



Review

Orthodontic Treatment and External Apical Root Resorption: A Study on the Worldwide Prevalence - A Scoping Review

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Main Points

- Mild external apical root resorption (EARR) prevalence does not correlate with severe resorption diagnosis after orthodontic treatment, indicating that EARR may only be well classified when it is advanced.
- Although cone-beam computed tomography is a precise diagnostic tool, inconsistency exists among studies.
- There is a lack of consensus and standardization in identifying EARR, highlighting the need for unified diagnostic and classification methods.

ABSTRACT

External apical root resorption (EARR) is an important concern in orthodontic practice. Despite extensive research, the reported prevalence, occurrence, and grade distribution of EARR remain heterogeneous, ranging from 0% to 100%. This review aimed (i) to analyse the available scientific evidence worldwide to ascertain conclusions regarding EARR prevalence and (ii) to identify and evaluate the most appropriate radiographic technique and complete/comprehensive assessment method for EARR. This review followed the JBI and PRISMA guidelines and included studies of any orthodontic treatment. The studies were analysed based on diagnostic imaging methods, quantification, categorisation, and other variables. Of the 1209 records identified, 81 studies were included. The evidence originated from six continents, predominantly Europe (33 studies), Asia (23 studies), and the Americas (13 studies from North America and 16 from South America). Across the studies, marked variability was observed in both the reported prevalence and the severity of EARR. Studies utilising two-dimensional techniques mainly reported no or only mild resorption in most incisors. Similarly, studies employing three-dimensional techniques found that mild or no resorption was predominant. However, severe EARR was rare in all studies, consistently affecting fewer than 5% of cases. Notably, discrepancies in severity and mean EARR values among studies were largely attributable to variations in techniques and classification systems. This inconsistency emphasises the urgent need for standardised diagnostics and a unified classification. Resolving these issues will provide clearer insights into EARR.

Keywords: Complications, EARR, prevalence, radiography, root resorption

INTRODUCTION

External apical root resorption (EARR) is a common iatrogenic consequence of orthodontic forces applied to teeth and can be identified radiologically in clinical practice.^{1,2} It is described as a destructive pathological condition that permanently affects the cementum and/or dentine of the tooth root and frequently manifests during orthodontic treatment.³ Despite extensive research on EARR, the specific factors influencing its onset, development, and severity remain unclear.^{1,3} EARR is a multifactorial condition influenced by both environmental factors and individual variations in susceptibility.³⁻⁵

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Although EARR is a condition of serious concern for orthodontic professionals, its occurrence remains unclear. Accordingly, reported rates of EARR after orthodontic treatment vary widely, with some studies describing values as low as 0%⁶ to 10%,⁷ and others indicating that up to 45% of the patients present some degree of resorption.⁸ This leads to considerable uncertainty regarding the proportion of orthodontic patients affected. Moreover, a substantial discrepancy exists in the EARR classification,^{9,10} quantification methods, and severity estimation¹¹⁻¹³ among studies.⁸

Although EARR in orthodontics has been studied for over a century, an exponentially increasing body of scientific evidence has become available only recently. While previous meta-analyses and systematic reviews have addressed and quantified EARR, they have not specifically investigated its prevalence.^{14,15} As a result, scientific evidence regarding the prevalence and average severity of EARR secondary to orthodontic therapy is still lacking.¹⁶

Therefore, this study primarily aimed to analyse the available scientific evidence worldwide to ascertain the prevalence of EARR in orthodontics. The secondary objective was to identify and critically evaluate the most appropriate radiographic technique and comprehensive assessment method for EARR.

METHODS

Protocols and Guidelines

This review followed the guidelines and protocols outlined in the JBI Manual for Evidence Synthesis and its template, and in the PRISMA extension for scoping reviews. No prior protocol registration was performed, which is consistent with the exploratory nature of scoping reviews and is acknowledged as a methodological limitation. However, the review adhered strictly to these methodological standards to ensure transparency and reproducibility.

Eligibility Criteria

The eligibility criteria for the studies included in this research are described below.

Participants: The studies must involve patients undergoing any orthodontic treatment for the first time (excluding retreatments).

Concept: The studies should include EARR measurements in at least one upper incisor and compare pre- and post-treatment scenarios using any radiographic diagnostic method.

Context: No specific context was required; it was considered open.

Type of sources: The year of publication and the study duration were not restricted by the eligibility criteria. The required study designs included case-control studies, case series, and prospective and retrospective longitudinal studies, whereas meta-analyses and systematic reviews were excluded.

Furthermore, studies were excluded if they included patients with syndromes, patients with prior treatment, patients with previous dental trauma, or patients with compromised periodontal status. In addition, all in vitro and animal studies, as well as studies focusing exclusively on impacted canines, were excluded.

No language restrictions were applied; non-English studies were screened using English abstracts, with full texts translated when necessary.

Search Strategy

A literature search was conducted using multiple sources, with PubMed and Scopus as the primary databases. Additionally, searches were performed using the Web of Science, SciELO, Google Scholar, and grey literature repositories. The search covered studies published from 1970 to July 2025, with the final search conducted on 30 July 2025. The complete search strategy and keywords used are provided in Supplementary File 1.

Study Selection

Screening was performed in the following phases: 1) search, 2) duplicate removal, 3) title screening, 4) abstract screening, and 5) full-text screening. All phases were independently reviewed by two reviewers.

In cases of disagreement at any stage of the screening process, the two reviewers reached consensus through discussion.

Data Extraction

Data were extracted by one reviewer and were later corroborated by a second reviewer. The predetermined variables of interest were documented as follows: author, year, country, study design, sample, ethnicity, diagnostic imaging method, quantification method, categorisation, mean EARR (mm/mm³/%), prevalence, calculated prevalence, prevalence in categories, assessed teeth, orthodontic techniques, treatment duration, age at the beginning of treatment, sex, and covariables.

For articles with incomplete data, attempts were made to contact the authors and obtain the missing information for inclusion.

RESULTS

Search Results

Our search strategy identified 1209 records, including 81 duplicates. After removing duplicates, 393 articles were screened by title, and 182 were selected based on their abstracts. Subsequently, 159 articles were assessed at the full-text level. 81 studies were included in the final analysis (Figure 1). The reasons for exclusion have been summarised in Figure 1. The specific reason for the exclusion of each article is detailed in Supplementary File 2.

Description of the Included Studies

The characteristics of the included studies are summarised in Supplementary Table 1. Detailed methodological and demographic characteristics are provided in Supplementary Table 1 and Supplementary File 3 to improve readability. To assess the prevalence of resorption, four groups were established to classify its severity: no EARR, mild EARR, moderate EARR, and severe EARR, as shown in Figure 2. The mild EARR classification included root resorption lesions of Malmgren grades 1 and 2¹⁷ (Figure 2).

Findings

The results are organised based on the radiographic diagnostic technique (2D or 3D), the treatment type (fixed or removable appliances), and the presence of additional quantitative data in the studies. Across all included studies, no or mild EARR predominated regardless of imaging modality or appliance type, while severe EARR was uncommon (Table 1).

Two-Dimensional (2D) Radiographic Assessment of EARR after orthodontic treatment with fixed appliances

In almost all studies using 2D imaging after fixed appliances, mild or no EARR was reported in the majority of cases (Figure

2). When the four upper incisors were analysed collectively, most patients exhibited no or only mild EARR. Nevertheless, four studies showed moderate or severe resorption in over 50% of the examined upper incisors.^{12,16,18,19}

When studies were scrutinised by tooth group (central vs. lateral upper incisors), a similar trend was observed. Only one study reported moderate or severe resorption in more than 50% of the central incisors.²⁰ Studies differentiating between only two categories (moderate/severe resorption vs. no/mild resorption) indicated a higher prevalence of moderate or severe resorption²¹⁻²³ with some reporting that up to 70% of the patients experienced severe or moderate resorption during orthodontic treatment.²¹ This finding appears to be influenced by the classification itself rather than reflecting a true increase in severe EARR.

Focusing on studies that specifically analysed each incisor individually, most²⁴⁻²⁹ reported that approximately 70% of teeth had no or mild resorption during orthodontic fixed appliances. Mild resorption represented the most frequent outcome across these studies³⁰⁻³² (Figure 2), reinforcing the predominance of low-severity EARR in 2D assessments.

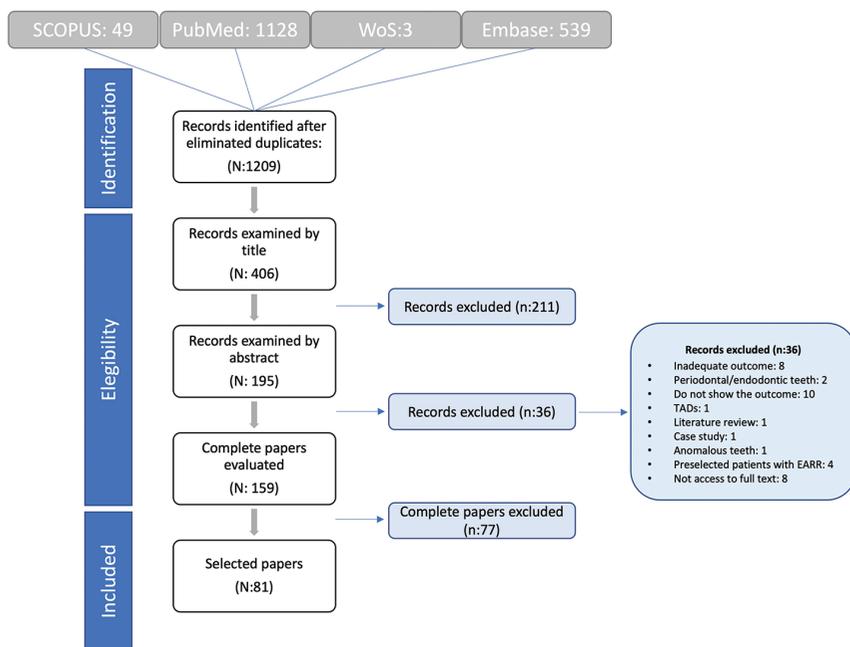
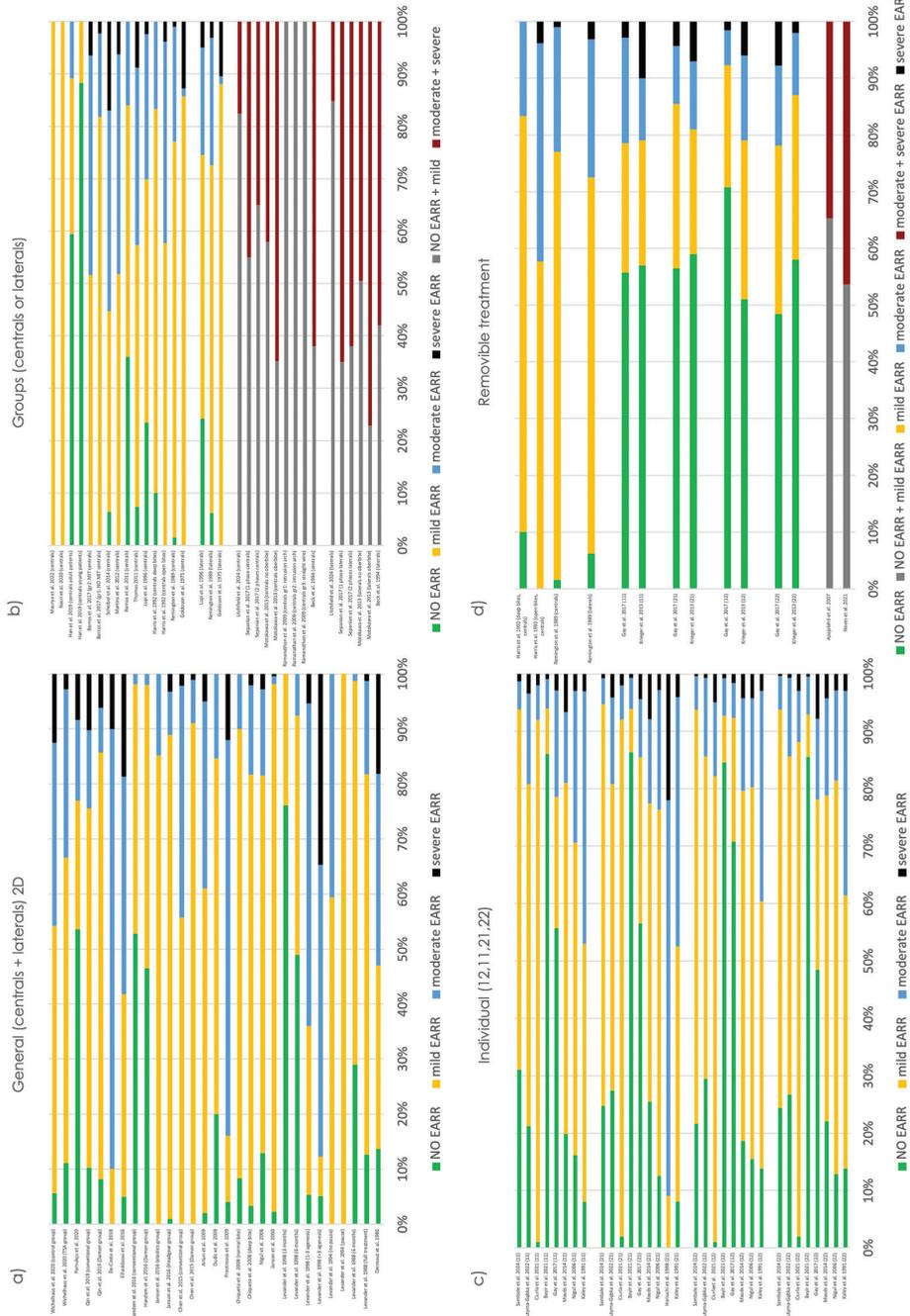
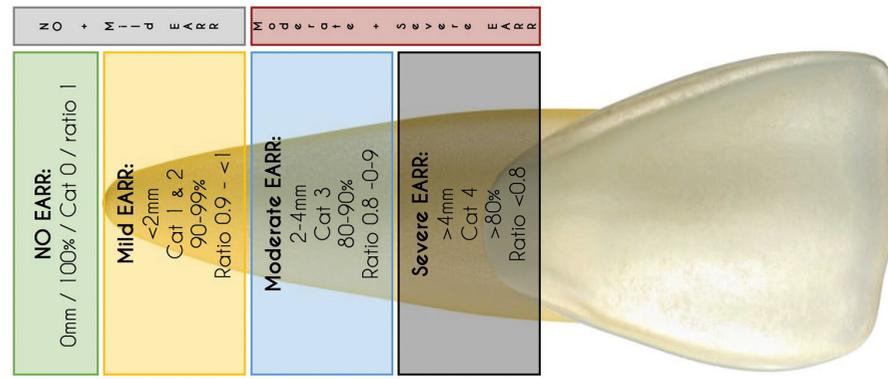


Figure 1. Flowchart of article retrieval.

Table 1. Summary of EARR prevalence according to imaging modality and appliance type

| Imaging modality | Appliance type | Predominant EARR severity | Severe EARR prevalence |
|------------------|----------------|---------------------------|------------------------|
| 2D | Fixed | No or mild | <10% in most studies |
| 2D | Removable | No or mild | Rare |
| 3D | Fixed | No or mild | <5% |
| 3D | Removable | No or mild | Rare or absent |

EARR, external apical root resorption.



NO + MILD EARR
MODERATE + SEVERE EARR

Figure 2. EARR prevalence diagnosed using two-dimensional methods.

EARR after orthodontic treatment with removable appliances

Studies analysing removable appliances have consistently reported a low prevalence of moderate-to-severe resorption. In studies using the four-group classification, fewer than 30% of patients had moderate or severe EARR (Figure 2), except for patients treated for open bite, who had a higher prevalence.³³

Considering studies that grouped moderate and severe resorption together, the majority still exhibited no or mild resorption. With the exception of the study by Linhartova et al.,¹¹ more than 50% of the sample presented mild or no resorption (Supplementary File 4). Overall, removable appliances assessed using 2D imaging were associated with mild or absent EARR.

Three-Dimensional (3D) Radiographic Assessment of EARR after orthodontic treatment with fixed appliances

Studies using 3D radiographic measurements and fixed appliances consistently reported a high prevalence of no or only mild resorption. In studies which classified EARR into four groups (none, mild, moderate, or severe EARR),^{6,34} approximately 70-90% of incisors exhibited no or mild EARR. Severe resorption was uncommon across all studies and classifications that used 3D diagnostic methods (Figure 2). Studies with a simpler two-category classification (no/mild vs moderate/severe EARR), reported lower proportions of no or mild resorption, with approximately 30% of incisors in this category.³⁵⁻³⁸ These differences were associated with the classification approach used across studies.

Notably, one of the included studies reported EARR only in the lateral incisors.⁶ Another study examined EARR using cone-beam computed tomography (CBCT) and panoramic radiography to improve the detection of severe EARR, reinforcing the higher diagnostic sensitivity of 3D imaging³⁹

(Supplementary File 5). Overall, studies employing 3D imaging demonstrated a consistently low prevalence of moderate and severe EARR following treatment with fixed appliances.

EARR after orthodontic treatment with removable appliances

In studies of removable appliances that analysed root resorption using 3D radiographic, linear, and volumetric assessment methods, severe resorption was consistently rare and was reported in less than 5% of cases. In fact, two of these studies reported neither moderate nor severe resorption^{40,41} (Supplementary File 6).

Additional Analysis of Incisors Resorption (Quantitative Data)

Across all included studies, mean root resorption values remained low, with an apical root loss generally not exceeding 2 mm (Figure 3). In studies where measurements were reported for individual teeth, the mean EARR rarely exceeded 1.5 mm. All measurements remained below 5 mm.

The samples analysed in this study originated from various locations worldwide. Most of the studies were conducted in Europe (33 studies), followed by Asia (23 studies) and the Americas (13 studies from North America and 16 studies from South America). The worldwide distribution is shown in Figure 4. However, no specific distribution based on their origin could be established due to substantial heterogeneity in the results.

DISCUSSION

This scoping review aimed to identify and map the prevalence of EARR after orthodontic treatment. Although the prevalence of EARR has been described in many studies, only a limited number of systematic reviews have estimated the actual

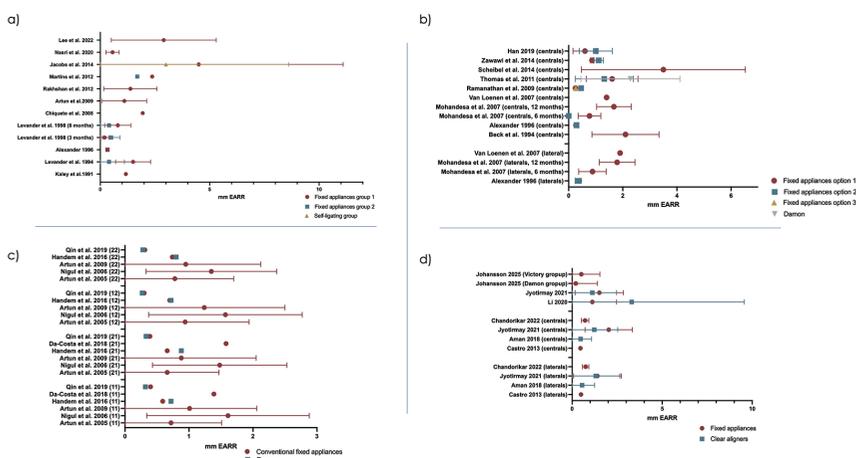


Figure 3. Overview of reported EARR values (in mm) in the included literature.

a) General (centrals + laterals) with 2D: Studies measuring EARR on all upper incisors in patients treated with fixed orthodontic treatment, b) Groups (central or lateral) with 2D: Studies measuring EARR on central and/or lateral incisors in patients treated with fixed orthodontic treatment, c) Individual (12,11,21,22) with 2D: Studies measuring EARR on incisor independently in patients treated with fixed orthodontic treatment, d) Fixed vs. clear appliances with 3D: Studies measuring the EARR using CBCT. EARR, external apical root resorption; CBCT, cone-beam computed tomography

Worldwide distribution of included articles

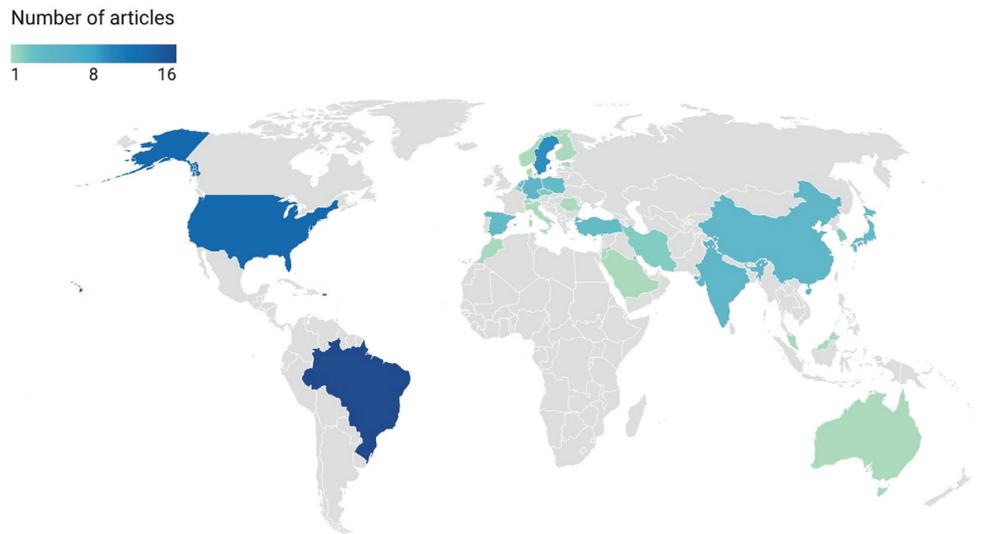


Figure 4. Worldwide distribution of the included articles.

occurrence of EARR across orthodontic treatment modalities. Our review, by analysing studies conducted worldwide, provides a broader picture of the expected prevalence of EARR in clinical practice.

Despite the wide geographic distribution of the included studies, spanning six continents and diverse populations, consistent global patterns of EARR prevalence were observed. Across studies conducted in Europe, Asia, North and South America, and other regions, the predominant finding was no or only mild EARR, regardless of geographic origin, population, or orthodontic technique. Severe EARR was consistently uncommon worldwide, particularly in studies using 3D-imaging, where it generally affected fewer than 5% of cases. This low prevalence of severe EARR represents an infrequent outcome of orthodontic treatment on a global scale. Although reported prevalence values varied substantially between studies, this variability appeared to be method-driven rather than region-specific, largely reflecting differences in radiographic techniques, quantification methods, and classification systems, and not true geographic or population-based differences. Consequently, no consistent regional pattern could be identified.

A significant challenge in comparing studies on EARR is the substantial heterogeneity of diagnostic procedures and measurement methods. While some authors relied on 2D techniques (panoramic radiography,^{16,30,39} periapical radiography,^{27,42} occlusal radiography,⁴ or lateral radiography,^{11,16,33}), others used 3D approaches, such as CBCT.^{6,35,36,39} The choice of imaging method directly affects the quantification of EARR: conventional radiographs are widely available and involve lower radiation exposure but may overestimate resorption, whereas CBCTs provide more detailed and accurate measurements yet are less commonly used in

clinical practice because of cost and higher radiation dose. This variability complicates cross-study comparison and likely contributes to the wide variability in EARR prevalence.⁹

Beyond diagnostic imaging, studies have used different approaches to quantify EARR, even when similar radiographic techniques were applied. For example, regarding panoramic and periapical radiography, some authors have used a visual scoring systems, as described by whereas others have used quantitative measurements in millimetres or percentages.^{40,43} The heterogeneity becomes even greater when comparing 2D and 3D methods: panoramic or periapical radiographs allow only linear measurements, whereas CBCTs enable volumetric analysis, providing data that cannot be captured with conventional radiographs.^{4,30,33,44}

Studies have used different criteria to classify EARR severity. Some adopt visual scoring systems, such as Levander et al.,¹⁹ later modified by Levander and Malmgren,¹⁷ while many others apply quantitative thresholds based on root shortening in ratios,¹² millimetres of EARR,^{45,46} percentage (%) of root loss,^{7,47} or volume (mm³) of EARR. This may partly explain the wide variability in reported prevalence and severity. To address this issue, this scoping review harmonised all data into a four-category system (none, mild, moderate, severe), allowing comparison among studies with different classification systems.

Upper incisors (central and lateral) are most commonly affected by EARR.² Furthermore, these teeth are easily available to researchers, and they typically undergo the greatest movement during treatment. Therefore, upper incisors are considered the most representative for assessing resorption in both arches.¹⁹

An additional consideration in interpreting EARR prevalence is how root changes are conceptually defined. Some researchers consider any detectable alteration of root surface as EARR,⁴¹

whereas others maintain that the EARR should not be considered until it extends up to 2 mm of root shortening.⁴⁴ This conceptual distinction influences how severity is interpreted and reported.¹⁷

In studies employing 2D diagnostic systems, severe EARR was reported in fewer than 10% of incisors in almost all cases. This likely reflects that severe EARR is readily apparent and can be diagnosed long before the end of orthodontic treatment, as observed on control radiographs. Only a few studies reported severe EARR above 10% of the incisors, and these exceptions were generally associated with specific clinical conditions when the incisors were analysed. Five studies analysed the incisors as a group,^{7,10,16,18,48} two studies divided them into groups of incisors,^{20,49} and only one analysed each incisor separately.²⁹ Among these, the study by Wichelhaus et al.¹⁰ reported severe EARR in one of the two groups analysed (i.e., the control group), but not in the torque-segmented archwire group. Dermaut and De Munck⁵⁰ analysed incisors subjected to real intrusion over time, and the other three studies^{16,18,19} presented special considerations that may be associated with a high risk of resorption during orthodontic treatment. Regarding studies analysing individual incisors, the only study reporting severe EARR in more than 10% of cases was conducted by Horiuchi et al.,²⁹ who specifically assessed the left central incisor; this finding may be limited by its focus on a single tooth.

Overall, the evidence from 2D studies indicates that severe EARR is rare, whereas most patients experience no or only mild resorption. This scenario changes significantly when studies employing 3D diagnostic methods are considered; the prevalence of EARR is consistently lower than in 2D analyses. Across both fixed and removable appliances, severe EARR represents less than 5% of all cases. Indeed, with clear aligners, severe EARR was practically non-existent; studies by Jyotirmay et al.⁴¹ and Li et al.⁹ did not identify any severe cases.

Some studies employed only a two-group classification (none/mild vs. moderate/severe), such as those by Castro et al.³⁵ and de Freitas et al.³⁶ In these cases, the larger second group appeared to consist mainly of moderate EARR, with relatively few severe cases. This pattern is consistent with the trend observed in studies employing the four-category classification, in which moderate EARR is more frequent than severe EARR.^{35,36}

However, there was no clear consensus among studies regarding the distribution of the EARR across the three categories. By contrast, agreement was greater for severe EARR, which was consistently reported at very low levels. This likely reflects that, until resorption becomes noteworthy and distinct, classification is not straightforward. As a result, it may not be possible to establish the extent of resorption precisely until it becomes evident and severe.

Across the included studies, the vast majority of cases exhibited mild resorption. This suggests that some degree of EARR is almost inevitable in most cases during orthodontic treatment. However, resorption is mild in most cases and falls within the

realm of acceptable risks during treatment.

From a clinical perspective, these findings indicate that although some degree of EARR may be expected during and after orthodontic treatment, it is predominantly mild and of limited clinical relevance. Nevertheless, the consistent occurrence of EARR underscores the importance of appropriate radiographic monitoring, particularly in prolonged treatments or complex tooth movement. Individual patient risk assessment remains essential, taking into account treatment-related factors, force magnitude, and biomechanics. Early identification of EARR may allow timely modification of treatment mechanics, thereby reducing the risk of progression to clinically significant resorption.

Although most EARR cases remain mild, certain patient- and treatment-related factors appear to increase the risk of more severe EARR. Specific factors include a history of dental trauma and, potentially, genetic variables related to bone and root metabolism. With respect to treatment mechanics, prolonged treatment duration, application of heavy forces, and specific types of tooth movement (intrusion, torque, and extraction space closure) have been linked to greater resorption. This consideration highlights the importance of individual risk assessment and the need for careful biomechanical assessment before initiating orthodontic treatment.

Mean EARR values across almost all studies were low, reflecting what clinicians are likely to encounter in orthodontic practice. Cases outside this range are rarely reported. Notably, studies that unified measurements across different incisors reported values that were generally greater than those obtained in studies presenting individualised measurements for each incisor.

When EARR was measured individually for each tooth using radiographs, the mean values remained below 2 mm. Studies reporting separate means for the central and lateral upper incisors showed results closer to 2 mm, particularly with conventional fixed appliances. In contrast, studies that collectively analysed all four incisors tended to report higher mean values.⁴⁷ Using 3D systems, mean EARR values were consistently lower, reflecting the greater measurement accuracy of CBCT, as demonstrated in previous research.¹⁵

This review has certain limitations that should be considered. As a scoping review, it synthesises evidence from studies with diverse methodological approaches, which limit quantitative comparisons. Evidence regarding removable appliances remains scarce despite their increasing use in contemporary orthodontic practice.

Future research should prioritise standardised diagnostic and classification systems, prospective multicentre studies with adequate follow-up, and the inclusion of diverse treatment modalities, particularly clear aligners, to obtain more robust and comparable estimates of EARR prevalence worldwide.

The primary aim of this review was to provide orthodontic professionals with an overview of the expected EARR associated with treatment. In addition, this study highlights the need to establish a unified, standardized diagnostic method for this pathology and to consolidate the classification system. Such standardisation would greatly facilitate comparisons across studies and improve the interpretation and applicability of future research.

CONCLUSION

The prevalence of mild EARR does not correlate with a diagnosis of severe EARR following orthodontic treatment. In most studies, a similar percentage of severe EARR was observed, whereas diagnoses in other categories varied considerably. This suggests that the diagnosis and classification of EARR may be limited until the resorption becomes notably severe. Despite the use of CBCT as a precise diagnostic method, the included studies lack consensus regarding the assessment method. The disparity in the reported mean EARR measurements secondary to orthodontic treatment with fixed appliances ranged from 0.13 ± 0.47 mm to 3.53 ± 3.03 mm.

This scoping review revealed a lack of consensus and uniformity among the studies analysed regarding the identification and classification of EARR following orthodontic treatment. This review highlights the urgent need for standardised diagnostic methods and a unified classification system for EARR after orthodontic treatment. Standardisation would improve the comparability between studies and the interpretation of results, and provide orthodontic professionals with clear expectations regarding the occurrence of root resorption after orthodontic treatment. The extensive range of diagnostic radiographic techniques, from 2D methods to 3D CBCT, and the diverse classification systems employed complicate comprehensive understanding of the prevalence and severity of EARR.

Footnotes

Author Contributions: Concept – R.S-C., A.I-L.; Design – R.S-C., P.I-D., A.I-L.; Data Collection and/or Processing – R.S-C., Y.C.; Analysis and/or Interpretation – R.S-C., P.I-D., Y.C., A.I-L.; Literature Search – R.S-C., Y.C.; Writing – R.S-C., P.I-D., A.I-L.

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Supplementary Link: <https://d2v96fxpocvxx.cloudfront.net/bda9171a-fae8-4995-8276-2138323f1e16/content-images/de648a28-b932-4dd3-b7a1-eee9caf3972b.pdf>

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