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Orthodontically Induced External Root Resorption between Clear Aligners and Multi-Bracket Appliances: A Systematic Literature Review

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Abstract

***Background*:** With the rising popularity of clear aligners therapy, understanding the incidence and severity of apical root resorption in patients following treatment with both clear aligners and fixed appliances becomes increasingly crucial. The purpose of this systematic review of the literature is to compare the incidence/severity of root resorption in patients treated with clear aligners and fixed appliances and to determine the main factors responsible of the variation in root resorption between these two systems. ***Materials and Methods*:** Pubmed, Cochrane, ScienceDirect and Google Scholar were used to search for systematic reviews, randomized or non-randomized controlled trials, cohort studies and case-control studies conducted in humans and published within ten years (since 2014 until 2023). AMSTAR 2, RoB 2 and NHLBI, NIH were used to assess the risk of bias of the included studies. ***Results*:** In total, 21 articles (human studies): 10 systematic reviews, 7 cohort studies (6 retrospective and 1 prospective), 3 randomized controlled trials and 1 case-control study were included. ***Conclusion*:** The majority of the studies showed that the incidence/severity of apical root resorption is less in clear aligners compared to fixed appliances treated patients. However, these studies are characterized by different baseline malocclusions, treatment durations/modalities, study designs flaws, inconsistency in outcomes measurement/calculation. Future high-quality clinical trials are needed to further support these results.

Keywords: Root resorption, aligners, fixed appliances, orthodontic force, orthodontic movement, treatment duration, CBCT.

1. INTRODUCTION

Today, many adults opt for more discreet orthodontic treatments, such as orthodontic aligners, for social or professional reasons. This reflects a growing demand for aesthetic and practical solutions in the field of orthodontics [1, 2].

Since its development in 1997, Invisalign® has gained worldwide popularity as an aesthetic alternative to fixed orthodontic appliances [3].

After its introduction, this system has been significantly developed and continuously improved in many aspects: different attachment designs such as optimized "SmartForce technology" attachements, new materials and new auxiliaries, such as "Precision cuts", “Power ridges” and “Power-arms” which were designed to enable additional treatment biomechanics [3].

Several other systems exist on the market such as (Bioliner™ Plus, Spark™, Clear Correct®, NuBrace®, eCligner®, ClearSmile®, Inline®, etc..) which offer different approaches in terms of design, manufacturing and processing steps. These options all aim to improve comfort and aesthetics and ensure optimal oral hygiene [4].

Unlike multi-bracket appliances, which are not only unsightly but also hinder good oral hygiene, causing plaque buildup around brackets, archwires and ligatures [5, 6] thus increasing the risk of gingival inflammation and bleeding and white spots of the enamel [7, 8], without forgetting the numerous follow-up visits for activation or adjustment of the device, and finally iatrogenic root resorptions which can constitute a medico-legal concern for clinicians [9].

Indeed, most previous studies have evaluated the incidence and severity of root resorption after orthodontic treatment with multi-bracket appliances [10-13]. As aligners are relatively newer, this topic is not yet clearly established, despite studies that have evaluated resorption with aligners, the advantage of aligners over fixed appliances in terms of resorption is still up for debate as their results are not consistent [14-17].

In this context, we carried out this work in the form of a systematic review with the aim of comparing the incidence and severity of orthodontically induced external root resorption (OIERR) in patients with dental malocclusion and treated with clear aligners or multi-bracket appliances. It is structured by four main sections: Introduction, Materials and Methods, Results, and Discussion (IMRaD structure).

2. MATERIELS AND METHODS

We carried out this systematic review of the literature according to the criteria published by the international PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analysis) recommendations. Ethical approval for carrying out the study was given by the "Thesis Committee" of the Faculty of Dental Medicine of Monastir in November 2023 and a declaration on the international PROSPERO register was made with the following protocol number: CRD42024502435.

2.1 Objective of the Study:

The purpose of this review was to answer the following question:

- In patients with dental malocclusion, does orthodontic treatment with clear aligners compared to multi-bracket appliances reduce the amount of root resorption?

2.2 Eligibility Criteria:

The PICOS (population, intervention, comparison, outcome, study design) format was used to formulate the clinical question with defined inclusion and exclusion criteria (Table 1). All articles included in this systematic review met the following criteria:

Table 1: Eligibility criteria

Domains	Inclusion Criteria	Exclusion Criteria
Participants	Human	Animal, Syndromic patients, Patients with traumatized teeth
Intervention	Orthodontic treatment with clear aligners	Orthodontic treatment with appliance other than clear aligners, Ortho-surgical treatment.
Comparaison	Control group or control side treated with multi-bracket appliances	Absence of control group or side in the selected studies
Outcome	Quantity of root resorption (in mm, mm^3 or %), Root length or volume in pre and post-treatment, RC/RR ratio	Other results
Study design	Systematic review (with or without meta-analysis), Randomized or non-randomized controlled trial with parallel arms or split mouth design, Cohort study (retrospective or prospective), Case-control study	Non-original article, Narrative review, Letter to the editor, Case report, Case series, Expert opinion

2.3 Information Sources and Search:

Two reviewers independently conducted a comprehensive search using a combination of controlled vocabulary (MeSH) and free text terms. PubMed, Cochrane, ScienceDirect and Google Scholar were searched from January 2014 to December 2023 (period of ten years). Other than publication date, the search restrictions included only English and French articles as well as full text and references availability. To answer the research question, it is necessary to search for all articles mentioning both aligners and multi-bracket appliances, therefore, articles which mention only aligners were not considered. To do this, MeSH keywords were selected and combined with Boolean operators AND/OR to obtain the search equations used on the different electronic databases. Keywords used in search were: ‘’Aligners’’, ‘’Root resorption’’, ‘’Fixed appliance’’, ‘’Conventional orthodontic treatment’’, ‘’Traditional orthodontic treatement’’, ‘’Invisalign®’’, ‘’Bracket’’, ‘’Brace’’ (Table 2). Subsequently, a manual search was carried out by scanning the reference lists of all the included articles.

Table 2: Details of the Database Search Strategy

Database	Search Strategy
PubMed	(("Orthodontic Appliances, Removable" [MeSH]) AND "Root resorption" [MeSH]) AND "Orthodontic Appliances, Fixed" [MeSH]
	"Aligners AND Root resorption AND Fixed appliance "
	(((Orthodont* OR Clear OR Removable) AND Aligner*) OR (Invisalign®)) AND (Conventional orthodontic treatement OR Traditional orthodontic treatement OR Brace* OR Bracket* OR Fixed appliance*) AND Root resorption
Cochrane	(MeSH descriptor: [Orthodontic Appliances, Removable] explode all trees) AND (MeSH descriptor: [Root Resorption] explode all trees) AND (MeSH descriptor: [Orthodontic Appliances, Fixed] explode all trees)
	Aligners AND Root resorption AND Fixed appliance
ScienceDirect	Aligners AND Root resorption AND Fixed appliance
Google Scholar	"Aligners" "Root resorption" "Fixed appliance" compared "Root resorption"
Manual search	Aligners AND Root resorption AND Fixed appliance

2.4 Study Selection:

The process of selecting studies was conducted independently and in duplicate. All pertinent articles were imported into Zotero, a bibliography generator. Initially, duplicate articles were eliminated. Subsequently, titles and abstracts were scrutinized for eligibility. Full-text reports were consulted for articles that appeared to meet the inclusion criteria. Ultimately, relevant articles were subject to comprehensive analysis. Disagreements regarding inclusion were resolved by discussion between the two authors.

2.5 Data Collection Process and Items:

Data from the chosen articles for this study were extracted using a predefined standardized form by two independent reviewers. The collected information included author, year, number of participants, intervention, outcomes, and author conclusions. In cases of doubt or disagreement between the two reviewers, resolution was achieved through discussion.

2.6 Risk of Bias of Individual Studies:

The assessment of the risk of bias (RoB) of the included studies was performed by several tools depending on the type of each study:

***The RoB 2 tool:**

This tool is designed to assess the risk of bias in randomized controlled trials. It provides a structured approach focusing on different areas of bias, covering various aspects of trial design, conduct and reporting [18]. The tool assesses 5 different areas (the randomization process, deviations from planned interventions, missing outcome data, outcome measurement, and selection of the reported outcome). Each domain is composed by a set of questions to gather relevant informations about the trial and each question involves 5 possible answers: "Yes", "Probably yes", "No", "Probably no" and "No information". The algorithm then processes the answers to these questions to generate a risk of bias judgment for each domain. Possible judgments include:

- Low risk of bias: indicates that the risk of bias for the specific domain is considered low.
- High risk of bias: suggests that the risk of bias for the domain is high.
- Some Concerns: Indicates that there are concerns about the risk of bias in the field, but that it does not meet the threshold for high risk.

***The AMSTAR 2 test:**

(AMSTAR revised), was used to assess the quality of systematic reviews, as well as the search strategy, presentation of results, bias, sources of conflicts of interest and funding and the bias of the authors. This assessment grid was found to be reliable, valid, precise and easy to use [19]. It consists of a series of 16 questions with 3 possible answers: “Yes”, “Partial yes” and “No”. If the systematic review is not accompanied by a meta-analysis then we write “No meta-analysis”. For the calculation of the total score, one point is assigned to each “Yes” response, half a point is assigned to each “Partial Yes” response, and no points are assigned to the “No” and “No meta-analysis” responses. For each study, the number of points obtained is transformed into a grade A, B or C, according to the protocol described below:

- Grade A: 11 to 16 points out of 16: high quality study.
- Grade B: 7 to 10 points out of 16: study of average quality.
- Grade C: 0 to 6 points out of 16: low quality study.

***The NHLBI, NIH quality assessment tool:**

This is a tool developed by the NIH (National Institutes of Health) [20] and used in our review to assess the methodological quality of cohort studies and case-control studies with control group. Each type of study has a very specific scale to assess its risk of bias. For cohort studies, the scale is made up of 14 questions to which 3 answers are possible: “Yes”, “No” or “Unsure”. A “yes” response indicates that the criterion is met and a point is thus awarded. For the answers “No” and “Unsure” no points are awarded. The total score is calculated as follows:

- High quality study: 12 to 14 points out of 14.
- Average quality study: 8 to 11 points out of 14.
- Low quality study: 0 to 7 points out of 14.

For case-control studies, the scale has 12 questions and the evaluation process follows the same approach as the previous scale. The calculation of the overall score is carried out as follows:

- High quality study: 10 to 12 points out of 12.
- Average quality study: 6 to 9 points out of 12.
- Low quality study: 0 to 5 points out of 12.

3. RESULTS

3.1 Study Selection:

The results of the electronic search and the subsequent article selection process were visualized in the PRISMA flow diagram, aligning with PRISMA guidelines. Initially, 370 studies were identified through both database and manual searches. Following the elimination of duplicates, 332 studies persisted, and only 24 advanced beyond the stage of title and abstract screening. Ultimately, 21 articles were included in the final selection, as depicted in the PRISMA flow diagram (Figure 1).

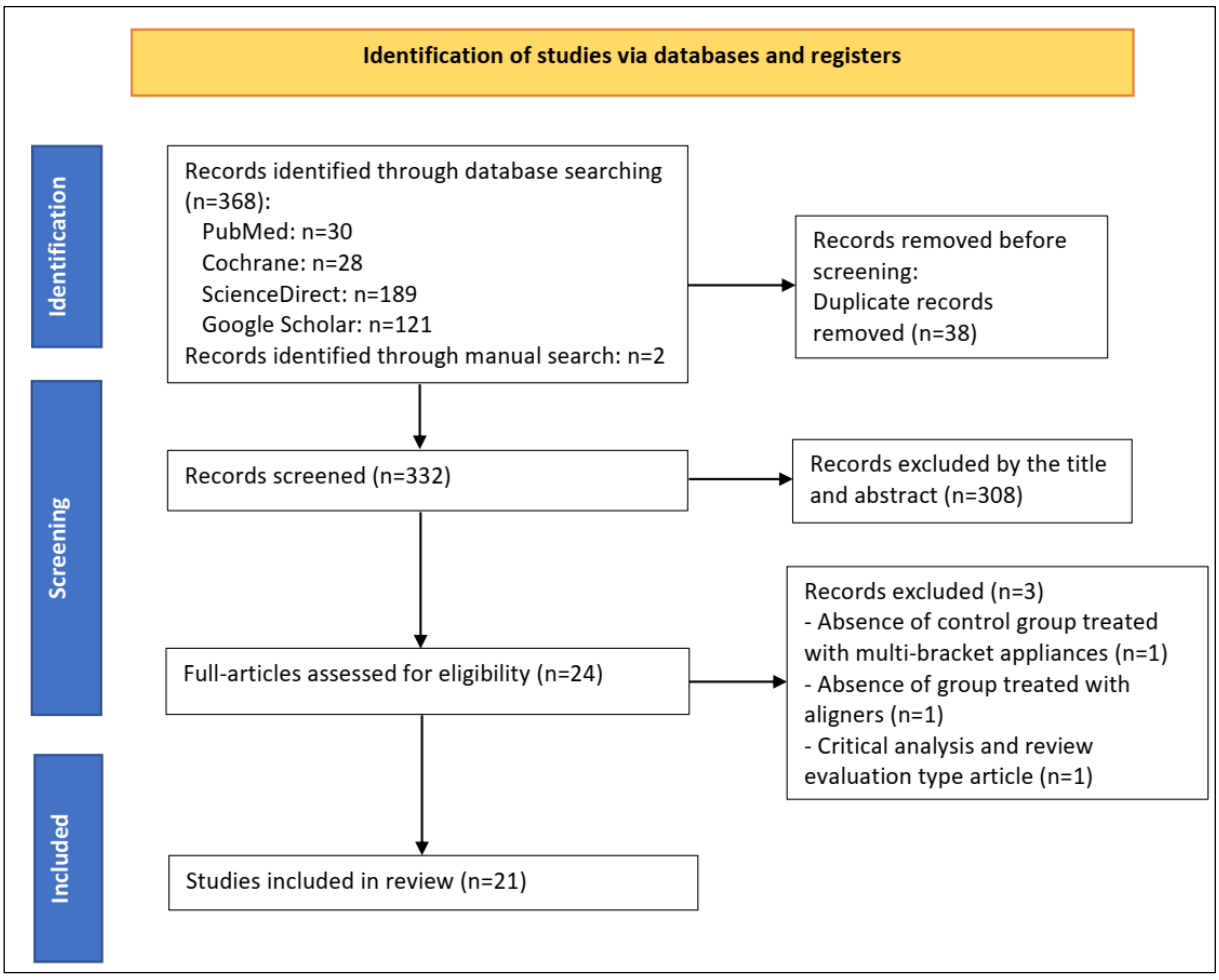

Fig-1: Flow chart according to the PRISMA statement

3.2 Study Characteristics:

21 relevant publications were identified as eligible according to the predefined inclusion criteria for this review: 10 articles were systematic reviews, 7 were cohort studies (6 retrospective and 1 prospective), 3 were randomized controlled trials and 1 case-control study. Studies were collected with a publication date limited to 10 years, from 2014 to 2023. The peak was reached in 2023, with 5 published articles identified that year. The curve is ascending showing the growing interest of researchers and dentists in this topic. There were 11 individual papers among the 21 articles that were included, with a total of 931 patients. In total, the sample size varied from 30 [39] to 372 [22]. Participants ranged in age from 14 to 25 years. They were teenagers and adults and had full permanent dentition. The orthodontic appliances used were clear aligners, mainly Invisalign®. In each study, the control group was treated with fixed orthodontic appliances.

3.3 Data Extraction and Synthesis

The 21 articles included in this systematic review and the data extracted from each study are shown in Table 3.

Table 3: Overview of included studies

3) Alejandro Iglesias-Linares [22]	**2)** Sachin Agarwel [2]	**1)** Marina G. Roscoe [21]	**Author**
2016	2015	2015	**Year**
Case-control study	Randomized clinical trial	Systematic review	**Study Design**
372 Caucasian patients (153 M and 219 F) were divided into 2 groups according to the absence of ERR or its presence. Patients have already worn either Invisalign® aligners or conventional brackets (CEOSA DM, Madrid). G1 : 198 patients and G2 : 174 patients.	57 patients (3 groups): G1 (24 patients; mean age 21.44 +/- 11.62 years), G2 (14 patients; mean age 14.82 +/- 4.26 years) and G3 (19 patients; mean age 14.47 +/- 3.99 years).	21 studies (514 participants). Only one randomized controlled trial that used aligners (27 patients: 54 first premolars; 12 M and 15 F; mean age 15.3 years).	**No of participants**
G1 (control): 0 =< RRE < 2 mm; 24.74% of cases with extractions; 61.8% of cases with ingressive movements. G2 (case): ERR> 2 mm; 26.43% of cases with extractions; 38.2% of cases with ingressive movements.	G1: semi-elastic polyurethane aligners. G2: self-ligating brackets. G3: Conventional brackets (3M Unitek™). Treatment without extractions for the 3 groups.	G1: ClearSmile® aligners. G2: Conventional brackets with light force of 25 g. G3: Conventional brackets with heavy force of 225 g. G4: control: absence of force. Treatment with tooth extractions. A positive torque movement is undergone by these teeth.	**Intervention**
Patients treated with aligners were twice predisposed to ERR than patients treated with brackets (Odds Ratio: 2.097; 95% CI [1.301 - 3.382]; p=0.002). When clinical and radiographic factors were adjusted with genotypic data, the results changed regarding susceptibility to ERR, indeed a statistically non-significant difference was found between the type of appliance and the amount of ERR (Odds Ratio: 1.662; 95% CI [0.945 - 2.924]; p=0.078).	The amount of ERR in lateral incisors was significantly lower in G1 (0.31 +/- 0.39 mm) compared to G2 (0.91 +/- 0.94 mm), (p=0.049) and G3 (0.75 +/- 0.99 mm), (p=0.022), but there was a non-significant difference (p=0.971) between G2 and G3. For the 2nd premolars, there was a non-significant difference (p=0.54) between G1 (0.17 +/- 0.10 mm), G2 (0.16 +/- 0.11 mm) and G3 (0.21 +/- 0.13 mm).	The premolars of G3 had the highest degree of ERR (9 times higher than G4; p<0.001) while G2 had the lowest incidence (5 times higher than G4; p<0.001) while for G1 this incidence was almost equivalent to that of G2 (6 times higher than G4; p<0.001).	**Outcomes**
Under the conditions of this study, it is evident that the predisposition to develop ERR with Invisalign® is similar to that with multi-bracket appliances.	There is less ERR in lateral incisors treated with aligners than with conventional or self-ligating brackets. There is no difference in the amount of ERR in maxillary 2nd premolars for the 3 systems.	There is a positive correlation between orthodontic force and the amount of ERR. Intermittency in tooth movement seems to be beneficial in reducing ERR because it allows the resorbed cementum to heal.	**Conclusion**

7) Osama Eissa [25]	**6)** Arwa Aldeeri [24]	**5)** Jianru Yi [23]	**4)** Rajae Elhaddaoui [4]
2018	2018	2017	2017
Retrospective cohort study	Systematic review	Retrospective cohort study	Systematic review
33 patients: 3 groups: G1 (11 patients; 5 M and 6 F; mean age 18.35 +/- 2.83 years), G2 (11 patients; 4 M and 7 F; mean age 17.71 +/- 2.22 years) and G3 (11 patients; 6 M and 5 F; mean age 17.44 +/- 2.39 years).	2 studies included in this review (87 patients): 1 randomized controlled trial (27 patients; 12 M and 15 F; mean age 15 years and 4 months) and 1 retrospective cohort study (60 patients; mean age 19 +/- 10.7 years for G1 and 22.2 +/- 11.5 years for G2).	80 patients (640 roots): 2 groups: G1 (40 patients: 9 M and 31 F; mean age 21.80 +/- 5.11 years) and G2 (40 patients: 11 M and 29 F; mean age 23.28 +/- 5.60 years).	3 studies (217 participants): only 2 studies that presented a control group: 1 randomized controlled trial (27 patients; mean age 15.3 years) and one retrospective cohort study (90 patients; 1080 teeth; mean age for G1 is 38.2 years and 15.8 years for G2).
G1: Invisalign® aligners (SmartTack®). G2: Damon Q® self-ligating brackets. G3: 3M Unity™ Victory Series conventional brackets. Treatments without extractions for the 3 groups.	1st study: the intervention has already been explained in article N°1. The amount of ERR was measured in pixels (= 0.01709 mm). 2nd study: G1: Invisalign® aligners. G2: Conventional brackets.	G1: aligners. G2: Conventional brackets (0.022" slot). Treatments without extractions for the 2 groups.	1st study: the intervention has already been explained in article N°1. 2nd study: G1: Invisalign® aligners. G2: multi-bracket appliances. Treatment without extractions for the 2 groups.
There was a statistically significant difference ($p<0.05$) between G1 and G3 and a statistically non-significant difference ($p>0.05$) between G1 and G2. For G2 and G3, the difference was statistically insignificant ($p>0.05$), with the exception of the right lateral incisors.	1st study: the outcomes has already been explained in article N°1. 2nd study: a statistically significant difference ($p<0.05$) between G1 (0.44 +/- 0.12 mm) and G2 (1.13 +/- 0.18 mm).	The average ERR value was 5.13 +/- 2.81% for G1 and 6.97 +/- 3.67% for G2. This difference is significant ($p=0.001$).	1st study: the outcomes has already been explained in article N°1. 2nd study: G1 showed no sign of ERR in all the 540 teeth evaluated, but for G2, ERR was detected in 2 to 50% of teeth, the incidence of severe ERR was 2.2% in the maxillary lateral incisors.
ERR represents an inevitable disadvantage of orthodontic treatment regardless of the technique used. However, the use of Invisalign® aligners (SmartTrack®) showed a lower ERR compared to conventional brackets in Angle Class I cases with mild to moderate crowding, and a non-significant difference compared to Damon Q® passive self-ligating system.	According to these 2 studies with a high level of evidence, aligners have a slightly higher risk of ERR than light forces and significantly lower than heavy forces.	Cases with extractions were not involved in this retrospective study due to the relatively high incidence of torque loss and angulation during space closure stage in previous aligner treatments and which improved clearly in current treatments.	Orthodontic treatment with aligners can cause ERR, however the incidence and severity of these ERRs remain less considerable compared to those caused by multi-bracket appliances.

10) Xuanwei Fang [28]	**9)** Spyridon N. Papageorgiou [27]	**8)** Scott Derek Currell [26]
2019	2019	2019
Systematic review	Systematic review	Systematic review
11 studies (1026 participants): a meta-analysis was done on 3 cohort studies (169 participants in total). 1st study (33 patients; 15 M and 18 F; mean age 17.83 +/- 2.48 years). 2nd study (56 patients; 27 M and 29 F; mean age 15.5 +/- 2.9 years) and 3rd study (80 patients; 20 M and 60 F; mean age 22.45 +/- 5.35 years).	11 studies (889 participants): only one retrospective non-randomized study that compared ERR between aligners and multi-bracket appliances (80 patients: 20 M and 60 F; 640 teeth; mean age 21.8 years for G1 and 23.3 years for G2	24 randomized controlled trials (1004 participants): only one study compared ERR between aligners and multi-bracket appliances (27 patients; 54 teeth; 12 M and 15 F; mean age is 15.3 years).
1st study: G1: Invisalign® aligners (SmartTrack®), G2: Damon Q® self-ligating brackets and G3: 3M Unitek™ conventional brackets. 2nd study: G1: Invisalign® aligners and G2: 3M Victory Series™ conventional brackets. 3rd study: G1: aligners and G2: multi-bracket appliances. Treatment without extractions for the 3 studies.	G1: aligners. G2: multi-bracket appliances. Treatments without extractions.	The intervention has already been explained in article N°1
Meta-analysis showed a statistically significant difference ($p<0.01$) in favor of a lower ERR for G1 (SMD= -0.65; 95% CI [-0.74; -0.55]). The analysis of each subgroup of incisors according to their position in the arch also showed a lower ERR for G1 compared to G2 and G3: mandibular central incisors (SMD= -0.53; 95% CI [-0.89; -0.18]; $p<0.01$), maxillary lateral incisors (SMD= -0.61; 95% CI [-0.79; -0.44]; $p<0.01$), maxillary central incisors (SMD= -0.61; 95% CI [-0.95; -0.27]; $p<0.01$), mandibular lateral incisors (SMD= -1.06; 95% CI [-1.26; -0.86]; $p<0.01$).	There is a lower ERR in G1 compared to G2 (MD: -1.84%; 95% CI: [-2.35% to -1.33%], $P<0.001$). There was a statistically significant difference between the 2 groups when comparing different types of teeth: maxillary central incisors: (mean difference = -1.13% [-2.20; -0.06], p=0.04), maxillary lateral incisors: (mean difference = -1.76% [-2.84; -0.68], p=0.001), mandibular central incisors: (mean difference = -1.15% [-2.07; -0.23], p=0.02) and mandibular lateral incisors: (mean difference = -3.30% [-4.24; -2.36], $p<0.001$).	The amount of ERR generated by the Clearsmile® segmented aligners was 5.9 times greater than the control group (no force), similar to the light force group (1.1 times), and significantly lower than the heavy force group (0.63 times).
Treatment with aligners does not prevent ERR during orthodontic treatment, but significantly decreases its incidence and severity compared to multi-bracket appliances. This is due to a system of intermittent forces and less jiggling movement. However, high-quality randomized controlled trials are needed to have more persuasive results.	Orthodontic treatment with aligners causes a significantly lower ERR than multi-bracket appliances. These data are limited, requiring further well-conducted individual trials to draw more robust conclusions.	The incidence and severity of ERR increases when orthodontic forces are applied. There is a positive correlation between ERR and continuous and heavy forces. Indeed, the amount of movement provided by aligners varies according to the duration of wear of the aligners. These intermittent forces allow the healing of the resorbed cementum, which then reduces the ERR.

13) Vaibhav Gandhi [31]	**12)** Ugnė Sadauskienė [30]	**11)** Yassir A.Yassir [29]
2020	2020	2020
Systematic review	Systematic review	Systematic review
16 studies (598 participants): of these studies, 9 studied ERR with multi-bracket appliances only, 5 studied it with aligners only, and 2 studies compared ERR between these two systems. A meta-analysis was carried out by summarizing the results of these 9 studies.	6 studies (686 participants): only 3 studies that presented a control group: 1st study (33 patients; mean age for G1 is 18.34 +/- 2.82 years and 17.52 +/- 2.3 for G2 and 17.34 +/- 2.22 years for G3). 2nd study (80 patients; mean age for G1 is 21.80 +/- 5.11 years and 23.28 +/- 5.60 years for G2) and 3rd study (372 patients; mean age for for G1 is 28.48 +/- 13.60 years and 26.29 +/- 13.66 years for G2).	28 systematic reviews are included in this review (2367 participants): only 5 studies compared ERR between aligners and multi-bracket appliances.
G1: aligners. G2: multi-bracket appliances. Treatment without extractions in these 9 studies.	1st study: G1: Invisalign® aligners (SmartTrack®). G2: Damon® self-ligating brackets. G3: 3M® conventional brackets. 2nd study: G1: aligners. G2: Conventional brackets. 3rd study: the intervention has already been detailed in article N°3. Treatment without extractions for the first 2 studies and presence of cases with extractions for the 3rd study. Presence of intrusive movements in the incisors of some cases in the 3rd study.	1st review: 21 articles: studying the influence of different levels of orthodontic forces on ERR. 2nd review: 3 articles: comparing the incidence and severity of ERR caused by the 2 systems. 3rd, 4th and 5th reviews (29 articles in total): assessing the root change in 2D or 3D after treatment with aligners or multi-bracket appliances.
Meta-analysis showed that the mean amount of ERR of the 4 maxillary incisors was less than 1 mm. Thus, the mean difference in ERR between G1 and G2 was statistically significant ($p<0.05$) only for the **#12** (G1: 0.36 mm, 95% CI = [0.26 - 0.47 mm] and G2: 0.74 mm, 95% CI = [0.51 - 0.97 mm]). However, for the **#21**, the **#22** and the **#11** the difference was statistically non-significant ($p>0.05$). In addition, there is a statistically non-significant difference ($p>0.05$) in the overall amount of ERR of the 4 maxillary incisors between the two systems (G1: 0.44 mm, 95% CI = [0.00 - 0.89 mm] and G2: 0.52 mm, 95% CI = [0.20 - 0.83 mm]).	1st study: Statistically significant ERR was found in all groups: G1: 0 to 1.4 mm. G2: 0.1 to 2.3 mm and G3: 0 to 2.5 mm. G3 patients showed a significantly higher ERR ($p<0.05$) than those in G1, but this difference was non-significant between G1 and G2 ($p>0.05$). 2nd study: the average RRE value found in the G1: 5.13 +/- 2.81% this value is significantly lower than that of the G2: 6.97 +/- 3.67%. 3rd study: a similar predisposition to RRE was found using both aligners and multi-attachment appliances.	ERR has been increased considerably with the application of high forces. The incidence and severity of ERR after aligner therapy were lower than those with multi-bracket appliances and comparable to low forces of the same appliances. An increase in treatment duration was found to be positively correlated with worsening of ERR.
According to this study, in cases of orthodontic treatments without extractions the amount of ERR is not significant (< 1 mm) for both systems. Indeed, among the maxillary incisors, only the **#12** showed a significantly higher amount of ERR with multi-bracket appliances than with aligners.	ERR during or after aligner therapy is unavoidable. However, the incidence and severity of these ERRs remain less important than those generated by fixed treatments. However, to have more accurate results and more reliable comparison, more complex cases requiring extractions must be included.	ERR can be expected to be higher in the following situations: heavy and continuous forces, treatment of severe malocclusions requiring complex mechanics and a long active treatment time.

16) Katia Critina Toyokawa-Sperandio [34]	**15)** Jyotirmay [33]	**14)** Yuan Li [32]
2021	2021	2020
Randomized clinical trial	Retrospective cohort study	Retrospective cohort study
40 patients: 2 groups: G1 (20 patients; 12 M and 8 F; mean age 23.60 +/- 5.65 years) and G2 (20 patients; 13 M and 7 F; mean age 20.56 +/- 4.51 years).	110 patients (576 roots): 2 groups: G1 (55 patients: 21 M and 34 F; mean age is 21.62 +/- 3.58 years) and G2 (55 patients: 23 M and 32 F; mean age 23.71 +/- 6.37 years).	70 patients (373 roots): 2 groups: G1 (35 patients: 13 M and 22 F; mean age is 24.71 +/- 7.48 years) and G2 (35 patients: 8 M and 27 F; mean age 22.51 +/- 6.47 years).
G1: Invisalign® aligners. G2: 3M Unitek™ conventional brackets, 0.022" x 0.030" slot. Treatment without extractions for the 2 groups.	G1: InLine® aligners; 56% of cases with extractions. G2: 3M® conventional brackets; 47% of cases with extractions.	G1: Invisalign® aligners; 54% of cases with extractions. G2: 3M Unitek™ Victory Series conventional brackets; 40% of cases with extractions.
A statistically significant difference in ERR only for the **#21** (G1: -0.52 +/- 0.57 mm; G2: -0.86 +/- 0.60 mm; p=0.037; the difference between the groups = -0.35 mm). For the rest of the incisors, the difference was statistically non-significant between the 2 groups, ranging from 0.03 mm for the **#11** to 0.35 mm for the **#21**.	The mean ERR obtained in G2 was 1.51 +/- 1.34 mm ($p<0.001$) compared to 1.12 +/- 1.34 mm (p=0.002) for G1. When the teeth were considered individually, the ERR in G2 was larger ($p<0.001$) than G1. In G2, the roots of all teeth underwent a reduction in length ($p<0.05$). In G1, this reduction concerned only mandibular central incisors ($p<0.05$) and maxillary incisors ($p<0.05$). Regarding severity degree of ERR, for G2: 19.45% of the roots had a 0° ERR; 62.32% presented a 1° ERR; 17.70% had a 2° ERR and 0.005% had a 3° ERR. On the other hand, for G1: 45.13% of the roots showed a 0° ERR; 54.86% had a 1° ERR and no root has presented a 2° or 3° ERR.	The prevalence of ERR in G1 (56.30%) was significantly lower than that in G2 (82.11%), ($p<0.001$). The severity of the ERR in the G1 (0.13 +/- 0.47 mm on average) was significantly lower than that of the G2 (1.12 +/- 1.34 mm on average), as well as for the roots individually compared between the 2 groups the difference was significant (all $p<0.001$). According to the classification of Sharpe *et al*., 43.70% of the G1 roots had a 0° ERR compared to 18.16% of the G2 and 56.30% of the G1 roots had a 1° ERR compared to 61.79% of the G2. No root in G1 had either a 2° or 3° ERR, compared to 19.24% of the G2 roots with a 2° ERR and 0.81% with a 3° ERR.
After 6 months of orthodontic treatment, aligners and multi-bracket appliances both cause a low degree of ERR in incisors with persistence of 97.12% of the initial root length, which does not alter the longevity or stability of the tooth	From this study, we can conclude that the amount of ERR in patients treated with aligners is less than that caused by conventional brackets. However, more studies with larger samples should be conducted to further support these findings.	The prevalence and severity of ERR in patients treated with aligners are lower than in patients treated with conventional brackets.

20) Wisama Withayanukonkij [38]	**19)** Hongyu Chen [37]	**18)** Ibtehal Almagrami [36]	**17)** Ines Dallel [35]
2023	2023	2023	2023
Randomized clinical trial	Retrospective cohort study	Retrospective cohort study	Systematic review
40 patients: 2 groups: G1 (20 patients; 8 M and 12 F; mean age 21.69 +/- 2.67 years) and G2 (20 patients; 7 M and 13 F; mean age 21.85 +/- 2.71 years).	59 patients (23 M and 36 F; 118 roots) in class II division 2: 3 groups: G1 (18 patients; mean age 22.67 +/- 3.12 years) and G2 (20 patients; mean age 23.60 +/- 3.19 years) and G3 (21 patients; mean age 23.71 +/- 3.44 years).	40 patients: 2 groups: G1 (20 patients; mean age 25.15 +/- 6.67 years) and G2 (20 patients; mean age 22.33 +/- 4.33 years).	26 studies: only 2 studies compared ERR between aligners and multi-bracket appliances: a case-control study (372 patients: 174 cases and 198 controls; mean age 27.38 +/- 13.63 years) and a retrospective cohort study (110 patients ; average age for G1 is 21.62 +/- 3.58 years and 23.71 +/- 6.37 years for G2).
G1: Aligners made by Duran® thermoplastic sheets. G2: Conventional brackets (Roth 0.022" x 0.028"). Treatment without extractions for the 2 groups. Movement of intrusion of 1st maxillary molars and extrusion of maxillary incisors.	G1: Invisalign® aligners. G2: 3M Unitek™ Victory Series conventional brackets. G3: Damon Q® self-ligating brackets. Treatment without extractions for the 3 groups.	G1: Invisalign® aligners. G2: Victory Series 3M Unitek™. Treatment without extractions for the 2 groups. G1: negative torque movement. G2: slight positive torque movement.	1st study: the intervention has already been explained in article N°3. Presence of cases with extractions. 2nd study: G1: InLine® aligners; 56% of cases with extractions. G2: 3M® conventional brackets; 47% of cases with extractions.
G1 showed a similar decrease in the length of the mesio-buccal (0.21 +/- 0.02 mm), disto-buccal (0.23 +/- 0.04 mm) and palatal (0.24 +/- 0.03 mm) roots, while G2 showed more ERR in palatal roots (0.47 +/- 0.16 mm) followed by mesio-buccal (0.39 +/- 0.06 mm) and disto-buccal roots (0,38 +/- 0,06 mm).	Root length and volume decreased significantly ($p<0.05$) in all groups. The lowest volume of ERR was observed in G1 (23.68 +/- 4.82 mm^3; 8.37 +/- 1.67%) compared to G2 (28.24 +/- 6.44 mm^3; 9.84 +/- 2.24%) and G3 (28.17 +/- 6.07 mm^3; 10.03 +/- 2.05%) ($p=0.029$). While in terms of resorption length, a non-significant difference ($p=0.9764$) was found between the 3 groups.	ERR in G1 (0.31 +/- 0.42 mm) was significantly ($p<0.05$) lower than in G2 (0.62 +/- 0.78 mm). The prevalence of ERR was 69% and 83% for G1 and G2, respectively. Regarding the severity of ERR: 31.1% of the incisors in G1 showed an ERR of 0° compared to 17.50% of G2 and 67.5% of the incisors in G1 showed an ERR of 1° compared to 80% of G2, while for an ERR of 2° the two groups reported the same percentage of severity of 1.30% and finally no incisor in G1 showed an ERR of 3° against 1.30% of G2.	1st study: a statistically insignificant difference in ERR between the 2 groups. 2nd study: the mean value of ERR for G2 was 1.51 +/- 1.34 mm compared to 1.12 +/- 1.34 mm for G1. The severity of the ERR on average in G1 was significantly lower than that of G2. When comparing each tooth individually, the ERR was larger in G2 than in G1 ($p<0.001$).
During 6 months of treatment, the amount of intrusion as well as ERR observed with aligners was about half the amount found with conventional brackets. The amount of ERR in molars was 1/3 of the amount of intrusion in the 2 groups.	Aligner treatment in Class II Division 2 cases may be effective in controlling root movement and reducing the incidence of fenestrations and ERR.	Both aligners and brackets cause a statistically significant increase in ERR in the incisor region, but greater prevalence and severity are associated with brackets.	According to this study, the amount of ERR is lower in patients treated with InLine® aligners compared to those treated with fixed appliances. Nevertheless, the predisposition to ERR with Invisalign® is similar to that with multi-bracket appliances.

21) Obaida Khalil [39]	2023	Prospective cohort study	30 patients (age between 12 and 18 years): 3 groups of 10 patients each. All patients experienced mild to moderate anterior crowding.	G1: Aligners without LLLT (Low Level Laser Therapy). G2: conventional brackets. G3: Aligners with LLLT. Treatment without extractions for the 3 groups.	**#41**: The highest ERR value was detected in G1 (-6.2 +/- 2.94 mm3) followed by G2 (-5.5 +/- 4.97 mm3) and then G3 (-5.3 +/- 2 mm3), (p=0.530). **#31**: The highest ERR value was found in G1 (-4.3 +/- 1.95 mm3) followed by G3 (-3.9 +/- 1.2 mm3) and G2 (-3.9 +/- 3.87 mm3), (p=0.413). **#42**: The highest ERR value was noted in G2 (-4.4 +/- 3.24 mm3) then G3 (-3.3 +/- 1.42 mm3) and finally G1 (-3.3 +/- 1.23 mm3), (p=0.90). **#32**: the highest value of ERR was found in G2 (-9.3 +/- 10.59 mm3) followed by G1 (-4.3 +/- 1.06 mm3) and then G3 (-3.4 +/- 1.65 mm3), (p=0.312). **#43**: The highest ERR value was found in G2 (-6 +/- 2.31 mm3) followed by G1 (-4.4 +/- 1.71 mm3) and then G3 (-4.1 +/- 2.38 mm3), (p= 0.106). **#33**: the highest ERR value was detected in G2 (-5.2 +/- 2.49 mm3) followed by G3 (-4.6 +/- 1.07 mm3) and G1 (-3.7 +/- 2.21 mm3), (p=0.296).	Aligners are very effective in treating cases with mild to moderate crowding. Thus, the ERR that results from this therapy is considered lower than that caused by multi-bracket appliances, but this difference is not significant. The use of laser has no effect on reducing the incidence of ERR.

3.4 Risk of Bias in Included Studies:

➢ **Randomized clinical trials:**

Using the RoB 2 tool; 2 studies were at low risk of bias and 1 study was at high risk of bias (Figure 2).

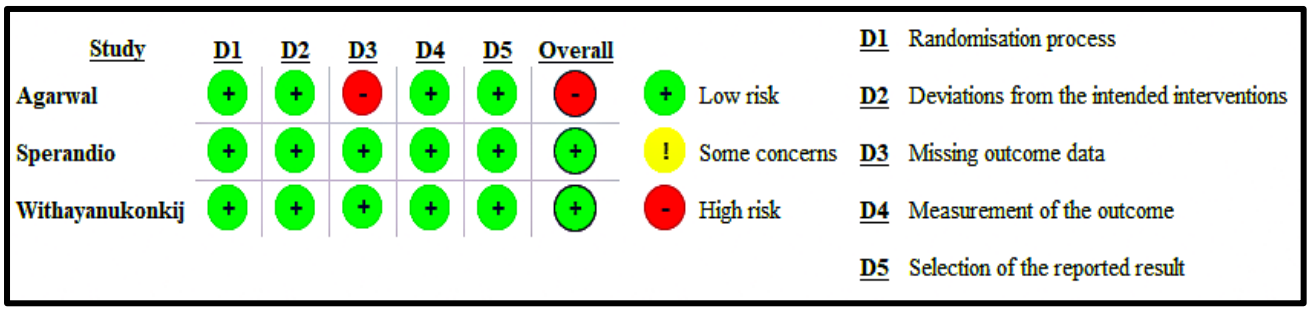

Fig-1: Risk of bias assessment according to RoB 2

➢ **Systematic reviews:**

Using AMSTAR 2 test, 4 studies presented a low risk of bias (Grade A), 4 studies were classified as moderately at risk of bias (Grade B) while 2 studies were assessed as low-quality reviews (Table 4).

Table 4: Risk of bias assessment according to AMSTAR 2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Grade
Roscoe [21]	Y	Y	Y	PY	Y	Y	N	Y	Y	N	NM	NM	Y	Y	NM	Y	**B**
Elhaddaoui [4]	Y	N	Y	PY	N	N	N	Y	N	N	NM	NM	N	Y	NM	Y	**C**
Aldeeri [24]	Y	Y	N	PY	Y	Y	N	PY	Y	N	NM	NM	Y	Y	NM	Y	**B**
Currell [26]	Y	Y	Y	Y	Y	Y	N	Y	Y	N	NM	NM	Y	Y	NM	Y	**A**
Papageorgiou [27]	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	**A**
Fang [28]	Y	Y	N	PY	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	**A**
Yassir [29]	Y	Y	Y	PY	Y	Y	N	Y	Y	N	NM	NM	Y	Y	NM	Y	**B**
Sadauskienė [30]	Y	N	N	PY	N	N	N	Y	N	N	NM	NM	N	Y	NM	Y	**C**
Gandhi [31]	Y	Y	Y	Y	N	Y	N	Y	Y	N	Y	Y	Y	Y	Y	Y	**A**
Dallel [35]	Y	N	N	PY	Y	Y	N	Y	Y	N	NM	NM	N	Y	NM	Y	**B**

Y: Yes; PY: Partially Yes; N: No; NM: No Meta-analysis.

➢ **Cohort studies:**

Using the NHLBI, NIH tool, 3 cohort studies were judged to be of high quality and 4 were rated as of moderate quality (Table 5).

Table 5: Risk of bias assessment according to NHLBI, NIH

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Quality
J. Yi [32]	Y	Y	U	Y	N	Y	Y	U	Y	Y	Y	Y	Y	Y	**Moderate**
O. Eissa [35]	Y	Y	Y	Y	Y	Y	Y	U	Y	Y	Y	Y	Y	Y	**High**
Y. Li [32]	Y	Y	Y	Y	Y	Y	Y	U	Y	Y	Y	Y	Y	Y	**High**
Jyotirmay [33]	Y	Y	U	Y	N	Y	Y	U	Y	Y	Y	Y	Y	Y	**Moderate**
Almagrani [36]	Y	Y	Y	Y	Y	Y	Y	U	Y	Y	Y	Y	Y	Y	**High**
H. Chen [37]	Y	Y	U	Y	N	Y	Y	U	Y	Y	Y	Y	Y	Y	**Moderate**
O. Khalil [39]	Y	Y	U	Y	N	Y	Y	U	Y	U	Y	U	Y	Y	**Moderate**

Y: Yes; N: No; U: Uncertain.

➢ **Case-control studies:**

Using the NHLBI, NIH tool; this case-control study was rated as moderate quality (Table 6).

Table 6: Risk of bias assessment according to NHLBI, NIH

	1	2	3	4	5	6	7	8	9	10	11	12	Quality
Iglesias [22]	Y	Y	Y	N	Y	Y	Y	N	Y	U	N	Y	**Moderate**

Y: Yes; N: No; U: Uncertain.

3.5 Certainty Assessment

The level of scientific evidence is assigned to each of the included studies according to the criteria outlined by the Oxford Center for Evidence-based Medicine [40] and presented in Table 7. Most articles were of grade B recommendation (80.9 %); level of evidence 2a was assigned to 42.8 % of the studies, 33.3 % were of level 2b and 4.7 % of the records were of level of evidence 3b. Only 4 studies were of grade A (19 %), 3 of them had a level of evidence of 1b and one had a level of evidence of 1a. Consequently, conclusions of a moderate level of evidence could be drawn from the review process. This suggests a moderate level of confidence in the results and conclusions derived from the review process.

Table 7: level of scientific evidence

Reference	Level of evidence	Grade of recommendation
[21]	2a	B
[2]	1b	A
[22]	3b	B
[4]	2a	B
[23]	2b	B
[24]	2a	B
[25]	2b	B
[26]	1a	A
[27]	2a	B
[28]	2a	B
[29]	2a	B
[30]	2a	B
[31]	2a	B
[32]	2b	B
[33]	2b	B
[34]	1b	A
[35]	2a	B
[36]	2b	B
[37]	2b	B
[38]	1b	A
[39]	2b	B

4. DISCUSSION

4.1 Summary of Evidence

It is widely admitted that the use of orthodontic forces frequently leads to an adverse effect of external root resorption in the treated teeth. Due to the absence of pathognomonic signs, OIERR is often detected by routine radiographic examinations [26]. In this context, Li Y *et al*., [32] conducted a retrospective study in which they investigated and compared the prevalence and severity of OIERR, using cone beam radiography, for the maxillary and mandibular incisors and canines (70 patients / 373 roots) after orthodontic treatment with presence of cases with extractions. They found that the prevalence and severity (mean) of OIERR in the Invisalign® group (56.30% and 0.13 +/- 0.47 mm) were significantly lower than the 3M Unitek™ Victory Series multi-bracket group (82.11 % and 1.12 +/- 1.34 mm) after 22 months of treatment. According to the classification of Sharpe *et al*., (1987), none of the teeth in the aligner group showed 2° or 3° resorption (the amount of ERR was always < 1 mm) on the other hand the multi-bracket group showed the highest value of ERR in maxillary canines (1.53 +/- 1.92 mm).

These results are consistent with a recent study published in 2023 by Almagrami I *et al*., [36] in which the authors explored, using cone beam, the prevalence and severity of ERR in maxillary incisors of patients treated without extractions. For the Invisalign® group, they found a significantly lower prevalence and severity (69 % and 0.31 +/- 0.42 mm) than those with the 3M Unitek™ Victory Series group (83 % and 0.62 +/- 0.78 mm). The most severe ERR was detected in central incisors of the multi-bracket group (0.68 +/- 0.97 mm). These results agree with the findings of Elhaddaoui R *et al*., [4].

These results are inconsistent with a case-control study conducted by Iglesias A *et al*., [22] on 372 patients. This study is the first to provide a comparative data on the incidence of ERR in a large sample of patients treated with Invisalign® or brackets while adjusting the response based on genotype, radiographic and clinical data. The researchers concluded that the predisposition to develop ERR with Invisalign® is similar to that with multi-bracket appliances. This can be explained by the presence of cases with extractions in this study and that only the tooth with the highest ERR rate was recruited in the statistical analysis. The substantial difference in the type of study with the studies described above may also contribute to this heterogeneity of results. Indeed, this study concluded that only subjects homozygous for the T allele of the IL1RN gene (rs419598) who are 3 times more predisposed to ERR than other subjects with a different genotype. Indeed, this study concluded that only subjects homozygous for the T allele of the IL1RN gene (rs419598) who are 3 times more predisposed to ERR than other subjects with a different genotype. Authors then believed that the failure to identify the DNA information of each subject leads to the inclusion of the risk inherent in certain genotypes, which leads to misinterpretation of the observed results of the effect of the device on ERR.

These findings coincide with the results of a recent study published in 2023 by Obaida K *et al*., [39] where they measured the volume of ERR (in mm^3) in mandibular incisors and canines, after 6 months of treatment, using cone beam radiography, in patients with mild to moderate anterior crowding and treated without extractions. They found that the volume of ERR in the aligner group was lower than the multi-bracket group for the canines and lateral incisors, but this difference was not significant. For the central incisors, the aligner group recorded a higher ERR than the multi-bracket group, but again this difference was not significant. This may be due to the presence of attachments on these teeth.

5 systematic reviews described the ex-vivo study conducted by Barbagallo L *et al*., [41]. The researchers found that the amount of resorption induced by aligners was relatively small and equivalent (1.1 times) to the resorption associated with the continuous and light forces of 25 g (cN) but significantly lower than the continuous and heavy forces (0.63 times).

A retrospective cohort study led by Yi J *et al*., [32], compared the amount of ERR in 640 teeth in patients treated without extractions with aligners and conventional brackets. ERR was measured using panoramic radiographs in the maxillary and mandibular incisors. To do this, they used the RC/RR ratio because several previous studies have suggested that this ratio remains stable in different panoramic shots [44, 45]. The researchers found that patients treated with aligners had a mean ERR value (5.13 +/- 2.81 %) that was significantly lower than those treated with multi-bracket appliances (6.97 +/- 3.67 %). This is consistent with the meta-analysis performed by Papageorgiou S *et al*., [27] and the meta-analysis performed by Currell S *et al*., [26].

Eissa O *et al*., [35] compared the amount of ERR produced after 18 months of treatment, in patients treated without extractions and with Angle class I, with Invisalign® aligners (SmartTrack®), the Damon Q® passive self-ligating system and the conventional 3M Unitek™ Victory Series system. They found that the amount of ERR with aligners is far lower than with conventional system for the four maxillary incisors. In contrast, the difference in ERR between aligners and self-ligating system was non-significant. Indeed, the low-friction Damon self-ligating bracket system was thought to produce low orthodontic forces, which may be more physiological for the periodontal ligament, and therefore less ERR would be expected [42].

This agrees with the randomized controlled trial conducted by Agarwal S *et al*., [2] They found that ERR in maxillary lateral incisors treated with aligners was significantly lower than conventional and self-ligating

brackets, while for the maxillary 2nd premolars the 3 groups showed a similar amount of ERR. This may be justified by the fact that the incisors are the teeth most affected by ERR during orthodontic treatment by the fact that they are mono-rooted teeth and that they undergo larger apical displacements than posterior teeth.

Jyotirmay *et al*., [33] conducted a study on 110 patients (576 roots) in which they investigated and compared the amount of ERR in patients treated with InLine® aligners and conventional 3M™ brackets for a period of 22 months with the presence of a few cases with extractions. The researchers found that the mean ERR with aligners (1.12 +/- 1.34 mm) was lower than with conventional brackets (1.51 +/- 1.34 mm) and that the most severe resorption was detected in maxillary canines (1.53 +/- 1.92 mm) with aligners and in maxillary central incisors (2.03 +/- 1.31 mm) with conventional brackets. According to the classification of Sharpe *et al*., and unlike the multi-bracket group, no tooth in the aligner group has reached the 2° or 3° stage of ERR.

However, a randomized controlled trial conducted by Toyokawa K *et al*., [34] investigated and compared, the ERR produced in maxillary and mandibular incisors using periapical radiographs after 6 months of treatment, without extractions, between aligners and multi-bracket appliances. They found that both of these systems cause a low degree of ERR and that neither incisor showed an ERR >= 1 mm in both groups. They also found that there was no significant difference in all the incisors except for the #21 which had a lower ERR with aligners. The authors concluded that limited tooth movement during a short treatment period of 6 months does not detect potential differences between the two groups. The duration of treatment may be a reason for the difference between the results of this study and the study conducted by Yi J *et al*., whose treatment duration was around 20 months, also the retrospective nature of this study, as well as the use of panoramic X-ray for the evaluation of ERR, which can deform the size of the teeth.

Another recent randomized controlled trial, conducted in 2023 by Withayanukonkij W *et al*., [38] compared the amount of intrusion as well as the amount of ERR using cone beam, for the 1st maxillary molars in patients with anterior open bite, skeletal class I, mild crowding and treated without extractions. After 6 months of treatment, they found that the amount of molar intrusion as well as the amount of ERR in the aligner group was about half compared to the conventional bracket group. The authors deduced that despite the greatest intrusive forces in the aligner group, the intermittent nature of this force decreased the amount of apical displacement and thus the amount of root resorption.

These results contradict the most recent systematic review included in our review and published in 2023 by Dallel I *et al*., [35]. The authors suggest that the use of aligners does not help minimize the incidence of ERRs, but decreases their severity due to the lower force delivered by aligners compared to multi-bracket appliances.

The meta-analysis performed by Gandhi V *et al*., [31] found that in cases of orthodontic treatments without extractions, there was a non-significant difference in the ERR in maxillary incisors, except for the #12 where the multi-bracket system presented a significantly greater amount of ERR than the aligner group.

The work of Fang X *et al*., [28] and Yassir A *et al*., [29] concluded that orthodontic treatment with aligners does not prevent ERR but considerably reduces their incidence and severity when compared with the multi-bracket system. They explained this by the discontinuous nature of the force delivered by the aligners, which are removable orthodontic appliances that can be removed by the patient for eating and oral hygiene maneuvers, which results in the absence of orthodontic force on the teeth for an average of 2 hours per day (wearing time of 22 hours/day) [2].

Sadauskienė U *et al*., [30] in their systematic review mentioned that CAD/CAM technologies allow us to plan and predict the direction and amount of movement of the teeth and to manufacture aligners accordingly. This helps distribute light forces in each aligner. In addition, the planning precise dental movement with aligners avoids parasitic movements and generates less inclination and unwanted palato-buccal movement and good control of the torque, these types of movements create excessive forces at the apex which absorbs the compressive stress resulting in an increase in apical stress per unit area [43].

4.2 LIMITATIONS

Additionally, our article selection was limited to studies available online and accessible for free, as well as those published or translated into English. This approach might have excluded relevant scientific studies published in other languages, posing a selection bias.

This review has some limitations that should be noted. First, our systematic review showed that most studies had a moderate level of evidence. In addition, the selection of articles was limited to studies available online and accessible free of charge, as well as those published or translated into French or English. This approach could have excluded relevant scientific studies published in other languages, which could constitute a selection bias. In addition, we have also limited ourselves to the last ten years of publication, which may also have been another selection bias. Finally, as in all systematic reviews, we may have missed studies, especially those that are ongoing.

CONCLUSION

In light of the results of our systematic review, thermoplastic aligners could be the cause of root resorptions after orthodontic treatment, however, the incidence and severity of these resorptions remain less significant compared to those reported with multi-brackets appliances. However, these results should be taken with caution, since the two techniques differ according to several criteria such as: indications, need for extractions, treatment duration, type and intensity of the delivered forces and planned orthodontic movements. These criteria can influence the incidence of root resorptions.

That said, the risk of root resorption when it is present, whatever the recommended technique, must be minimized by taking all the necessary precautions to do so, because unfortunately, we do not yet know of any orthodontic treatment capable of preventing root resorption.

To conclude, we can return to what Allan Brodie mentioned in the '50s: “Root resorptions are to orthodontic treatment what scars are to surgical treatment”.

Finally, it is crucial to direct future studies towards clinical research such as randomized controlled trials, with rigorous methodology, adequate sample sizes and a sufficiently long follow-up period to provide a high level of evidence regarding comparison of root resorption between aligners and multi-bracket appliances.

Declarations Section:
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Consent for publication: Not applicable

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Authors’ Contributions:
YA: study conception and design and data collection
AH and FA: analysis and interpretation of results
DI and WA: draft manuscript preparation
ST and AA: revised the text
All authors reviewed the results and approved the final version of the manuscript

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