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Review Article

# Apical root resorption in orthodontic patients treated with clear aligners and pre-adjusted edgewise appliance: A systematic review and meta-analysis

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## Abstract

Apical root resorption (ARR) is a physiological course associated with the erosion of cementum or dentin, which results in the reduced root apex of a tooth. This condition represents an irreversible loss of tissue at the tip of the tooth's root and is considered the primary abominable adverse effect associated with orthodontic tooth movement. Factors that have been identified as potentially impacting the extent of apical root resorption include age, gender, nutritional status, genetic factors, the form of orthodontic device used, the pressure applied during treatment, the decision to extract or not extract teeth, the period of treatment, and the amount a tooth or teeth are moved during orthodontic correction.

**Objective:** The main reason for this study was to see if a discrepancy persists in the extent of ARR during orthodontic treatment between PEA and CAT.

**Data Sources:** A search of pubmed Medline, Cochrane Central Register of Controlled Trials, and Google Scholar was performed and the studies that have evaluated the amount of apical root resorption using PEA or CAT were selected for this systematic review. Database research, elimination of duplicate studies, data extraction, and risk of bias were performed by authors independently and in duplication.

**Conclusion:** The average ARR in CAT is less than that compared to PEA.

**Keywords:** Apical root resorption(ARR), Clear aligner therapy (CAT), Pre-adjusted edgewise appliance(PEA), Root length

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## 1. Introduction

Apical root resorption (ARR) is a physiological course associated with the erosion of cementum or dentin, which results in the reduced root apex of a tooth.[1] This condition represents an irreversible loss of tissue at the tip of the tooth's root and is considered the primary abominable adverse effect associated with orthodontic tooth movement.

While a variety of factors can influence ARR, including genetic predisposition and traumatic incidents, orthodontic treatment is a recognized contributor to this phenomenon.[2,3] Factors that have been identified as potentially impacting the extent of apical root resorption include age, gender, nutritional status, genetic factors, the form of orthodontic device used, the pressure applied during treatment, the decision to extract or not extract teeth, the period of treatment, and the amount a tooth or teeth are moved during orthodontic correction.[4]

Apical root resorption (ARR) can lead to an altered crown-to-root ratio in the affected teeth, and in severe cases, even tooth loss, significantly impacting the quality of life for patients and the overall results of orthodontic treatment. Given that most structural damage to the root surface is irreversible, dental professionals must identify both protective and risk factors to facilitate the prevention of ARR.[4,5] Consequently, evaluating the orthodontic patients for root resorption during treatment becomes a very important consideration.

To assess the intensity of apical root resorption (ARR), it is essential to conduct radiographic examinations. Numerous investigations have employed panoramic or periapical radiographs for ARR measurement.[6,8] However,

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these methods come with inherent limitations related to the amplification and perversion associated with 2D radiography. To overthrow those challenges, some studies have resorted to utilizing the crown to root length proportion.[6] A superior alternative is the utilization of CBCT, offers distinct advantages over 2D radiography. CBCT excels in identifying and quantifying of root resorption while eliminating the issues of image magnification and distortion that affect 2D radiography.[9-11]

Fixed-appliance treatments have evolved into a crucial aspect of contemporary orthodontics and signify a substantial focal point.[12] The integration of the PEA has revolutionized orthodontics and currently serves as the most prevalent orthodontic appliance globally. As the quantity of adults opting for orthodontic treatment continues to rise, the demand for aesthetic options in orthodontic therapy has also increased. CAT has turned up as an attractive aesthetic substitute for patients in need of orthodontic care. However, there exists some variability in the documented extent of ARR associated with each technique.

## 2. Aims and Objectives

The study aims to measure the extent of ARR in patients undertaking treatment with CAT and PEA.

Accordingly, we performed this systematic review and meta-analysis to

1. To note the similarity or dissimilarity and analyse the degree of ARR seen during orthodontic treatments employing PEA and CAT.
2. Analyse the extent of root resorption in different anterior maxillary and mandibular teeth during orthodontic procedures using PEA and CAT.

## 3. Materials and Methods

### *3.1. Registration & protocol*

The protocol of the review has been registered with PROSPERO, bearing the registration number CRD42023452671. The present systematic review adheres to the principles outlined in the Cochrane Handbook for Systematic Reviews of Interventions, version 5.1.017[13] and follows the reporting guidelines outlined in the PRISMA statement.[14]

### *3.2. Focused review question*

Is there a difference in ARR in orthodontic patients treated with CAT and PEA?

### *3.3. Eligibility criteria*

| | |
|---|---|
| P=Population | studies in which patients requiring Orthodontic therapy |
| I=Intervention | studies in which patients requiring Orthodontic treatment with clear aligners |
| C=Comparator | studies involving individuals who are in need of orthodontic treatment utilizing the PEA |
| O=Outcome | Apical Root Resorption |
| S=Studies | Retrospective study, Retrospective Cohort study, Retrospective Comparative study, Pilot study, Prospective Clinical study |

### *3.4. Information sources and search strategy*

The search was done in the PubMed/MEDLINE, Google Scholar, and Cochrane databases by firstly searching articles related to the topic of ARR and either CAT or PEA. Then the year specification has been added and finally all the articles with both of the categories within the year specification have been included: ("2010"[Date - Completion]: "2023"[Date - Completion]) AND (apical root resorption) AND (fixed appliance) AND ("2010"[Date - Completion]: "2023"[Date - Completion]) AND (apical root resorption) AND (aligners).

### *3.5. Study selection*

A primary search yielded 1882 articles cumulatively. The procedure for the search has been demonstrated with the exclusion criteria in the Prisma flow chart in **Figure 1**. After careful evaluation, six studies were selected for inclusion in this review (refer to the Data extraction table). First, each study was determined by the orthodontic technique used to correct the malocclusion. These selected studies encompassed both CAT and PEA techniques and assessed (ARR). Of the final six articles[15-20] included in the review, two quantitatively assessed ARR in permanent upper and lower anterior teeth,[15,18] while one study quantitatively assessed ARR in permanent upper and lower central and lateral incisors.[16] Additionally, one study quantitatively addressed ARR in permanent upper central and lateral incisors.[17]

### *3.6. Inclusion criteria*

1. Articles from 2010-2023 are only included.
2. Published in English
3. Studies addressing apical root resorption
4. Patients who received orthodontic treatment with PEA or CAT
5. Studies irrespective of any radiograph taken
6. All permanent teeth present with no missing teeth(except third molars)

### *3.7. Exclusion criteria*

1. Any articles before 2010
2. Systematic Reviews and Meta-Analysis
3. Evidence of prior inflammatory root resorption
4. Presence of any Periodontal/endodontic problems
5. H/O Trauma
6. Othe Functional or removable appliances
7. H/O TMJ disorders

*3.8. Study characteristics*

Among the six selected studies[15-20], there was a diverse range of study designs, which included one prospective clinical study[19], two retrospective cohort studies[15,18], one retrospective study[16], one pilot study[20], and one retrospective comparative study[17]. Ethical committee approval[15,17-20], Informed consent[15,18]. Comprehensive information regarding the appliance type employed in each article, the design of the study, the method of radiography employed for measuring ARR, participant numbers, demographic characteristics, and the study outcomes (specifically, ARR in permanent incisors of the upper arch) can be found in **Table 1**.

The objectives, length of the procedure, methodologies of estimation, and unique findings of each study are detailed in the following sections. The MINORS index to compute the risk of bias, with all articles achieving a score of over 10 out of a possible 16 points. The most commonly lacking regions in the evaluation included information regarding the consecutive patient inclusion, assessment of the study's endpoint in an unbiased fashion, and the absence of an evaluation of the study size. Detailed information on the risk of bias assessment can be found in **Table 2.** The studies were categorized into two groups based on the type of orthodontic treatment administered to the patients. In the PEA group, all subjects received labial orthodontic prescriptions.

Among the studies using PEA, four employed the Victory Series, one used 3M Unitek (California, USA) with MBT prescription, one adhered to the Roth prescription, and no specification for the prescription of the bracket used in the treatment. Subjects in the CAT group underwent treatment with Invisalign in three studies, smart-track aligners in one study, inline aligner Mumbai in one study, and one study did not provide information about the design of aligners used.

**Figure 1.** PRISMA Flow Diagram

*3.9. Data extraction*

We developed a tailored data collection form for the purpose of gathering data from the chosen studies. This form encompassed essential information such as author names, publication year, study type, intervention specifics, participant characteristics, treatment duration, and measurement of the outcome. Data extraction was carried out independently by the authors, with cross-verification. In instances where data was missing, an effort was made to reach out to the study authors. Should any discrepancies arise, a third reviewer was consulted to offer an impartial resolution to the conflict.

**Table 1**: study characteristics including study ID, size of the sample, design of the study, type of CAT and PEA used, method for assessing ARR, conclusion of the author

*3.10. Risk of bias and quality assessment of individual studies*

To appraise the reliability of non-randomized studies meeting the specified eligibility criteria, independent pairs of reviewers undertook assessments, ensuring sufficient reliability. The assessments covered the rightness of the aim of the research, appropriate protection of the allocation, implementation of patient blinding, blinding of the person collecting the data and result assessors, attrition range of follow-up (indicating the percentage of subjects with unascertainable outcomes), and the pre-determined determination of the size of the study. The MINORS was used to gauge the potential bias in non-randomized studies.[21] Twelve specific events were considered for the assessment of bias, as a higher event rate permits a more precise estimation of the impact of the variables under scrutiny. Each event was assigned a score: 0 if unreported, 1 if reported inadequately, and 2 if reported adequately. The highest achievable score for non-comparative studies was 16. Instances, where only abstracts were available, were automatically categorized as carrying a high risk of bias. Through consensus disagreements between the two reviewers were resolved. In cases where a consensus could not be reached, the final decision was determined by the independent judgment of a third reviewer. **Table 2** shows the quality assessments of the studies included.

**Table 2.** Risk of bias assessment using the minors checklist

*3.11. Risk of bias across studies*

We assessed the potential bias of publication for each of the permanent upper and lower anterior teeth individually. After adjusting for factors such as type of intervention (CAT vs. PEA), CBCT dimension, and treatment, an analysis of the funnel plots plotting standard error against residuals revealed no discernible asymmetric patterns. There was no indication of publication bias.

*3.12. Risk of bias within studies*

Based on the MINORS scale utilized for evaluating the ROB, one study attained a score of[16,19] while the remaining studies received scores of 17-2017,[18-20] (respectively), 19 (two studies each),[18,20] and which represented the highest score within our systematic review.[15] The majority of the studies did not provide information regarding the loss of follow-up. One study did not specify its bias assessment, two studies did not define their follow-up periods, and two studies did not mention the prospective calculation of the study size. Consequently, considering the risk of bias in each study when interpreting the outcome obtained from this meta-analysis is imperative. The results of the heterogeneity analysis were notably specific to the sample size, particularly the quantity of studies. Insignificant heterogeneity was indicated by subgroups with limited studies. Subgroups with limited studies indicated insignificant heterogeneity.

## 4. Results

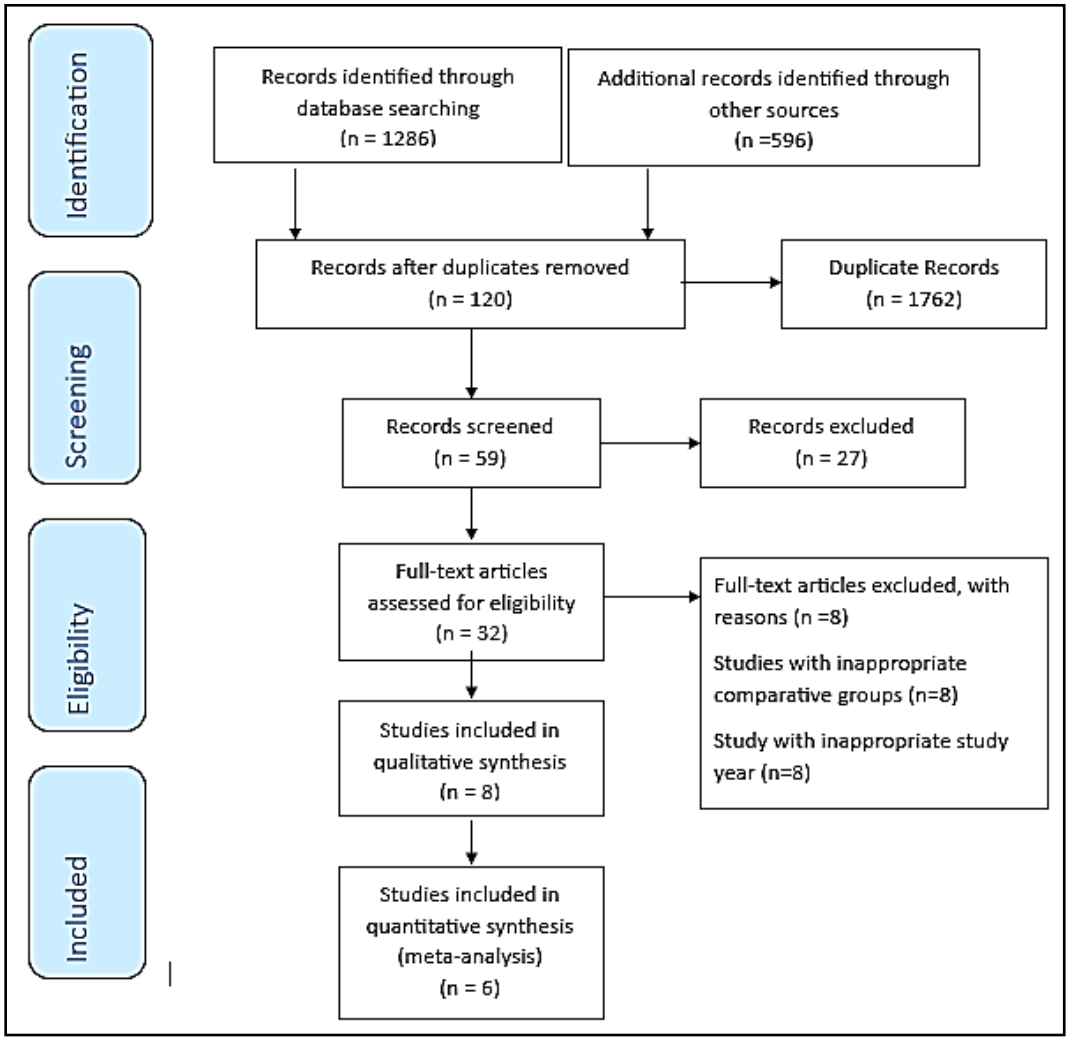


**Figure 1:** PRISMA flow diagram

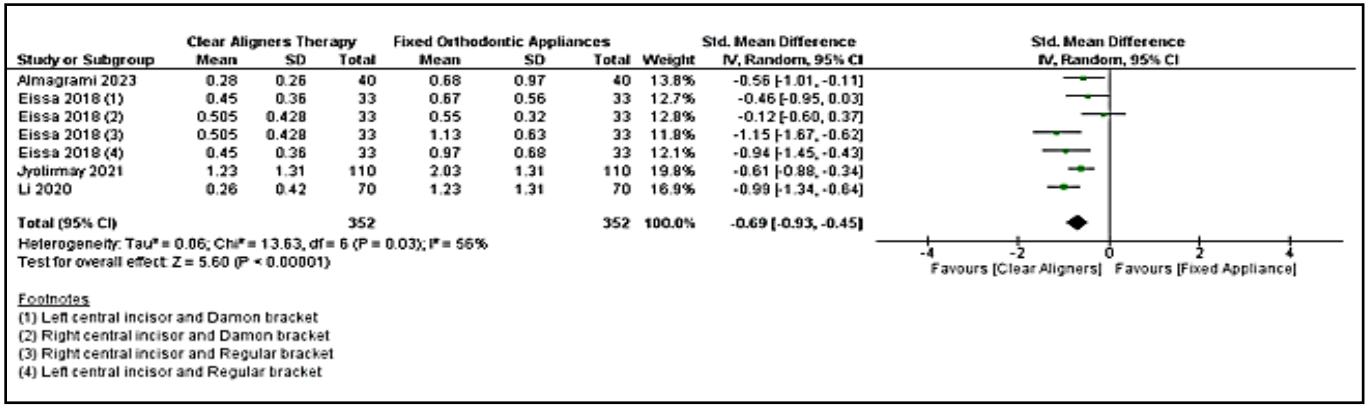


**Figure 2:** Forest plot of the Upper Central Incisor

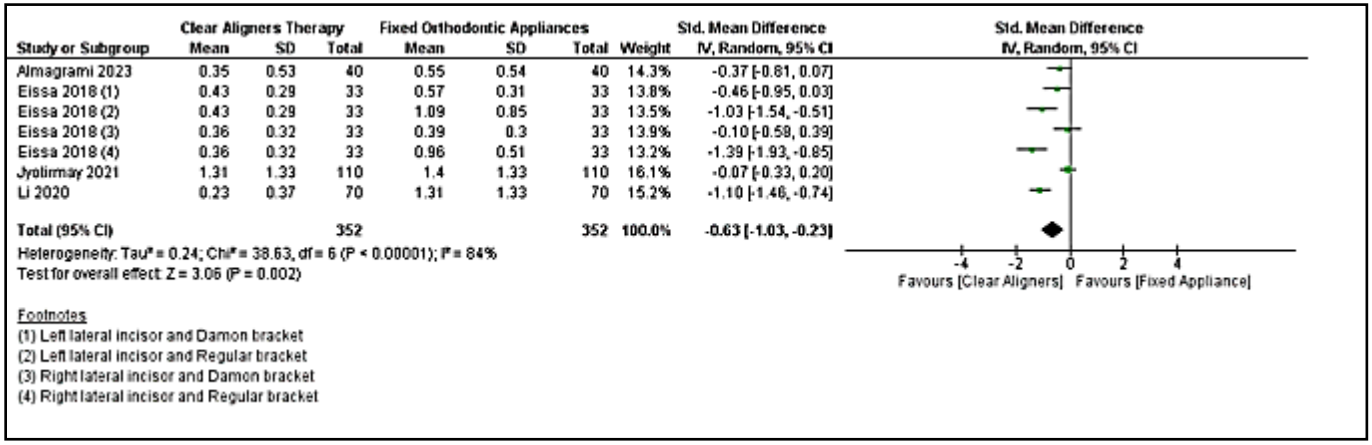


**Figure 3:** Forest plot of the upper lateral incisor

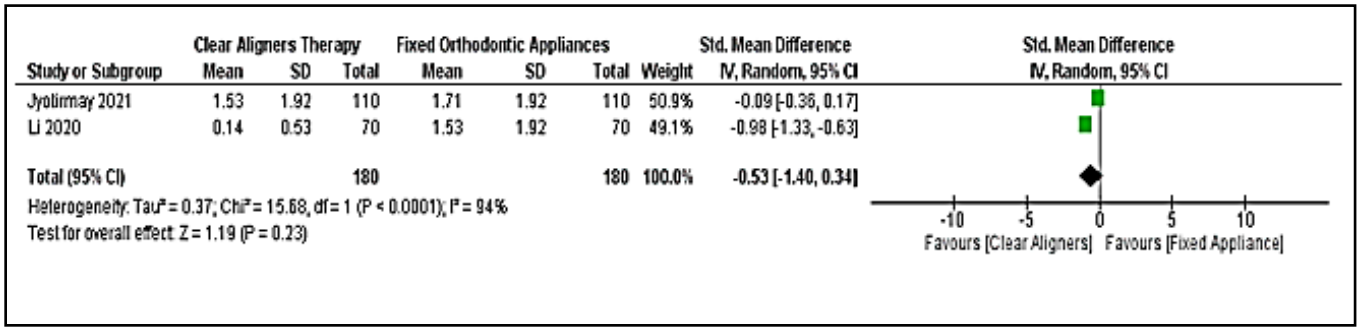


**Figure 4:** Forest plot of the upper canine

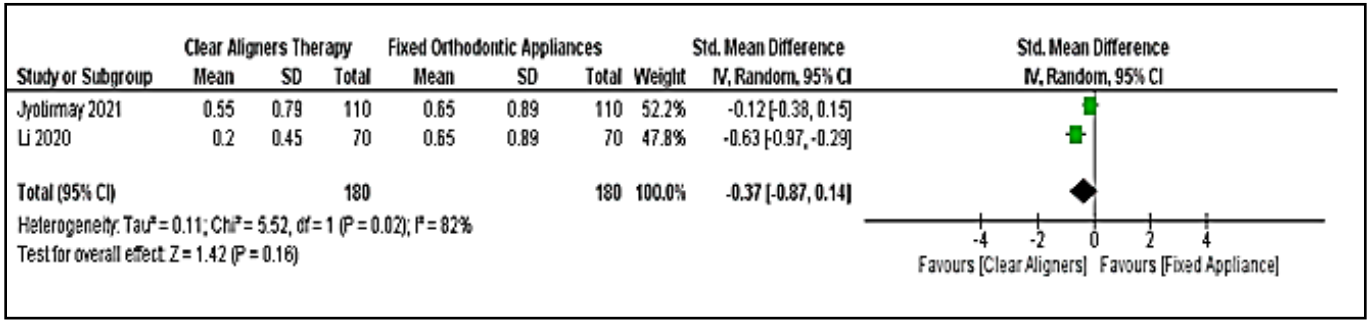


Figure 5**:** Plot of the lower central incisor

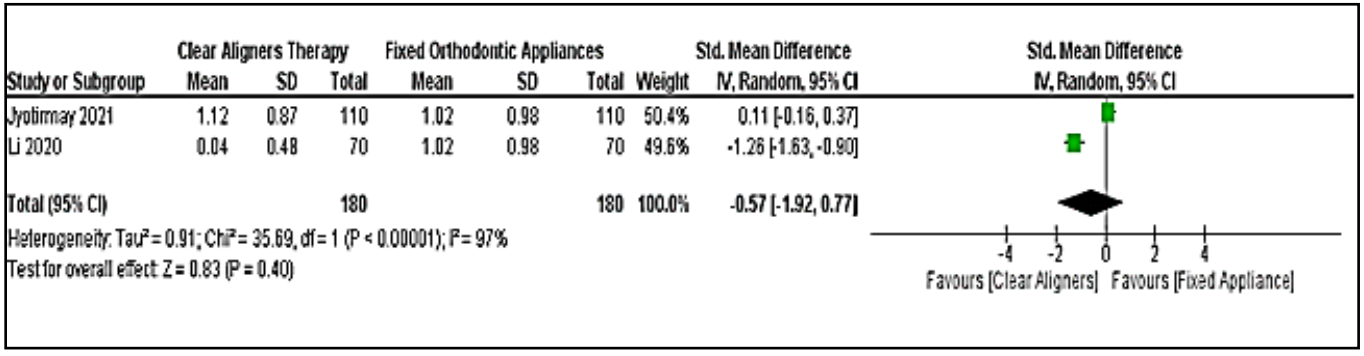


**Figure 6:** Forest plot of the lower lateral incisor

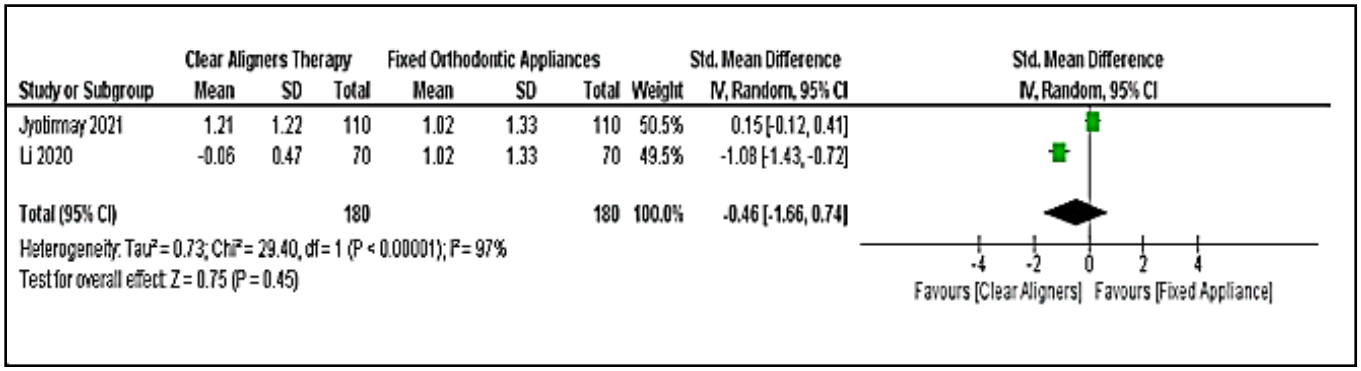


**Figure 7:** Forest plot of the lower canine

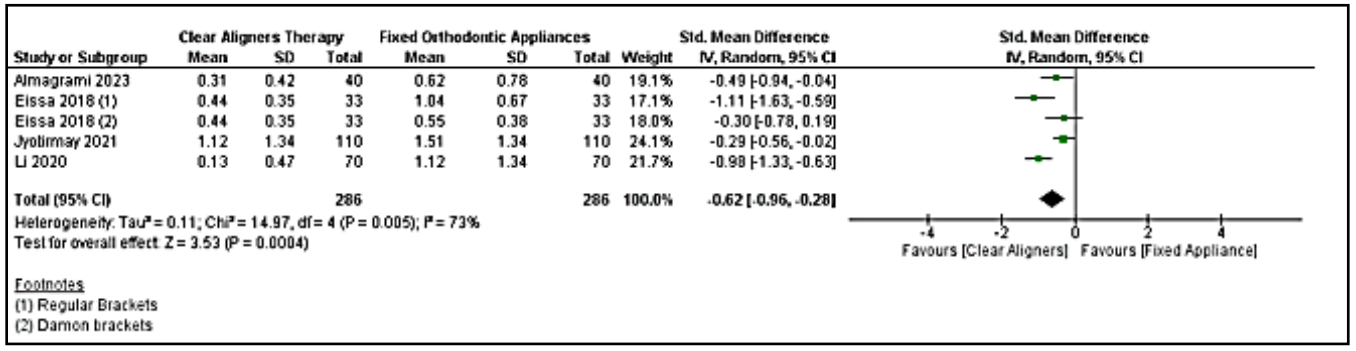


**Figure 8:** Forest plot of the Total average apical root resorption

**Table 1:** Study characteristics including study ID, size of the sample, design of the study, type of CAT and PEA used, method for assessing ARR, conclusion of the author

| S.no | Study ID | Mean Age | Sample size | Study design | Type of aligner(Intervention) | Type of pre-adjusted edgewise appliance (comparator) | method of assessing ARR | Authors Conclusion |
|---|---|---|---|---|---|---|---|---|
| 1. | Almagrami et al 2023[17] | mean age 25.15±6.67 years for CA 22.33±4.33 years for FA | 40 | retrospective comparative study | Invisalign® (Align Technology, California, USA) | Victory Series; 3 M Unitek, California, USA | The root length was measured before and after the treatment from the CEJ to the apex of the root | Increased ARR in the upper anterior region with higher prevalence and severity in patients receiving FAs |
| 2. | Khalil et al 2023[19] | 12 to 18years | 30 | prospective clinical study | clear aligner | roth appliance in 0.22 slot | | Root resorption accompanied with aligners is considered less than fixed appliances however the difference is not significant. |
| 3. | Jyotirmay et al 2021[18] | 23.71 ± 6.37-FA 21.62 ± 3.58-CA | 110 | a cohort study which was retrospective | clear aligners[inline aligners mumbai] | Victory Series; 3 M Unitek, California, USA | Root length was measured before and after treatment root length was measured from the midpoint of the incisal edge up to the root apex with the help of the Blue Sky Plan software program (Blue Sky Bio, USA) | resorption at the root apex is less in patients who are treated using clear aligners as compared with those treated with conventional fixed orthodontics appliances |
| 4. | Li et al 2020[15] | average age 23.61 ±7.03 years | 70 | retrospective cohort study | Invisalign, Align Technology, California, USA | Victory Series; 3 M Unitek, California, USA | Before and after the treatment the length of the root [mid-point of the incisal edge/cusp to the apex] using the Dolphin 3D 11.9 program | The prevalence and severity of ARR measured on CBCT in patients with CAT were less than those in patients with FA |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 5. | Eissa, et al 2018[20] | 14-25 years | 33 | pilot study | aligners [Smart Track®] | 3M Unitek, California, USA, Damon-Q self-ligating brackets (Ormco) | Before and after treatment using CBCT the lengths of the permanent upper central and lateral incisors were measured | Smart Track® aligners showed less decrease in root length as compared to conventional pre-adjusted edgewise appliances<br>No significant difference in root resorption<br>between aligners and passive self-ligating Damon Q<br>systems were found. |
| 6. | J. Yi et al. 2018[16] | 22.54yrs | 80 | retrospective study | clear aligner therapy[invisalign ] | pre-adjusted edgewise 0.022 in slot | A straight line was drawn connecting the mesial and distal cemento-enamel-junction. The lengths of the crown and root were was calculated from cemento-enamel-junction line to incisal edge and root apex respectively. | Clear aligner therapy may have a superiority in reducing external apical root resorption compared to fixed orthodontic treatment in non-extraction patients. |

**Table 2:** Risk of bias assessment using the minors checklist (MINORS)

| Study Id | A clearly stated aim | Inclusion of consecutive patients | Prospective collection of data | Endpoints appropriate to the aim of the study | Unbiased assessment of the study endpoint | Follow-up period appropriate to the aim of the study | Loss to follow up less than 5% | Prospective calculation of the study size | *An adequate control group | *Contemporary groups | *Baseline equivalence of groups | *Adequate statistical analyses | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Li et al.2020[15] | 2 | 2 | 2 | 2 | 2 | 1 | 0 | 2 | 2 | 2 | 2 | 2 | 20 |
| Yi et al.2018[16] | 2 | 2 | 1 | 2 | 1 | 1 | 0 | 0 | 2 | 2 | 2 | 2 | 17 |
| Almagrami et al. 2023 | 2 | 2 | 1 | 2 | 1 | 0 | 0 | 2 | 2 | 2 | 2 | 2 | 18 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jyotirmay et al 2021[18] | 2 | 2 | 1 | 2 | 2 | 1 | 0 | 1 | 2 | 2 | 2 | 2 | 19 |
| Khalil et al 2023[19] | 2 | 2 | 1 | 2 | 0 | 1 | 0 | 0 | 2 | 2 | 2 | 2 | 16 |
| Eissa, et al 2018[20] | 2 | 2 | 1 | 2 | 2 | 0 | 0 | 2 | 2 | 2 | 2 | 2 | 19 |

The items are scored 0 (not reported), 1 (reported but inadequate) or 2 (reported and adequate). The global ideal score being 16 for non-comparative studies and 24 for comparative studies.

*For study with control group

The calculated heterogeneity among the studies was: Tau* = 0.11; Chi* = 14.97, df = 4 (P = 0.005); I^2 = 73%. The test for the overall effect resulted in Z = 3.53 (P = 0.0004).

### *3.13. Deriving the synthesis, different planned analysis methods, and summarised methods*

The primary measure of treatment effect in this study was apical root resorption (ARR) after non-extraction orthodontic therapy. The collected data were categorized into two main groups based on the type of intervention: ARR associated with the PEA and CAT. Most studies focused on the assessment of ARR in permanent upper and lower anterior teeth and were included in the meta-analysis. The meta-analyses aimed to measure the average ARR for specific anterior permanent upper and lower teeth and the average ARR across these teeth. The standard deviation (SD) associated with the mean ARR was evaluated using teeth-specific SDs and the correlations between teeth, as estimated from the mean ARRs reported in the articles included.

We utilized Review Manager (RevMan) 5.3 for conducting the statistical analysis. The aggregated findings were presented as the mean and standard deviation for continuous data and as relative risks (RRs) for dichotomous data, both accompanied by 95% confidence intervals (CIs) and P&It. A significance level of $P < 0.05$ was employed to determine statistical significance. To assess statistical heterogeneity, we applied the I^2 test at a significance level of $\alpha = 0.10$. In cases where I^2 exceeded 50%, the random-effects model was employed.

## 5. Discussion

The main reason for this study was to see if a discrepancy persists in the extent of ARR during orthodontic treatment between the use of PEA and CAT. The search strategy employed was thorough, involving searches across multiple databases. To ensure inclusivity and minimize bias, no filters were applied based on language or publication date.

### *5.1. ARR with PEA and CAT*

A total of four articles (1,3,4,6) met the inclusion criteria for quantitative analysis [refer **Table 1**]. Subsequently, seven meta-analyses were conducted to assess both the overall average and the ARR for individual teeth during orthodontic treatment involving CAT and PEA. In a study conducted by Eissa et al. in 2018[5] two distinct fixed appliances were utilized for orthodontic treatment within the fixed orthodontic appliance group, namely, regular brackets and Damon brackets. For quantitative assessment, data for both methods were considered as separate studies for comparison with clear aligners. Additionally, the study by Eissa et al. in 2018[5] presented a separate analysis for the right and left maxillary central incisors. Therefore, each side, along with the different types of brackets, was considered as distinct entities for quantitative synthesis.

#### *5.1.1. Total average apical root resorption (***Figure 8***)*

The meta-analysis of five studies assessing the standardized mean difference for Total average ARR observed between CAT and PEA groups was carried out a using random effect model. The standardised mean difference favored the clear aligner therapy group as compared to FA orthodontic appliances group showing a significant statistical difference (SMID, -0.62, 95% CT = -0.96 - -0.28, p-0.0004, I'=73%).

#### *5.1.2. Upper Central Incisor apical root resorption (***Figure 2***)*

The pooled outcomes from 7 studies, assessing the standardized mean difference for upper Central Incisor ARR observed between CAT and PEA group was carried out a using random effect model. The standardised mean difference favoured the CAT group as compared to the PEA group showing a significant statistical difference (SMID, -0.69, 95% CT = -0.93 - -0.45, p-0.00001, 1=56%).

#### *5.1.3. Upper Lateral Incisor apical root resorption (Figure 3)*

The pooled outcomes from 7 studies, assessing the standardized mean difference for upper Lateral Incisor ARR observed between CAT and PEA group was carried out a using random effect model. The standardised mean difference favored the CAT group as compared to the PEA group showing a significant statistical difference (SMID, -0.63, 95% CI = -1.03 - -0.23, p-0.002, 1=84%).

#### *5.1.4. Upper Canine apical root resorption (***Figure 4***)*

The pooled outcomes from 2 studies, assessing the standardized mean difference for upper Canine ARR observed between the CAT and PEA appliances group was carried out a using random effect model. The standardised mean difference favored the CAT group as compared to PEA group but no statistically significant results were found. (SMID, -0.53, 95% CT = -1.40 - 0.34, p-0.23, 1=94%).

#### *5.1.5. Lower Central Incisor apical root resorption (Figure 5)*

The pooled outcomes from 2 studies, assessing the standardized mean difference for Lower Central Incisor ARR observed between CAT and PEA group were carried out a using random effect model. The standardised mean difference favored the CAT group as compared to PEA group but no statistically significant results were found.(SMI, -0.37, 95% CI = -0.87 - 0.14, p-0.16, T=82%).

#### *5.1.6. Lower Lateral Incisor apical root resorption (***Figure 6)**

The pooled outcomes from 2 studies, assessing the standardized mean difference for lower Lateral Incisor ARR observed between CAT and PEA group was carried out using random effect model. The standardised mean difference favoured the CAT group as compared to the PEA group but

no statistically significant results were found. (SMID, -0.57, 95% CT = -1.92 - 0.77, p-0.40, 1 =97%).

*5.1.7. Lower Canine apical root resorption (***Figure 7***)*

The pooled outcomes from 2 studies, assessing the standardized mean difference for lower Canine ARR observed between CAT and PEA groups was carried out using the random effect model The standardized mean difference favored the CAT group as compared to the PEA group but no statistically significant results were found. (SMID, -0.46, 95% CI = 1.66 - 0.74, p-0.45, F=97%).

*5.2. Limitations*

One limitation is the absence of prospective studies, particularly (RCTs), in the present article. The majority of studies focusing on apical root resorption (ARR) are retrospective in design. Additional research is required, which includes cases involving tooth extractions, along with an assessment of other parameters such as skeletal or dental malocclusion. This would provide a more comprehensive evaluation of the prevalence and intensity of ARR after the utilization of CAT and PEA. Another constraint pertains to the cost-effectiveness of employing aligner therapy.

## 6. Conclusions

1. ARR is seen in both CAT and PEA groups but the average ARR in CAT is less than that compared to PEA.
2. The average ARR is more in the maxillary teeth when compared to the mandibular teeth.
3. In the maxillary teeth the incisors are more prone to ARR when compared to the other teeth in the arch.

## 7. Abbreviation

**ARR-**Apical root resorption, **CAT-**Clear aligner therapy,

**PEA-**Pre-adjusted edgewise appliance

## 8. Source of Funding

None.

## 9. Conflict of Interest

None.

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