



Interpretation of the Comparison of Root Resorption Between Dental Aligners and Fixed Appliances by Literature Review

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Article History	Abstract
Received: 12 June 2023 Revised: 05 Sept 2023 Accepted: 09 Sept 2023	<i>There are insufficient studies that analyze the degree of root resorption (RR) in treatment with orthodontic appliances, whether these are clear dental aligners (CAT) or fixed appliances (FAT). The aim of the study was to interpret the comparison of root resorption between dental aligners and fixed appliances in orthodontic treatment by means of a review of the literature. The study was exploratory and searched the PubMed, Google Scholar, and Angle Orthodontic databases, as well as the websites of the Journal of Clinical Orthodontics, BMC Oral Health, International Orthodontics, American Journal of Orthodontics, European Journal of Orthodontics and Dentofacial Orthopedics, with publications between 2016 and 2021. It was evidenced that CAT presents lower RRE (Malmgren grade 2) compared to FAT (Malmgren grade 3). It was found that RRE is multifactorial (sex, treatment time, existence of previous extractions, dislacerated roots, and even predispositions of each person), in addition it will always depend on the treating orthodontist and the treatment plan used plus the collaboration of the patient. It was interpreted that radiographs can alter the measurements because they are less precise, underestimating the real root measurement of each dental organ and because in molars the roots overlap, thus altering the measurement, so it is recommended to use cone beam computed tomography, which are more accurate and sensitive in this aspect. The authors make suggestions for possible topics related to longitudinal studies, case-control studies, in vitro studies, and advanced imaging studies.</i>
CC License CC-BY-NC-SA 4.0	Keywords: External Root Resorption (ERR), Clear Aligner Therapy (CAT), Fixed Appliance Therapy (FAT), Literature Review, Orthodontic Appliances

1. Introduction

This research analyzes the degree of root resorption (RR) in the treatment with orthodontic appliances, whether these are transparent dental aligners (CAT) or fixed appliances (FAT). RR can be defined as irreversible damage to the root of a tooth, involving cementum and dentin (Aldeeri et al., 2018; Liu et al., 2021) and its severity may vary depending on different factors (Dindaroğlu, 2016; Guo et al., 2016). RR is characterized by being one of the most frequent problems encountered by the orthodontist when performing a treatment, since the dental organs will be subjected to forces (continuous and intermittent) that generate movement and when these are not handled correctly there can easily be this inconvenience (Elhaddaoui et al., 2017).

CAT are resin polymers that are coupled to the morphology of dental organs, sequential and that works with intermittent forces that allows the root cement to heal and, therefore, cause lower RR, while FAT uses brackets *with stainless steel wires that work with continuous forces which could be a determining factor to present higher RR* (Li et al., 2020)). To analyze this problem it is necessary to take into account factors such as: sex; treatment time; existence of previous extractions; Crowding; type of malocclusions; predispositions of each person; and even approximation to the palatine cortical plate (Fernandes et al., 2019; Sharab et al., 2015; Aman et al., 2018; Aman et al., 2018).

The interest of this study is to deepen the information on existing external root resorption (RRE), with different types of orthodontic appliances. Over the years, strategies are developed that reduce RRE rates. According to Alansari et al., dental aligners are of first choice in adult patients, due to their greater aesthetics, hygiene and comfort (Alansari et al., 2019).

On the other hand, FAT remains trusted by specialists who decide to treat severe malocclusions, for its time in the market and for having more studies in its favor, considering also that some of its representatives (self-ligating brackets) cause less resorption by the use of light forces and always depending on the actions of the treating dentist, The only drawback is aesthetics, as adults prefer something more subtle so as not to alter their self-esteem before society (Alansari et al., 2019; Osama et al., 2018).

There is a lack of studies regarding ERN with the use of complete treatments with CAT, or this information is limited, so some authors such as Aman et al. and Yi et al. mention being the first to focus on this type of study, emphasizing that only one of them uses cone beam computed tomography (CBCT) for its measurements in a large sample of patients (Aman et al., 2018; Yi et al., 2018). In order to compare the RRE grade, we chose to use the scoring system of Olle et al., which describes: absence of RR (grade 0); resorption up to 2 mm (grade 1); resorption less than 1/3 of the root (grade 2); resorption up to 1/3 of the root (grade 3); Resorption greater than 1/3 of the root (grade 4) (Olle Malmgren et al., 1982).

The most commonly used methods to observe prevalence and severity are panoramic and periapical radiographs (2,6,14) for several years, while today CBCT (15) reveals accurate data on the loss of tooth structure, emphasizing its greater sensitivity and specificity. When using panoramic radiographs there is a risk of overlapping roots, different errors due to distortions, underestimation of root length and increases difficult to avoid, which does not happen with CBCT that works hand in hand with software that helps better data collection (Aman et al., 2018; Yi et al., 2018).

It should be noted that Aman et al., mentions that there is less RRE using CAT because orthodontists generally use it for crowding or simple diastemas, but it is currently known that CAT is capable of treating even classes III, with correct knowledge and case studies, plus a good treatment plan, but there are still limitations in terms of this information (Aman et al., 2018).

The present study, in addition to being current, is of great importance because the interpretation of the comparison of root resorption between dental aligners and fixed appliances in orthodontic treatments can help determine which treatment method is safer and more effective for patients. The bibliographic review allows to gather information from previous studies and thus, make decisions based on scientific

evidence. Therefore, the objective of this study is to interpret the comparison of root resorption between dental aligners and fixed appliances in orthodontic treatments, through a literature review.

2. Methods

The study was exploratory and relied on hermeneutics to interpret the literature review. A database of current scientific articles published in scientific recognition journals was created, which studied the presence of RRE in orthodontic treatments, either with CAT or FAT. A search of information was performed in the databases PubMed, Google Scholar and Angle Orthod, as well as in the websites of the *Journal of Clinical Orthodontics*, *BMC Oral Health*, *International Orthodontics*, *American Journal of Orthodontics*, *European Journal of Orthodontics and Dentofacial Orthopedics*, in order to obtain reliable information. published between the years 2016 and 2021, and to help clarify the full dimension of the investigation.

This information contributed to the development, analysis, and support of this study.

Inclusion Criteria; (1) Studies in people with permanent dentition and complete root formation; (2) Articles published in English, Portuguese and Mandarin journals; (3) Articles published between 2016 and 2021; (4) Articles mentioning ESR as a result of orthodontic treatment (CAT and FAT). Exclusion Criteria; (1) Animal studies; (2) Articles showing root resorption in patients with bone effects or supernumerary teeth; (3) Articles that discuss gene-only root resorption

1. Results And Discussion

Information was collected from 104 scientific articles that mentioned RRE, but only 26 scientific articles met the defined inclusion and exclusion criteria. Of these, 6 duplicate articles were eliminated, thus studying 20 articles, classified as follows: 5 bibliographic review articles, 4 meta-analysis articles and 11 case studies. Table 1 shows the studies found that compare FAT and CAT expressed in Malmgren grades. Table 2 shows the findings on the factors that influence root resorption. Based on the bibliographic review, articles with great scientific relevance were analyzed, of the total of articles reviewed, only 20% directly mentioned data involving resorption with CAT and FAT, emphasizing that the results were obtained through the interpretation of people who did not know either the control groups, nor the data of the patients so that the investigations are as accurate as possible.

In this way, Osama et al. study 33 patients where only the maxillary incisors were analyzed for being uniradicular and also the most prone to root resorption, in this study resorption with aligners from 0 to 1.4 mm (Malmgren grade 2); resorption with Damon 0.1 to 2.3 mm (Malmgren grade 3); and resorption with *brackets* regular 0 to 2.5 mm (Malmgren grade 3). Thus, it was demonstrated that patients treated with fixed appliances had greater resorption than those treated with transparent aligners, with a resorption difference of <0.05 mm. (Osama et al., 2018).

This study was carried out with a CBCT, starting by finding the sagittal plane of each dental organ and later with the Mimic 19 software began to determine the measurement that went from the incisal edge of each dental organ to the most apical part of the root, thus finding, each of the measurements, this process was carried out before and after treatment.

Table 1. Studies comparing FAT and CAT expressed in Malmgren grades.

Author	Sample	Teeth studied	R.R.E With CAT		RRE Degree Malmgren	R.R.E With FAT		RRE Degree Malmgren	
Osama et al. (11)	33 Patients	Maxillary incisors	0	to mm	1.4	Grade 2	0.1 to 2.3 mm		Grade 3
							0 to mm	2,5	Grade 3
Aman et al. (9)	160 Patients	Maxillary incisors	0.51 mm to 0.65 mm			Grade 2	1.36 to 1.42 mm		Grade 2
Yi et al. (12)	80 Patients	Incisors Mandibular jaws is	2,82% (0 to 1.4 mm)			Grade 2	3,67% (0,5 to 2.3 mm)		Grade 3
Li et al. (6)	70 Patients	incisors and Canines	0,13 ± 0.47 mm			Grade 1	1.12 ± 1.34 mm		Grade 2

Table 2. Factors Influencing Root Resorption.

Author	Year of publication	Factors influencing ESR	Lower RRE	
			CAT	FAT or Same RRE
Aldeeri et al. (1)	2018	Yes	X	
Fang et al. (16)	2019	Yes	X	
Mohammed et al. (21)	2020	It does not mention	X	
Gandhi et al. (24)	2021	It does not mention		X
Elhaddaoui et al. (5)	2017	Yes	X	
Wattson et al. (18)	2019	Yes	X	
Osama et al. (11)	2018	It does not mention	X	
Aman et al. (9)	2018	Yes	X	
Gay et al. (19)	2017	Yes		X
Wang et al. (25)	2017	It does not mention	X	
Yi et al. (12)	2018	No		
Li et al. (6)	2020	Yes	X	
Iglesias-Linares et al. (14)	2017	Yes		X
Liu et al. (2)	2021	Yes	X	
Krieger et al. (15)	2016	No	X	
Sondeijker et al. (22)	2020	Yes	X	
Guo et al. (4)	2016	Yes		X
Deng et al. (17)	2018	Yes	It does not mention	
Pamukçu et al. (23)	2020	Yes	It does not mention	
Yi et al. (26)	2016	Yes		X

In the studies by Aman et al., upper incisors treated with CAT were also evaluated with a sample of 160 patients, due to the time available and the amount of data they reflected, thus the average resorption of upper central incisors was 0.53 mm and that of lateral incisors was 0.56 mm (Malmgren grade 2) (Aman et al., 2018)) The author highlighted the importance of the use of CBCT for the measurements of the RRE because, it is more sensitive and specific, thus avoiding errors in the mediations and overestimations, the measurements were similar to those of Osama et al. (2018), where, the sagittal plane of each dental organ was searched and with the help of the ICAT software (1.7.7) we proceeded to measure from the most apical part of the root to a line of relationship between the union amelo cementaría.

In addition, it mentions that there were different factors that are believed to alter the results such as sex, since there was greater RRE in male patients than in female patients; type of crowding, presenting less RRE in mild crowding; and finally the approximation of the apices towards the palatine cortical plate at the end of the treatment where there was greater RRE compared to those teeth that approached the labial cortical plate (Aman et al., 2018). Yi et al (2018) studied 80 patients, with whom 640 teeth were analyzed, dividing them into 320 teeth (40 patients) for the use of CAT and 320 teeth (40 patients) to use FAT, thus concluding that the mean value of the RR present with CAT was 2.82%, while with FAT it was 3.67%, thus demonstrating that there is less RR with aligners.

However, only upper incisors were analyzed, as there is a lack of precision when measuring the length of roots with multiradicular teeth on radiographs, and the need for a CBCT study, in addition to the most updated versions of CAT, to be able to rely on absolute and non-relative changes is emphasized. Not all factors influence, but, if it does the duration of treatment. Li et al studied 373 roots in a computed tomography study of 70 canine to canine patients, finding that on average with the use of CAT 0.13 ± 0.47 mm (Malmgren grade 1) and FAT 1.12 ± 1.34 mm (Malmgren grade 2), concluding that with CAT there is less RR, compared to FAT. In this research, CBCT was the imaging resource, where it was measured from the most prominent cusp or edge of each dental organ, to the apex of the root, and with the help of the Dolphin 3D program, the millimeter difference between an image of before and after treatment was calculated (Li et al., 2020).

70% of the articles read mentioned a very noticeable influence of factors such as: sex, treatment time, existence of previous extractions, crowding, type of malocclusions and approach to the palatine cortical

plate (Aldeeri et al., 2018; Li et al., 2020; Aman et al., 2018; Iglesias-Linares et al., 2017; Fang & Liu, 2019; Deng et al., 2018). In addition, that this RRE was present in all teeth, but due to time or difficulties to be able to observe the loss of tooth tissue. The most prone teeth (lateral and central incisors) were analyzed (Wattson & Dobles 2019), for this reason the articles have been analyzed in a very meticulous way. Aldeeri et al mention the presence of higher RRE in white or Hispanic patients compared to Asian patients, and according to their results there is a lower RRE with the use of CAT (Aldeeri et al., 2018).

Fang et al. (2019) carry out a very detailed literature review on factors that mainly collaborate with the RRE presented in their study, the factors with the most predisposition were: sex, treatment time, degree of movement, severity of crowding, previous blows suffered by the dental organs, use of accessories (such as garters), among others. FAT works with repeated and continuous movements unlike CAT, this plus a good job of the orthodontist and patient collaboration makes CAT present lower RRE.

According to Elhaddaoui et al., (2017) several factors are influencing, among them are emphasized the treatment time used, incorrect occlusion, patients in need of extractions and over bites. They also mention a lower resorption with CAT, but this result should be taken with caution, since the two types of orthodontics have different indications, movements or forces, which is why more studies are needed to prove the validity of this.

Wattson et al. (2019) argue that there are factors that can influence ESR such as biological, clinical, even mechanical factors, but that until the publication of their article no absolute relationships were established with them. In addition, no treatment can prevent RRE because it depends on inflammatory processes that lead to resorption caused by osteoclasts and repaired by osteoblasts to be able to move the teeth, but whether the RRE is severe or not, will depend on the type of force used, therefore, CAT presents lower RRE as well as the use of light forces. Gay et al. (2021) present in their study the influence of different factors that can cause RRE such as a complicated case of occlusion or the anatomy of the tooth to be treated. In addition, they mention that like any orthodontic treatment CAT will also produce RRE.

For Iglesias-Linares et al. the factors that mostly influence the presence or absence of RRE are clinical and radiographic factors, based on this they conclude that there is a very similar reabsorption for both CAT and FAT (2017). Liu et al. (2021) identify factors that could predispose to increased RRE, such as tooth extraction, tooth organ type, extrusion motion, and dental intrusion. RRE was present, but this was mostly mild and only in a few cases moderate, unlike with fixed appliances where there is more severe RRE.

Krieger et al. (2016) found no clinically outstanding factors, and when using the CAT system only 54% of patients presented RRE, which is a much lower figure compared to FAT studies where approximately 79% present RRE. Guo et al. (2016) did not find a major difference between the resorption presented by CAT and FAT, but they do highlight the influence of factors such as sex and root movement, but they need to be studied more thoroughly. Deng et al. (2018) reveal that their study found higher SRE in patients who had previous dental extractions or within the treatment and emphasize the need for more studies on this topic.

Of all the articles studied, 60% mentioned that the use of CAT reflects lower RRE compared to FAT, this is evidenced when compared with the degree of resorption, according to Malmgren et al. (1982), where CAT presented an average reabsorption of grade 0 and at most grade 2 (0 to 1.4 mm), while FAT presented this reabsorption of grade 0 and can easily reach grade 3 (0.1 to 2.7 mm). Only 25% of the articles mention equal or greater resorption with FAT, but these are based on studies of panoramic radiographs which may be flawed and less accurate (Yi et al., 2018; Gandhi et al., 2021).

Taking into account that 26.7 % of the articles mentioned that their results were based on the use of panoramic radiographs, even so, more reabsorption with FAT was evidenced, but that they presented certain drawbacks because they reflected a 2D image (Guo et al., 2016; Li et al., 2020; Aman et al., 2018; Yi et al., 2018) and that 3D studies are needed, which can be achieved with a CBCT. This method

shows us lower RR, which means that panoramic radiographs may underestimate tissue loss in dental organs (Fang et al., 2019; Deng et al., 2018; Wang et al., 2017). Mohammed et al. in their study do not mention or attribute any factor, whether internal or external, and conclude that CAT may never eliminate RRE, but it does decrease it significantly compared to FAT, according to their bibliographic analysis.

Sondeijker et al. mention that factors such as: sex, age, hygiene, extractions can influence and that in comparison FAT will present higher RRE because many orthodontists do not take into account mechanical parameters when following the treatment, which does not happen with CAT who has already elaborated the sequence and the type of force that must be exerted thanks to the manufacturing assisted by CAD-CAM technology, where the movements that each dental organ must have will be visualized based on mathematical algorithms (Sondeijker et al., 2020).

In addition, according to the articles read, CAT does not eliminate root resorption completely, simply that it occurs in smaller proportion, and some authors attribute it to the intermittent force with which it works (Fang et al., 2019; Mohammed et al., 2020). In the studies analyzed, severe malocclusions were not treated with CAT, since during the time of treatment plus the time of acceptance and year of publication of the CAT article evolved.

The benefits offered by CAT were observed, not only in aesthetics, comfort and shorter treatment time, but that resorption compared to FAT is significantly lower. Pamukçu et al. (2020) mention that RRE is not the result of a single factor that affects its prevalence, but is the result of factors that interrelate with each other, and that may be related to predispositions of each person. Gandhi et al. mention that after their research they do not find a significant difference in the presence of RRE, both with FAT and CAT, since it does not exceed 1 mm, and they do not mention any factor that may be involved in RRE (24). Wang et al. (2017) do not mention any factors, but conclude that patients using FAT tend to have higher RRE than those using CAT. The strength, the technique used in the treatment of malocclusion and the distance that the tooth travels are the main factors according to Yi et al. (2016).

Aldeeri et al. (2018) analyzed 236 articles, after studying them in depth and selecting those that meet the inclusion and exclusion criteria (2 articles), they conclude that CAT is superior in terms of low risk of RRE compared to FAT. But it will depend on the selection of the orthodontist's treatment plan, consistent with the results found in this research.

According to Mohammed et al., the ESR will depend on the correct treatment plan, the collaboration of the patient and the orthodontist, but they consider it very necessary to include studies with fewer confounding factors to reach much more reliable results and emphasize that their results should be taken with caution (2020).

Some of the clinical recommendations to reduce RRE that are suggested are to inform the patient that RRE may exist during the planned treatment, and that if this involves extractions, this resorption will be more severe due to the distance that the tooth must be mobilized

Gay et al. (2021) studied CAT with 71 patients from 2014 to 2015 and found that ESR begins at week 2 to 5, but is not radiographically evident until week 12 or 16 (19). Both Gandhi et al. and Iglesias et al. (2017) mention in their conclusions that there is a similar RRE with the use of CAT and FAT, contrary to what is determined in this article.

In order to understand this reabsorption, different authors choose to relate it to external factors, with this article it is corroborated with Pamukçu et al. (2020) who, in addition to studying the ESR present with 2 types of ERW, in their study mention that the same ESR may be due to sex, considering that most of their population are women and they have higher SRR or that it may be due to the age of the patients because adults have the most ESR, thus reaching the conclusion that this SRR is multifactorial and that the predispositions of each individual must always be taken into account.

This article does not affirm the results of Krieger et al. (2016) who do not find a statistically significant relationship in terms of factors that interfere with ESR, concluding that they have no clinical relevance.

Li et al. (2019) mention that there are alterations when taking a 2D X-ray because the RRE occurs in all three dimensions and when using Rx the radiographic image and its diagnosis can be altered, so the Rx are not an effective reliable method, due to elongations or overlaps of roots as molars. In addition, it is concluded by a CBCT measurement, that dental aligners cause lower RRE, this with a sample of 373 roots of 70 patients. For their part, Fang et al. also emphasize in their section that there are alterations in the measurement of RRE with the use of Rx and clarify that dental aligners do not eliminate RRE, since they only reduce it significantly.

Gandhi et al. (2021) analyze as many articles in which they are measured with X-ray as articles that use CBCT, where the articles they use for their CBCT measurements disclose lower RRE, than panoramic and periapical radiographs, since these present greater tooth loss, thus concluding that 2D radiographs may underestimate the amount of RRE.

According to Mohammed et al. intermittent forces cause lower RRE, in addition to a good treatment plan and patient collaboration, this would be explained by the fact that there is less RRE with CAT (21). Wattson et al. in their study conclude that the most susceptible pieces or those that present greater RRE are the maxillary incisors, highlighting the lateral incisors. This is consistent with the research of Gay et al. (2017) who mention that the maxillary incisors are mostly affected, but this is due to the greater movement they will have inside the mouth, their own root structure, and the relationship with both the bone and the periodontal membrane.

Yi et al. (2018) studied 80 patients who are treated with both FAT and CAT, but focusing on the presence of RRE that exists when dental extractions are not performed during treatment, concluding that CAT is superior to FAT in these cases. This article agrees with the studies of Aman et al. (2018) where, in addition to mentioning that it is one of the first studies that are known, with a large sample of patients studying a complete orthodontic treatment with CAT plus measurement of the RRE with a CBCT. Therefore, it stands out that more studies are needed to compare the RRE with different specific movements that occur in orthodontics (torque, rotation, among others).

Aldeeri et al. also mention the lack of existing information regarding studies on RRE that are presented with aligners or comparisons of this with other types of appliances. In addition, they do not present a more precise methodology, with strict selection criteria, meticulous measurements, in order to reduce the possibilities of alterations in the results. The same scarcity of information can be observed in Fang et al. (2019) where, after reviewing 116 studies for consistent information on CAT and FAT, they only use 11 studies for qualitative analysis and only 3 for meta-analysis.

Finally, Elhaddaoui et al. mention in their article that the CAT system is also known as thermoplastic splints or dental aligners. According to Li et al. (2020) the correct way to take an image using CBCT is for each of the patients to sit, motionlessly, with the Frankfurt plane parallel to the floor, in order to achieve a higher resolution in the images (Elhaddaoui et al., 2017).

The authors of this literature review consider that regarding the comparison of root resorption between dental aligners and fixed appliances in orthodontic treatments, several future studies could be suggested to deepen this area. Some possible lines of research include; (1) Longitudinal studies: perform long-term follow-up of patients treated with dental aligners and fixed appliances to evaluate the amount of root resorption that occurs with each method. In this way, it could be determined if any technique is more likely to cause long-term root resorption; (2) Case-control studies: compare the amount of root resorption that occurs in patients treated with dental aligners and fixed appliances that have similar clinical characteristics, such as severity of dental crowding or duration of treatment; (3) In vitro studies: Perform experiments in simulated dental models to compare the amount of root resorption that occurs with different orthodontic treatment techniques. This could help identify possible causes of root resorption and develop preventive measures to reduce its occurrence; (4) Advanced imaging studies:

Use advanced imaging technologies, such as cone beam computed tomography (CBCT) or magnetic resonance imaging (MRI), to assess root resorption more accurately and determine if there are differences between dental aligners and fixed appliances. Overall, more studies are needed to fully understand the relationship between root resorption and different orthodontic treatment techniques.

2. Conclusion

In the present study, the comparison of root resorption between dental aligners and fixed appliances in orthodontic treatments was interpreted through a bibliographic review. It was evidenced that CAT presents lower RRE (Malmgren grade 2) compared to FAT (Malmgren grade 3), which may be due to the type of forces with which each one works, in addition to FAT working with continuous forces that do not give time for the cement to heal, while CAT when working with intermittent forces helps to heal the root cement. It was found that the RRE is multifactorial (sex, treatment time, existence of previous extractions, dislacerated roots, and even predispositions of each person), in addition it will always depend on the treating orthodontist and the treatment plan used plus the collaboration of the patient. It was interpreted that radiographs can alter the measurements because they are less precise, underestimating the real measurement of the root of each dental organ and because in molars the roots overlap thus altering the measurement, so it is recommended to use CBCT, which are more accurate and sensitive in this aspect. There is a need for more studies on RRE with CAT to avoid bias in the results since CAT and FAT work with different indications, needs and strengths, and may be the main cause of CAT presenting lower RRE in most studies. In general, more studies are needed to fully understand the relationship between root resorption and different orthodontic treatment techniques, so the authors make suggestions for possible topics related to longitudinal studies, case-control studies, in vitro studies, and advanced imaging studies.

Conflict of interest

The authors indicate that they have no conflicts of interest regarding this article.

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