption (ERR)	Maxillary and Mandibular incisors/ canines with aligner therapy	Comparison between conventional and aligner therapy	ERR in millimeter through Panoramic radiographs	21 months
3.	Eissa O et al., 2018[15]	33 patients requiring orthodontic treatment	Case-controlled clinical trial	Aged between 14 and 25 years	Completion of root apices, a specific range of crowding (4–6 mm), and the absence of Class II or III malocclusion,	Smart Track® aligners, Damon-Q self-ligating brackets, and regular pre-adjusted edgewise brackets.	Evaluate and compare the effects of the three orthodontic treatments on root resorption in the maxillary incisors.	Degree of root resorption observed in the maxillary incisors post-orthodontic treatment.	Period necessary for the orthodontic treatment
4.	Fowler B et al., 2010[16]	90 female patients who underwent orthodontic treatment	Observational study	Aged 10–58 years	External Apical Root Resorption (EARR) in different tooth groups of both the maxilla and mandible.	Conventional edgewise appliance and the Invisalign clear removable aligners.	The comparison was between the incidence and severity of EARR in patients in both groups	Presence and severity of EARR in different tooth groups	Period necessary for the orthodontic treatment

Continued on next page

Table 1 continued

5.	Gay et al., 2017[17]	71 healthy adult patients with Class I malocclusion	Observational study,	age range from 32.8 ± 12.7 years old.	Root and crown lengths of 1083 teeth were evaluated before and after Invisalign treatment	Patients were treated with Invisalign® aligners, and panoramic radiographs were used to measure tooth dimensions	Comparison was between the EARR	One tooth affected by a reduction in root length, with an average of 6.38 ± 2.28 teeth affected per patient.	Period necessary for the orthodontic treatment
6.	Iglesias-Linares A et al., 2017[18]	372 Caucasian patients who had completed orthodontic treatment	Case-control study	The age range was 28.48 years	Angle classification, type of orthodontic treatment, treatment time, vertical and sagittal apical displacement, and genetic variations	Comprehen- sive orthodontic treatment either with removable aligners (Invisalign) or fixed appliances (straight wire technique)	Patients treated with removable aligners to those treated with fixed appliances	Presence or absence of orthodontically induced external apical root resorption	Period necessary for the orthodontic treatment
7.	Krieger E et al., 2013[19]	100 healthy patients treated with removable thermoplastic aligners	Retrospective study	The average age of 37.7 years	Changes in root-crown ratio (RCR) before and after orthodontic treatment	Treatment involved using aligners with additional attachments to enhance retention.	Pre- and post-treatment panoramic radiographs and lateral cephalograms were compared to assess tooth movement and root-crown ratio changes.	relative changes in RCR, real orthodontic tooth movement, and the incidence/severity of root length reduction	The mean treatment time was 19.8 months

Continued on next page

Table 1 continued

8.	Wang G et al., 2017[20]	28 patients who underwent orthodontic treatment	Comparative study	Not mentioned	Assessed root resorption and bone defects using CBCT images	Patients were divided into two groups bracketless invisible appliances and straight wire appliances.	Compared the incidence and severity of root resorption and bone defect	Significant difference in root resorption between the experimental and control groups	Three-time points: pre-operation, 6 months after operation, and post-operation
9.	Yi J et al., 2018[21]	80 non-extraction patients who received orthodontic treatment	Retrospective study	Age range is 21.80 ± 5.11years	Assessed EARR by analyzing panoramic radiographs taken before and after treatment to measure crown and root lengths of various incisors	Patients were divided into two groups based on the treatment modality received: Conventional Anchorage Treatment or Functional Orthopedic Treatment.	Compared the occurrence and severity of EARR between the Conventional Anchorage Treatment and Functional Orthopedic Treatment.	Conventional Anchorage Treatment resulted in significantly less EARR compared to Functional Orthopedic Treatment.	Period necessary for the orthodontic treatment.
10.	Barbagallo et al., 2008[22]	27 patients undergoing orthodontic treatment	Randomized controlled trial	Mean age: 15.3 years	External root resorption	Orthodontic treatment using fixed appliances (segmental technique) and aligners (ClearSmile)	Levels of force (conventional system): light (25 g), heavy (225 g) and aligners	Compared with the control group, the heavy force group presented the highest incidence of resorption, followed by the aligner-treated group. The light forces group displayed the lowest RR	8 weeks

Continued on next page

Table 1 continued

11.	Brandon et al., 2010[23]	90 patients 1080 teeth (CI, LI, C) maxillary and mandibular	Retrospective cohort study	Average age: 15.8 years; aligners group: 38.2 years	External root resorption	45 patients: orthodontic treatment using fixed appliances (Edgewise technique 45 patients: orthodontic aligner treatment (Invisalign)	Comparison of posttreatment incidence and severity of RR between fixed appliances and aligners	The group treated by Invisalign showed no signs of RR on any of the 540 evaluated teeth. Regarding the fixed appliances, RR was noted in 2.2 % to 50 % of teeth. The incidence of root resorption was 2.2 %, observed at maxillary lateral incisors	Fixed appliances: 19.7 months Invisalign: 20.36 months

2.2. Search strategy

We used an interdisciplinary framework that included cohort studies, case-control studies, and randomized clinical trials while developing our methodological strategy. We looked into how platform switching affected clinical results and whether it was related to changes in bone levels. We carefully reviewed original research papers, review articles, bibliographies, and pertinent citations to make sure the review was thorough, with a focus on finding Randomized Clinical Trials (RCTs).

We used the Cochrane Central Register of Controlled Trials, EMBASE, and MEDLINE/PubMed databases in our search method. We obtained articles from 2000 to 2023, with no limitations on language or year of publication, so our data collection and analysis could cover a wide range. During the search process, MeSH terms such as "Orthodontics," "Tooth Movement Techniques," "Root Resorption," "Tooth Root," "Orthodontic Appliances, Removable," "Clear Aligners," "Dental Occlusion, Anomalous," "Malocclusion," "Tooth Diseases," "Dental Pulp Diseases," were employed as search keywords.

The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) Checklist was closely matched to the study's methodology to guarantee that its recommendations were followed. Following PRISMA principles, the inclusion and exclusion criteria were carefully set in advance and applied uniformly to all of the examined papers. Scholars thoroughly analyzed entire texts to determine whether they met the predetermined inclusion requirements. To find pertinent studies in databases like MEDLINE/PubMed, Cochrane Central Register of Controlled Trials, and EMBASE, the search strategy detailed in Table 1 was closely adhered to. To find any more pertinent papers, a manual search of the reference lists of the included research was also done (cross-referencing). The systematic methodology in research selection and evaluation, along with adherence to the PRISMA criteria, guaranteed a thorough and rigorous synthesis of the existing literature. Figure 1 shows the PRISMA flowchart for our systematic review.

3. Selection Criteria

3.1. Inclusion criteria

1. Cohort studies, case-control studies, randomized clinical trials (RCTs), and comparative clinical studies were the main areas of emphasis for the inclusion criteria
2. Research involving individuals receiving clear aligners only as part of their orthodontic treatment.
3. Articles discussing the primary or secondary result of root resorption.
4. No language restrictions to guarantee a thorough inclusion of pertinent studies.
5. Studies that provide information on root resorption during clear aligner orthodontic therapy.

3.2. Exclusion criteria

1. Articles unrelated to root resorption in clear aligner orthodontic therapy are excluded.
2. Expert opinions, editorials, letters, conference abstracts, and grey literature.
3. Research concentrating only on traditional braces or other orthodontic tools, or research including populations not treated with clear aligners.
4. Research lacks crucial information or methodological specifics relevant to the evaluation of root resorption or the use of clear aligners

The determination of inclusion and exclusion criteria was guided by the aspects of Study design, Participants, Interventions, Comparisons, and Outcomes (SPICO).

3.3. PICO criteria

Population: Individuals getting clear aligner orthodontic treatment.

3.4. Intervention

Using just clear aligners for orthodontic treatment.

3.5. Comparison

Various clear aligner treatment kinds, treatment time variations, age groups, or comparisons with conventional orthodontic treatments (braces, for example) could all be considered as possible comparison groups.

3.6. Outcome

The main result is the measurement and evaluation of root resorption. This covers the extent, occurrence, and site of root resorption that happens during or following clear aligner orthodontic treatment.

3.7. Study design

The majority of the research examined root resorption in patients treated with clear aligners, including cohort studies, case-control studies, randomized clinical trials, comparative clinical studies, and systematic reviews/meta-analyses.

3.8. Screening and selection

Two authors worked together to conduct the search and screening, and their degree of agreement was measured using a κ value of 0.83, which indicates a high degree of concordance. The search-turned-up articles underwent a thorough evaluation for inclusion or exclusion according

Table 2: ROBANS bias

Domain	Aman C et al., 2018[13]	Cai et al., 2015[14]	Eissa O et al., 2018[15]	Fowler B et al., 2010[16]	Gay et al., 2017[17]	Iglesias-Linares A et al., 2017[18]	Krieger E et al., 2013[19]	Wang G et al., 2017[20]	Yi J et al., 2018[21]	Barbagallo et al., 2008[22]	Brandon et al., 2010[23]
Random sequence generation	1	3	1	1	2	1	1	2	1	1	1
Allocation concealment	1	3	1	1	1	1	1	1	1	1	1
Selective reporting	1	1	1	1	1	1	1	1	1	1	2
Other bias	2	1	2	2	1	2	2	2	2	2	2
Blinding of Participants and Personnel	1	1	1	1	1	1	1	1	1	1	1
Blinding of outcome assessment	1	3	1	2	2	1	1	3	1	1	3
Incomplete outcome data	1	2	1	1	1	1	1	1	1	1	1
Total	8	14	8	9	9	8	8	11	11	8	11

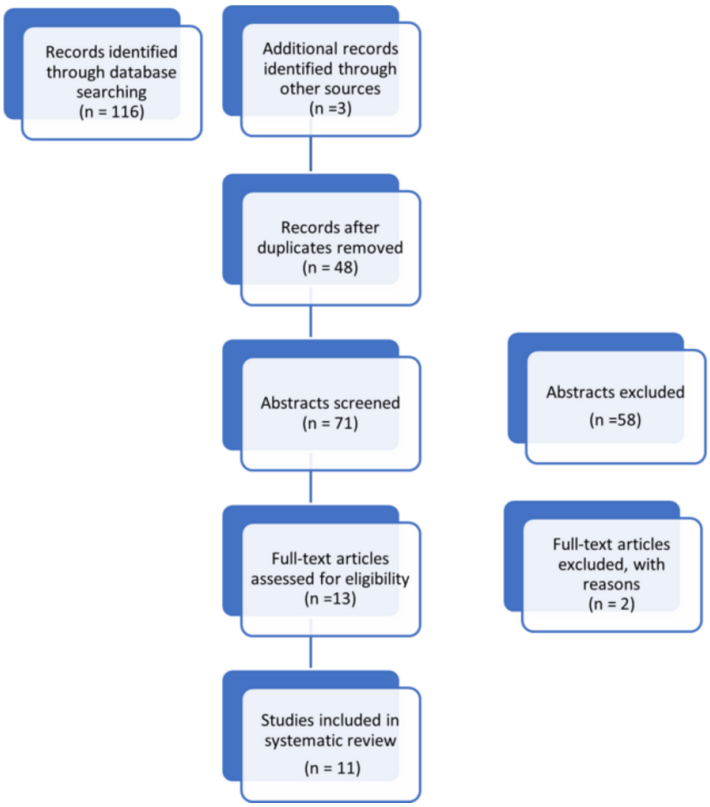

Figure 1:

to predetermined standards, which were divided into four phases.

Citations that did not meet the criteria for consideration were immediately disregarded during the first stage. Moving on to Step 2, one reviewer carefully assessed the abstracts and titles of every article that was retrieved to make sure that they fulfilled the predefined standards. Articles that did not fit within the boundaries of inclusion were immediately eliminated, and those that raised questions were thoroughly examined in their entirety. When there was uncertainty, the viewpoint of a second reviewer was sought out for assessment.

Moving on to Stage 3, every article that was chosen in Stage 1 was carefully examined by two separate reviewers to confirm that it matched the specified eligibility requirements. In this stage, papers with improper study designs or insufficient baseline and endpoint outcome measures were excluded. Furthermore, papers lacking proper referencing were disregarded.

At last, Stage 4 involved a careful study of every article that was considered appropriate for inclusion and the extraction of relevant data from each one. Critical evaluations of the clinical approaches used in all the research under review were conducted, with an emphasis on the types of interventions and results that were looked into in each specific study.

3.9. Data extraction

The first author carried out the first round of data extraction, after which the second author reviewed and improved it. For every full-text article that satisfied the predetermined inclusion criteria, data extraction was done automatically. As shown in Table 1, this procedure used digital tools (Office Excel 2013 software, Microsoft Corporation) in a consistent format. The aggregated data were methodically divided into discrete parts, including information on authorship and year of publication, study design, participant demographics, age range, intervention details, comparator components, and final results.

3.10. Assessment of risk of bias

Given the experimental character of the studies—which were Randomized Clinical Trials—ROBANS (Risk of Bias Assessment Tool for Non-randomized Studies) criteria were employed to mitigate potential bias. These details are listed in Table 2. (1) Random sequence generation; (2) Allocation concealment; (3) Selective reporting; (4) Other kinds of bias; (5) Blinding of Participants and Personnel; (6) Blinding of Outcome Assessment; and (7) Incomplete Outcome Data were among the domains covered by the assessment.

Research that presented thorough data in each of these areas was categorized as exhibiting an excellent degree of methodological rigor, as Table 2 illustrates. Individuals who were able to exhibit two or three of these criteria were acknowledged as having a respectable standard of quality. On the other hand, studies with insufficient data on most of the criteria were labelled as having a lower quality level.

4. Results

All citations were imported, and 116 studies in all were found as described in Table 1. Following the removal of duplicates, abstract screening, and full-text article review, two studies were removed following full-text analysis for the following reasons: 1. No root resorption assessment; 2. Localized or staged an intervention. Consequently, 16 studies were still needed for qualitative analysis and 11 studies were appropriate for a systematic review.

Five of these were retrospective studies[11,13,14,19,21] that solely included CAT patients, the remaining one was a case-control genetic study, and the remaining four were cohort studies. Every study that was included evaluated the ERR in the maxillary incisors, and the majority of them also looked at the mandibular and canine incisors. The premolars and molars ERR were examined in two investigations. One study used a grading system, while all other studies reported ERR by measuring absolute or relative root length. Three cohort studies, in which just the incisors were evaluated and no teeth were pulled, were included in the review.

4.1. Risk of bias

We used the ROBANS-I technique to assess the risk of bias among the studies as one of the four levels (low, moderate, serious, and critical), as none of the included research were RCTs. As shown in Table 2, the assessment's overall outcome indicated that six studies had a moderate risk of bias, and the remaining five had a substantial risk of bias. Measurement of results was the most challenging domain, followed by confounding and straying from planned actions.

5. Discussion

We assessed the incidence of ERR brought on by CAT and then compared the variation and severity of ERR between CAT and FAT for this systematic review and meta-analysis. Out of the 11 included studies, six indicated lower incidence and severity of ERR in CAT compared to FAT, seven, twenty-four, two described almost the same incidence and severity, and ten, and eleven reported no significant ERR in CAT. ERR severity in CAT was substantially lower than in FAT, according to a meta-analysis.

In line with the systematic review, Fowler observed that the maxillary lateral incisors experienced the most significant resorption. Furthermore, subgroup analysis in this study demonstrated a more substantial decrease in ERR in the mandibular lateral incisors.[16]

In all the 11 studies, patients received treatments using transparent aligners, and at least one tooth resorption was seen in each of the subjects. This suggested that using transparent aligners won't be able to prevent the incidence of ERR, much like other orthodontic treatments. According to studies from Castro et al. and Krieger et al.,[19,24] 46% of the teeth in CAT showed evidence of dental recession (ERR); in contrast, Wang et al. and Gay et al. reported occurrences of 85.3% and 41.81%, respectively. Since Wang et al.'s study did not involve any tooth extractions, the technique may have contributed to the study's noticeably higher incidence.[20] ERR was measured by measuring both the reduction in root length and the resorption of all surrounding surfaces, whereas root length may not have been shortened. While root/tooth length, or RCR, is the primary measure used in the majority of other research to assess root resorption, certain teeth with unreduced root length may nevertheless have ERR.

Differences in ERR arise from variations in the mechanical characteristics of CAT and FAT. Clear aligners, when periodically removed for eating and oral hygiene, generate intermittent forces. Sawicka et al. found lower ERR with intermittent forces during orthodontic treatment. However, limited data is comparing the impact of continuous and intermittent forces on ERR post-full orthodontic treatment. Additionally, repetitive tooth movement induced by jiggling forces increases ERR incidence.[21] While CAT can reduce ERR compared to FAT by facilitating predictable tooth movement and preventing recurrent tooth shifts, its effectiveness relies on full patient participation and well-designed treatment plans by orthodontic specialists.

Barbagallo et al. assessed CAT and FAT using light and heavy forces, respectively, for localized orthodontic treatment—an aspect not covered in our study. Their findings suggested that the impact on External Root Resorption (ERR) in CAT is comparable to the effects of mild force in FAT. Similarly, the study conducted by Gay et al. reached the same conclusion.[22]

Out of the eleven studies incorporated in the systematic review, seven addressed additional factors potentially influencing ERR in CAT and FAT. These factors encompassed variables such as gender, treatment duration, direction and extent of tooth movement, malocclusion type and severity, crowding intensity, proximity to the cortical plate post-treatment, use of elastics, genetic factors, and others. Among these, only the study by Aman et al. identified gender as a significant risk factor for ERR ($P = .04 < .05$), indicating that males experienced higher ERR than females.[23] However, the remaining trials found no notable distinctions in ERR.[10,24] Two other studies mitigated this factor by maintaining an equal distribution of males and females in both the experimental and control groups.[17,20]

Age and treatment duration were not identified as confounding variables. Extended treatment duration in Fixed Appliance Therapy (FAT) has been associated with severe External Root Resorption (ERR), as reported by Segal et al.[23] Interestingly, even with a slower tooth movement velocity in Clear Aligner Therapy (CAT) compared to FAT, there may be a reduced occurrence of ERR. Additionally, research indicates that the treatment duration for CAT can be as short as or even less than that of FAT.[21] Different types of malocclusions during orthodontic treatment with clear aligners can significantly impact tooth length. For instance, in Class I malocclusion with less than a half-step Class II molar, ERR was markedly lower than in Class II malocclusion, with no significant difference observed in other malocclusion categories. The treatment objectives and strategies employed will also influence the extent of tooth movement, thereby affecting ERR.

Moreover, it was discovered that the severity of crowding presents a risk factor for ERR. In patients undergoing FAT, ERR was significantly lower in cases with mild crowding compared to those with severe crowding.[6] However, there is currently no study comparing ERR between FAT and CAT in patients with different degrees of crowding. Additionally, tooth extractions, involving more movement and a longer healing period than alternative options, may be associated with an elevated risk of endodontia-related complications (ERR). Notably, studies related to extraction cases and ERR in CAT exhibited a high level of bias among the eleven studies included in the qualitative analysis. Four studies included extraction cases, six studies excluded them from the outset, and one study did not specify its inclusion or exclusion of extraction cases.

Among the four studies investigating extraction cases,[17,19,20,22] three indicated that Clear Aligner Therapy (CAT) could reduce External Root Resorption (ERR), while only one reported no noticeable difference in ERR between CAT and Fixed Appliance Therapy (FAT). Among the three studies included in the quantitative analysis, two specifically excluded extraction cases, while the third did not clarify whether tooth extraction was part of its inclusion or exclusion criteria. The limited number of studies including extraction cases made it challenging to determine the impact of tooth extraction on the observed differences in ERR between CAT and FAT.

The evaluation of study quality suggests that all the studies included in this review exhibit a moderate to high risk of bias. Therefore, caution should be exercised in interpreting the findings of this review. Based on the reasoning above, CBCT is a more valid and trustworthy tool for measuring outcomes, which is the most troublesome domain. This implies that to reduce measurement bias, CBCT may be used in subsequent research to calculate ERR. Future research should also be more carefully planned to reduce bias brought on by straying from planned

interventions and confounding variables.

This review did not look at any RCTs, and there is a chance of bias because the ERR has not been measured consistently. Furthermore, only non-extraction instances were included in the majority of publications, and investigations into cases with more severe crowding were not conducted, which could potentially lead to confounding factor bias. More excellent research with minimal bias risk is advised.

6. Conclusion

There may be differences in the frequency and intensity of ERR between CAT and FAT. In multiple investigations, CAT demonstrated reduced ERR severity, although it did not completely eradicate its recurrence. Mechanical characteristics, length of therapy, degree of malocclusion, and number of extraction instances were factors affecting ERR. The included studies' quality assessment indicated a moderate to substantial risk of bias, highlighting the need for more thorough research using reliable measuring techniques, especially when utilizing CBCT imaging.

7. Source of Funding

None.

8. Conflict of Interest

None.

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Cite this article: Sachdev R, Reddy A, Md Nasir Khan Y, Ponnusamy A, Rohini T, Chhabria V. Root resorption in orthodontic treatment with clear aligners: A systematic review. *J Contemp Orthod* 2024;8(2):102-113.