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Original Research Article

Risk factors associated with orthodontically induced root resorption: experimental study

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Abstract

Introduction: Orthodontic tooth movement involves periodontal remodeling induced by mechanical forces, triggering an inflammatory response that facilitates bone resorption and deposition. However, orthodontically induced external apical root resorption (OIRR) is a frequent and undesirable side effect of treatment. Despite extensive research, its etiology remains unclear, with multiple intrinsic and extrinsic factors proposed as potential contributors. **Objective:** This study aimed to assess the risk factors associated with orthodontically induced root resorption through an experimental approach. Additionally, it sought to compare resorption levels between canines and premolars in cases with and without extractions. **Material and methods:** A sample of 37 orthodontic patients was analyzed, with 7 undergoing premolar extractions. Digital periapical radiographs were obtained at baseline and after treatment, and root resorption was classified according to the Levander and Malmgren index. Statistical analysis was performed using the Chi-square and Fisher's Exact tests, with a significance level of 5%.**Results:** No significant differences were found in the degree of resorption between canines and premolars, regardless of extraction status ($p > 0.05$). However, all evaluated teeth exhibited some degree of resorption. **Conclusion:**

Root resorption is a multifactorial process, and its occurrence was observed in all patients. Routine radiographic monitoring is essential, particularly for treatments exceeding six months, to minimize severe resorption risks and optimize treatment outcomes. Future studies should further investigate contributing factors to improve clinical management.

Introduction

To establish a proper position for misaligned teeth, there must be a remodeling of the periodontium, stimulated by an orthodontic force. Orthodontic tooth movement is a process of mechanically induced bone remodeling. In response to the applied force, an inflammatory process begins in the periodontal ligament and alveolar bone. Bone resorption occurs on the pressure side, where the periodontal ligament is compressed, and increases on the tension side, where the periodontal ligament is stretched. This allows the tooth to migrate through the alveolar bone. Orthodontically induced external apical root resorption (OIRR) is a common and detrimental adverse consequence of tooth movement caused by inflammation [10, 12, 18].

Despite the prevalence and severity of OIRR, little is known about its pathology and etiology. According to authors Bayir and Gumus, factors such as bone density and morphology, root shape, previous trauma, type of malocclusion, patient's pre-treatment age, patient's gender, duration of active treatment, orthodontic mechanics and force magnitude, and type of orthodontic treatment, with or without extractions, have been reported as significant for the occurrence of OIRR [4].

Tooth resorption is a process that results in the loss of dentin and/or cementum, creating an unfavorable crown-to-root ratio and potentially being associated with bone mass loss. When tooth resorption occurs during orthodontic treatment, there is a risk that the resorption process will continue, possibly leading to mobility if severe. Apical resorption greater than 3 millimeters equates to a loss of 1 millimeter of periodontal attachment. To minimize the risk during orthodontic treatment, it is important to identify factors before treatment [6, 15].

OIRR is a decrease in root structure involving the apices and is a common phenomenon in modern orthodontic treatment [6].

The present study aims, through an experimental approach, to evaluate the risk factors associated with orthodontically induced root resorption. Additionally, it seeks to compare the level of resorption between canines and premolars in cases with extractions and without extractions, both treated orthodontically.

Material and methods

Sample

The patients were selected based on the following inclusion criteria: presence of all permanent teeth except the third molars; no previous orthodontic treatment; absence of agenesis, malformation, dental defects, supernumerary teeth, endodontic treatment, impacted teeth, open or deep bite, and posterior and anterior crossbite. The exclusion criteria during treatment included: dental intrusion movement, retraction of canines and premolars, history of trauma, need for dental retraction, changes in the incisal portion of the canine crowns, changes in the cusp tip of the premolars during orthodontic treatment, and endodontic treatment. The teeth evaluated in the present study were the upper canines and premolars.

Orthodontic treatment

The treatment was conducted by the same orthodontist for all patients, using the Straight Wire technique with a 0.22" x 0.028" slot (Abzil, 3M, São José do Rio Preto, Brazil). The wire sequence used was as follows: 0.014" NiTi, 0.016" NiTi, 0.018" SS, and 0.017" x 0.025" SS. The NiTi wire remained in the arch for one month, while the others remained on average for two months.

Root evaluation

Two digital radiographs of each patient were evaluated by two specialists in dental radiology, after training and calibration. The Kappa test was applied to verify the intra- and inter-examiner agreement level, resulting in an agreement level between 0.85 and 0.92, evaluated with a one-week interval. The radiographs were analyzed using Adobe Photoshop imaging software (version CS5) on a 23-inch Dell monitor (Round Rock, Texas, USA).

Periapical radiographs were obtained using the parallelism technique, taken at the beginning of the treatment (6 to 9 months after the start) and at the end of the treatment (12 to 24 months after the completion of the alignment and leveling phase). All radiographs were performed by the same professional. The time interval between the initial and final radiographs varied from 6 to 12 months, with an average of 9 months. This variable period was determined according to the amount of movement required for dental alignment and leveling. The radiographs were digitized using a transparency scanner (HP 4050, Palo Alto, CA, USA). To acquire the radiographic images, the Heliodent 70 Dental X-Ray device (Sirona - The Dental Company, Bensheim, Germany) was used, operating at 70 kVp and 10 mA, with Kodak Insight films (Eastman Kodak Co, Rochester, NY, USA).

Using Adobe Photoshop software (version CS5), the total longitudinal length of the teeth in the radiographic image was obtained by measuring the distance from the incisal coronal points (IC) to the root apex (RA). The IC point was determined as the midpoint of the incisal edge in the mesiodistal length of the canines and the most prominent cusp tip in the premolars. The RA point was located at the apical portion of the root apex (figures 1 and 2). These measurements were performed twice for each tooth by both evaluators.

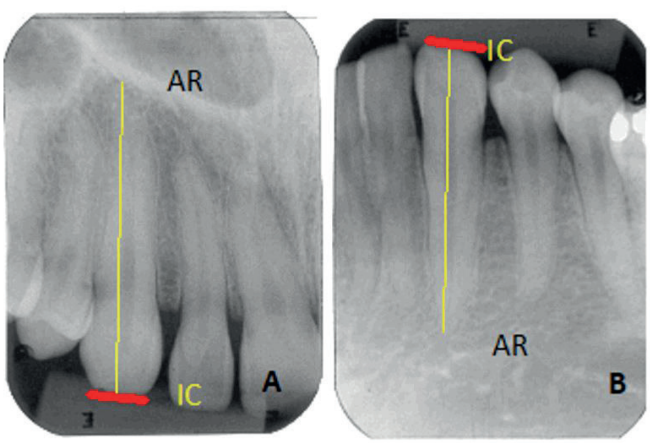

Figure 1 (A and B) – Points and lines used to standardize the measurement of tooth length in digital radiographic images. IC: incisal coronal point; AR: root apex point

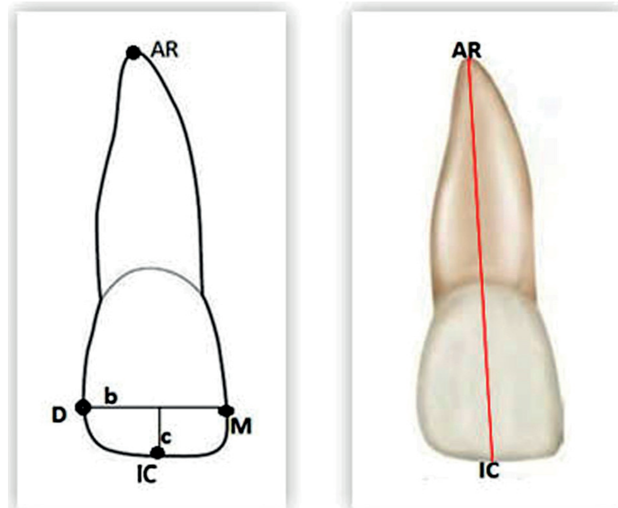

Figure 2 – Points and lines used to standardize the measurement of tooth length in digital radiographic images. IC: incisal coronal point; AR: root apex point

The index of root resorption was categorized according to the severity of root resorption, following the classification of Levander and Malmgren: Grade 0 for no root resorption; Grade 1 for irregular root contour or resorption up to 1 mm; Grade 2 for resorption between 1 and 2 mm; Grade 3 for apical resorption between 2 and 3 mm; Grade 4 for resorption exceeding 3 mm, surpassing one-third of the original root length.

If root resorption exceeded 2 mm during the intermediate phase of treatment, the applied force would be reduced, the interval between appointments increased, and periapical radiographs would be taken every six months. When root resorption was less than 2 mm, the same methodology would be followed until the end of treatment.

To correct potential distortions between radiographs, the distance between the cementoenamel junction and the incisal edge of the tooth, considered invariant, was measured at both time points. A simple proportion was used to calibrate the second radiograph.

In the present study, internal factors evaluated included patient age, sex, root shape, apical morphology, and classification of malocclusion. External factors were standardized across all patients to avoid bias and included type of appliance, orthodontic technique used, and continuous force.

After data tabulation, statistical analysis was conducted using the Chi-square test and Fisher's Exact Test, with a significance level of 5%. These tests were employed to identify statistically significant differences in the data.

Results

The sample comprised 37 orthodontic patients, among whom 7 underwent premolar extraction treatment, totaling 12 extracted upper teeth. Both groups showed a predominance of males with Class II malocclusion, with a mean age of 23.4 ± 7.18 years for the extraction group and 21.73 ± 8.29 years for the non-extraction group. The treatment duration for both groups was approximately two years (table I).

Table I – Characteristics of the study population

	Extraction group		Non-extraction group	
	n	**%**	**n**	**%**
Sex				
Male	2	71.4	11	63.3
Female	5	28.6	19	36.7
Angle's malocclusion				
Class I	0	0	11	36.6
Class II	6	85.7	12	40
Class III	1	14.3	7	23.4
Age (Mean ± SD)	23.4 ± 7.18		21.73 ± 8.29	
Treatment duration in months (Mean ± SD)	23.8 ± 5.87		22.13 ± 6.52	

There was no statistical difference in the degree of resorption between canines and premolars in cases with and without extraction ($p > 0.05$) (table II). Both groups exhibited some degree of resorption.

Table II – Comparison between groups of resorption index according to degree

	Extraction group	Non-extraction group	p*
Tooth evaluated	**%**	**%**	
Tooth 13			
Grade 0	0	13.3	
Grade 1	14.2	30	
Grade 2	57.2	23.3	0.355
Grade 3	0	10	
Grade 4	28.6	23.3	
Tooth 23			
Grade 0	0	15.6	
Grade 1	60	28.1	
Grade 2	0	15.6	0.47
Grade 3	20	9.3	
Grade 4	20	31.2	

To be continued...

Continuation of table II

	Extraction group	Non-extraction group	p*
Tooth evaluated	**%**	**%**	
Tooth 15			
Grade 0	14.2	6.6	
Grade 1	42.8	40	
Grade 2	28.5	23.3	0.838
Grade 3	0	13.3	
Grade 4	14.28	16.6	
Tooth 25			
Grade 0	20	15.6	
Grade 1	20	37.5	
Grade 2	20	18.7	0.926
Grade 3	20	9.3	
Grade 4	20	18.7	

* p-value from Chi-square and Fisher's Exact Test

Discussion

External apical root resorption (EARR) is considered a significant limitation in achieving ideal orthodontic outcomes, as it is irreversible and can be silent yet aggressive. It is widely recognized as the most common complication following orthodontic treatment, raising concerns among both orthodontists and patients undergoing treatment. Therefore, the primary objective of this study was to experimentally determine the prevalence of EARR in premolars and canines during orthodontic treatment, as well as to evaluate potential predisposing factors for EARR based on the experiment and existing literature [13].

Patients with longer total treatment durations demonstrated significantly more EARR. The duration of orthodontic treatment has been suggested to contribute significantly to apical root resorption [4]. Similarly, Shahrure *et al*. [13], in their study of 120 initially diagnosed severe EARR cases, found that 3.23% of patients developed severe EARR, while 96.77% exhibited clinically acceptable root resorption (mild to moderate). Intergroup comparison of treatment duration showed a statistically significant difference between the two groups. The primary factor underlying the association between EARR and treatment duration is greater tooth movement [4]. This occurs because longer treatment durations typically involve more extensive tooth movements, which may lead to increased root resorption. The treatment time itself may not correlate positively with root resorption but rather with the increased number of movements that can occur during longer treatments [11]. However, these studies did not measure resorption in cases involving upper premolars and canines specifically, highlighting the importance of further investigation into each tooth individually, as in the present study.

The risk of root resorption increases with age due to decreased vascularization of the periodontal membrane and increased bone density [7]. On the other hand, Pastro *et al*. [11] stated that the age at the start of treatment is not a risk factor for root resorption. Similarly, Choi [5], in their study, also agreed that age was not identified as a risk factor for external apical root resorption (EARR), affirming that there is no significant relationship between chronological age and root resorption.

Low magnitude forces are preferable because heavy forces increase the risks of root resorption and hyalinization. It is suggested that intermittent forces rather than continuous forces be applied to prevent severe root resorptions [10]. According to Dindaroğlu and Doğan [7], as force increases, root resorption also increases. Light forces produce favorable tooth movement with minimal discomfort and pain, whereas heavy forces exceeding the capillary blood pressure of 20-25 gm/cm of the root surface initiate initial tension, latency phase, and progressive tooth movement (3 phases). Exceeding this pressure can cause tissue necrosis. Application of even higher force levels will result in physical contact between teeth and bone, leading to resorption at pressure sites and hindering resorption or hyalinization in adjacent medullary spaces. The optimal rate of tooth movement with minimal irreversible damage to the root, periodontal ligament, and alveolar bone is considered ideal, without traumatizing dental or periodental tissues and without redundantly moving dental roots with patient comfort [9, 7]. Patients show individual responses to applied forces, demonstrating varying degrees of resorption in different teeth.

Root geometric shapes can affect force distribution through the root and alveolar bone. Teeth with root dilacerations are prone to root resorption [7]. Root morphology does not have a significant relationship with severe EARR, likely due to the high percentage of rhomboid roots in the Shahrure et al. sample, which are associated with reduced EARR risk [13]. Amuk *et al.* [2], in their study on implanted upper canines, evaluated root resorption and root shape. Curved roots and positive root-cortex ratio showed significantly higher EARR values than impacted upper canines with normal roots and negative root-cortex ratio. They concluded that apical root resorption is influenced by the proximity of the root to the palatal cortical plate during orthodontic treatment. Their results revealed that a positive root-cortex ratio significantly increased EARR in orthodontically erupted canines [2]. However, in the sample of this article, there was no statistical difference in the degree of resorption between canines and premolars in cases with and without extraction during treatment.

Conclusion

Both groups showed some degree of root resorption, both for canines and premolars; however, there was no significant difference in the degree of resorption between them. Nevertheless, external root resorption is a multifactorial phenomenon; therefore, radiographic control should be routinely performed, especially in patients undergoing orthodontic treatment for more than six months, aiming to minimize the risk of severe resorption and achieve a more effective treatment outcome. The importance of future studies, such as the present experimental work, is emphasized.

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