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Orthodontic treatment with clear aligners and apical root resorption

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Abstract

Background and aim: The aim of this systematic review was to evaluate the link between clear aligner therapy and apical root resorption and to compare the amount of apical root resorption using different orthodontic appliances – clear aligners and fixed orthodontic treatment.

Materials and methods: Electronic and manual search for articles was carried out with specific inclusion and exclusion criteria. All selected studies had to be published in English between 2009 and 2019.

Results: 6 articles met the criteria and were selected for this systematic review. 3 of 6 studies presented comparisons between results of clear aligner therapy and fixed appliance treatment. The external root resorption after treatment with clear aligners was similar or significantly lower than with use of fixed appliances. Other 3 studies were only investigating results of treatment with clear aligners. The incidence of root resorption ranged between 46% and 81%. However, only 3,69% to 6,31% of all teeth were affected by considerable root length reduction (>20%).

Conclusion: Both incidence and severity of apical root resorption are lower after clear aligner therapy compared with root resorption results using fixed orthodontic treatment.

Keywords: Orthodontic treatment; Clear aligners; Apical root resorption.

1. INTRODUCTION

Orthodontically induced external apical root resorption (ARR) is a permanent loss of tooth structure (cementum and/or dentin) and pathological side effect of orthodontic treatment [1]. This complication results from combination of individual biologic variability, genetic predisposition and the effect of mechanical factors [1,2,3]. Orthodontic appliance and treatment technique can be important factors in the degree of ARR because of different treatment duration, amount of tooth movement and strength of applied forces [1].

During the last decade, clear aligner therapy (CAT) is becoming increasingly popular among patients and doctors. Orthodontists are treating young and adult patients by application of CAT because of its better esthetics and comfort during the treatment compared to fixed appliance treatment (FAT) [4,5]. The majority of studies and review articles investigated ARR as a result of orthodontic treatment when fixed orthodontic appliances were used. Whereas the data about the frequency and amount of ARR caused by aligner therapy is scarce.

Because of recent trend to widely use CAT for orthodontic treatment, the aim of this systematic review was to evaluate the link between CAT and ARR, to compare the amount of OIEARR using different orthodontic appliances - CAT and FAT.

2. MATERIALS AND METHODS

2.1 Search strategies

The electronic and manual search for articles was carried out in the following data bases: PubMed, Wiley, Science Direct, Cochrane Library. Applied keywords in MeSH were [aligners AND root resorptions].

2.2 Inclusion and exclusion criteria

We included articles that met all the following criteria:

1. Randomized controlled trials (RCTs), non-randomized controlled trials, prospective and retrospective studies
2. Studies published in English between 2009 and 2019
3. Studies evaluating the incidence and the severity of apical root resorption during treatment with orthodontic aligners alone or compared with fixed appliance treatment
4. Studies that analyzed orthodontic treatment in humans

Exclusion criteria was:

1. Case reports
2. Literature reviews
3. Studies only involving fixed appliance treatment

3. RESULTS

3.1 Search results

Based on selected keywords, a total of 23 articles were selected from four data bases. 15 articles were selected after title review and abstract analysis. Following the evaluation of full article, 6 articles were accepted for this systematic review (Figure 1).

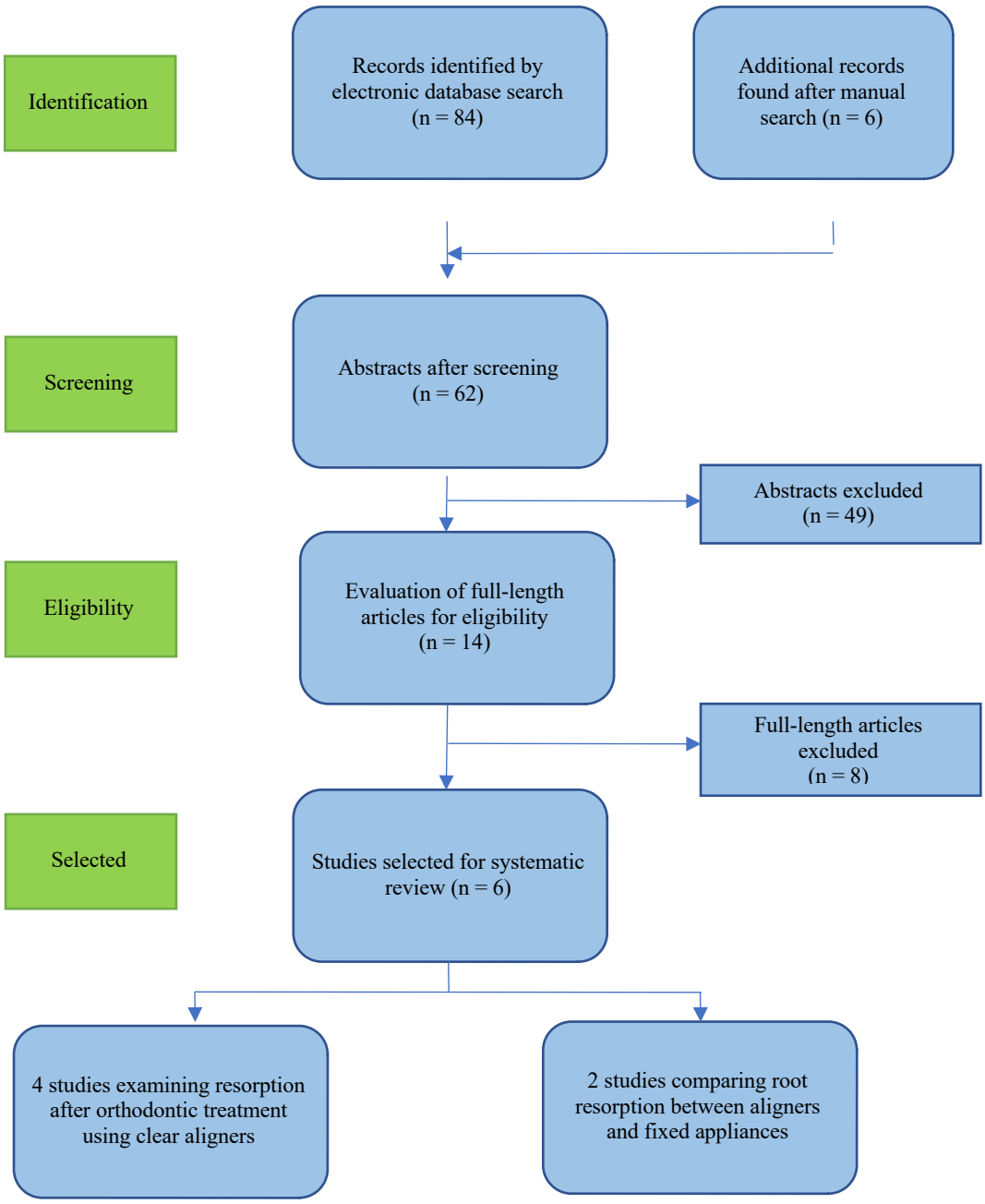

Figure 1: Flow diagram of the studies that were included in this systematic review

3.2 Study characteristics

Systematized and detailed information about selected studies is shown in Table 1. 2 of 6 included studies were retrospective cohort studies, one non-randomized clinical trial, one case-control genetic association study, one prospective and one pilot study.

3 of 6 studies were comparing CAT and FAT results:

-pilot study by Eissa et al. (Tanta University, Egypt) measured teeth length, using CBCT scans, before and after treatment with Smart Track® clear aligners, SL Damon brackets and 3M regular edgewise brackets [6]. The results show that patients treated with regular edgewise brackets are characterized by significantly higher resorption than those treated with aligners ($P<0.05$). No significant difference was noted between SmartTrack and Damon groups ($P>0.05$);

-retrospective cohort study by Yi et al. (Sichuan University, China) compared panoramic radiographs before and after treatment for patients that were treated with clear aligners (CAT group) and fixed brackets (FAT group) [7]. The mean value of EARR in CAT group (5.13±2.81%) was significantly less than in FAT group (6.97±3.67%);

-case-control genetic association study by Iglesias-Linares et al. (Complutense University of Madrid and University of Seville, Spain) also compared root resorption after CAT and FAT [8]. They concluded that a similar apical root resorption predisposition was identified using either removable aligners or fixed appliances.

Other 3 studies were investigating CAT results alone:

-non-randomized clinical trial by Krieger et al. (Johannes Gutenberg University, Germany) measured 1600 teeth after treatment with clear aligners [9]. More than half (54%) of all teeth showed no measurable reduction of root length. Only 6.31% of all teeth showed 20% or more reduction of root length;

-retrospective cohort study by Farouk et al. (Al-Ahzar University, Egypt) compared and measured CBCT scans before and after clear aligner treatment [10]. Patients were divided in two groups according to treatment protocol: Group I consisted of patients treated with Invisalign SmartTrack® clear aligners and high frequency mechanical vibration (HFV) device VPro5, Group II consisted of patients that were in treatment only with Invisalign SmartTrack® clear aligners, without additional HFV device. Researchers concluded that Group II showed a statistically significant reduction of tooth lengths compared to the Group I, which did not show statistically significant root resorption after the treatment.

-prospective study of Gay et al. (University of Torino, Italy) found that 81% of the 1083 measured teeth treated using clear aligner therapy presented a reduction of tooth length [11]. But average root length reduction after the treatment was less than 10% of original tooth length.

Table 1: Systematized and detailed information about selected studies

Study	Study design	Appliances used	Patients	Evaluated teeth	Root length measuring method	Treatment duration	Main results
Eissa et al., 2018 [6]	Pilot study	Group I: Smart Track® clear aligners Group II: SL Damon brackets Group III: 3M regular edgewise brackets	Group I: n=11 (M=5, F=6), mean age: 18.34±2.82y Group II: n=11 (M=4, F=7), mean age: 17.71±2.22y Group III: n=11 (M=6, F=5), mean age: 17.34±2.38y	Maxillary incisors	CBCT scans before and after treatment	Group I: 15.14±1.94m Group II: 15.75±1.74m Group III: 16.22±2.75m	Statistically significant root resorption was found in all groups: Group I 0-1.4 mm Group II 0.1-2.3 mm Group III 0-2.5 mm Patients that were treated with regular edgewise brackets showed significantly higher resorption than those treated with aligners (P<0.05). No significant difference was noted between SmartTrack and Damon group (P>0.05).
Yi et al., 2018 [7]	Retrospective cohort study	Group I: clear aligner therapy (CAT) Group II: fixed orthodontic treatment (FAT) (regular edgewise brackets)	Group I: n=40 (M=9, F=31), mean age: 21.80±5.11y Group II: n=40 (M=11, F=29), mean age: 23.28±5.60y	Maxillary, mandibular central and lateral incisors	Panoramic radiographs, before and after treatment	Group I: 22.08±4.51m Group II: 20.83±5.29m	The mean value of ARR in CAT group was 5.13±2.81%, which was significantly less than in FAT group (6.97±3.67%).

Iglesias-Linares et al., 2017 [8]	Case-control genetic association study	Invisalign® clear aligners and fixed orthodontic treatment	Group I (>2mm ERR): n=174 (M=70, F=104), mean age: 28.48±13.60y Group II (none or <2mm ERR): n=198 (M=783, F=115), mean age: 26.29±13.66y	Maxillary incisors	Panoramic radiographs, before and after treatment	Group I (>2mm ERR): 30.73±12.37m Group II (none or <2mm ERR): 29.56±11.64m	A similar apical root resorption predisposition was identified using either removable aligners or fixed appliances.
Krieger et al., 2013 [9]	Non-randomized clinical trial	Invisalign® clear aligners	n=100 (M=37, F=63), mean age 37.7y	Maxillary, mandibular incisors and canines, first maxillary and mandibular molars	Panoramic radiographs, before and after treatment	19.8m	In 54% of 1600 measured teeth no measurable root length shortening was determined. Reduction of tooth length was: >0-10% in 27.75% of cases; >10-20% in 11.94% of cases; >20% in 6.31% of cases.
Farouk et al., 2018 [10]	Retrospective cohort study	Group I: Invisalign SmartTrack® clear aligners + high frequency mechanical vibration (HFV) device VPro5	Group I: n= 15 Group II: n=15, mean age of both groups: 26±11y	Maxillary incisors	CBCT scans before and after treatment	12 months or until completion of treatment, whichever period was shorter	statistically significant decrease in tooth lengths was found in Group II compared to the Group I, which did not show statistically significant root resorption after the treatment.

		Group II: Invisalign SmartTrack® clear aligners					
Gay et al., 2017 [11]	Prospective study	Invisalign® clear aligners	n=71 (M=25, F=46), mean age: 32.8±12.7y	Maxillary incisors, canines, first premolars and first molars	Panoramic radiographs, before and after treatment	14.0m	Reduction of tooth length was found in 81% of the 1083 measured teeth. Severity of reduction of root length was: >0-10% in 25.94% of cases; >10-20% in 12.18% of cases; >20% in 3.69% of cases. Average root length reduction after the treatment was <10% of original tooth length.

4. DISCUSSION

The aim of this systematic review was to evaluate the link between CAT and ARR, to compare the amount of ARR using different orthodontic appliances - CAT and FAT. As ARR is very common complication among orthodontically treated patients and it is a multifactorial pathological event, it is very hard to find one leading factor for this complication [2, 12, 13].

4.1 Teeth affected by ARR and evaluation tools

In three of the selected studies only maxillary incisors were evaluated, in other three studies maxillary incisors were evaluated together with other teeth. The main reason why only maxillary incisors are taken into consideration is because in previous studies it was determined that these teeth are most susceptible to resorption during orthodontic treatment using fixed appliances [13, 14, 15, 16, 17, 18]. But none of the included studies in this analysis reported that maxillary incisors are the most vulnerable to ARR during orthodontic treatment.

Also, in older studies when cone-beam computed tomography (CBCT) was not so widespread tool, researchers were measuring only single-rooted teeth length on panoramic or periapical radiographs because it is very hard to accurately measure the length of multi-rooted teeth only using this radiographs. So later studies concluded that the amount of ARR seems to be underestimated in panoramic or periapical radiographs compared to CBCT [19, 20]. Despite this, Krieger et al. and Gay et. al. included multi-rooted teeth into observation and calculated teeth length from panoramic radiographs before and after treatment [9, 11]. To avoid distortion of results due to different degrees and magnification of panoramic radiographs, both authors calculated root-crown ratio before and after orthodontic treatment.

Now CBCT has been widely applied to dental field and it is accurate and reliable measuring tool because it allows for measuring of tooth's length in all three dimensions [21]. But still only two studies included in this review were using CBCT for teeth length measuring and they both are the latest researches from all 6 included studies [6, 10].

4.2 Different mechanical approaches between CAT and FAT may influence different results of ARR

One of the main differences between CAT and FAT from patient's perspective is that they can remove aligners before eating and toothbrushing. This frequent removal and insertion of aligners creates intermittent forces for teeth and it was already concluded that this irregular pressure to surrounding periodontal structures allow cementum to heal during the absence of pressure [22, 23, 24]. Meanwhile during FAT, continuous forces and intense mechanical stimulations are created and usually we are not able to accurately measure the amount of force that is applied to one tooth [25, 26]. This leads to a long-term impairment of blood circulation in periodontal structures, which consequently results in higher risk of ARR [15, 23, 26].

CAD/CAM technologies allows us to plan and forecast the direction, amount of teeth movement and fabricate the aligners accordingly. This helps to distribute the light forces in every aligner, which is 0,2 mm of movement every 7-

14 days [27, 28]. However, treatment using fixed appliances usually generates 1 mm of movement per month [29, 30]. Also, accurate planning of teeth movement with aligners can generate less tipping, unwanted proclination during leveling phase compared to treatment with conventional appliances. These types of movements create excessive force to the periodontium, cortical bone and later, after initial alignment with braces, we create back-and-forth movement, while this rarely happens during CAT [31, 32, 33]. And this difference between CAT and FAT can explain why studies with aligner treatment usually show less ARR than studies with fixed appliances [6, 7, 28, 34].

4.3 Connection between complexity and duration of the treatment and amount of ARR

Back-and-forth movement that was mentioned before is usually more frequent when using orthodontic appliances and this is one of many reasons why FAT treatment becomes prolonged and usually needs longer than expected pre-treatment. And many studies have already stated that the longer the duration, the more severe the root resorption is [7, 32, 35, 36, 37].

The other reason why researchers find less ARR after treatment with aligners than fixed appliances may be different treatment complexity. 3 of 6 studies that were included in this analysis examined patients in clear aligner therapy only, not including fixed appliances for comparison [9, 10, 11]. In all of these three studies only class I malocclusion with anterior crowding was included. Two other studies that were comparing CAT and FAT also excluded class II, III and tooth extraction cases (except for the third molar extraction) [6, 7]. One study did not separate patients into classes of malocclusion or different treatment [8]. Investigation of only class I cases compromised the results of ARR amount and severity after the treatment. In order to receive more reliable results, comparison of the results of ARR before and after the treatment should be carried out with more complex and longer treatment and cases requiring extraction.

Based on results of this systematic review, we can conclude that apical root resorption during and after the orthodontic treatment with clear aligners is not unavoidable. But both incidence and severity of ARR are lower after clear aligner therapy compared with ARR results with fixed orthodontic treatment.

However, these conclusions should be accepted critically, because CAT cases included in studies are relatively mild or easy. To get more accurate results, researchers should include extraction and other complex cases for CAT, as clear aligner companies are now able to offer protocols for extraction treatment.

5. ACKNOWLEDGEMENTS AND DISCLAIMERS

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