CYCLIC AND TORSIONAL FATIGUE RESISTANCE OF THREE DIFFERENT THERMALLY TREATED NICKEL-TITANIUM ROTARY INSTRUMENTS

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ABSTRACT

Background: The aim of this study was to evaluate the cyclic fatigue and torsional fatigue resistance of three thermally treated rotary instruments, such as: Logic 2 25.05 (LOG 25.05), Edge Taper Platinum 25.06 (EDT 25.06) and ProTaper Gold 25.08 (PTG 25.08).

Methods: A total of 60 rotary instruments of LOG 25.05, EDT 25.06 and PTG 25.08 were used (n=20). Cyclic fatigue tests were performed at 36°C using an artificial stainless steel canal with a 60º angle and a 5-mm radius of curvature. The time (in seconds) and number of cycles to fracture (NCF) was recorded. The torsional test evaluated the torque and angle of rotation to failure at 3 mm from the tip according to ISO 3630-1. The fractured surface of each fragment was observed by using scanning electron microscopy (SEM). Data were analyzed using one-way ANOVA and Holm-Sidak's tests for multiple comparison, the level of significance was set at 5%.

Results: EDT 25.06 had highest cyclic fatigue resistance (time and NFC), followed by LOG 25.05 and PTG 25.08 ($P<0.05$). There were no significantly difference between LOG 25.05 and ETP 25.06 regarding the NCF ($P>0.05$). In relation the torsional test, the LOG 25.05 and ETP 25.06 presented similar torque ($P>0.05$). The PTG presented greater torque than the other groups ($P<0.05$). The PTG 25.08 presented the lowest angular rotation to fracture than the other groups ($P<0.05$). The SEM images demonstrated typical features of cyclic and torsional fracture.

Conclusion: In conclusion, the LOG 25.05 and ETP 25.06 presented similar cyclic and torsional properties. The PTG 25.08 showed greater torsional strength.

KEYWORDS: Endodontics. Nickel-Titanium. Endodontic instruments.

INTRODUCTION

The introduction of nickel-titanium (NiTi) rotary instruments in endodontics provided several advantages: faster preparation, safer procedures, and greater canal centering ability than stainless steel instruments[1,2]. However, these instruments continue to be susceptible to separation caused by cyclic or torsional fatigue[3].

Instrument separation is strongly affected by instrument features (cross-section, taper, core diameter, and type of NiTi)[4]. The manufacturers have proposed several modifications to the instrument's

design and the thermal treatment of the NiTi to improve the flexibility and resistance to fatigue during root canal preparation[5]. Also, it is important to emphasize that the clinician should know the mechanical properties of the instruments to ensure safe clinical use according to the root canal anatomy [6,7].

The ProTaper Gold (Dentsply-Sirona, Baillagues, Switzerland) is the new generation of ProTaper Universal (Dentsply-Sirona, Baillagues, Switzerland), which use the same sequence and design but with different type of NiTi alloy[7]. One of the main features of all generation ProTaper instruments is the variable taper along the spiral flutes, reducing the metal mass volume and higher flexibility[7,8].

The EdgeTaper Platinum (EdgeEndo, Albuquerque, NM) is a heat-treated rotary system that presents convex triangular cross-section and the technique preparation of ProTaper Gold system[9,10]. Accordingly with the manufacturers, the Fire Wire™ thermal treatment and a progressive changing taper design along the instrument favor high flexibility. Previous studies reported that Edge Taper platinum 25.06 presented greater cyclic fatigue resistance and lower torsional resistance than ProTaper Gold 25.08 [9,10].

Recently, a novel heat-treated NiTi rotary system was introduced in the market, Logic 2 Rotary system (Easy Equipamentos Odontológicos, Brazil). This system has an S-Shaped cross-section and is manufactured by controlled memory technology. In this second generation, the manufacturer reduced the 0.06 taper to 0.05 mm/mm of the instrument #25. Also, the when the diameter of the instruments reaches 1.0mm of diameter on the spiral flutes, the wire becomes a cylinder, that is, without taper. According with the manufacturer, these modifications promoted the volume reduction of metal mass along of the spiral flutes, favoring greater preservation of dentin during canal shaping and flexibility.

To date, there is no reporting available the cyclic and torsional fatigue resistance of the new Logic 2 rotary system. Therefore, the aim of this study to investigate the cyclic and torsional fatigue resistance of the Logic 2 25.05, EdgeTaper Platinum and compare it with the ProTaper Gold instruments. The null hypotheses tested were as fallow:

(1) There would be no difference in cyclic fatigue resistance among the instruments;
(2) There would be no difference in the torsional properties (maximum torque and angular rotation) among the instruments.

MATERIALS AND METHODS

The sample size calculation was performed based on a pilot study using G*Power v3.1 for Mac (Heinrich Heine, University of Düsseldorf, Düsseldorf, Germany) by selecting the ANOVA: Fixed effect, omnibus, one-way of the F family. An alpha-type errorof 0.05, a beta power of 0.095, and an effecti size of 0.08 were used. A total of eigh instruments per group were indicated as the ideal size required for noting significant differences. Ten instruments were used because of an additional 20% was calculated to compensate for possible outlier values that might lead to samples loss.

A total of 60 NiTi instruments (25 mm) were used for this study. The samples were divided into three groups (n=20), as follows: LOG 25.05, EDT 25.06 and PTG 25.08 systems. Previously to the mechanical tests, all instruments were inspected under a stereomicroscope (Carls Zeiss, LLC, EUA) at 16x magnification to detect possible defects or deformities; none were discarded.

Cyclic fatigue Test

The cyclic fatigue test was performed using a custom-made device that simulated an artificial canal made of stainlless-steel, with a 60^0 angle of curvature and a 5-mm radius of curvature, as previously described[9,13]. The cyclic fatigue tests were performed at body temperature ($36^\circ \pm 1^\circ C$) using a histology water bath equipement (Leica HI 1210), which allowed to control the temperature [11, 12]. A total of 600 mL of water was used to fill the the equipement container to the desired level, allowing that the simulated canal was totally submerged on the water. The temperature was controlled using a digital thermometer of the equipement and infrared thermometer during all the test.

A total of 10 instruments for each system were used, coupled to a VDW Silver Motor (VDW, Munich, Germany) connected to the cyclic fatigue device. Instruments were activated according to the manufacturers recomendations, as follow: LOG 25.05 (950 RPM and 4N.cm), ETP (300 RPM and 3 N.cm), and PTG (300 RPM and 3 N.cm). The time to failure was recorded using a digital chronometer and video recording was made simultaneously to ensure the exact time of instrument fracture. The number of cycles to failure (NCF) was calculated using the following formula: time to failure (in seconds) X RPM/ 60.

Torsional fatigue Test

The torsional tests were performed, based on ISO 3630-1 (1992), as previously reported[9,13]. A total of 10 instruments of each rotary system were used. The test was performed to measure the maximum torque and angular rotation until instrument failure using a specific program and torsion machine (MicroTorque; Analógica, Belo Horizonte, MG, Brazil). The three millimeters of the instrument tips

were clamped into a mandrel connected to a geared motor. The geared motor operated in clockwise rotation, at speed set to 2 rpm for all the groups.

SEM Evaluation

The instruments were assessed by SEM evaluation (JEOL, JSM-TLLOA, Tokyo, Japan) to determine the topographic features of the fragments. The instruments were cleaned in an ultrasonic cleaning device (Gnatus, Ribeirão Preto, São Paulo, Brazil) in distilled water during 3 minutes before SEM evaluation. All the fractured surfaces of the instruments were examined at 200x and 1000x magnification in the center of the surface.

RESULTS

The mean and standard deviatons of time and NCF of the cyclic fatigue test are shown in **Table 1**. The EDT 25.06 had a significant higher time to fracutre, followed by the LOG 25.05 and PTG 25.08 (P<0.05). Regarding the NCF, there was no signifincatly difference between LOG 25.05 and EDT 25.06 (P>0.05). PTG 25.08 presented the lowest values of NCF (P<0.05).

The mean and standard deviations of torque (maximum torsional strength - N.cm) and angular rotation (°) to fracture are show in **Table 1**. There was no significant difference between LOG 25.05 and EDT 25.06 regarding the maximum torsional strength (P>0.05). The PTG 25.08 presented the highest torsional strength values (P<0.05). In relation of the angular rotation, the LOG 25.05 and EDT 25.06 presented similar angular values to fracture (P>0.05). The PTG 25.08 presented the lowest angular values than the other groups (P<0.05).

Table 1. Mean values of time (in seconds), number of cycles (NCF), Torque (N.cm) and angular rotation (°) of instruments tested.

Instruments	Cyclic Fatigue				Torsional Fatigue			
	Time (seconds)		Cycles (NCF)		Torque (N.cm)		Angles (°)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
LOG 25.05	244.7[a]	50.11	1427[a]	92.20	1.13[a]	0.121	705.3[a]	109.10
EDT 25.06	290.6[b]	08.55	1453[a]	42.76	1.08[a]	0.112	625.3[a]	34.28
PTG 25.08	146.5[c]	12.27	732.7[c]	61.32	1.52[b]	0.097	444.1[b]	30.64

SD, standard deviation.

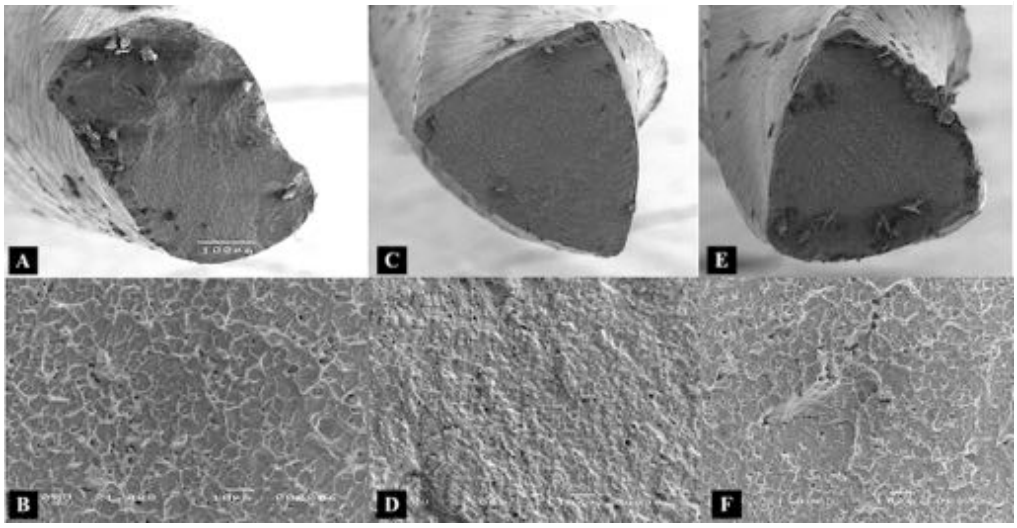
Different superscript letters in the same column indicate statistical differences among groups (P < .05).

The SEM evaluation of the fractured surface revealed similar and typical features of cyclic and torsional behavior. The cyclic fatigue test crack caused crack initiation area and microscopic dimples (**Fig. 1**). The torsional test generated a concentric abrasion marks, with a dimple surface with micro-voids at the center (**Fig. 2**).

DISCUSSION

The instrument separation during root canal preparation might occur due to cyclic and torsional fatigue [14,3]. The evaluation of mechanical properties of engine-driven NiTi instruments can be valid information for the clinicians, helping them to choose the suitable instrument for constricted or curved canals[4,9,13]. Therefore, the laboratory studies of cyclic and torsional fatigue can provide information of their mechanical properties, which could be extrapolated to their resistance to fatigue during canal preparation[9,15]. During a literature review, there was no study evaluating the mechanical properties fatigue resistance of Logic 2 25.05 rotary instrument. For this reason, the aim of this study aimed to evaluate the cyclic and torsional

Figure 1: SEM images of fractured surfaces of separated fragments of Logic 2 25.05 (A,B), Edge Taper Platinum (C, D) and ProTaper Gold (E, F) instruments after cyclic fatigue testing. The images show numerous dimples, a feature of ductile fracture.



fatigue resistance of Logic 2 25.05 and to compare with ProTaper Gold 25.08 and EdgeTaper Platinum 25.06.

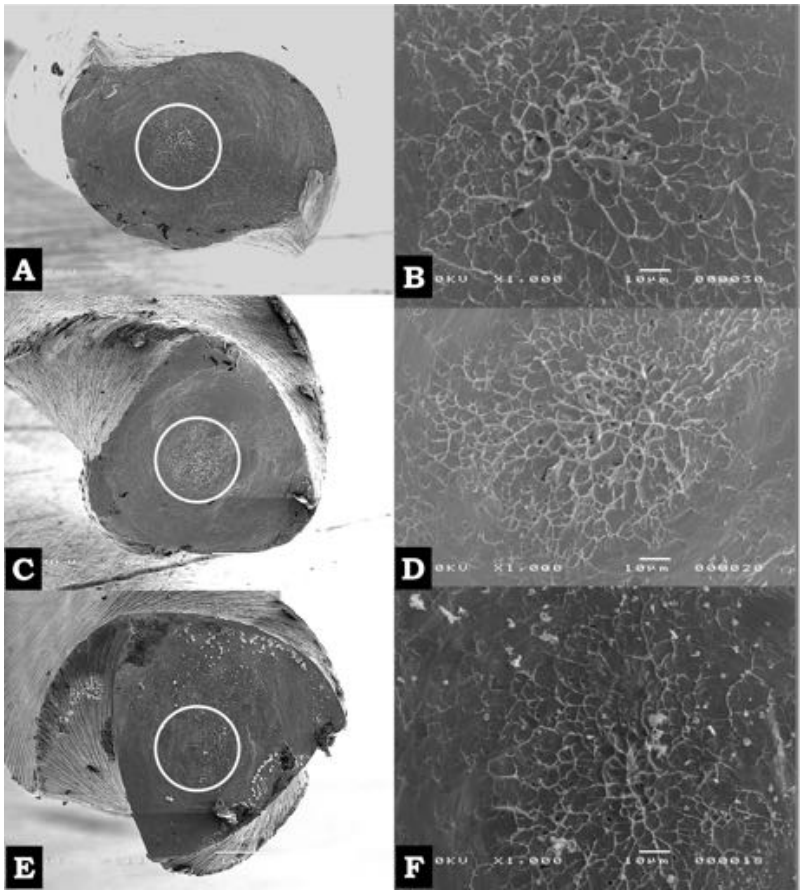
The methodology used in this study was already validated and previously published in peer-reviewed journals[11-13]. It is important to high light that there are no specification or international standards for cyclic fatigue methodology of NiTi instruments. Plotino et al.[16] affirmed that the artificial canal should reproduce the instrument size and taper of the instruments tested to ensure a accurate canal trajectory in terms of radius and angle of curvature. However, this is not possible in the current study because the taper of the instruments differed among them. Therefore, the testing condition was standardized using same tapered artificial canal for all the groups (0.40 mm diameter at most apical portion, and 0.08 mm of fixed taper).

Another methodological point that needs to be addressed is the static cyclic fatigue model used in this study, as previously reported[8,9,13,15]. It has been a huge discussion on literature regarding the use of static model to evaluate cyclic fatigue resistance. Some authors, stated that static model induces higher localized stress, reducing the time and number of cycles to fatigue and not reproduces the clinical use of the instruments[17,18]. On the other hand, Dederich and Zakariasen[19] stated that the dynamic model could create a torsional stress depending on the design of the tube or artificial groove, which could modify the results. Therefore, it would be necessary the use of axial motion without any lateral movement during the tests, which is complicated, as reported by Hullsman et al.[17]. For this reason, this study used the static test because the dynamic analysis seems to be a more sensitive method and could create other variables beyond the type of the instrument.

The first results of the present study demonstrated significant differences in the cyclic fatigue resistance among the instruments. The EDT 25.06 presented highest time to fatigue followed by LOG 25.05 ($P<0.05$). There was no significant difference regarding the NCF between EDT 25.06 and LOG 25.05 ($P>0.05$). PTG 25.08 presented the lowest time and NCF to fatigue ($P<0.05$). Therefore, the first null hypothesis was rejected. Although all tested instruments have the same tip size (0.25mm), it has different taper values, cross-section design, and type of NiTi among then. PTG 25.08 and EDT 25.06 present convex triangular cross-section, and LOG 25.05, an S-shaped cross-section. Also, the PTG and EDT present fixed taper along the first three millimeters of the tip, while LOG has a fixed taper along with the spiral flutes. Previous studies have shown that cross-section design and taper values can provide large metal mass volume of the instruments, reducing the flexibility and the cyclic fatigue resistance [4,13,15]. Therefore, it could be speculate that PTG presented higher metal mass volume at the maximum point of stress during the cyclic fatigue test, explaining the results.

Other points that need to be discussed are the different thermal treatments of the instruments and the rotation speed used during the tests. The thermal treatments of the NiTi alloys can induce a higher percentage of the martensitic phase, which has a key role effect on the instrument's flexibility[2,5,20]. Previous reports have indicated that instruments with a greater amount of martensitic phase tend to present more flexibility and

Figure 2: SEM images of fractured surfaces of separated fragments of Logic 2 25.05 (A,B), Edge Taper Platinum (C, D) and ProTaper Gold (E, F) instruments after torsional test, with the circular box indicating the concentric abrasion mark at 200X magnification ; the right column shows the concentric abrasion mark at 1000x magnification, the skewed dimples near the center of rotation are typical features of torsional failure.



higher cyclic fatigue resistance [5,20]. Our results demonstrated that EDT 25.06 and LOG 2 25.06 showed greater cyclic fatigue resistance between PTG 25.08. Probably, the type of thermal treatment of Protaper Gold favors less martensitic phase and, an association of the design of the instruments, less flexible instruments. The results of this study are in agreement with previous studies that stated that EDT 25.06 is more cyclic fatigue resistant than PTG 25.08 [9,10] and that control memory technology used in LOG 2 25.06 favor greater flexibility than Gold instruments [13,21]. Future studies should be conducted by differential calorimetry to complete our results.

Despite controversial literature regarding the influence on the rotational speed in the instrument's cyclic fatigue, these instruments were tested following the manufacturer's recommendations. It could be speculated that instruments with higher rotation speed should more stressed [22,23]. It would be expected that LOG 25.05 should present less time and NCF to fatigue, which did not occur. Therefore, the other points previous discussed had more influence on these results.

The methodology used in the torsional test was also reported and validated in previous studies [11,13]. This test aims to evaluate the maximum torsional strength and angular rotation to fracture, submitting then to a higher level of torsional stress[13,24]. The results of this study pointed out to significant differences among the tested instruments. Therefore, the second null hypothesis was also rejected. PTG 25.08 presented significant higher torsional strength and lower angular rotation to fracture than EDT 25.06 and LOG 2 25.05 ($P<0.05$); no significant difference was found between EDT 25.06 and LOG 2 25.05 ($P>0.05$). The possible explanation of our results could be related with the different design (cross-section, taper) and thermal treatments of the NiTi, as previous discussed. Previous studies have shown that NiTi instruments with greater metal mass volume tend to present higher torsional load [4,9]. Also, previous studies showed that the thermal treatment of PTG favor less flexibility than FireWire™ and CM-Wire treatment of EDT and LOG, respectively[9,10]. Probably, the PTG 25.08 probably present higher metal mass volume at the first 3 mm of the tip of the instruments and a less % martensitic phase on the NiTi, which could explain our results. It is important to emphasize that all values of torque to fracture were lower than those indicated by the manufacturers, which is a significant data to the clinician, suggesting that the torque values could be reduced during the use.

The SEM analysis showed the typical features of cyclic and torsional fatigue for the three tested reciprocating files. After the cyclic fatigue test, all of the instruments evaluated showed crack initiation areas and overload zones, with numerous dimples spread on the fractured surfaces. After the torsional test, the fragments showed concentric abrasion marks and fibrous dimples at the center of rotation.

CONCLUSION

In conclusion, with limitation of this study, the LOG 25.05 and ETP 25.06 presented similar cyclic and torsional fatigue resistance. The PTG 25.08 showed greater torsional strength.

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THE POST TRANSFIXED IN THE CORONAL CAVITY INCREASES THE FRACTURE RESISTANCE OF WEAKENED AND DIRECTLY RESTORED TEETH? A SYSTEMATIC REVIEW.

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ABSTRACT

Introduction: The objective of this systematic review was to answer the question: Does the intraradicular post transfixed in the dental crown increases the fracture resistance of weakened and directly restored teeth? Methods: Electronic databases (MEDLINE/PubMed, LILACS, SCOPUS, EMBASE, Scientific Electronic Library Online - SCIELO, and Central Register of Controlled Trials - CENTRAL) were searched until March 2021, without language or year restriction. Grey literature was also searched through Google scholar and OpenGrey repository. Only in vitro stud-ies were included that evaluated the influence of the use of intraradicular post trans-fixed in the crown in the buccopalatal/lingual direction in the fracture resistance of the dental crown. Relevant results were summarized and evaluated. The risk of bias was also assessed in the studies. Results: Initial screening of databases resulted in 249 studies, of which 109 were excluded for being duplicates. Of 140 eligible pa-pers, fourteen studies met the inclusion criteria and were selected for full-text read-ing. Of these, two studies were excluded for not having access to the full article. All selected articles were classified as low risk of bias. Conclusion: Based on the studies, it is possible to conclude that the use of a transfixed post in the crown increases the fracture resistance of weakened and directly restored teeth.

KEYWORDS: Dental stress analysis. Operative dentistry. Systematic review. Tooth crown.

INTRODUCTION

Restoration of endodontically treated teeth is a very complex procedure, since in most cases these elements present major coronary impairments. According to Santos-Filho et al.[1], the resistance to fracture of endodontically treated teeth is directly related to the quantity and quality of the remaining dental structure, thus being a determining factor for the longevity of the restorative procedure.

Usually, when tooth fracture occurs, it is associated with fracture of the cusps. This fact deserves special attention, as there is a risk of the fracture line extending below the bone crest, which may cause the loss of the tooth piece or hinder its restoration[2].

Direct restorations with composite resin, when properly executed, can be a viable form of treatment because, in addition to the low operating cost, it does not require additional wear on healthy dental tissue. Plotino et al.[3] found no statistical difference in the fracture resistance of molars, with extensive loss of tooth structure and treated

with composite resin restorations by the direct or indirect technique.

A fact that is already known and established in the scientific literature is that the use of intraradicular posts for restoration of endodontically treated posterior teeth does not increase the strength of the remaining tooth. The intraradicular post only has the function of promoting the retention of the restorative material[4].

A treatment alternative that is being tested in order to increase the fracture resistance of fragile and endodontically treated teeth is the use of posts transfixed horizontally on the buccal and palatal/lingual walls. Studies by Beltrão et al.[5], and Fávero et al.[6] observed that groups that received transfixation of posts and restoration with composite resin showed a significant increase in fracture resistance when compared to groups restored with resin alone. In addition, there was a lower degree of impairment of the tooth structure due to the fracture.

(1) To date, no systematic review has been performed evaluating such information. Therefore, the objective of this systematic review is to answer the following question: "The intraradicular post transfixed in the dental crown increases the fracture resistance of weakened and directly restored teeth?".

MATERIALS AND METHODS

This systematic review was conducted in accordance with the recommendations provided by the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines[7] and was registered in the International Prospective Register of Systematic Review (Registration number CRD42021262954).

Search strategy

The search was performed independently by two examiners (B.N.P and V.M.W) in the following electronic databases: MEDLINE/PubMed, LILACS, SCOPUS, EMBASE, *Scientific Eletronic Library Online* (SCIELO), and *Central Register of Controolled Trials* (CENTRAL). The search was conducted for articles published until March 2021, without language or year restriction. Grey literature was also searched through Google scholar and OpenGrey repository.

The electronic search strategy was developed using the most cited descriptors in previous publications on this theme combining Medical Subject Heading (MeSH) terms and text words (tw.). For each database, the following terms were combined: *((Restorations) OR (Direct restoration)) AND ((Resistance) OR (Fracture) OR (Failure) OR (Fracture strength)) AND (Horizontal post).*

Additional screening on the selected studies' references was performed, and the related articles were searched in the PubMed database. All articles selected were imported into the Mendeley© (Mendeley Ltd, London, United Kingdom) reference manager to catalogue the references and facilitate the exclusion of duplicates.

Eligibility criteria

The eligibility criteria were based on the PICOS strategy (PRISMA-P 2015)[8,9], as follows:

* Population (P): posterior permanente human teeth;
* Intervention (I): use of intraradicular post transfixed in the dental crown in the buccopalatine/lingual direction;
* Comparison (C): direct composite restoration without transfixed intraradicular post;
* Outcome (O): fracture resistance of the dental crown;
* Study design (S): in vitro studies.

Selection of the studies

The first stage consisted of excluding the duplicated studies, considering only once, and examining the selected studies' retrieved titles and abstracts by two independent authors (B.N.P. and V.M.W.). When it was not possible to judge the studies by title and abstract, the full text was accessed and read for the final decision. The second stage consisted of reading the potentially eligible studies' full texts based on the PICOS strategy's eligibility criteria. Disagreements on study inclusion were solved by a consensus with a third author (T.A.F.M.).

Data extraction

Two authors (B.N.P. and V.M.W.) independently collected the data from the included studies. Disagreements were solved by a third author (T.A.F.M.). The following data were extracted from the included studies: publication data (authors, year, and country of origin), study characteristics (teeth evaluated, type of control, groups tested, type of restorative cavity, restorative material, type of intraradicular post, type of resistance test, applied force in the test, and outcome information). In cases of missing data, the authors were contacted three times by e-mail.

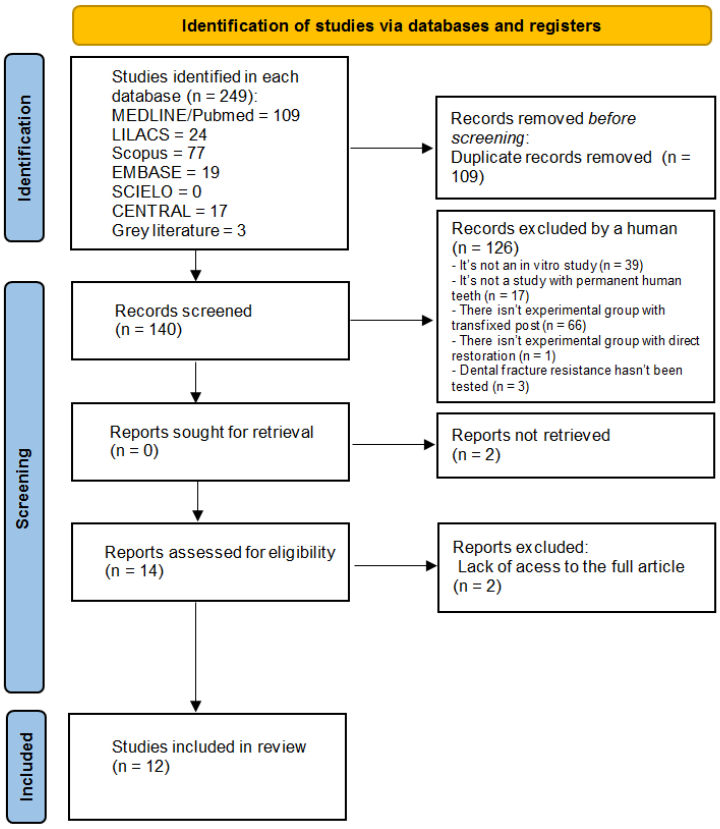
Risk of bias assessment

The methodological risk assessment of bias for each study was performed by two independent authors (B.N.P. and V.M.W.), and, in case of disagreement, it was resolved by a third author (T.A.F.M.).

As this review only included in vitro studies, the criteria were adapted to allow for a critical analysis of the studies. The risk of bias between six domains (description of the sample size calculation, randomization of teeth, presence of a control group, description of restorative methods, description of the fracture resistance test used, and statistical method) was evaluated. The studies were classified into: low risk, moderate risk, and high risk.

A "yes" was assigned where the parameters were found, and a "no" in the absence of them. Articles in which none or two of these parameters were not found were classified as low risk of bias; those with three or four parameters were considered to be at moderate risk of bias; with five or six parameters, high risk of bias.

Figure 1 - PRISMA flow diagram representing the systematic review



RESULTS

Study Selection

Initial screening of databases resulted in 249 studies. Of these articles, 109 were excluded as they were duplicates. From the analysis of the titles and abstracts, 126 studies were exclude and fourteen studies met the inclusion criteria and were selected for full-text reading. Two studies[10,11] were not found for the analysis of the full text and were excluded. Thus, twelve papers were included in this systematic review. Figure 1 presente the flow diagram of the search strategy.

Data Extraction

Table 1 presents the characteristics and main findings of the included studies. Authors of studies with insufficient data were contacted by e-mail, but no additional information was received.

The SEM evaluation of the Regarding the dental group in which the in vitro study was performed, most used maxillary premolars[13,17,19,21] and maxillary third molars[5,6,14,15] followed by maxillary or mandibular premolars[16,18], only mandibular premolars[12] and mandibular first molars[20].

Regarding the type of restorative cavity, practically all studies were carried out in class II – MOD cavities[5,6,12,13,15-21], with except for the study by Bainy et al.[14] which was in a class II – MO cavity.

The fiberglass post was the retainer that predominated in the selected transfixation studies, with a variety of commercial brands: RelyXTM posts[12], Reforpost® posts[5,6,13-16], Whitepost DC® posts[17,18], GranTEC posts[20], and EvenStick NET posts[21]. Only the study by Mesquita et al.[18] used zirconia post instead of fiberglass.

As for the type of resistance test performed, most studies applied vertical compressive load[5,6,13-19]. The studies by Aslan et al.[12], and Scotti et al.[20] applied oblique compressive load (45°) and Scotti et al.[21] oblique compressive load (30°).

Regarding the results found, practically all studies analyzed observed that the use of transfixed post horizontally in a class II restorative cavity significantly increased tooth fracture resistance. Only in the study by Scotti et al.[21] it can be observed that the insertion of glass fibers in direct composite restorations was not able to guarantee a significant increase in fracture strength or a significant change in the fracture pattern.

Risk of bias assessment

Table 2 summarizes the risk of bias of the selected in vitro studies. According to the evaluated parameters, all studies included in this review were qualified with low risk of bias. The parameter that was not found in most studies was the description of the sample size calculation.

Table 1 - Data extracted from the included studies.

Author (s) (Year of publication)	Country of origin of the study	Dental Group	Experimental groups	Type of restorative cavity	Restorative material	Type of post used	Type of resistance test (Applied force)	Main findings
Aslan *et al.* [12]	Turkey	Mandibular premolars	Group 1: intact teeth (positive control); Group 2: unfilled MOD cavity (negative control); Group 3: MOD + composite resin; Group 4: 10-mm-long fiber post + composite resin; Group 5: 5-mm-long fiber post + composite resin; Group 6: Ribbond in the occlusal surface + composite resin; Group 7: horizontal fiber post + composite resin.	MOD cavity	Flowable composite resin (Filtek Flow; 3M ESPE, St. Paul, MN, USA) + resin composite (Filtek Ultimate; 3M ESPE, St. Paul, MN, USA)	Glass fiber posts (RelyX™ Fiber Post, 3M ESPE, Deutschland GmbH, Germany)	Oblique compressive load (45°). 0.5mm/min	Usage of horizontal post or occlusal Ribbond usage increased the fracture resistance of root canal-treated premolars with MOD cavities.
Bahari *et al.* [13]	Iran	Maxillary premolars	Group 1: intact teeth (positive control); Group 2: endodontically treated teeth without restoration (negative control); Group 3: composite resin restoration; Group 4: placement of fibers at occlusal position; Group 5: splinting the buccal and palatal walls with horizontal fiber posts; Group 6: placement of fibers at the occlusal position after splinting the buccal and palatal walls with horizontal fiber posts.	MOD cavity	Valux Plus composite resin (3M Dental Products, St. Paul, MN, USA)	Reforpost® (Angelus, Londrina, PR, Brazil) glass fiber posts	Vertical compressive load. 0.5mm/min	Fiber insertion had no additional reinforcing effect on the fracture strength following composite resin restoration.
Bainy *et al.* [14]	Brazil	Maxillary third molars	Group 1: intact teeth (positive control); Group 2: endodontically treated teeth without restoration (negative control); Group 3: restoration with SonicFill 2® system; Group 4: restoration with braided glass fiber and SonicFill 2® system; Group 5: restoration with transfixed glass fiber post and SonicFill 2® system.	MO cavity	Bulkfill flow resin (3M ESPE, St. Paul, MN, USA)+ Single-Fill TM Bulk fill resin (Kerr Corporation, Orange, CA, USA)	Reforpost® (Angelus, Londrina, PR, Brazil) glass fiber posts	Vertical compressive load. 10kN/0.5mm/min	The glass fiber, regardless of composition, increases the fracture strength of endodontically treated teeth. The use of a glass fiber post attached to the dental crown seems to provide more favorable rehabilitation when the fracture position is determined.
Beltrão *et al.* [5]	Brazil	Maxillary third molars	Group 1: healthy tooth (positive control); Group 2: endodontically treated teeth without restoration (negative control); Group 3: MOD cavity + endo + transfixed post; Group 4: MOD cavity + endo + composite resin; Group 5: MOD cavity + endo + composite resin + transfixed post.	MOD cavity	Flow resin composite (DFL Indústria e Comércio Ltda., Rio de Janeiro, RJ, Brazil) + Resin composite Filtek Z-250 (3M Espe, St. Paul, MN, USA)	Reforpost® (Angelus, Londrina, PR, Brazil) glass fiber posts	Vertical compressive load. 10kN/1mm/min	The fiber glass post transfixed horizontally in a MOD cavity significantly increased the fracture resistance of the teeth restored with resin composite.
Bromberg *et al.* [15]	Brazil	Maxillary third molars	Group 1: healthy tooth (positive control); Group 2: onlay indirect restoration; Group 3: inlay indirect restoration; Group 4: direct composite resin; Group 5: direct composite resin + transfixed post.	MOD cavity	- Lava Ultimate (lot N719292, expiration date April 2020; 3M ESPE) - Resin composite Filtek Z350XT (3M Espe, St. Paul, MN, USA)	Reforpost® (Angelus, Londrina, PR, Brazil) glass fiber posts	Vertical compressive load. 10kN/1mm/min	Endodontically treated molars restored with transfixed fiberglass post plus composite resin had fracture resistance similar to those restored with onlay, which was higher than that for inlay or composite resin only.
Fávero *et al.* [6]	Brazil	Maxillary third molars	Group 1: healthy tooth (positive control); Group 2: endodontically treated teeth + MOD	MOD cavity	Flow resin composite (Ultradent Products, South Jordan, UT, USA.) +	Reforpost® (Angelus, Londrina, PR, Brazil) glass fiber posts	Vertical compressive load. 10kN/1mm/min	The use of two fiberglass posts with resin composite was able to increase the

			cavity + 2 fiber posts 1.5 mm in diameter + resin composite restoration; Group 3: endodontically treated teeth + MOD cavity + 2 fiber posts 1.1 mm in diameter + resin composite restoration; Group 4: resin composite restoration; Group 5: MOD cavity; Group 6: MOD cavity + endodontic treatment.		resin composite Amelogen Plus (Ultradent Products, South Jordan, UT, USA.)			fracture strength of endodontically-treated molars when compared with teeth restored with resin composite only
Ferri *et al.* [16]	Brazil	Double-rooted first premolars	Group 1: intact teeth (positive control); Group 2: endodontically treated teeth without restoration (negative control); Group 3: restoration with composite resin; Group 4: fiber post placed horizontally in the center of the middle third of the crown + restoration with composite resin; Group 5: fiber post placed horizontally 2 mm below the center of the middle third of the crown + restoration with composite resin.	MOD cavity	Bulkfill flow resin (3M ESPE, St. Paul, MN)+ resin composite Z250 resin (3M ESPE, St. Paul, MN)	Reforpost® (Angelus, Londrina, PR, Brazil) glass fiber posts	Vertical compressive load. 10kN/0.5mm/min	The position of a fiber post seems to affect fracture location. The use of fiber posts, regardless of position, increases fracture resistance of endodontically treated teeth.
Karzoun *et al.* [17]	Syria, Saudi Arabia, and Germany	Maxillary premolars	Group 1: intact teeth (positive control); Group 2: endodontically treated teeth without restoration (negative control); Group 3: MOD cavity with resin composite restoration; Group 4: MOD cavity with resin composite restoration and a horizontal fiber post inserted between buccal and palatal walls; Group 5: MOD cavity with a horizontal fiber post only.	MOD cavity	Flowable composite (Opallisflow; Dentscare LTDA, Joinville-SC, Brazil) + Resin composite Filtek Z350XT (3M Espe, St. Paul, MN, USA)	Whitepost DC® (FGM, Joinville, SC, Brazil) glass fiber posts	Vertical compressive load. 1mm/min	Horizontal glass fiber post in a MOD cavity increased significantly the fracture resistance of the endodontically treated upper premolars.
Mesquita *et al.* [18]	Brazil	Premolars with one and two roots	(S = single-rooted; D = double-rooted) Group SS: sound single-rooted; SNR: endodontics (E) + MOD cavity preparation; Group SR: E + MOD + resin restoration (RS); Group SP: E + MOD + RS + horizontal zirconia post (ZP); Group DS: sound double-rooted; DNR: E + MOD; Group DR: E + MOD + RS; Group DP: E + MOD + RS + ZP.	MOD cavity	Bulkfill flow resin (3M ESPE, St. Paul, MN) + resin composite Z250 resin (3M ESPE, St. Paul, MN)	Zirconia posts were manufactured and customized	Vertical compressive load. 10kN/0.5mm/min	Single-rooted premolars were more resistant to fracture than double-rooted premolars. The restorative treatment using a horizontally transfixed zirconia post improved fracture resistance, resembling that of a healthy tooth.
Mergulhão *et al.* [19]	Brazil	Maxillary premolars	Group 1: intact teeth (positive control); Group 2: conventional composite resin; Group 3: conventional composite resin with a horizontal glass fiber post inserted between buccal and palatal walls; Group 4: bulk-	MOD cavity	Flowable composite (Filtek Bulk Fill Flowable Restorative, 3M ESPE) + conventional composite resin Filtek Z350XT (3M ESPE, St. Paul, MN)	Whitepost DC® (FGM, Joinville, SC, Brazil) glass fiber posts	Vertical compressive load. 1mm/min	Endodontically treated maxillary premolars restored with conventional composite resin with or without horizontal fiber post, bulk-fill composite, and ceramic inlay showed fracture resistance similar to that of sound teeth.

			fill flowable and bulk-fill restorative composites; Group 5: ceramic inlay.					
Scotti *et al.* [20]	Italy, and Switzerland	Mandibular first molars	Group 1: intact teeth (positive control); Group 2: endodontically treated teeth without restoration (negative control); Group 3: direct composite restoration; Group 4: fiber-post-supported direct composite restoration; Group 5: direct composite reinforced with horizontal mesio-distal glass-fibers; Group 6: buccal-palatal glass-fibers.	MOD cavity	Flowable composite (GrandioSo Heavy Flow; Voco, Cuxhaven, Germany) + composite resin (GrandioSo; Voco)	Glass fiber posts (GranTEC; Voco)	Oblique compressive load (45°). 0.5mm/min	For the direct restoration of endodontically treated molars, reinforcement of composite resins with glass-fibers or fiber posts can enhance fracture resistance.
Scotti *et al.* [21]	Italy	Maxillary premolars	Group 1: intact teeth (positive control); Group 2: endodontically treated teeth without restoration (negative control); Group 3: direct composite restoration with fiber-reinforced composite (everX Posterior GC); Group 4: direct composite restoration (Filtek Supreme XTE); Group 5: a horizontal layer of high-viscosity flowable composite (G-aenial Flow) was placed on the pulp chambre floor, 10mmx3mm glass fibers were inserted into the cavity; Group 6: same procedure as in group 5 except the direct restoration was made incrementally with FSXTE; Group 7: composite overlays were placed.	MOD cavity	- composite resin (GrandioSo; Voco) - composite resin (GrandioSo; Voco) - composite resin (GrandioSo; Voco) + composite resin composite resin (GrandioSo; Voco)	Glass fiber posts (everStick NET, GC)	Oblique compressive load (30°). 0.5mm/min	For the direct restoration of endodontically treated premolars, the insertion of glass fibers into direct composite restorations was unable to guarantee a significant increase in the fracture resistance or a significant change in the fracture pattern.

DISCUSSION

The longevity and fracture strength of direct restorations in endodontically treated teeth is an important factor in clinical success. Studies show that tissue loss is the main factor affecting the tooth survival rate[22,23]. Previous systematic reviews[24,25] reported that the biomechanical behavior of endodontically-treated teeth, by using a fatigue test, is influenced by the number of surfaces of the teeth involved during these tests. The authors noted that the most importante biomechanical change in endodontically-treated teeth was related to the loss of dental tissue, which suggests that it should be preserved.

With the exception of Bainy et al.[14], most of the included studies simulated class II preparations (MOD). Magne[26] stated that, if both of the proximal marginal ridges were removed, the stress concentration becomes greater. MOD cavity preparation reduces the structural stability by about 63%[27].

Regarding the teeth evaluated, most studies tested premolars[12,13,16-19,21], with only few studies using molars[5,6,14,15,20]. Premolar teeth are more frequently exposed to destructive lateral forces than molar teeth[28]. According to Wu et al.[29], and Bianchi et al.[30], the premolar presentes an unfavourable anatomical configuration whose inclination of the cusps makes them more susceptible to fracture when subjected to occlusal loading, relative to the other posterior teeth.

The use of intraradicular posts, cemented inside the root canal, is proposed to promote retention to the restorative material, and not to increase the tooth fracture resistance per se[4]. According to Saatian et al.[31], all types of intraradicular posts produce some degree of tension within the root dentin, causing some stress force to be transmitted vertically along the root[32], which can cause deeper levels of fractures and complexity[11]. Thus, some studies have tested the capacity of strengthening the tooth structure with the use of posts transfixed in the buccolingual

direction in the crown, during the restorative process.

In order to assess the distribution of occlusal and masticatory loads of teeth, forces are usually applied parallel of obliquely to the tooth axis. Maximum bite force in human beings with normal occlusion is around 222 N to 445 N in premolars[33], and around 424 N to 630 N in molars[34].

In studies with premolars, it can be observed that the use of a post transfixed in the dental crown promoted an increase in resistance. Aslan et al.[12] (365.49 N in horizontal fiber post group; 416.07 N in positive control group; 86.88 N in negative control group), Bahari et al.[13] (1023.33 N in horizontal fiber post group; 1073.63 N in positive control group; 461.83 N in negative control group); Ferri et al.[16] (1253 and 1156 N in horizontal fiber post group; 2451 N in positive control group; 32.63 N in negative control group); Karzoun et al.[17] (961.3 N in horizontal fiber post group; 994.5 N in positive control group; 411.8 N in negative control group); Mergulhão et al.[19] (934.5 N in horizontal fiber post group; 949.6 N in positive control group); Mesquita et al.[18] (1438.8 N in horizontal fiber post group; 1619.3 N in positive control group; 524.9 N in negative control group); Scotti et al.[21] (515.96 and 499.79 N in horizontal fiber post group; 934.91 N in positive control group; 100.80 N in negative control group).

In studies with molars, positive results were also observed with the use of the transfixed post associated with the direct restorative technique. Bainy et al.[14] (2493 N in horizontal fiber post group; 3563 N in positive control group; 1001 N in negative control group); Beltrão et al.[5] (2645.4 N in horizontal fiber post group; 4289.8 N in positive control group; 549.6 N in negative control group); Bromberg et al.[15] (2693 N in horizontal fiber post group; 4514 N in positive control group); Fávero et al.[6] (3100.4 and 2988.5 N in horizontal fiber post group; 3830.4 N in positive control group; 572.93 N in negative control group); Scotti et al.[20] (499.26 and 582.22 N in horizontal fiber post group; 831.83 N in positive control group; 282.86 N in negative control group).

All analyzed studies tested posts transfixed in the dental crown in the buccolingual direction. Only in the study by Scotti et al.[20] also analyzed the transfixation of the post in the mesiodistal direction. According to the data obtained in the article, the fracture resistance did not differ significantly regarding the direction of the transfixed post.

The transfixed post procedure can be performed with either one or two posts. Beltrão et al.[5] obtained a mean resistance of 2,645 N by using a single fiberglass post, whereas Fávero et al.[6], using 2 posts of 1.1- or 1.5-mm diameter, produced 2,988 and 3,100 N, respectively. Despite the similarity, one can observe that using 2 posts produces higher fracture resistance.

Bainy et al.[14] also investigated the use of a fiberglass tape associated to a direct restoration with composite resin, and reported similar results to the transfixed post group. In tis study, the authors used Interlig® tape in all the inner surfaces of the pulp chamber (buccal, lingual, distal and mesial). According to Belli et al.[35], the use of polyethylene ribbon fibers beneath composite resin restorations in endodontically treated teeth can promote an increased fracture resistance compared to composite resin restorations only. Polyethylene ribbon fibers can modify the stresses at the restorative material-dentin interface. In this context, bonding ability of the fiber, associated to the composite resin, might increase the tooth fracture resistance. On the other hand, Bahari et al.[13] used a fiberglass tape under the restored occlusal surface and found no significant difference from the group in which only direct composite resin restoration was performed. The discrepancies between the results of studies might be attributed to the absence of standardized preparation techniques and/or differences in position of fibers.

Bromberg et al.[15], and Mergulhão et al.[19] compared, in the experimental groups, indirect inlay restorations, made in the laboratory and cemented in the tooth, to the situation of direct composite resin restoration with a transfixed post. The authors obtained lower strength data in the direct method.

The restorative procedure must be carefully planned, evaluating the prognosis and risk of coronary fracture. The use of a transfixed post associated with the direct restorative procedure does not present any technical difficulties. It is a technique that has a lower cost than indirect restorations and satisfactory esthetics[6]. According to Kim et al.[36], this is a relatively quick and simple procedure and can be performed by the endodontist or general dentist at a low cost. Furthermore, the use of a transfixed post, as observed in the study of Ferri et al.[16], can also predict and induce the location of a possible future fracture.The horizontal placement of posts in the center of the middle third of the crown is associated with a greater chance of fractures at the cusp level, without involvement of the pulp floor. These fractures have a better prognosis and result in better tooth survival and restoration. In this study, teeth that received other treatments, including the use of horizontally transfixed posts, placed 2 mm below the conter of the middle third of the tooth crown, most fractures were catastrophic, occurring at, or below, the floor of the pulp chamber.

However, in vitro studies with dynamic fatigue process and clinical studies are needed in order to

consolidate and confirm the laboratory findings of this alternative direct restorative technique.

CONCLUSION

Based on the analyzed studies, it is possible to conclude that the use of a transfixed post in the dental crown increases the fracture resistance of weakened and directly restored teeth. However, clinical studies are needed to validate this finding.

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Table 2 - Risk of bias assessment of the in vitro studies.

Study	Description of the sample calculation	Randomization process	Presence of control group	Description of restorative methods	Description of the fracture resistance test used	Statistical method	Risk of bias
Aslan *et al.* [12]	No	Yes	Yes	Yes	Yes	Yes	Low risk
Bahari *et al.* [13]	Yes	Yes	Yes	Yes	Yes	Yes	Low risk
Bainy *et al.* [14]	Yes	Yes	Yes	Yes	Yes	Yes	Low risk
Beltrão *et al.* [5]	No	Yes	Yes	Yes	Yes	Yes	Low risk
Bromberg *et al.* [15]	Yes	Yes	Yes	Yes	Yes	Yes	Low risk
Fávero *et al.* [6]	No	Yes	Yes	Yes	Yes	Yes	Low risk
Ferri *et al.* [16]	No	Yes	Yes	Yes	Yes	Yes	Low risk
Karzoun *et al.* [17]	No	Yes	Yes	Yes	Yes	Yes	Low risk
Mesquita *et al.* [18]	No	Yes	Yes	Yes	Yes	Yes	Low risk
Mergulhão *et al.* [19]	No	Yes	Yes	Yes	Yes	Yes	Low risk
Scotti *et al.* [20]	No	Yes	Yes	Yes	Yes	Yes	Low risk
Scotti *et al.* [21]	No	Yes	Yes	Yes	Yes	Yes	Low risk

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AN UNUSUAL REPAIR OF PERFORATING INTERNAL INFLAMMATORY ROOT RESORPTION; A CASE REPORT OF ENDODONTIC TREATMENT

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ABSTRACT

Internal inflammatory root resorption (IIRR) can occur as a complication of dental trauma which leads to progressive loss of the root structure. An early diagnosis could influence the therapeutic approach. Nevertheless, endodontic treatment in these situations is challenging, with a doubtful prognosis. The present report described a perforating IIRR, resulting from a trauma suffered four years previous. A 15-year-old female patient was presented to the endodontic clinic, reporting pain in the maxillary incisor region. Intraoral radiography revealed a large radiolucent area compatible with IIRR, communicating with the periodontium in the middle third on the distal root face of the right central incisor. The root canal of the right central incisor was chemo-mechanically prepared. Calcium hydroxide (CH) paste was used and renewed periodically four times. Root canal filling was performed only in the cervical third, up to the level of the root resorption. During follow-ups, tooth was asymptomatic. Radiographically, there was evidence of periapical tissue repair and bone tissue formation. The tooth remained asymptomatic 3 years afterwards. The present case report supports the idea that a satisfactory intracanal decontamination allows a favorable environment for tissue repair.

KEYWORDS: Calcium hydroxide. Dental pulp necrosis. Root canal therapy. Root resorption.

INTRODUCTION

Internal inflammatory root resorption (IIRR) occurs when an inflammatory response within the pulp tissue leads to the activation of dentinoclastic cells.[1,2] The American Association of Endodontics (AAE) consensus, based on the revision of Levin et al. (2009), establishes that this type of resorption can be considered a result of the presence of microorganisms within the root canal, causing pulpitis and a resorption area.[1,2] When active, the IIRR results in a tooth with some necrotic and infected pulp tissue, as well as some pulp tissue with irreversible pulpitis.[1,2]

In the case of internal resorption, loss of mineral structure of the teeth will occur.[3,4] The available evidence suggests that dental injuries such as traumas are one of the main etiological factors related to this condition.[5] Clinically, cases of IIRR can be easily overlooked once it occurs asymptomatically, and internal resorptive destruction of the dentinal structure may be detected radiographically only at an advanced

stage.[6] Early treatment of this pathological condition is imperative to avoid root perforation and, consequently, tooth extraction. Thus, endodontic treatment is a highly recommended therapeutic approach.[3]

Currently, there are few reports on root perforation induced by internal root resorptions[7,8] and the clinical procedures that can be performed to resolve the case. This treatment considered the elimination of causal factors such as bacterial infection, interruption of the progressive resorption mechanism and stimulation of hard tissue repair in the resorption area through chemo-mechanical preparation and the use of calcium hydroxide (CH) pastes.[7] Additionally, mineral trioxide aggregate (MTA) has been used for root canal filling and filling of perforation defects.[9] The present study aims to report the management of a perforating IIRR in the middle third on the distal face of the root in an upper central incisor.

CASE PRESENTATION

Written informed consent was obtained from the patient for the publication of the case report.

A 15-year-old female patient was presented to the endodontic clinic reporting pain in the upper right lateral incisor. The patient reported a history of dental trauma, which had occurred four years ago, in the region of teeth #11 and #12. The patient reported that had never felt any pain after the trauma, henceforth, never sought dental care.

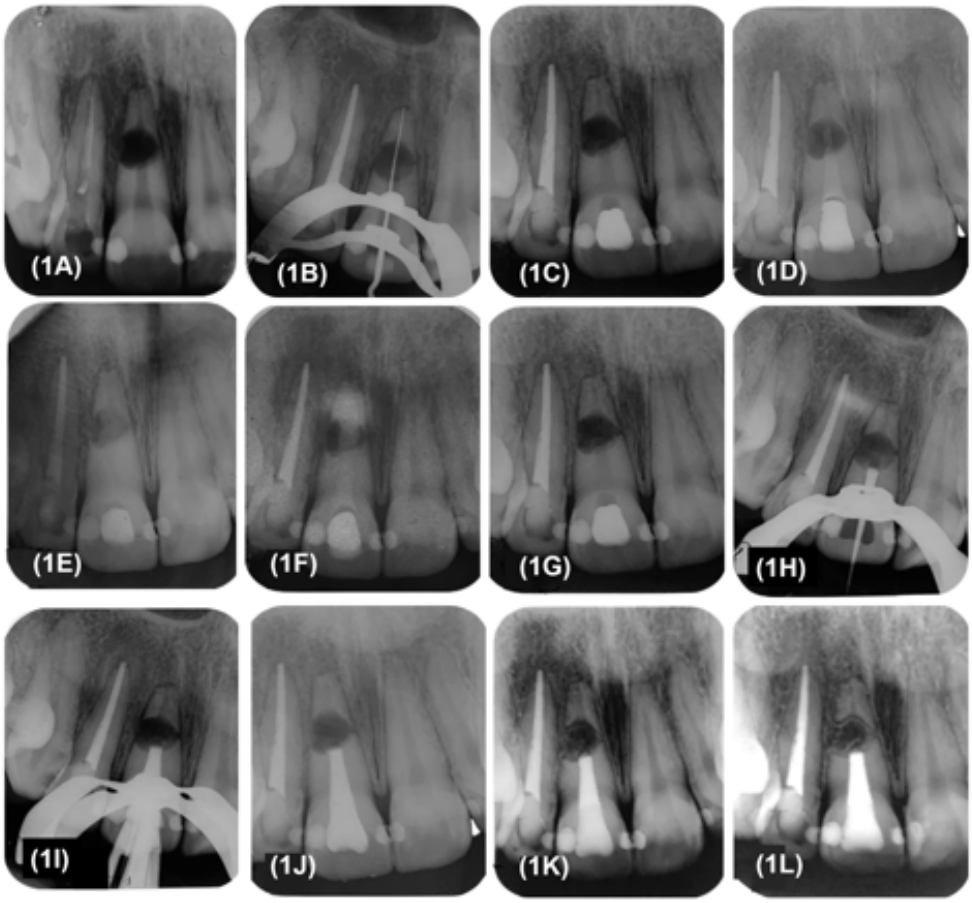
A general practitioner attended the patient and performed endodontic treatment of tooth #12. The clinician referred the patient to an endodontist for evaluation of tooth #11. Radiographically, it was verified a resorptive area on tooth #11. There was no chronicle of orthodontic treatment and the patient denied the presence of parafunctional activity. The patient's medical and family narrative was non-contributory.

Tooth #11 was asymptomatic. The crowns of teeth #11 and #12 were free of dental caries, however, a chromatic alteration was observed in the crown of tooth #11, which responded negatively to thermal pulp test, as well as to the vertical and horizontal percussion tests. The mucosa corresponding to the regions of teeth #11 and #12 presented a normal clinical appearance, without protuberances or fistulas. Periodontal probing depths and tooth mobility were considered normal.

Intraoral periapical radiography (Kavo Focus; Kavo Kerr, São Paulo, SP, Brazil) showed that tooth #12 had a poorly filled root canal (Figure 1A). An extensive radiolucent area was observed with great communication with the periodontium in the middle third on the distal face of the root of tooth #11, compatible with internal root resorption. Based on clinical and radiographic information, it was determined a diagnosis of active-stage IIRR, as the tooth responded negatively to pulp sensitivity tests, suggesting partial necrosis, but without radiographically visible apical periodontitis[1].

The differential diagnosis of an internal or external inflammatory root resorption was based on the accurate observation of the radiographic image, where the contours of the resorption area included the root canal. Given the advanced stage of resorption and the

Figure 1. (A) Preoperative periapical radiograph of teeth #11 and #12. **(B)** Radiograph showing the establishment of the working length of tooth #11. **(C)** Tooth #11 filled with calcium hydroxide paste. **(D-G)** Radiographic evaluation of tooth #11 after intracanal medication exchange. **(H)** Selection of gutta-percha cone. **(I)** Root canal obturation using the inverted gutta-percha technique. **(J)** Follow-up radiograph after 1 year, evidencing formation of bone tissue. **(K)** Follow-up radiography after 2 years. **(L)** Follow-up radiography after 3 years, showing tissue repair and bone formation.



reduced amount of tooth structure, the root was at high risk of fracture and tooth loss. Despite endodontic treatment showing a dubious prognosis, instead of extraction, endodontic treatment was performed with periodic changes of intracanal medications and radiographic follow-ups.

Root canal retreatment was performed on tooth #12. The procedures performed on tooth #11 were as follows: local anesthesia with 2% mepivacaine containing 1:100.000 epinephrine (2% Mepiadre; DFL, Rio de Janeiro, RJ, Brazil) was administered. Tooth #11 was isolated with a rubber dam. The pulp chamber was accessed with diamond burs mounted on a high-speed motor (Kavo, Joinville, SC, Brazil) under copious water irrigation. At this stage, the pulp chamber was empty and the pulp tissue was necrotic. However, profuse bleeding occurred in the pulp chamber when the root canal was explored with a #25 K-file (Dentsply, Maillefer, Baillaigues, Swizerland) at the level of the resorption area due to the presence of inflamed granulomatous tissue. Bleeding was contained by rinsing with saline solution at each visit using a 30-gauge Navitip needle (Ultradent Products Inc., South Jordan, USA) for a duration of 2–3 minutes inserted at the level of the resorption area, with a total volume of 20mL of saline solution.

The root canal was irrigated with 10mL of 1% sodium hypochlorite (NaOCl; Formula e Ação, São Paulo, SP, Brazil) and saline solution. The access to the apical third of the root canal was obtained using a #15 K-file, trespassing the resorption area. The working length was determined 1mm short from the radiographic apex (Figure 1B). Root canal preparation was performed at the working length up to a #80 K-file. The root canal was rinsed with 10mL of 1% NaOCl after the use of each instrument. At the end of instrumentation, the root canal was irrigated using 3mL of 17% ethylenediaminetetraacetic acid (EDTA; Formula e Ação, São Paulo, SP, Brazil).

The cervical and apical thirds of the root canal were dried with paper points (Dentsply, Maillefer, Baillaigues, Swizerland). Subsequently, CH powder (Maquira, São Paulo, SP, Brazil) was mixed with propylene glycol (Sigma Aldrich, São Paulo, SP, Brazil) until a viscous paste was obtained. The paste was introduced into the root canal by a #40 Lentulo spirals (Dentsply, Maillefer, Baillaigues, Swizerland) (Figure 1C) and the access cavity was temporarily sealed with glass ionomer cement (Vitro Fil LC; DFL, Rio de Janeiro, RJ, Brazil).

After 1 month, the patient returned to the clinic and was asymptomatic. CH paste was removed from the root canal by using 1% NaOCl, 17% EDTA, and saline solution with the aid of a size #45 K-file. A freshly mixed CH paste was inserted into the root canal in the same manner as previously mentioned and the access cavity was temporarily sealed with glass ionomer cement. Radiographic evaluations were performed, and the images suggested disruption of the apical root third and improvement in bone density (Figures 1D, 1E). These procedures were performed again after 2, 3, and 4 months, accomplishing four changes of the CH pastes (Figures 1D, 1E, 1F, and 1G). After that, the radiolucent resorption area suggested to have decreased in size.

Six months afterwards, periapical radiograph evidenced bone formation. Root canal was filled in the cervical third, up to the level of resorption, using the inverted gutta-percha technique with a zinc-oxide and eugenol sealer (Endofill, Dentsply, Rio de Janeiro, RJ, Brazil) (Figures 1H, 1I).

Follow-ups after 12, 24, and 36 months were performed. Tooth remained asymptomatic. Periapical radiographs were taken and evidenced hard tissue formation in the perforation area and remodeling of the root surface. The resorption area presented newly formed bone tissue, simulating a replacement resorption with maintenance of the periodontal ligament space (Figures 1J, 1K, and 1L). Oral hygiene instructions were also given at each follow-up.

DISCUSSION

Inflammatory root resorption can cause tooth loss. Patients usually seek dental care when there is noticeable change in the color of the tooth crown, or changes in the oral mucosa and/or pain.[10] Late clinical interventions can result in an unsatisfactory outcome. In addition, if the tooth structure is severely compromised and perforation has occurred, the prognosis is poor and tooth extraction should be considered. In the present case report, the initial radiograph showed an extensive root resorption with periodontal communication. In this situation, in addition to hindering the removal of the inflamed tissue, it contributes to tooth fragility and increases susceptibility to fracture. However, the literature states that even in unfavorable conditions, endodontic treatment remains a viable approach for tooth preservation.[8,9]

The literature often reports the difficulty in differentiating the diagnosis between internal and external root resorption.[3,6] Both conditions have the presence of inflamed tissue and, when located coronally, a typical pink clinical appearance known as 'pink spot', related to the presence of vascularized connective tissue containing osteoclasts, is often observed without the presence of other symptoms.[10] In this case report, clinical and radiographic parameters determined the diagnosis as internal root resorption. In this situation, some

characteristics can be observed, such as well-defined margins; uniform radiolucency; symmetrical distribution of the root; canal walls with a balloon-like shape and often filled with inflamed tissue when observed during chemo-mechanical preparation.[5,11]

It is imperative to differentiate the active and non-active IIRR. When the blood supply is lost, the apical portion of the pulp will necrose, and the dentinoclasts will die. Thus, resorption will no longer be active.[1,2] Subsequently, microorganisms will metabolize the necrotic pulp tissue, resulting in apical periodontitis.[1,2] The present case did not present apical periodontitis, suggesting an aggressive IIRR.

The mentioned tissue factors promote great difficulties in the endodontic treatment of IIRR, including excessive bleeding.[10] The use of NaOCl in low concentration for tissue dissolution, and the subsequent use of saline solution, avoiding periradicular tissue injuries and patient discomfort are essential.[8] In addition, the removal of pulp tissue interrupts the blood supply and the arrival of clastic cells, preventing the progression of resorption.[3,5,8,10] However, if resorption perforates the root, communicating the root space with the periodontium, the treatment process can be more challenging. In these situations, the use of CH pastes is recommended, in an attempt to stimulate the formation of mineralized tissue.[8]

In the present case reported, CH paste changes were performed four times, with a total of 30 days of intracanal paste permanence, aiming at a satisfactory ionic release, providing a favorable environment for tissue neoformation.[12] Superior intratubular penetration of CH pastes with a viscous vehicle rather than an aqueous vehicle have been previously observed[12], for this reason, CH powder was mixed to propylene glycol to obtain a viscous paste.

Previous studies have suggested that a high alkaline pH and greater ionic are related to the use of CH powder mixed with viscous vehicles.[13-15] Furthermore, it has been shown that the greater the intratubular penetration of the CH paste, the greater its ability to reach microorganisms, favoring a greater disinfection capacity. This is mainly due to the increase in pH (approximately 12) along the entire root length, favoring the elimination of bacteria such as *Enterococcus faecalis*, which can survive at pH 11.5.[16]

It is necessary to mention that when communication with the periodontium occurs, due to the extension of the IIRR, the destruction of adjacent periodontal tissues may occur. Thus, endodontic treatment can be performed by sealing the perforation using a biocompatible material.[4] In these cases, MTA has been the material of choice for the surgical or non-surgical treatment of the perforation.[9] However, in the present case, it was observed in the clinical and radiographic follow-ups that, after several changes of the CH pastes, there was formation of bone tissue in the resorption area.

The inverted gutta-percha technique was chosen for filling the cervical third of the root canal. Throughout the follow-ups, the presence of periodontal ligament was observed, without ankylosis formation. These clinical approaches ensure tooth maintenance, avoiding surgical procedures or tooth extraction.

The present case report is in agreement with Kaval et al.,[8] in which relates the healing mechanism to a three-step process: root canal disinfection, interruption of osteoclastic activity, and initiation of new tissue formation within the resorption area and root canal.[8] It should be noted that the absence of root canal filling of the apical third did not impair the repair process, since during the 36 months of follow-up endodontic retreatment was not necessary. Thus, it is possible to affirm that the chemo-mechanical procedures play a fundamental role in the reduction of bacteria to levels compatible with those to allow tissue healing, and that the use of CH pastes contributed to the elimination of remaining bacteria, and ionic release, creating an environment favorable to tissue neoformation.[12]

CONCLUSION

Conservative endodontic techniques can interrupt the IIRR process and induce the production of mineralized tissue even in the presence of perforation. CH with viscous vehicle showed great potential for bone tissue stimulation.

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CONFLICTS OF INTEREST

None.

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