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ASSESSMENT OF EXTERNAL ROOT RESORPTION DURING THE FIRST STAGE OF THE ORTHODONTIC TREATMENT: A PROSPECTIVE CONE BEAM TOMOGRAPHY STUDY

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Introduction: predisposition to root resorption as a result of a dental movement may be a consequence of clinical, biological, and biomechanical factors that should lead the clinician to objectively assess each patient to reduce associated risk factors.

Objectives: to establish an association between clinical and tomographic findings related to external root resorption (ERR) using cone beam tomography (CBCT) on maxillary incisors during the first stage of the orthodontic treatment.

Methods: an observational, follow-up, cohort study that analyzed the association between clinical and radiographic variables on maxillary incisors using CBCT before placing fixed orthodontic appliances and finishing the first stage of orthodontic treatment in 20 patients was performed.

Results: using the Levander and Malmgren criteria on root length, no statistically significant changes were observed at any evaluation time. When exploring the association between malocclusion type, the vertical component, and type of orthodontic appliance used, no statistically significant changes were observed for teeth 11, 12, 21, and 22 (Vp KW>0.05). However, significant changes in class I patients compared to class III in tooth 22 were observed.

Conclusions: it is important to evaluate using 3D tools from the beginning of the orthodontic treatment to assess the individual risk of developing ERR as the etiology of such condition is multifactorial. It is noteworthy to mention that, after 6 months, no diagnosis of significant ERR was made. However, a reduction in total root length was observed in most patients. The selected clinical variables did not have an impact on the first stage of the orthodontic treatment.

Keywords: Orthodontics, Tooth resorption, Biomechanical phenomena, Cone beam computed tomography.

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The authors declare no conflicts of interest.

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***Orthodontics** / Orthodontie*

ÉVALUATION DE LA RESORPTION RADICULAIRE EXTERNE AU COURS DE LA PREMIERE PHASE DU TRAITEMENT ORTHODONTIQUE: ÉTUDE PROSPECTIVE A L'AIDE DE LA TOMOGRAPHIE A FAISCEAU CONIQUE

Introduction: la prédisposition à la résorption radiculaire à la suite d'un mouvement dentaire peut être la conséquence de facteurs cliniques, biologiques et biomécaniques qui devraient amener le clinicien à évaluer objectivement chaque patient afin de réduire les facteurs de risque associés.

Objectifs: établir une association entre les résultats cliniques et tomographiques liés à la résorption radiculaire externe (RRE) en utilisant la tomographie à faisceau conique (CBCT) sur les incisives maxillaires au cours de la première étape du traitement orthodontique.

Méthodes: une étude de cohorte observationnelle et de suivi a analysé l'association entre les variables cliniques et radiographiques sur les incisives maxillaires à l'aide de la tomographie à faisceau conique avant la mise en place d'appareils orthodontiques fixes et à la fin de la première étape du traitement orthodontique chez 20 patients.

Résultats: en utilisant les critères de Levander et Malmgren sur la longueur des racines, aucun changement statistiquement significatif n'a été observé à aucun moment de l'évaluation. En explorant l'association entre le type de malocclusion, la composante verticale et le type d'appareil orthodontique utilisé, aucun changement statistiquement significatif n'a été observé pour les dents 11, 12, 21 et 22 (Vp KW>0,05). Cependant, des changements significatifs ont été observés chez les patients de classe I par rapport à la classe III pour la dent 22.

Conclusions: Il est important d'utiliser des outils 3D dès le début du traitement orthodontique pour évaluer le risque individuel de développer une ERR, car l'étiologie de cette affection est multifactorielle. Il convient de mentionner qu'après 6 mois, aucun diagnostic d'ERR significatif n'a été posé. Cependant, une réduction de la longueur totale des racines a été observée chez la plupart des patients. Les variables cliniques sélectionnées n'ont pas eu d'impact sur la première phase du traitement orthodontique.

Mots-clés: Orthodontie, Résorption radiculaire, Biomécanique, Tomographie à faisceau conique.

Introduction

An orthodontic treatment exhibits a risk of external root resorption (ERR), which may be defined as a progressive loss of dentine and cement that leads to shortening or complete loss of the root structure. The scientific literature reports an incidence from 73% to 90% in different severity stages [1-4], being the lateral and central maxillary incisors the most affected teeth, followed by central and lateral mandibular incisors and the mesial root of the first mandibular molar [3, 4]. During the orthodontic treatment, localized areas of pressure and tension are generated, which stimulate the periodontal ligament cells, specially inflammatory cells, to release cellular and molecular mediators that initiate a sterile acute inflammatory reaction associated to clastic cells, such as osteoclasts, cementoblasts, and odontoblasts, which ultimately create an acidic environment, by releasing hydrogen ions and proteolytic proteins, that decalcifies and reabsorbs hard tissues, including bone, cement, and dentine. This is a complex and dynamic process involving qualitative and quantitative changes after the releasing of cellular and molecular markers [5, 6].

ERR may be classified as apical or cervical according to the affected area [7] or as superficial, inflammatory, and reparative according to the biological or inflammatory process. A superficial resorption is a self-limiting process of the external surface of the root followed by spontaneous repair by intact cells from the periodontal ligament. The inflammatory resorption reaches the dentinal tubules from the necrotic zone of the pulpal tissue and bone substitutes the portion of the affected tooth (ankylosis) in the reparative resorption [8]. As for the severity, Levander and Malmgren classified it a low, moderate, severe, and extreme or aggressive using a scale of 1 to 4 [9-11]. It is estimated that root resorption is dependent on biomechanical, infectious and/or inflammatory stimuli, among others [12].

Different papers report the influence of diverse risk factors that predispose the onset of ERR. The first factors are related to intrinsic conditions from the patient (phenotypical components), while the second are extrinsic and directly related to the orthodontic treatment. The intrinsic conditions include gender, age, ethnicity, related systemic conditions, genetic predisposition, and specific characteristics of the stomatognathic system, such as bone morphology and density, root morphology, the severity of the malocclusion, overjet, dental growth stage, pulpal status, alveolar bone replacement, previous orthodontic treatment, and predisposition to oral conditions [12-14].

Among the factors related to root anatomy, single-rooted and conical-shaped teeth are considered as risk factors since the orthodontic load will be applied directly to the apex, which will cause more displacement and longer treatment times [13, 15]. Assessment after the orthodontic treatment using conventional and mesial angulated periapical radiographies has shown that the maxillary incisors are the most affected teeth regarding root resorption. Evaluations using periapical radiographies and CBCT showed that teeth with shorter roots exhibit smaller changes compared to teeth with longer roots as the latter require higher orthodontic loads, thus leading to higher displacement that will cause changes in root morphology and dimensions [7, 16].

Environmental or extrinsic factors include medication or substances that interfere with bone metabolism, dentaoalveolar trauma (especially after reimplantation), endodontic treatment, and oral habits, such as tongue thrust, bruxism, and chronic onychophagy [14, 17]. The biomechanical factors include load duration, type (continuous, interrupted, or intermittent), and magnitude, the direction of dental movement, the orthodontic archwire sequence, the type of orthodontic appliance used, the amount of dental movement related to the amount of apical movement, and the duration of the orthodontic treatment [6, 9, 12, 15, 18, 19]. In addition, the orthodontic technique, the use of rectangular archwires and class II elastics, and the need for extractions are associated with an increased risk of ERR as uncontrolled loads may be generated, which will cause an increase in the rate of dental movement [7, 20].

When comparing different orthodontic techniques, the use of dental aligners has demonstrated a reduction in the incidence of ERR. Nonetheless, Castro *et al.* assessed maxillary and mandibular incisors using panoramic radiographies before and after orthodontic treatment and reported that 46% of teeth subjected to aligners exhibited ERR[21], while Fang *et al*. and Gay *et al*. reported values of 85.3% [24] and 41.81% [22], respectively. Conversely, Sawicka *et al*. found lower ERR using interrupted loads compared to continuous loads, which leads to the conclusion that no orthodontic technique can reduce the risk of ERR completely [23].

Considering the aforementioned, the initial diagnosis and follow-up of orthodontic patients, including the clinical, cellular, and biomechanical factors, has led to include the use of the CBCT. The diagnostic accuracy and early detection of ERR is of great importance to determine the therapeutic approach or changes to be implemented during the orthodontic treatment to provide a successful therapy. However, the panoramic and/or periapical radiographies have been normally used during the diagnostic stage of the orthodontic treatment. These bidimensional techniques limit the obtention of well-defined images as compared with 3D techniques, such as the CBCT, which allow more accurate diagnoses. CBCT requires a shorter exposure time, delivers low radiation doses, and provides incomparable 3D reconstruction abilities that do not depend on the angulation of the dental roots [16, 26].

Limitations of 2D images have been extensively reported. McKee *et al.* demonstrated that mesiodistal angulations in teeth from both jaws are not precise when using panoramic radiographies [24]. Kim *et al*. analyzed multiple ERR using CBCT and found a more accurate diagnosis and locations of the ERR areas [25]. The depth and direction of the root resorption are essential details when analyzing images, since axial, coronal, and sagittal projections provide more accurate information. Therefore, CBCT images must be indicated in patients with previous traumatic lesions and orthodontic treatment in order to detect an ERR [26].

CBCT involves lower exposure to radiation compared to conventional radiography and computed axial tomography (CAT) since it uses a cone-shaped X ray instead of the collimated spread beam of the conventional radiography. Studies using CBCT have found that absorbed radiation in anatomical parts of the head, neck, and upper body are 40% lower than CAT [27, 28]. Gibbs mentions that the amount of radiation from diagnostic aids such as panoramic, lateral cephalic, and periapical radiographies would be in the same range, or even higher, than CBCT, without the benefits offered by the latter [29] The radiation dose from CBCT varies according to the device, field of vision, and factors related to the technique (kV, mA, and exposure time). Image quality may also vary according to the CBCT source and a radiation dose equivalent to what is necessary to take 4-15 panoramic radiographies [26]. Dudic *et al*. showed that ERR was diagnosed in 44% of the teeth when using panoramic radiographies, while the value increased to 69% when CBCT was used [30].

Previous analyses have reported the association between factors related to the onset of ERR, which are essential to understanding the correlation between clinical and radiographic findings that lead to a higher risk of developing ERR. Therefore, the objective of this work was to establish an association between clinical and tomographic findings related to ERR using CBCT in orthodontic patients during the first stage of the orthodontic treatment at Universidad Cooperativa de Colombia.

Materials and methods

This is an observational, follow-up, cohort study on patients who entered the orthodontic specialization at Universidad Cooperativa de Colombia, Medellin-Envigado campus. Recruitment was performed using a census of all the patients who met the inclusion criteria for a follow-up period of 6 months. A written consent was obtained from every patient. Participation did not involve additional treatments. A CBCT was taken at the 6-month time. This work was approved by the ethics committee from Universidad Cooperativa de Colombia (Act 053-2018).

Patient collection

Patient collection was performed at the time of the first consultation. Every patient older than 18 years of age, who met the inclusion criteria, was invited to participate. Verbal and written information on the objectives of the investigation was provided. An exhaustive medical and dental chart, in a format approved by the university, was filled out with the 20 patients who met all the criteria. Exclusion criteria included patients with systemic conditions, the presence of oral habits (onychophagy, bruxism, tongue thrust), alcoholism, smoking, use of medication with inhibitory effects on bone metabolism (aspirin, tetracyclines, bisphosphonates), use of steroids, patients with previous root resorption, history of dental trauma, presence of dental/root anomalies (shape and size), patients with syndromes or craniofacial alterations, agenesia of lateral incisors, previous orthodontic treatment, and dental whitening.

Information sources

Information sources included the clinical assessment using data collected from 20 patients (13 female, 7 male) in a range between 20 and 35 years of age. Data included age, gender, malocclusion type, vertical component, type of orthodontic appliance, and root morphology. A CBCT was taken before the orthodontic treatment (T1) and 6 months after initiation (T2) to observe morphological changes indicating the onset of ERR since many studies have demonstrated that different degrees of severity may be observed after the first three months of orthodontic treatment.

Cone beam computed tomography

Each CBCT was taken at the same location (Cero 70 Oral Radiology Center, Sabaneta location). Root length and integrity between T1 and T2 were assessed using the classification of ERR by Levander and Malmgren (low, moderate, severe, and extreme) (31). For CBCT acquisition, a J Morita tomograph (Veraview 3D R100) and a computer (Dell Precision T3610, Windows 7 Ultimate, Intel Xeon CPU-E5 1607 processor, 8 GB RAM, 500 GB main disc and 500 GB backup disc) were used. The tomograph´s settings were established at kV:90, mA:7, and exposure time: 9.3s. An expert oral radiologist and maxillofacial surgeon performed the respective readings (intraclass correlation coefficient of 0.95 in a 2-week interval). Every measure was performed using the I-Dixel software where the three planes of space were aligned to assess the maxillary lateral incisors:

1. the root length was divided into three zones (cervical, middle, and apical) from the cementoenamel junction (CEJ) to the apex. The error margin was ±0.2mm. Measurement of the cervical third was taken at the limit with the middle third; the middle third was taken at the limit with the apical third and the apical third was taken in the root apex zone (Figure 1).

2. the root width was measured in the coronal axis mesiodistally at the three previously described zones (Figure 2).

3. the root length was measured from the CEJ to the apex (Figure 3).

4. the crown/root ratio was measured at the sagittal plane by obtaining the distance between the incisal edge and the alveolar ridge (buccal side) and from this point toward the apical zone (Figure 4).

5. the periodontal ligament was assessed by observing its continuity in the axial plane using the magnifying glass.

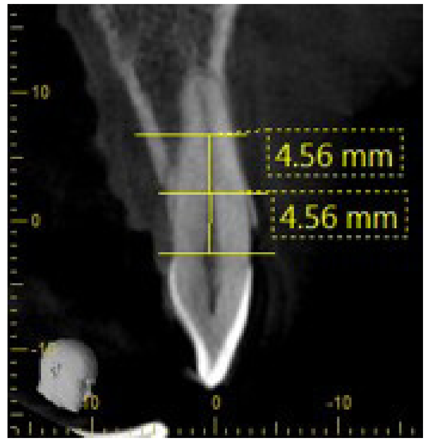

Figure 1. Root thirds

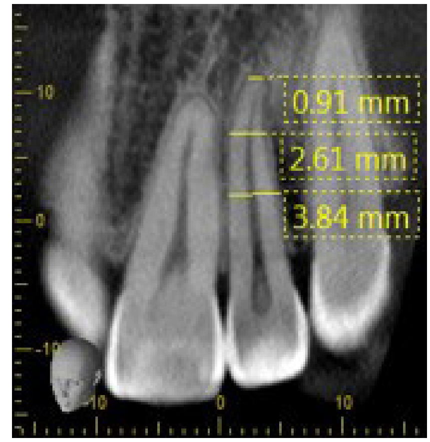

Figure 2. Mesiodistal root width

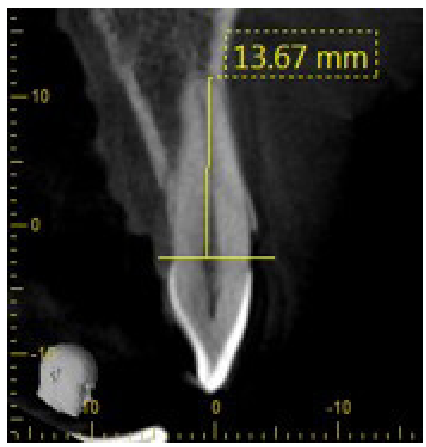

Figure 3. Root length

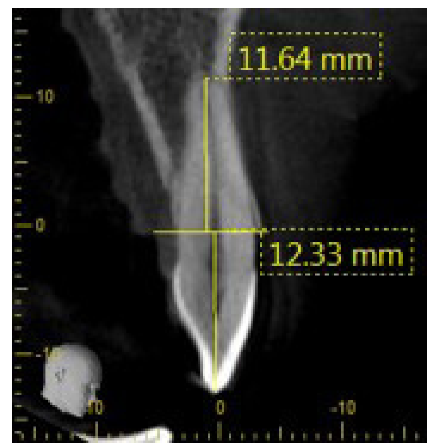

Figure 4. Crown/root ratio

Statistical analyses

A descriptive analysis through estimation of relative and absolute frequencies or summary measures (central tendency, dispersion, and position) according to the nature of the variables was performed.

The evaluation of changes in root length during the first stage of the orthodontic treatment was performed using the t-test of related samples; the changes in root width were assessed using the Wilcoxon test; the association between clinical and radiographic factors with the reduction in root length was analyzed using the Kruskal Wallis H test and the analysis of multiple comparisons using the Dunn's test. A previous verification of the normal distribution was performed using the Shapiro Wilk test.

An exploratory analysis using two multiple linear regression models was used to identify the clinical factors that were truly associated with the reduction in root length in teeth 12, 11, 21, and 22 thus dismissing the confusion effect between independent variables and to determine the explicative capacity of the associated factors by estimating the determination coefficient (R^2).

All analyses were performed using the IBM SPSS 28. A P value <0.05 was used as the criterion to accept or reject the null hypothesis.

Results

The average age of the studied population was 26.6±4.9 years, being 20 years the youngest and 35 years the oldest. As for gender, 65% of the population was composed by female subjects.

When analyzing the clinical variables, the highest frequency was shown by the class I malocclusion (50%), followed by the class III malocclusion (30%). 50% of the population showed a normal vertical component, the remaining showing open and deep bite. Most patients did not show any previous dental extraction (95%). 61,9% of the patients presented conventional orthodontic technique and 28,6% a self-ligating approach (Table 1, Figure 5)

The evaluation of the root length at the two established times for maxillary central and lateral incisors did not show significant changes (tooth 11: DM=0,085; Vp = 0,809, tooth 12: DM = 0,02 mm; Vp = 0,970, tooth 21 DM =0,017; Vp = 0,963; tooth 22: DM= 0,01 mm; Vp= 0,980, Table 2). In this regard, the frequency of resorption for teeth 11 and 21 was 94.7% and 81.3%, respectively. For teeth 12 and 22, it was 66.7% and 90%, respectively.

Table 1. Clinical characteristics of the studied population

		Number	%
Malocclusion type	Class I	10	50
	Class II division 1	1	5
	Class II division 2	3	15
	Class III	6	30
Vertical component	Normal	10	50
	Open	3	15
	Deep	7	35
Extractions	Yes	1	5
	No	19	95
Type of appliance	Conventional	12	61.9
	Self-ligating	6	28.6
	Aligners	2	9.5

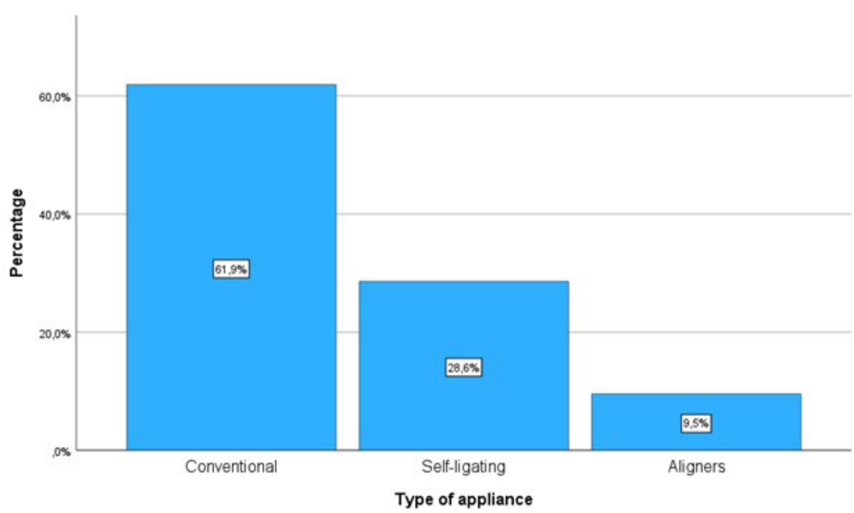

Figure 5. Type of orthodontic appliance

Table 2. Changes in root length during the follow-up period

	Time	Mean	SD	DM	P value*
Root length tooth 11 T1	T1	12.421	1.03524	0.085	0.809
	T2	12.336	1.16745		
Root length tooth 12 T1	T1	12.7667	1.46431	0.0188	0.970
	T2	12.7855	1.56519		
Root length tooth 21 T1	T1	12.2670	1.16745	0.017	0.963
	T2	12.2500	1.10896		
Root length tooth 22 T1	T1	12.7686	1.46431	0.0119	0.980
	T2	12.7805	1.53778		

* t-test of related samples. Significant when $p < 0.05$

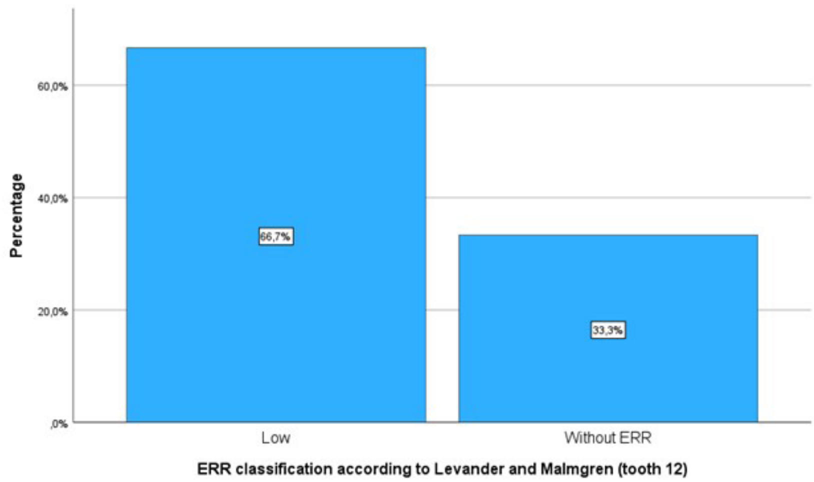

Figure 6. ERR classification according to Levander and Malmgren (tooth 12)

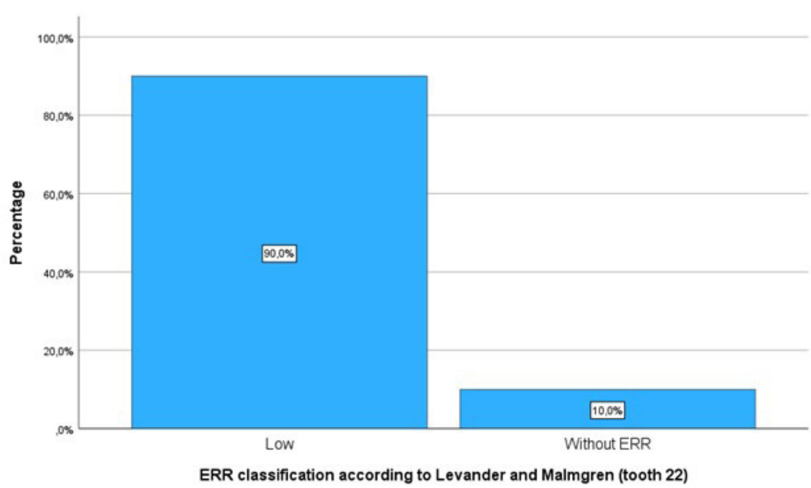

Figure 7 . ERR classification according to Levander and Malmgren (tooth 22)

Table 3. Root width during the follow-up period

	Time	Mean	SD	DM	P value *
Apical root width 12	T1	0.8190	0.30300	0.11850	0.169
	T2	0.7005	0.22563		
Apical root width 22	T1	0.7660	0.24150	0.13250	0.087
	T2	0.6335	0.23471		
Apical root width 11	T1	0.8385	0.39613	0.9200	0.223
	T2	0.7465	0.35783		
Apical root width 21	T1	0.8425	0.29488	0.5750	0.268
	T2	0.7850	0.28858		

* t-test of related samples

These frequencies may be classified as low according to Levander and Malmgren (Figures 6 and 7)

Regarding the root width measurements, the central and lateral incisors did not show significant changes at the apical, middle, and cervical thirds at both times. However, minimum variations were observed at the root thirds at T2 with a minimum range of 0.02 mm and a maximum of 0.18 mm at the cervical third of tooth 22 and tooth 12, respectively (Table 3).

The comparative analyses of the difference in root length related to the malocclusion type, vertical component, and type of appliance did not show an association with significant changes in the root length, except for tooth 12 in class I malocclusion, where significantly higher differences were observed (Me= 0.14 mm) in the root length compared to class III malocclusion (Me= 0.03 mm) (Vp Dunn´s test= 0,037) (Table 4).

A multiple linear regression model was applied to control for confounding effects between independent variables and to assess their association with root resorption in tooth 12. This analysis identified that sex and malocclusion type explained 24.8% of the resorption in that tooth, the average of ERR was 0.075mm higher in males compared to females and the average of ERR was 0.07mm higher in class I malocclusion compared to class III. The differences between this class and class II were not statistically significant (table 5). Similarly, a regression model was applied to assess resorption in tooth 22, identifying that none of the clinical-type independent variables were associated with this condition (table 6).

Table 4. Difference in root length according to clinical variables

			Median	Q1	Q2	Min	Max	P value*
Tooth 22	Malocclusion type	Class I	0.07	0.04	0.13	0	0.29	0.163
		Class II	0.07	0.03	0.09	0	0.09	
		Class III	0.01	0	0.05	0	0.07	
	Vertical component	Normal	0.06	0.01	0.08	0	0.14	0.291
		Open	0	0	0.05	0	0.05	
		Deep	0.08	0	0.09	0	0.29	
	Type of appliance	Conventional	0.05	0	0.13	0	0.29	0.591
		Self-ligating	0.06	0	0.07	0	0.08	
		Aligners	0.04	0	0.08	0	0.08	
Tooth 12	Malocclusion type	Class I[a]	0.14	0.08	0.17	0.03	0.37	0.043
		Class II[a,b]	0.06	0.03	0.27	0.02	0.46	
		Class III[b]	0.03	0.01	0.06	0	0.11	
	Vertical component	Normal	0.1	0.04	0.17	0	0.37	0.116
		Open	0.02	0.01	0.03	0.01	0.03	
		Deep	0.1	0.06	0.14	0.01	0.46	
	Type of appliance	Conventional	0.04	0.02	0.14	0.01	0.46	0.591
		Self-ligating	0.09	0.05	0.17	0	0.37	
		Aligners	0.22	0.06	0.37	0.06	0.37	
Tooth 11	Malocclusion type	Class I	0.07	0.06	0.1	0.03	0.43	0.065
		Class II	0.33	0.16	0.53	0.05	0.67	
		Class III	0.02	0.01	0.07	0	0.38	
	Vertical component	Normal	0.06	0.03	0.13	0	0.43	0.671
		Open	0.07	0.07	0.39	0.07	0.39	
		Deep	0.09	0.01	0.27	0.01	0.67	
	Type of appliance	Conventional	0.07	0.06	0.12	0.01	0.39	0.385
		Self-ligating	0.21	0.03	0.43	0	0.67	
		Aligners	0.01	0.01	0.01	0.01	0.01	
Tooth 21	Malocclusion type	Class I	0.05	0.02	0.21	0	0.4	0.744
		Class II	0.1	0.08	0.12	0.08	0.12	
		Class III	0.05	0.04	0.39	0.03	2.8	
	Vertical component	Normal	0.05	0.03	0.13	0	0.4	0.336
		Open	0.04	0.04	0.04	0.04	0.04	
		Deep	0.24	0.06	1.6	0.04	2.8	
	Type of appliance	Conventional	0.08	0.04	0.21	0.04	2.8	0.435
		Self-ligating	0.05	0	0.08	0	0.4	
		Aligners	0.22	0.05	0.39	0.05	0.39	

*H Kruskal Wallis test. Significant when $p < 0.05$

Table 5. Multiple linear regression model – difference in root length in tooth 12 according to demographic and clinical variables

	Coefficients		
Model	B	Sig.	R^2
Gender (male compared to female)	0.075	0.031	0.248
Malocclusion I(compared to Malocclusion III)	0.070	0.042	
Malocclusion II(compared to Malocclusion III)	0.002	0.964	

Dependent variable: difference in root length, tooth 12 (T1-T2). Significant when $p < 0.05$

Table 6. Multiple linear regression model – difference in root length in tooth 22 according to clinical variables

Model	Coefficients B	Sig. p value
Malocclusion type	-0.023	0.069
Type of appliance	-0.015	0.514
Vertical component	0.014	0.427

Dependent variable: difference in root length, tooth 22 (T1-T2). Significant when $p < 0.05$

Discussion

A common objective when performing a safe therapy in orthodontics is to determine the magnitude of an optimal load to each tooth to avoid secondary effects, such as ERR. Such resorption is the result of factors that lead to alterations in the osteoclastic activitiy and is considered a common complication of the orthodontic treatment involving different severity stages and is more frequently observed in the maxillary lateral incisors, since their roots are a predisposing factor [31]. The type of biomechanical loads, type of appliance, and duration of the orthodontic treatment have been associated with the onset of ERR. However, many other factors are associated with a higher risk of developing ERR, such as age, malocclusion type, root morphology, and absence of teeth [32].

Considering the incidence of ERR and that the diagnosis is usually late as the symptoms occur when the condition has progressed, it is important to diagnose ERR early to implement a plan of action. When assessing the conventional radiographic aids, inaccurate values have been reported due to magnification and structure superimposition, which is overcome by CBCT as this technique allows for better visualization despite the changes in position that teeth exhibit during an orthodontic treatment. It is, therefore, imperative to follow-up orthodontically treated patients with ideal radiographic aids that allow rapid detection of changes in the root structure, such as the CBCT, which provides images in the three planes of space with a 95% sensitivity for ERR and allows detection of ERR as soon as 3 months into the orthodontic treatment.

Liedke and Durack have reported the diagnostic ability of CBCT to detect ERR *in vitro* due to its high specificity and sensitivity [33,34]. Ren *et al*. demonstrated low ERR classification values of 98.8% and 41.3% for CBCT and periapical radiographies, respectively, showing a significant difference between both techniques and confirmed that CBCT is superior over a periapical radiography to detect a simulated low ERR [35]. These results support the findings of the current investigation with 20 patients.

Despite the fact that the investigations by Levander and Malmgren [11] were performed using periapical radiographies, the current study could confirm that most patients develop visible signs of ERR during the initial stages of the orthodontic treatment. Nonetheless, such resorption is observed as a slight change in the apical contour of the root without an actual shortening of the root. The evaluation performed between T1 and T2 in the current investigation did not show significant changes in root resorption and the observed frequencies could be classified as low according to Levander and Malmgren.

Smale *et al.* [36] evaluated the predictive value of early signs of resorption in maxillary incisors after 6 months of treatment and reported that 4.1% of the patients showed resorption of over 1.5mm on average, with a maximum value of 2.7mm, using a digital reconstruction technique, which is a reliable method to adjust for projection errors, comparing the pre-treatment and post-treatment radiographies. The computed evaluation of apical root resorption showed an average of 0.53mm (SD 0.47) for the four incisors. The average for central incisors was 0.48mm (SD 0.53) and 0.59 (SD 0.68) for lateral incisors. It was observed that 13.4% of the patients had at least one tooth with apical shortening of 2.0mm or more in the initial stages of the orthodontic treatment. This result is in disagreement with the findings of the current investigation, where the highest reduction in root length was 0.085mm for tooth 11, 0.018mm for tooth 12, 0.017mm for tooth 21, and 0.011 mm for tooth 22.

The comparative analyses between the difference in root length of the studied central and lateral incisors and the established clinical variables (malocclusion type, vertical component, and type of appliance) did not indicate an association to significant changes in root length. However, for tooth 22, patients with class I malocclusion exhibited significantly higher differences in root length compared to class III patients. This may be explained by the fact that other individual variables may play an important role in the developing of ERR. A systematic review by Dos Santos *et al.* demonstrated a lack of association between the malocclusion type and the severity of root resorption. However, the authors stated that, after analyzing the three malocclusion types, the class II malocclusion ranged between 48.3% and 53.5% in three out of the six papers that were assessed.

Dindaroğlu and Doğan stated that there is a controversy regarding the increase in the risk of developing ERR with the age. Brezniak and Wasserstein support such association as there is a reduction in the vascularization of the periodontal membrane and an increase in the bone density, which may be correlated with the findings of the current investigation that included young adults. Conversely, Cheng *et al.* did not relate the chronological age with root resorption.

The categorization of external factors is important for the clinician to assess the individual risk of patients to develop ERR. Villaman-Santacruz *et al*. did not find significant differences in ERR between conventional and self-ligating techniques. A similar result was reported by Cheng et al. using different techniques [39]. Kawashima-Ichinomiya et al. reported higher ERR with conventional versus self-ligating approaches [41]. As more adults seek for orthodontic treatment, the demand for more esthetic techniques increases. The use of aligners is an esthetic option for patients who want different treatment options. Many papers have evaluated the different effects of the conventional therapy, but a disagreement on the amount of ERR using other techniques remains active. Gandhi *et al*. measured the amount of ERR in the maxillary incisors and could not find significant differences using these treatment approaches, except in tooth 12 where the conventional group showed higher ERR compared to the aligners group.

Conclusion

The diagnostic objectivity in orthodontics is related to the assistance of radiographic aids since they guide the clinician to evaluate, in an effective manner, the status of the dental and osseous structures. In addition, they provide scientific, technical, and legal support to the specialist. Therefore, orthodontic professionals must have the criteria to assess the quality and relevance of such images to establish timely and accurate pre and post-operative diagnoses to establish a proper treatment plan. A radiographic follow-up using 3D images from the early stages of the orthodontic treatment is recommended to reduce the risk of developing ERR considering the diversity of factors involved in the onset of such complication. After 6 months of orthodontic treatment, the analysis using CBCT showed that most patients exhibited apical remodeling with shortening of the root length, especially in tooth 22 in patients with class I malocclusion. Other clinical variables, such as the type of appliance and vertical component, did not have an impact on the early stage of the active orthodontic treatment.

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