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Review Article

Comparing Root Resorption in Fixed vs. Clear Aligner Orthodontics: A Radiographic Study

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ABSTRACT

This study aimed to investigate and evaluate the amount of external apical root resorption (EARR) in incisors after receiving orthodontic treatment employing fixed orthodontic appliances (FOA) or clear aligners (CAT). PRISMA criteria were used in conducting the systematic review. Retrospective studies and randomized control trials that used cone beam computed tomography, periapical radiography, and 2D panoramic radiography to assess EARR levels in anterior teeth following orthodontic treatment with CAT and FOA were included in this review. The PICO model was used to formulate the review's main question: does CAT result in lower levels of EARR than fixed orthodontic appliances? There were six articles in the review. One entailed article was a randomized clinical trial, while the other five were retrospective cohort studies. According to the meta-analysis, CAT had a lower EARR than FOA (SMD = 0.76, 95% CI = -1.17, -0.34; P < 0.00001). According to the subgroup analysis, maxillary central incisors had EARR that was statistically substantially lower; maxillary lateral incisors (SMD = -0.65, 95% CI = -0.98, -0.32; P = 0.0001), mandibular central incisors (SMD = -0.40, 95% CI = -0.65, -0.16; P = 0.001), and maxillary lateral incisors (SMD = -0.40, 95% CI = -0.70, -0.10; p = 0.009). This meta-analysis suggests that CAT is better than FOA in terms of EARR in the area of the anterior teeth.

Keywords: External apical root resorption, Clear aligner therapy, Fixed orthodontic appliances therapy, Anterior teeth

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Introduction

In place of permanent orthodontic equipment, more and more patients are choosing the more pleasant and aesthetically pleasing alternative treatment approach known as clear aligner therapy (CAT). From a mechanical perspective, the number of orthodontic pressures delivered to teeth by transparent aligners is theoretically different from that of fixed orthodontic equipment [1]. Research has indicated that the development of external apical root resorption (EARR) is significantly impacted by orthodontic pressures [2].

The precise nature of root resorption brought on by orthodontic treatment is yet unknown [3]. The cause of this syndrome is known to be multifaceted. Variables that affect root resorption can be either patient-related (e.g., age, gender, genetics, diet) or treatment-related (e.g., force utilized during treatment, length of therapy, appliance type, usage of elastics, extraction treatment, etc.) [4]. Heavy orthodontic forces are additionally known to generate noticeably larger amounts of EARR than low forces [3]. Thus, several scientific papers [5-

7] reveal that EARR is caused by the strong orthodontic pressures produced by orthodontic equipment.

EARR is a frequent inflammatory reaction that occurs in 27.7% of instances when fixed orthodontic appliances are being used for treatment [5]. To expose the cementum and hasten root resorption, the process is linked to the removal of the hyalinization zone from periodontal ligament blood vessels, which is initiated by microphage-like cells [3]. Because orthodontic teeth travel further, research has indicated that maxillary incisors are more vulnerable to EARR than other teeth [8]. In contrast to the constant forces generated during treatment with fixed orthodontic equipment, the pressures put on the teeth by aligners are intermittent. Furthermore, aligners exert less tension on teeth than permanent orthodontic equipment [9]. Because they induce stress in the radicular-apical region, these traits may affect EARR [10]. Patients receiving orthodontic therapy need to have their root resorption evaluated by an orthodontist [11]. Numerous studies have looked at EARR during CAT, but the findings are conflicting; some claim that EARR is lower with CAT than with fixed orthodontic equipment, while others suggest that CAT may raise EARR [4, 9, 12-16]. To determine the root-crown ratio and assess the teeth's lifespan, panoramic, periapical radiography, or cone-beam computed tomography is utilized [17].

This meta-analysis aimed to compare the severity of EARR during treatment with fixed orthodontic equipment and transparent aligners, as well as to update the existing research.

Materials and Methods

Protocol and registration

This systematic review was done using PRISMA guidelines. The PROSPERO (International Prospective Register of Systematic Reviews) database was updated with the systematic review process. Number of enrollment: CRD42021240269.

Focused question

The PICOS model was used to pose the query:

- Population (P): individuals who need orthodontic treatment due to malocclusion.
- Clear aligner treatment is an intervention/exposure to a risk factor (I).
- Control (C): treatment with fixed orthodontic appliances.
- Result (O): reduced amount of external apical root resorption.

When compared to fixed orthodontic equipment, can clear aligner treatment result in reduced levels of external apical root resorption?

Search strategy

On November 6, 2022, a systematic search of the medical literature was performed to determine all peer-reviewed papers published between 2016 and 2022 that analyzed the amount of EARR in patients who received CAT or fixed orthodontic tools. Keyword combinations "Clear Aligner Appliances," "Fixed Orthodontic Appliances," and "Root Resorption" were used in MEDLINE (searched via PubMed), EMBASE (searched via ScienceDirect), the System for Information on Grey Literature in Europe, The Cochrane Library (Cochrane Central Register of Controlled Trials), and LILACS electronic bibliographic databases. The search was then expanded by searching the included articles' references for possible publishing.

Study selection and data collection process

After doing an electronic database search, three writers (K.J., M.V., and A. Var.) chose publications that seemed to fit the review's requirements and had suitable titles and abstracts. The final choice was decided following an examination of the full-text papers. If there were any differences, the fourth reviewer (A. Vas.) would have attempted to settle the dispute.

Inclusion criteria

1. Clinical studies that included orthodontic patients.
2. Studies published in English.
3. Studies that performed 2D panoramic radiographs, periapical radiographs, or cone beam computed tomography (CBCT) before and after orthodontic treatment.
4. No radiographic evidence of EARR before orthodontic treatment.
5. Retrospective studies, randomized control trials.

Exclusion criteria

1. Systematic reviews, case series, meta-analyses, and case reports.
2. In vitro studies or animal studies.
3. Articles that did not compare fixed orthodontic appliances with clear aligners.
4. Articles published more than 5 years ago.

Methodological quality

This systematic review was evaluated for overall quality and risk of bias using the Cochrane collaboration's ROBINS-I technique [18] and the Cochrane risk-of-bias test for randomized trials (RoB 2), as well as assessment of confounders, research participant choosing, categorization of interventions, departure from planned interventions, insufficient data, assessment of outcomes, and picking reported outcomes.

Statistical analysis

The research sample sizes, averages, and standard deviations were taken out to do a meta-analysis. To assess the standard mean difference (SMD) in EARR between patients who had clear aligner therapy and fixed orthodontic appliance therapy, a 95% CI was calculated using an inverse variance approach with a random effect model meta-analysis. The heterogeneity of the studies was assessed using Cochran's Q and I^2 tests. When $P < 0.05$ for Q statistics or $I^2 > 50\%$, the heterogeneity was deemed significant. With the use of Review Manager 5.4.1 software, summarized quantitative data were visually shown in forest plots [19]. Sensitivity analysis was used to examine if the results were stable and whether the results were affected in any way by the omission of particular research.

Results and Discussion

Study selection

Figure 1 shows the choice process for the study. 1276 articles were found in the first search of the electronic database. Following the elimination of articles deemed irrelevant based on their abstracts and titles, 10 full-text articles were obtained, and their appropriateness was assessed. Four papers were eliminated for the following reasons: two research projects were eliminated due to being theses [20, 21], one research was deemed inappropriate because it was a case-control genetic connection research [22], and the other research was eliminated due to its being published in Mandarin [23]. As a result, the qualitative and quantitative data analysis contained six articles [9, 12, 14, 16, 24, 25].

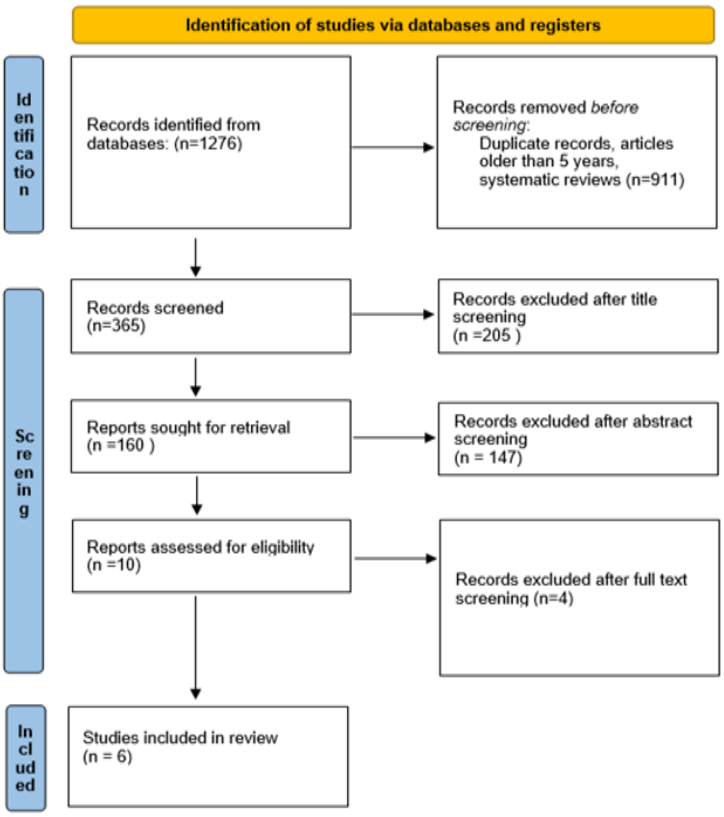


Figure 1. PRISMA flow diagram

Study characteristics

Table 1 displays the features of the six papers included in the review. Five of the six papers were retrospective cohort research, while one was a randomized clinical trial. The papers had publication dates ranging from 2017 to 2022. Many participants varied in age from 14-31 years, ranging from 33-110 years (a total of 391 patients had been recruited in all six investigations).

There was no significant difference in treatment duration across modalities. All of the trials included in this review compared clear aligner treatment to fixed orthodontic equipment. Two studies [12, 25] compared transparent aligners to two distinct fixed orthodontic products. Four of the six studies analyzed mandibular incisors, and all six tested maxillary incisors [9, 14, 16, 24]. Dogs were also assessed in two investigations [14, 16]. Four researchers used CBCT to quantify EARR [9, 12, 16, 25], one research used a 2D panoramic radiograph [14], and one research used a 2D periapical radiograph during assessments [24].

Table 1. General characteristics of the selected studies

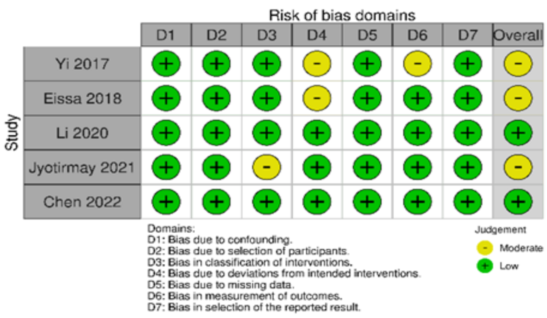
	Reference	**Study type**	**Participants (sample size)**	**Intervention (type of appliance)**	**Participants (mean age, years (SD))**	**Participants (gender)**	**Evaluation method**	**Evaluated teeth**	**Outcome (root resorption)**
1	Eissa *et al.* [12]	Retrospective	33 patients	G1:Smart Track® aligners, G2: Damon-Q self-ligating brackets, G3:Regular pre-adjusted edgewise brackets	G1: 18.34 (2.82) G2: 17.71 (2.22) G3:17.34 (2.38)	G1: 5 males, 6 females G2: 4 males, 7 females G3: 6 males, 5 females	CBCT	Maxillary central incisors,maxillary lateral incisors	G1: 0.44 ± 0.35mm, G2: 0.55 ± 0.38mm, G3: 1.04 ± 0.67mm
2	Li *et al.* [14]	Retrospective	70 patients	G1: Invisalign clear aligners, G2: Conventional fixed orthodontic appliances (Victory Series)	G1: 24.71 (7.48) G2: 2.51 (6.47)	G1: 13 males, 22 females G2: 8 males, 27 females	CBCT	The maxillary and mandibular canines, as well as the central and lateral incisors, make up a total of 373 teeth.	G1: 0.13 ± 0.47mm G2: 1.12 ± 1.34mm
3	Yi *et al.* [9]	Retrospective	80 patients	G1: Clear aligner therapy (sequential thermoplastic appliances) G2: Fixed orthodontic appliances (pre-adjusted edgewise appliance)	G1: 21.80 (5.11) G2: 23.28 (5.60)	G1: 31 females, 9 males G2: 29 females, 11 males	Digital panoramic radiographs	Maxillary and mandibular central and lateral incisors (total 640 teeth)	G1: 5.13 ± 2.81%, G2: 6.97 ± 3.67%
4	Jyotirmay *et al.* [16]	Retrospective	110 patients	G1: Fixed appliances (3M, USA) G2: Clear aligners	G1: 23.71 (6.37) G2: 21.62 (3.58)	G1: 32 females, 23 males G2: 34 females, 21 males	CBCT	Maxillary and mandibular central and lateral incisors, maxillary and mandibular canines (total 576 teeth)	G1: 1.51 ± 1.34 mm G2: 1.12 ± 2.36 mm
5	Toyokawa-Sperandio *et al.* [24]	Randomized clinical trial	39 patients	G1: OAs (SmartTrack, InvisalignTM; Align Technology, San Jose, CA, USA). G2: Fixed metallic orthodontic appliance (slot 0.022” × 0.030”, 3M Unitek, Monrovia, CA, USA)	G1: 23.60 (5.65) G2: 20.56 (4.51)	G1: 8 females, 12 males G2: 7 females, 13 males	Periapical radiographs	Maxillary and mandibular incisors (total 312 teeth)	G1: 0.66 ± 0.19 mm G2: 0.73 ± 0.21 mm

6	Chen *et al.* [25]	Retrospective	59 patients	G1: fixed orthodontic appliances with 0.022-in slot (Victory Series; 3M Unitek, Calif). G2: Damon Q with a 0.022-in slot (DQ; Ormco, Orange, Calif). G3: Aligners (Invisalign, Align Technology, Calif)	G1: 23.60 (3.19) G2: 23.71 (3.44) G3: 22.67 (3.12)	G1: 11 females, 9 males G2: 13 females, 8 males G3: 12 females, 6 males	CBCT	Maxillary central incisors	G1: 0.87 ± 1.08 mm G2: 0.94 ± 1.41 mm G3: 0.92 ± 0.87 mm

Note: G = treatment group, SD = standard deviation, % = percentage, CBCT = cone beam computed tomography

Quality assessment

Based on the ROBINS-I tool, there were negligible dangers of perplexing, participant selection, data shortages, and reported results choice bias in all five papers. Two out of five studies exhibited moderate bias from deviations from targeted interventions [9, 12], one research had a moderate risk category on intervention bias [16], and one study had a moderate risk of evaluating findings [9]. Two research revealed a low chance of bias for each component analyzed [14, 25]. According to the Cochrane risk-of-bias evaluation for randomization (RoB 2), one study showed a moderate risk of bias in blinding participants and staff [24]. There were three studies with low risk of bias [14, 24, 25] and three with high risk overall [9, 12, 16] **(Figure 2)**.



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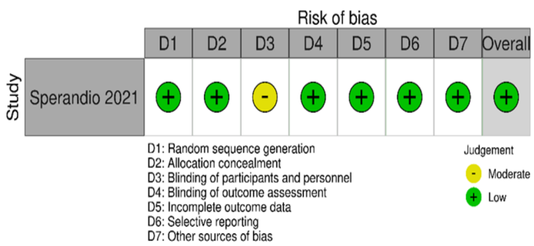

b)

Figure 2. Quality assessment

Quantitative synthesis of the results

Even with differing scales, the CAT dramatically improved this outcome, according to the evaluation of the EARR data (SMD = 0.76, 95% CI = -1.17, -0.34; P < 0.00001). But because of the substantial variation between the studies (P = 0.004, I2 = 60%), subgroup analyses were conducted based on the tooth group (maxillary central incisors, maxillary lateral incisors, mandibular central incisors, and mandibular lateral incisors) **(Figure 3)**.

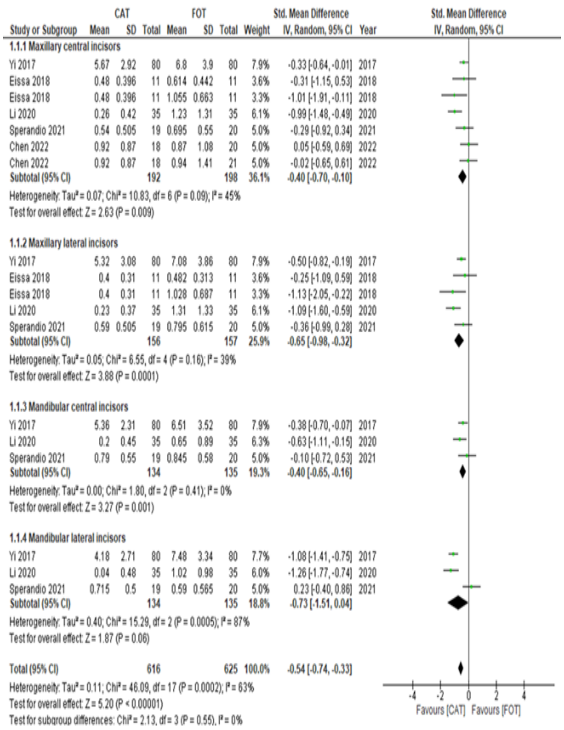

Figure 3. Quantitative subgroup analysis

EARR in maxillary central incisors

EARR in maxillary central incisors was assessed in five investigations [9, 12, 14, 24, 25]. A meta-analysis revealed that CAT had a smaller quantity of EARR (SMD = -0.40, 95% CI = -0.70, -0.10; P = 0.009), and no substantial variations in heterogeneity were detected among research (P = 0.09, I2 = 45%). According to the sensitivity analysis, the results are not substantially altered when specific papers are eliminated from the meta-analysis.

EARR in maxillary lateral incisors

EARR in maxillary lateral incisors was assessed in four investigations [9, 12, 14, 24]. A meta-analysis revealed that CAT had a smaller quantity of EARR (SMD = -0.65, 95% CI = -0.98, -0.32; P = 0.0001), and no substantial variations in heterogeneity were detected among investigations (p = 0.16, I2 = 39%). According to the sensitivity analysis, the results are not substantially altered when specific papers are eliminated from the meta-analysis.

EARR in mandibular central incisors

EARR in maxillary central incisors was assessed in three investigations [9, 14, 24]. A meta-analysis revealed that CAT had a smaller quantity of EARR (SMD = -0.40, 95% CI = -0.65, -0.16; P = 0.001), and no substantial variations in heterogeneity were detected among investigations (P = 0.41, I2 = 0%). According to the sensitivity analysis, the results are not substantially altered when specific papers are eliminated from the meta-analysis.

EARR in mandibular lateral incisors

EARR in mandibular central incisors was assessed in three investigations [9, 14, 24]. A meta-analysis revealed that CAT had a smaller quantity of EARR (SMD = -0.73, 95% CI = -1.51, -0.04; P = 0.06), and substantial variations in heterogeneity were detected among investigations (P = 0.0005, I2 = 87%). According to the sensitivity analysis, the results of the meta-analysis are dramatically altered when the research by Toyokawa-Sperandio *et al*. [24] is excluded. Without that research, a meta-analysis showed that CAT had a smaller quantity of EARR (SMD = -1.13, 95% CI = -1.41, -0.85; P < 0.00001), and no substantial variations in heterogeneity were detected among investigations (P = 0.57, I^2 = 0%).

Comparing the incidence of EARR in maxillary and mandibular incisors during CAT and FOAT and analyzing the existing literature were the primary goals of this systematic review. Our options were restricted to retrospective studies and a single randomized clinical trial, though, because there were very few publications that compared transparent aligners and fixed orthodontic equipment in the same research. Clear aligner treatment, however, has far lower levels of EARR, according to a meta-analysis that was conducted.

Although EARR incidence was decreased in the CAT group, according to the meta-analysis's findings, this treatment method is still not an exception to EARR. In the CAT group, 56.3% of patients had at least one tooth affected by EARR [14]. In contrast, 20.05% of patients in the fixed orthodontic appliances therapy (FOAT) group experience 2° or 3° root resorption, suggesting that the number and level of the EARR in the FOAT group are significantly more advanced. Furthermore, all of the EARR incidents seem to have only a 1° EARR according to Sharpe's approach to determining the degree of root resorption [26]. Additionally, Eissa *et al*. study compared the occurrence of EARR between pre-adjusted edgewise brackets and Damon brackets [12]. There were no notable variations discovered. Likewise, studies conducted by Liu and Guo [23], Aras *et al*. [27], and Chen *et al*. [28] were unable to demonstrate that one type of permanent orthodontic appliance was better than another in terms of EARR.

In this comprehensive review, EARR incidence was assessed by CBCT in four researches [9, 12, 16, 25], 2D periapical radiography in one research [24], and 2D panoramic radiography in one investigation [14]. Because it gives three-dimensional data, CBCT is preferable to 2D panoramic radiography because it allows a physician to study root resorption at both the buccal and lingual sides. Clinicians can therefore assess EARR with high accuracy thanks to CBCT. Because 2D radiographs are known to enlarge and distort pictures, particularly in the front tooth region, the number of EARR observed using 2D techniques was approximately 0.2 mm more than that found using 3D methods, according to a meta-analysis conducted by Gandhi *et al*. [4]. After eliminating the research by Yi *et al*. that used a 2D radiograph to assess EARR, the sensitivity analysis showed no discernible changes. Instead of using absolute values, the findings may be adopted as changes in the relative root-crown ratio. Following orthodontic treatment, tooth crown lengths stay relatively constant, except for a small percentage of patients who grind their incisors. The precision of the relative change in the root-crown ratio may be appropriate even though the panoramic radiographs taken before and following the treatment differ in terms of distortion and magnification.

Gandhi *et al*. [4] released a previous comprehensive review that covered retrospective data and randomized clinical trials conducted between 2009 and 2019. We have reviewed the most recent publications from 2017 to 2022. Gandhi *et al*. [4] found no discernible difference in EARR between CAT and fixed orthodontic appliance therapy, while our research revealed that EARR is more common in the group receiving fixed orthodontic equipment.

It's still unclear exactly how EARR works, although it's thought to be directly related to orthodontic pressures and apical movement distance [1, 8]. When compared to FOAT, orthodontic pressures applied to teeth by CAT are intermittent from a mechanical perspective [9]. The prevalence of EARR is greater in teeth exposed to continuous orthodontic pressures than in those exposed to intermittent ones, according to the Aras *et al*. research [27]. This phenomenon may be explained by the fact that the cementum, which is subjected to sporadic stresses, has time to heal. This is especially true for patients using transparent aligners, who typically take them off while eating or taking care of their health. Numerous investigations looked at how EARR changed with the length and force application intensity, and they concluded that the volumes of root resorption craters were related to the force magnitudes [2, 3, 8]. The included studies assessed clinical and demographic data as well as risk variables, including age, skeletal pattern, sex, treatment length, extraction and non-extraction cases, type of malocclusion, and crowding severity. Nevertheless, none of the aforementioned topics were regarded in the earlier articles as statistically significant contributors to EARR. The sample of presently accessible research is small, which results in inadequate statistical power when taking into account the constraints of this meta-analysis. Furthermore, clinical heterogeneity might be inferred for several reasons even while statistical heterogeneity was not shown. First, whereas several of the included studies quantified EARR in millimeters, one used a percentage of the root resorption to analyze it. Second, one research measured EARR using a 2D panoramic radiograph, another utilized 2D periapical radiographs, and still another employed CBCT.

Conclusion

The present meta-analysis leads us to the conclusion that CAT is typically better than fixed orthodontic equipment in terms of the amount of EARR in the anterior tooth area. However, these results should be viewed with caution since further methodologically sound clinical trials are needed to provide more definitive evidence.

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Ethics Statement: None

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