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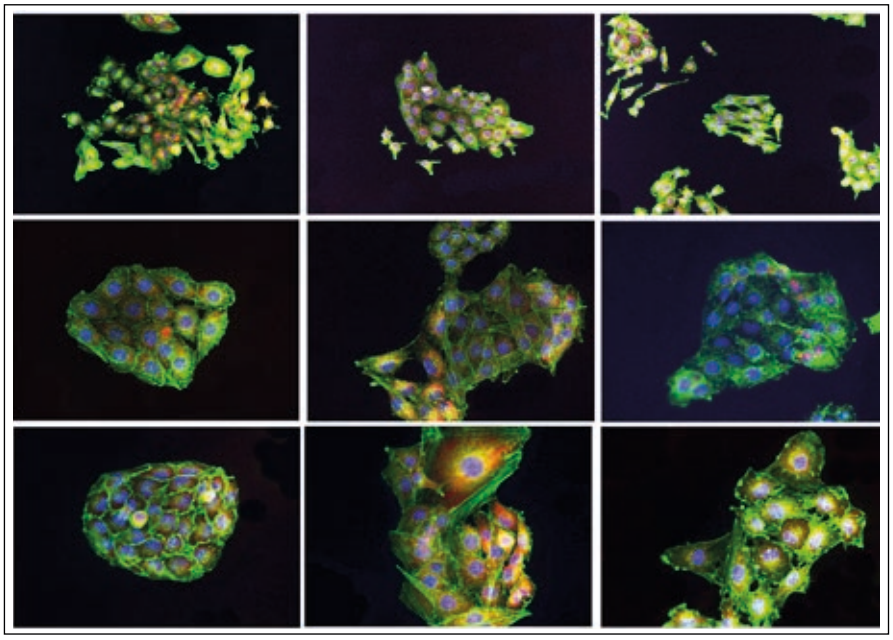

▸ Original Articles

Effect of smear layer removal using different chelators on push-out bond strength of bioceramic sealer

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Hot modified technique: a novel modified obturation technique using biosealers

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REGISTRATION Court of Milan n° 89, 3 March 2009

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Sandro Rengo
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Editorial

Bioceramics, a turning point

The evolution of materials has provided a significant progress within the endodontic field, improving the traditional techniques and establishing high success rates over time.

Calcium silicate-based materials, also known as bioceramics, are able to react with water through a hydraulic setting reaction to produce a solid mass capable to enlarge with time, be dimensionally stable and provide a perfect sealing. In addition, these materials are demonstrated to be characterized by biocompatibility, bioactivity and antibacterial properties showing unique features, such as mineralized tissue formation, cell proliferation induction and tissue repair. From a clinical point of view, bioceramics have become commonly used materials in the different branches of endodontics, namely vital pulp therapy, repair of perforation, orthograde and retrograde canal obturation and endodontic regeneration.

In this regard, within the present issue, several scientific papers dealing with the different use of calcium silicate hydraulic materials has been published. Specifically, a study had proved the differentiation potential of a newly developed materials for pulp capping and an immunohistochemical analysis had evaluated the effect of two cements in terms of furcation perforation repair. Moreover, bioceramic sealers had been evaluated by two additional papers, in which bond strength and use during a hot modified obturation technique had been studied, respectively.

The advent of such materials has definitely marked a turning point within the endodontic field, not only in terms of technological progress, but also in the clinical application and therapeutic choice. Obviously, future researches are needed with the aim to enhance physical and biological properties, as well as to demonstrate the efficacy during procedures that nowadays are considered innovative and just supported by preliminary results.

Peer review under responsibility of Società Italiana di Endodonzia.

10.32067/GIE.2023.37.01.14

ORIGINAL ARTICLE

Postoperative pain after foraminal enlargement in teeth with necrosis and apical periodontitis: a prospective and randomized clinical trial

ABSTRACT

Aim: *To evaluate the effect of working length (WL) on postoperative pain in root canal treatment with foraminal cleaning (FC).*
Methods: *One hundred patients with an indication for root canal treatment of teeth diagnosed with pulp necrosis were selected for the study. The teeth were divided into two groups according to the established WL: in group I (n=50), the WL was established at the 0.0 mark on the electronic apex locator (EAL) display. In group II (n=50), the WL was established 1 mm beyond the 0.0 mark on the EAL display. Both groups were treated with the WaveOne Gold reciprocating system (Dentsply Maillefer).*
Results: *Postoperative pain was measured 12, 24 and 48 h using a modified verbal descriptor scale ranging from no pain to maximum pain. In both groups, a significant difference in postoperative pain was observed between all time points analyzed. There was no statistically significant difference in postoperative pain between the two groups. FC performed in single-visit root canal treatment with WL measurement at the 0.0 mark on the EAL display or 1 mm beyond results in a similar intensity of postoperative pain in teeth with pulp necrosis.*
Conclusion: *The working length did not influence endodontic postoperative pain.*

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Introduction

Although the apical limit of root canal instrumentation is a controversial topic in root canal treatment, studies have shown a high prevalence of bacterial biofilms in the region of the cemental canal and apical foramen. In certain cases, these biofilms can extend to the extraradicular apical surface (1, 2). Therefore, root canal disinfection as close as possible to the major apical foramen keeps this region clean and free of debris and provides a favorable environment for periapical repair [3]. Root canal instrumentation short of the apical foramen might leave pulp remnants, infected tissue, bacteria, biofilm, and unfilled and unprepared areas that can result in endodontic failure (4-7). The endodontic filling materials should stop on the cemento-dentinal junction, otherwise overfilling would cause inflammatory responses in periapical tissues (8).

For a correct determination of working length (WL), an electronic apex locator (EAL) has been shown to accurately detect the apical constriction and the major apical foramen (9). However, the measurements provided by the EAL can vary from -0.5 to +0.5 mm from the apical foramen and may therefore underestimate the position of the major apical foramen in some cases (10-12).

The apical third of the canal is considered a critical zone, as it can concentrate a large number of microorganisms that will perpetuate periradicular inflammation (13, 14). Bacterial biofilms are found in the apical third of the root canal system in up to 80% of teeth with apical periodontitis (15). Removal of bacterial biofilms from the apical foramen is achieved by foraminal cleaning (FC) and may lead to successful results of endodontic treatment in cases of apical periodontitis (16, 17). FC consists of intentional mechanical widening of the apical foramen diameter in order to reduce the bacterial load in the apical ramifications by removing contaminated cementum and dentin and by filling up the apex to promote tissue repair (4, 16, 17, 19).

One of the main concerns regarding enlargement of the apical foramen is the possibility of postoperative pain caused by instrumentation and irritation of periapical tissue (18, 19). Pain after root canal treatment can be defined as a feeling of discomfort and occurs in 3% to 58% of patients, regardless of pulp and periapical status (20). Silva (2013) found the same rate of postoperative pain in the presence or absence of FC. Other authors reported increased pain within the first days after treatment (21). Postoperative pain can be caused by tissue debris, dentin scrapings, microorganisms, and irrigating solutions that are extruded from the apical foramen to the periapical tissues during root canal preparation (22).

FC can be performed with the root canals instrumented at the 0.0 reading on the EAL display or beyond this measure in cases of teeth with necrotic pulp and periapical pathosis (8, 9, 20, 21). The aim of the present randomized clinical trial was to evaluate the incidence of postoperative pain in root canal treatment with FC performed at different WL on teeth with pulp necrosis. The null hypothesis tested was that there is no significant difference in the incidence of postoperative pain after FC performed with WL measured at the 0.0 reading on the EAL display or 1 mm beyond.

Materials and Methods

Sample size calculation

The sample size was calculated (G*Power 3.1.9.4, Heinrich-Heine University, Düsseldorf, Germany) using the results of Silva (16). In that study the smallest effect size between groups was 0.1335. Assuming α=0.05 and a power of 0.80, a sample size of 46 teeth per group would be needed in the current study considering two groups and three time points. The number of teeth per group was increased to 50 to compensate for dropouts.

Sample selection

The institutional Ethics Committee on Research Involving Humans of the Review Board of the Centro de Pesquisas

Odontológicas São Leopoldo Mandic approved this randomized clinical trial (Protocol No. 2.065.851). The study was registered in the Brazilian Clinical Trials Registry (ReBEC) under registration number RBR-6bv5hy.

Three hundred consecutive patients of both sexes aged 17-69 years, who attended a private practice between July and November 2017 and who had maxillary and mandibular (anterior or posterior) teeth with a diagnosis of pulp necrosis, were scheduled for primary endodontic treatment. The canal was considered narrow when a #15 hand flexo file reached the working length, and a #20 hand flexo file did not reach this point. The canal was considered wide when a #25 hand flexo file reached the working length, and a 30 flexo file did not reach this point. If a #35 hand flexo file reached de working length the tooth was excluded from the experiment. After exclusion criteria one hundred teeth were randomly assigned to two groups according to the established WL. The WL was established at the 0.0 reading on the EAL display in group (0.0) (n=50) and at 1 mm beyond the 0.0 reading in group (+1.0) (n=50) (Fig. 1).

Randomization was carried out according to the order of patient appointment, i.e., the first patient was selected for group (0.0), the second for group (+1.0), and so on. The participants were blinded and not informed about the allocation. However, the operator was not blinded to the interventions because of the nature of the interventions.

Inclusion criteria

The criteria for inclusion in this study were necrotic teeth with or without apical radiolucency (maximum size of 2.0x2.0 mm), without clinical signs such as fistula, edema and sensitivity to palpation, and without a history of endodontic management. Patients who had taken anti-inflammatory agents or analgesics in the last 10 days, patients requiring antibiotic premedication for dental treatment, patients with systemic diseases, and patients allergic to ibuprofen were excluded from the study. Teeth with an incomplete apex, teeth in which a Wave One Gold 35/06 file (Dentsply Maillefer, Tulsa, OK, USA) has reached working length without any resistance, teeth with a maximum periodontal probing depth of 3 mm, and teeth with internal and external root resorption were also excluded. Furthermore, patients with a history of dental trauma or endodontic management, patients whose treatments could not be completed in a single session or lasted more than 90 min, and patients in whom the apical patency of the root canals could not be established were excluded.

The treatment protocol was explained to all patients who signed a written informed consent form. Endodontic treatments were performed in a single session by a single operator with 10 years of experience. The maximum duration of each session was 90 min.

Treatment protocol

All treatments were performed using an operating microscope (Alliance, São Paulo, São Carlos, Brazil) at 10X to 25X magnifications by an endodontic specialist with 8 years of experience. Pulp status was determined by a negative cold test (Endo-Frost, Coltene-Whaledent) and was confirmed by the absence of bleeding when entering the pulp chamber. Rubber dam

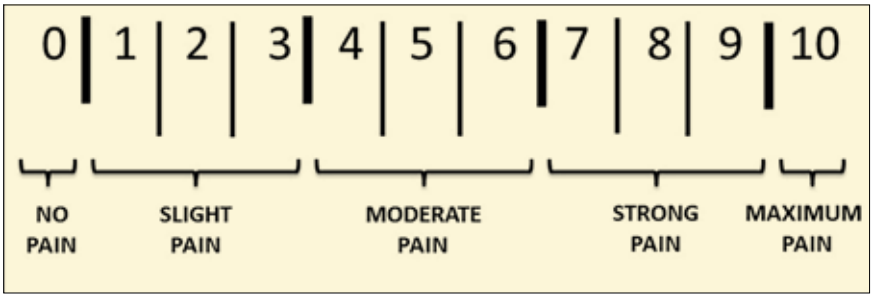


Figure 1
Modified verbal descriptor scale.

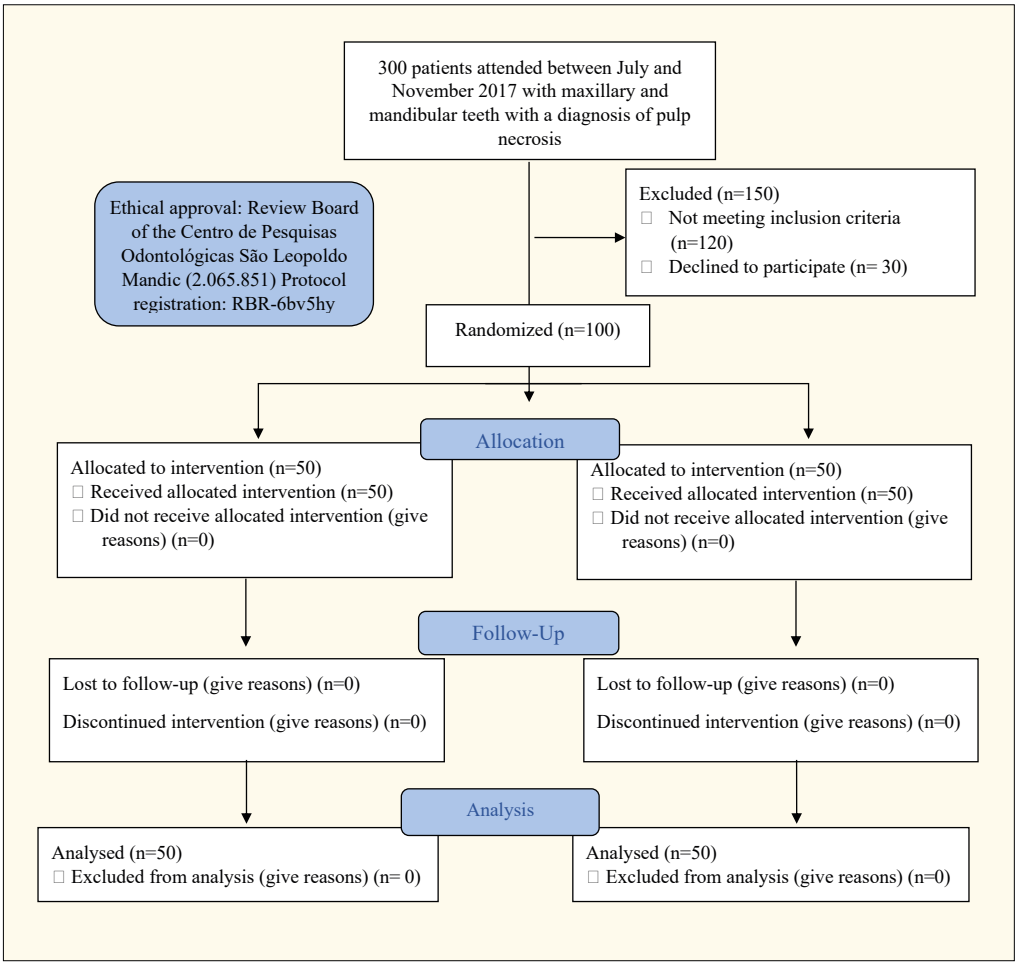


Figure 2
Flowchart of participants through the trial according to the Consolidated Standards of Reporting Trials.

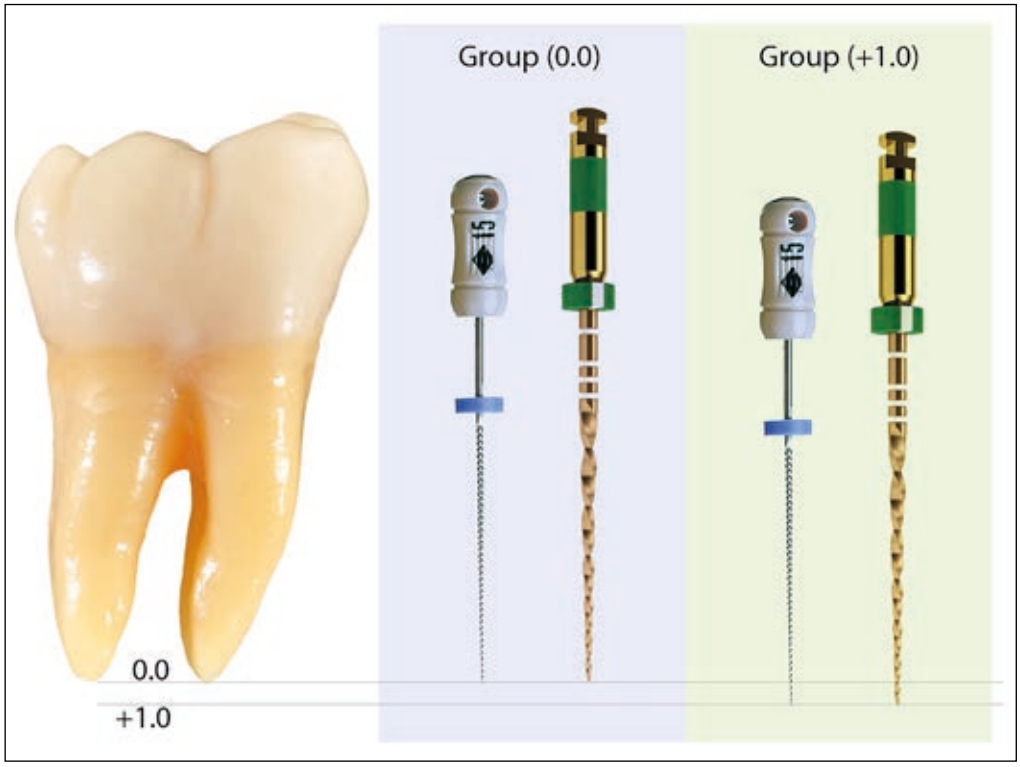
isolation was used in all cases. Local anesthesia 2% lidocaine with 1:100,000 epinephrine (DFL, Rio de Janeiro, Rio de Janeiro, Brazil) was administered as needed for patient comfort, using the infiltrative technique for maxillary teeth and inferior alveolar nerve block for mandibular teeth. No supplemental injections were used. The canals of the groups were instrumented by the crown-down technique. The cervical and middle thirds were decontaminated and enlarged using a single-file reciprocating instrumentation technique with WOG primary 25/07 files (Dentsply Maillefer) driven by a 6:1 reduction handpiece (Sirona Dental Systems) that was powered by a torque-controlled motor (VDW Silver Motor, Munich, Germany). The "WAVE-ONE ALL" pre-set reciprocating program was used.

The root canals were irrigated with a syringe (20 mmx0.55 mm needle) containing 1 mL of 2% chlorhexidine gel (VisNature, Itajaí, Santa Catarina, Brazil) before the use of each file and after the use of each instrument and the root canals were then rinsed with 5 mL saline solution (23, 24). The WL was established by introducing #10 and #15 K-files up to the apical foramen and confirmed with a Romipex A-15 apex locator (Romidam Ltd., Kiryat Ono, Israel).

Apical preparation was performed using WOG primary 25/07 reciprocating instruments for narrow root canals and WOG medium 35/06 instruments for wider canals. The manufacturer's recommendations were followed, the file is chosen according to the working length adjustment (Figure 3).

The files were introduced into the root canal with in-and-out movements (pecking

Figure 3
Foraminal Cleaning Protocols.



motion) at an amplitude of 1-3 mm per movement until the WL predefined for each instrument was reached. After the completion of root canal instrumentation, each canal was irrigated with 1 mL of 17% EDTA (Biodinâmica, Ibiporã, Paraná, Brazil) by ultrasonic activation with an E-1 Irrisonic tip (Helse Dental Technology) for 30 seconds, with three successive changes for a total of 3 mL EDTA per canal. The root canals were then dried with a silicone cannula (Capillary Tips, Ultradent) and paper points (Dentsply Maillefer, Tulsa, OK, USA) and filled with gutta-percha (Odous De Deus Ltda.) and the AH Plus sealer (Dentsply Maillefer, Tulsa, OK, USA) using warm vertical compaction with a thermocompactor (Odous Touch). The 3-mm cervical portion of the root canal was sealed with Coltosol (Vigodent) and the coronal access cavity was restored using resin composite. The occlusion was checked and adjusted.

Assessment of postoperative pain

For accurate assessment of pain intensity, each patient received a modified verbal descriptor scale (VDS), which is the combination of a verbal rating scale measuring pain from no pain to maximum pain and a numerical rating scale scoring pain from 0 to 10 (25). The level of pain was rated as follows: (0) no pain: the treated tooth felt asymptomatic; (1 to 3) slight pain: the tooth was slightly painful for a short period of time, but there was no need to take analgesics; (4 to 6) moderate pain: the tooth caused pain which was tolerable or was rendered tolerable by analgesics; (7 to 9) strong pain: the tooth caused long-lasting pain that disturbed normal sleep and required narcotic analgesics; (10) maximum pain: the tooth caused continuous pain that disturbed normal activity or sleep and analgesics had no effect (26) (Fig. 2).

The patients were instructed to place a mark on the number of the scale (from 0 to 10) that represented the intensity of the experienced pain. The level of discomfort was rated 12, 24 and 48 h after endodontic treatment (18). The patients were instructed to take ibuprofen (400 mg, one tablet every 8 hours for 3 days) in cases of moderate pain or to return to the clinic for

Table 1
Characteristics of the groups studied

	Group (0.0)		Group (+1.0)		
	n	%	n	%	
Male	19	38.0	16	32.0	
Female	31	62.0	34	68.0	P=0.675
Maxillary teeth	31	62.0	36	72.0	
Mandibular teeth	19	38.0	14	28.0	P=0.395
Anterior teeth	24	48.0	26	52.0	
Posterior teeth	26	52.0	24	48.0	P=0.842
Analgesic consumption	11	22.0	11	22.0	P=1.000
Presence of apical lesion	23	46.0	18	36.0	P=0.405
Sealer extrusion	18	36.0	32	64.0	p=0.005

Chi-square test with significance at p<0.05.

A significant difference was only observed in endodontic sealer extrusion from the apical foramen (p=0.005).

control in cases of severe pain. All patients were contacted by phone or by instant messaging (WhatsApp Messenger, WhatsApp Inc.) after 48 h to record the level of postoperative pain at the three time points analyzed. The patients were asked whether or not they had taken medication after treatment and how much.

Statistical analysis

Another operator analyzed the data. The incidence of postoperative pain was recorded and is expressed as percentage. Data were submitted to statistical analysis using Fisher's exact test and the Mann-Whitney test for nonparametric data. The Statistical Package for the Social Sciences 20.0 (SPSS Inc., Chicago, 2006) was used to determine significant differences at p<0.05.

Results

The demographic and clinical features of the patients of the two groups are presented in Table 1. The mean age of the patients enrolled in this study was 36.5 years. There was no significant difference in gender (p=0.675), tooth position [upper or lower (p=0.395), anterior or posterior (p=0.842)], radiographic presence of apical radiolucency (p=0.405), or medication use (p=1.000) between groups. However, a significant difference was observed in endodontic sealer extrusion from the apical foramen (p=0.005), which was more frequent in group (+1.0).

The number of patients who experienced pain was small and the pain did not exceed the slight level. There was no statistically significant difference in the incidence of postoperative pain between group (0.0) and group (+1) (p>0.05) at any of the three time points analyzed (Table 2). In both groups, postoperative pain was significantly reduced (p < 0.05) at 12, 24 and 48 h after root canal treatment (Table 2).

Discussion

The radiolucency of a periapical lesion caused by endodontic infection may only be visible on radiographs in the case of extensive cortical bone destruction or erosion (27). Consequently, periapical ra-

Table 2
Mean and standard deviation of pain intensity in the treatment groups after 12, 24 and 48 h

	12 h	24 h	48 h
Group (0.0)	1.10 (±1.97)a	0.24 (±1.14)b	0.02 (±0.14)c
Group (+1.0)	1.22 (±2.14)a	0.50 (±1.25)b	0.20 (±0.70)c
***p-value**	0.906	0.118	0.089

**Significant difference between groups (0.0) and (1.0).*
Pain scores in the same row followed by different letters differ significantly between time points.
Mann-Whitney test with significance at p<0.05.
Chi-square test or Fisher's exact test with significance at p<0.05.

diographs alone do not permit to confirm the presence or absence of periapical lesions (27, 28). Therefore, teeth diagnosed with pulp necrosis with or without apical radiolucency were included in the present study (28) and no significant difference in the radiographic presence of apical radiolucency was observed between groups. Only asymptomatic teeth were included because preoperative pain can exacerbate the postoperative pain and influence the reliability of the results (29). There was no significant difference in tooth position [upper or lower, anterior or posterior] between groups.

The success of apex locators is accepted in the 0.5- to 1.5-mm range from the tip of the file to the radiographic apex. This acceptable radiographic range occurs in 81.5% and 97% of cases. However, when we evaluate the effectiveness for the determination of apical constriction the success rate changes to between 43.9% and 89.1% (30). Several authors have suggested that apical preparation plays an important role in eliminating a larger number of microorganisms from the root canal (19, 31-33). Failure in measuring WL can impair root canal preparation.

Teeth with pulp necrosis and apical periodontitis have been associated with a high frequency of biofilms in the cemental canal and apical foramen (6, 34). Within this context, disinfection procedures as close as possible to the apical foramen keep this region clean and free of debris and provide a favorable environment for periapical repair (3). In this study, FC was performed with the root canals instrumented at the 0.0 reading on the EAL display or 1 mm beyond this measure, as reported in previous studies that proposed penetration into the apical foramen or beyond to debride and to remove contaminated dentin and bacteria in the lateral canals and apical ramifications and to completely fill the root canal (4, 8, 35, 36).

In a study with dogs, De-Souza Filho (4) demonstrated tissue repair in cases of pulp necrosis after foraminal enlargement 2 mm beyond the apical foramen (4). Foraminal enlargement improves healing of teeth with periapical lesions (4, 37) and enlargement three size larger is of benefit in endodontic treatment and increases the rate of successful healing of periapical lesions (37, 38).

The FC has numerous advantages such as cleaning the apical region and cemental canal and decontamination of the apical major foramen, with the possibility of greater contact of irrigating substances with the apical filling (39). The irrigation protocol of the present study was the same as that reported in previous clinical studies in which chemical agents were used in gel form during instrumentation (either hypochlorite or chlorhexidine). The root canals were irrigated with saline after the introduction of each instrument to flush out the remaining gel and debris from the root canal (23, 24, 34, 40). Chlorhexidine gel (2%) was used as a chemical agent because it exerts antimicrobial effects

similar to those of 5.25% sodium hypochlorite (NaOCl) (41, 42) and due to its exclusive property of substantivity, which results in long-lasting antimicrobial activity (43, 44). In addition, chlorhexidine has biocompatibility with periapical tissues (45, 46), which is interesting for FC. Tamaru-Filho (2002) observed a lower cellular inflammatory response to 2% chlorhexidine when compared to 0.5% NaOCl. Despite the cellular cytotoxicity of NaOCl and chlorhexidine, 5.25% NaOCl was found to elicit a greater inflammatory response (47).

A major concern in some studies is the possibility of postoperative pain after FC related to physical damage to the periapical tissues and extrusion of infected debris from the root canal into the periapical space, which can cause irritation and inflammation (18, 19). The canals were prepared by preflaring the coronal portion prior to negotiation of the apical portion and WL determination, reducing the amount of apically extruded debris and postoperative pain (48).

The evaluation of pain is difficult because pain is a subjective and individual experience of each patient. A major concern is to assign the inconvenient symptomatic sensation to any specific factor of the root canal treatment because this treatment comprises complex procedures such as injection of a local anesthetic, pressure from the rubber dam clamps, and prolonged mouth opening (18, 49). The scale used for pain assessment must be clear and precise, must be fully understood by the patient, and must provide accurate data for analysis (26, 50). A modified VDS was used for the accurate assessment of pain after root canal treatment. This scale is the combination of a verbal rating scale and a numerical rating scale with a 11-cm line divided into 11 intervals (from 0 to 10), which are divided into five categories: no pain, slight pain, moderate pain, strong pain, and maximum pain (26). This scale is a simple, sensitive, and effective method for assessing pain intensity from the patient's perspective. The patients completely understood the categories.

Postoperative symptoms after root canal treatment are usually short-lived and tend to increase within 24 to 48 h (51,52), and this may be a limitation of this type of study. In the present study, postoperative pain was significantly reduced ($p<0.05$) in both groups at 12, 24 and 48 h after root canal treatment. The number of patients who experienced pain was small and the pain did not exceed a slight level. There was no statistically significant difference in the incidence of postoperative pain between group (0.0) and group (+1.0) ($p>0.05$) at any of the three time points analyzed (Table 2). Despite the significant difference in endodontic sealer extrusion from the apical foramen ($p=0.005$), which was more frequent in group (+1.0), no significant difference in postoperative pain or analgesic consumption was observed between groups at the different time points evaluated. These findings suggest that sealer extrusion was not associated with pain (40) and that instrumentation at or beyond the apical foramen promotes better disinfection, with no increase in postoperative pain (4, 8, 17, 20).

The findings of the current clinical trial are in contrast to a previous study (21) that reported a significant increase of pain levels in the FC group. Saini (21) performed two-visit root canal treatment and used 3% NaOCl, while 2% chlorhexidine gel with saline was used in the present study. The latter reduces the irritant potential of the extravasated substance in contact with the apical tissue (44, 45).

In other studies, FC and non-enlargement techniques resulted in the same postoperative pain (20). These results show that neither FC nor apical extrusion of the endodontic sealer increase the incidence or duration of endodontic pain during the postoperative period. The results suggest that FC has no influence on postoperative pain.

Conclusion

FC performed with WL measured at the 0.0 reading on the EAL display or 1 mm beyond his clinical trial did not influence postoperative endodontic pain.

Clinical Relevance

Cleaning the root canal along its entire length, including the apical foramen, is essential for successful endodontic treatment. This cleaning cannot cause post-operative pain. No significant difference in the incidence of postoperative pain was found for the evaluated working lengths.

Conflict of Interest

None.

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There was no financial support or relationships that may present a conflict of interest by disclosing any financial agreements you have with a company whose product appears prominently in the submitted manuscript, or with a company making a competing product, or any conflict related to the technology or methodology. And there is no interest in disclosure.

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ORIGINAL ARTICLE

Effect of polydopamine surface pre-treatment on push-out bond strength of customised short fiber reinforced post

ABSTRACT

Aim: *To evaluate and compare the effect of silane and polydopamine functionalized surface treatment on the push out bond strength of customised fiber reinforced post system cemented to root dentin.*
Methodology: *Thirty single rooted premolar teeth were endodontically treated followed by post -space preparation. Fiber reinforced posts systems (EverStick-POST Stick, ESP) were randomly assigned (n=10) for surface treatment with Polydopamine (group 1), silane (group 2) and control (no treatment) (group 3), following which posts were cemented using resin cement. Following 24 hours, each sample was subdivided into four slices (2 mm thick) to determine the push out bond strength in the coronal and middle thirds and expressed in megapascals (MPa). Data was statistically analyzed using Post hoc Tukey HSD and Student t tests using one-way ANOVA (p=0.05). Failure modes were investigated using a stereomicroscope. Surface treated posts from each group were also analysed under SEM.*
Results: *Polydopamine surface treatment showed significantly higher push out bond strength than silane and control groups in the middle third (p<0.05) with more of mixed type of failures in both the experimental groups. SEM images revealed good homogenization and surface deposition of polydopamine molecules on the post surface.*
Conclusion: *Polydopamine surface treatment showed positive effect than silane on the adhesion of customised fiber reinforced post to root dentin.*

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Introduction

Restoration of endodontically treated teeth with extensive tooth loss requires the placement of intra-canal post to rehabilitate the lost structure. This helps to preserve the structural integrity of the crown and root to increase the durability of the tooth. The placement of post aids in sufficient build-up to retain the core and to reinforce the roots by resisting occlusal loads (1). Over the decades, fiber reinforced posts (FRP) have become the material of choice, due to their modulus of elasticity that is almost equivalent to dentin. This enables better resistance to catastrophic failures under extensive fracture loads. Moreover, they provide esthetic life-like appearance and negligible corrosion (2). The durability of FRP lies in a strong bond between the residual dentin/core material and post, enabling the interface to dissipate stresses under functional loading. Debonding of post system is the most common failure attributing to ineffective polymerization, weak cementation interfaces and inadequate post-canal fit (3). In order to increase the bond strength and durability, various surface pre-treatment strategies of FRP have been proposed in literature ranging from silane-coupling agents, airborne particle abrasion, hydrofluoric acid, laser, hydrogen peroxide that have proven to significantly increase their retention and bonding (4). The most common surface treatment method is silanization which helps in enhancing chemical bond at the interface. Silane coupling agents (SCA) contain methacryloxyproyl trimethoxysilane that possesses catenation property and vacant orbitals which make it reactive. However, SCA produces a non-homogenous layer which results in a weak chemical bond (5).Various studies have evaluated the effect of silane on bond strengths of fiber posts and proved that SCA treatment alone could not prevent dislocation of FRC post. Thus, debonding of FRP remains the main challenge that needs to be focussed (6-8).

Also, several studies investigated the influence of voids within the cement-post interface on the bond strength of FRP (9-11) Micro-CT analysis on post-cement interface restored either with oval or circular showed that the volume of cement was greater with oval posts compared to circular posts (12). This leads to more volume of cement at the interface that contributes to increased solubility and subsequent microleakage. In such cases, use of a customised FRP will result in conservation of tooth structure and the use of minimal cements. Individually formed posts using strips of polyethylene or glass fibres as an alternative to prefabricated fiber posts provided higher fracture resistance than preformed FRP in oval-shaped canals (13). EverStick-POST Stick (GC, Europe, NV (ESP)) is one such post system which is more pliable, mouldable and flexible post comprising of continuous and unidirectional embedded E glass fibers within a polymer matrix that can be anatomically customised. The matrix contains linear phase polymers, polymethacrylathe (PMMA), and a cross-linked polymer 2,2-bis[(4-2-hydroxy-3-methacryloloxypropoxy) phenylpropane] (poly bis-GMA). These fibers are manufactured using IPN (Interpenetrating Polymer Network) technology which facilitates penetration of resin cement into the post thereby increasing the bonding and a well-sealed resin cement-dowel interface (14). Anna et al showed no post-cement failures with the ESP suggesting better interfacial adhesion of cement to these posts (15). However, several studies also mentioned the need for various other surface treatment methods for ESP, as surface treatment with hydrofluoric acid or sandblasting swith aluminium oxide particles were found to be ineffective for improving the bonding of resin core materials to ESP (16-18).

Recently, polydopamine pre-treatment of conventional FRP has proven a novel strategy for surface functionalization. PDA is a mussel-derived surface protein which can be easily deposited on all types of organic and inorganic substrates with uniform film thickness and durability. In addition, it possesses various functional groups such as catechol, amine and imine which make it suitable for promoting ad-

hesion on various surfaces (19). PDA exhibits hydrophillicity and biocompatibility onto coated materials such as polyethylene, silicone rubber and glass particles (20). PDA forms an ultrathin active layer and chemical structure that can support the matrix surface and cause a significant rise in the bond strength (21). Kanyılmaz et al have evaluated PDA functionalization significantly increased the adhesion strength of fiber posts (22). However there is no current literature evidence on the performance of customisable FRP on PDA surface treatment. Hence the aim of this study was to evaluate and compare the effect of silane and PDA functionalized surface treatments on the push out bond strength of ESP cemented to root dentin. The null hypothesis was PDA does not have any effect on the push out bond strength of EFP system.

Materials and Methods

Specimen preparation

Freshly extracted, thirty, single rooted mandibular premolars without cracks, caries, restoration or root-filling were selected for this study. The teeth were cleaned using ultrasonic scalars to remove the calculus and decoronated at the level of cementoenamel junction (CEJ) using a low speed diamond disc under water cooling, to obtain 14mm long roots. The working length was determined using a size 10-K file 1 mm short of the apical foramen. The roots were then embedded in self-cured acrylic resin. Root canals were prepared using ProTaper Gold rotary files in crown-down manner by a single operator and irrigated with 5mL of saline and 5 mL of sodium hypochlorite. Final irrigation was done using 17% EDTA solution and dried using absorbent paper points. All thirty teeth were sectionally obturated till 4mm of apical third of root and post-space preparation was done using Peeso-reamer no. 3 to a depth of 9 mm. The most suitable size of Everstick post was selected according to canal morphology. The depth of the prepared canal was measured using a periodontal probe and the post was cut accordingly using sharp scissors. The end of the post was cut obliquely in order to make the post tapered and fit into the canal. The post was adapted to the canal and light cured for 20 seconds. Post was then removed and light-cured for 40 sec and a layer of enamel resin was applied to the post surface to activate the IPN feature. These posts were kept in a dark container temporarily in order to protect them from light.

Preparation of PDA

PDA was prepared according to the protocol given by Chen et al (23) 0.08 gm of dopamine hydrochloride and 0.04 gm of tris-buffer (oxidizing agent) were measured using an electronic balance and added to a beaker containing 40 mL of distilled water. The solution was subjected to sonication using a magnetic stirrer for 10 min and kept aside for use.

Post surface treatment

The samples were randomly divided into three groups as per the surface treatment protocol (n=10).

Group 1 – PDA. The posts were immersed into this PDA solution for 14 hours for functionalization. After this procedure, the posts were removed and dried.

Group 2 – Silanization. The surface of the posts were coated with silane-coupling agent (Monobond N, IvoclarVivadent, Liechtenstein) for 5 min. and then air-dried.

Group 3 – Control group did not receive any surface treatment.

Two post of each group was prepared separately and subjected to Field emission-scanning electron microscopy (FE-SEM) (Zeiss Leo 440 QEMSCAN SEM, Carl Zeiss AG, Germany) analysis after surface pre-treatment to evaluate the surface morphological changes.

Post cementation

The adhesive strategy recommended by the manufacturer was followed. Briefly, self-etch adhesive (Variolink N, Ivoclar Vivadent, Schaan, Liechtenstein) was applied and left for 10 seconds and dried. The post surfaces and the root canal were coated with resin cement (Variolink dual

cure, Ivoclar-Vivadent, Schaan, Liechtenstein) that was mixed according to the man ufacturer's instructions. The posts were gently seated into the post spaces with finger pressure. The excess cement was removed and the samples were then cured from the coronal side for 20s with a light curing device (Bluephase G2, Ivoclar-Vivadent, Schaan Liechtenstein) using 1.200 mW/cm^2 power.

Evaluation of Push-out bond strength [PBS]
The roots were sectioned horizontally using a diamond disc to obtain dentin post assembly slices of 2 mm thickness, obtaining total of 20 slices from coronal and middle third for each group. Each of these slices was transferred to a specially designed metal apparatus with 2 mm diameter holes. PBS was evaluated in Instron Testing Machine using a punch pin of 1mm diameter, with a load of 450 N at a crosshead speed of 0.5mm/s until failure was used. The values of maximum force applied were obtained in Newtons (N) and the PBS value of coronal and middle slices were calculated using the formula:

$$\text{Push out bond strength} = \frac{\text{Maximum force}}{\text{Area } (2\pi rh)}$$

where
r means radius of the dentin slices
h height of the dentin slice

The mean bond strength value of the 20 slices each for the coronal and middle third was calculated as megapascals (MPa). Statistical analysis of the PBS data was performed using SPSS statistics software. Normal distribution of data was confirmed using Shapiro Wilk's test. The data were statistically analyzed using Post hoc Tukey HSD and Student t tests using one-way ANOVA. The significance level was set at 0.05 (P=0.05).

Analysis of failure mode
All the failed specimens were analyzed using a stereomicroscope (Leica M205, Leica-Microsystems, Germany) at 25x magnification to find out the type of failure. Adhesive, cohesive and mixed types of failure were categorized for all the specimens and percentage of each failure pertaining to each group was calculated. The interfaces at the root surface were also visualized under SEM (Zeiss Leo 440 QEMSCAN SEM, Carl Zeiss AG, Germany) for evaluation of surface topography of dentinal wall and resin penetration.

Results

PBS Evaluation
Group 1 showed significantly higher mean PBS as compared to groups 2 and 3 in the middle third of the root. However, mean PBS values obtained at coronal third did not show much significant difference between them. On intragroup comparison, coronal third showed significantly higher mean bond strength values than those of the middle third for all the groups ($p<0.05$).

Table 1
Mean comparison of push-out bond strength values following surface treatment of EFP in coronal third

Group	N	Mean	Std Deviation	95% Confidence Interval for Mean		Minimum	Maximum
				Lower Bound	Upper Bound		
Pda coronal	20	5.64	0.59	5.22	6.07	4.91	6.52
Silane coronal	20	5.04	1.00	4.33	5.76	3.98	7.03
Control coronal	20	3.94	0.61	3.51	4.38	2.93	4.55

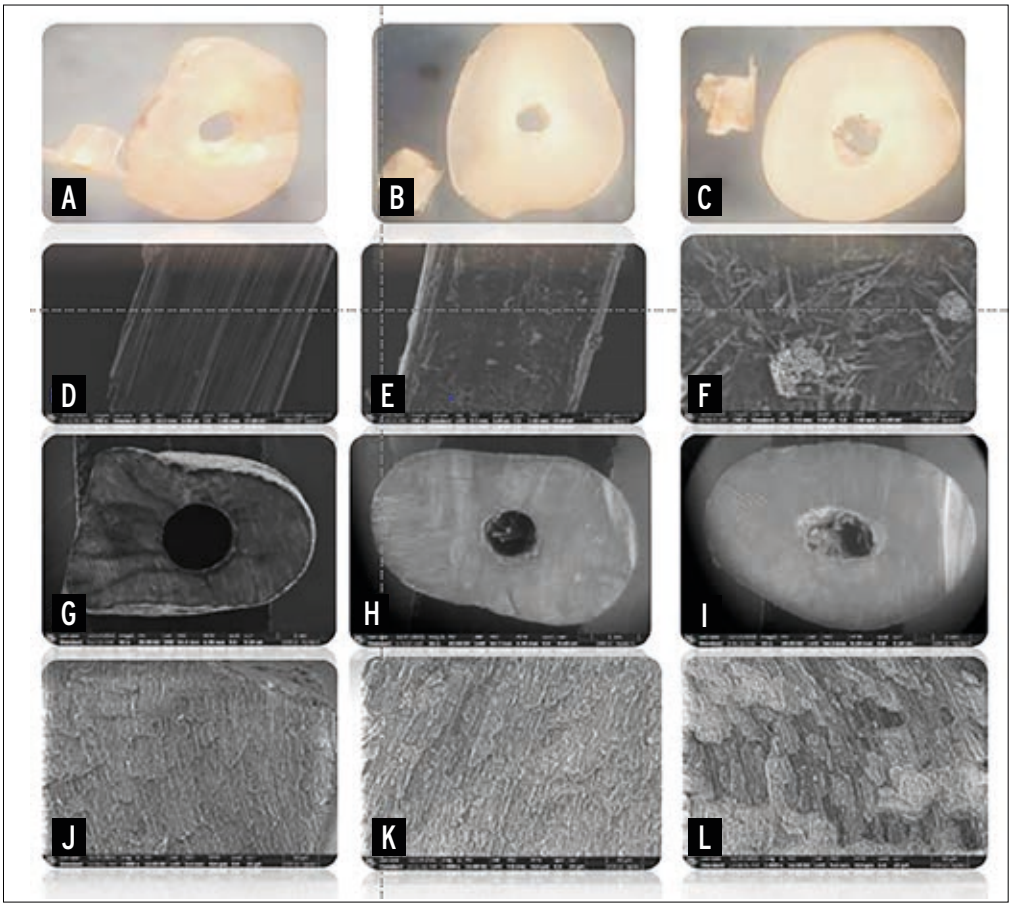

Figure 1
(A-C) Stereomicroscopic images of EFP samples after push-out bond strength testing under stereomicroscope (50x). SEM images of EFP surfaces after different surface treatments (250x); **(D-F)** SEM images of EFP surfaces after different surface treatments (250x); **(D)** control sample showing no surface alteration on EFP surface; **(E)** SCA sample shows non-homogenous deposition on EFP surface; **(F)** PDA sample shows a rough surface with random orientation of E-glass fibers increasing micro-retention. **(G-I)** Representative EFP samples after push-out bond strength tests (50x). SEM images confirm a mixed type of failure in PDA group with remnants of resin cement, dentin and EFP. **(J-L)** Cement-dentin inter-diffusion zone of various samples (1000x). **(J)** The smoother surface of control post, **(K)** well-defined hybrid layer or formation of resin tags was not discernible in SCA treated EFP. **(L)** PDA treated EFP surfaces showed long and continuous resin tags.

Stereomicroscopic analysis (Fig 1A-C) revealed that the numbers of dentin-cement interface failure were significantly more of mixed type in both the groups. There was no significant difference in the number of adhesive failure between silane and PDA treated groups.

Sem analysis of surface treated post
SEM image of untreated post (Fig 1D) shows revealed smooth surface without any irregularities. However, SCA and PDA surface treated posts (Fig 1E, F) showed a rough surface, creating spaces for micro-mechanical retention. Comparatively PDA treated EFP resulted in relatively higher irregularities.
As shown in Fig. 1K-L, SEM images of SCA and PDA functionalized EFP samples showed cement-dentin inter-diffusion zone with long and continuous tags. PDA treated samples showed more homogenously functionalized surface creating spaces for micromechanical retention with residual adhesive cement depicting superior bonding ability. However, adhesive interface of SCA treated samples showed smooth and regular orientation of resin tags.

Table 2
Mean comparison of push-out bond strength values following surface treatment of EFP in middle third

Group	N	Mean	Std Deviation	95% Confidence Interval for Mean		Minimum	Maximum
				Lower Bound	Upper Bound		
Pda middle	20	4.44	0.66	3.97	4.91	3.48	5.47
Silane middle	20	2.75	0.39	2.47	3.03	1.99	3.16
Control middle	20	1.82	0.44	1.50	2.13	1.05	2.39

Table 3
Failure patterns of tested specimens (%)

	Cohesive (%)	Adhesive (%)	Mixed (%)
Pda	10	40	50
Silane	25	35	40
Control	15	50	35

Discussion

The results of the present study shows that surface treatment of posts either with SCA or PDA had enhanced the PBS of post/dentin interface significantly compared to the control group. Moreover PDA showed significantly higher PBS than other experimental groups thus rejecting the null hypothesis. EPS with 48% of its volume with fiber in its composition has different cross section, which was not always symmetrical and round, as distinct from the other two posts. This was supported by the SEM observation of the present investigation. The pre-treated post removes the resin matrix from the surface of the posts, resulting in an enhancement of the surface roughness and in a greater exposure of the fibres when compared to comparison to the untreated post. This attributes the lower PBS seen in control group.

Despite an abundance of literature evidence on the various pre-treatment strategies, no surface treatment agent has proven to show effective adhesion (1). SCA is one of the most common pre-treatment strategies and it is used to cement indirect ceramic and metallic crown, ceramic laminates and repair E-glass fiber reinforced resin composites, and filler reinforced resin composites (24). Prado et al reported greater performance of SCA compared to 24% H_2O_2 pre-treatment on fiber posts surfaces based on push-out bond strength (25). A systematic review of 178 studies concluded that SCA with post surface pre-treatment alone cannot improve the retention and clinical survival of fiber posts (26). Two studies reported that the silane treatment of fiber posts did not prevent dislocation (27,28). Therefore, SCA alone is insufficient for attaching to non-silica based materials.

When considering the PBS, middle third of the root was significantly lesser than the coronal third. This can be attributed to the less degree of conversion which leads to incomplete polymerization due to lesser accessibility of the curing light (29). Also, the reduced dentinal surface area for adhesion compared to coronal third accounts for lesser PBS. Moreover, SCA have proven to favour methacrylate based systems rather than epoxy based systems (30). Gradually overtime the volatility of the solvent in SCA could also influence the bond performance of the same. Furthermore, the key step in the action of SCA is hydrolysis which is strongly pH dependent (31).

Moreover, the silanization performance is affected by its silane concentration, similarity in their functional groups with the resin monomer functional groups, blending with cross-linking silanes, their pH,

nature of the solvent mixture (24). Also, surface treatment with hydrofluoric acid or sandblasting with aluminium oxide particles were not found to be effective methods for improving the bonding of resin core materials to EPS (1).

PDA is a recently emerging bio-coating material generated from the catechol derivative dopamine which has been devised with the capacity to bind to universal substrates (19). Dopamine oxidation produces a polymer that contains indole and dopamine units in various oxidation states, as well as pyrroles to a lesser amount. The chemical properties of PDA is attributed to the presence of oxidised o-quinone and o-hydroquinone groups in its chemical structure (32,33). In addition, PDA possesses functional groups like imine, amine and thiol which enhance the hydrophilicity and wet adhesion. PDA coatings have been shown to be highly effective and biocompatible adhesives with enhanced action especially in protein bonding. Moreover, it has been used to increase the interfacial adhesion in a range of different fiber-reinforced composites, achieving significant improvements in dry strength and modulus for carbon, glass and polymer fibers. Chen et al. designed a novel PDA pre-treatment approach involving dopamine functionalization to increase the adhesion of glass fiber post surfaces to luting cements. He also demonstrated that hydrogen peroxide and PDA combination of surface treatment of prefabricated FPS resulted in higher bond strength (23). However, this was the first kind of comparative study between PDA and SCA coated EFP system on PBS. The higher PBS contributed by PDA surface treatment compared to the SCA group can thus be attributed to the presence of various functional groups and superior wet-adhesion ability of PDA (34, 35). The stronger adhesive ability with the substrate could be due to the higher the dopamine content and immersion time. Fiber posts treated with dopamine solution for longer time might have resulted in a surface modification of post with various functional groups such as hydroxyl, carboxyl and amino groups. This could have reacted with organic functional monomers improving hydrophillicity and chemical combination attributing to higher bond strength of this group.

On PDA intragroup comparison, middle third and coronal did not show any statistical significant difference on PBS due to the wet adhesion ability, increases in the hydrophillicity of the post surface thus providing a better chemical bond to the resin cement (19, 20). PDA does not destroy the structures or material properties of the substrate at the same time by stabilizing the bond strength. Shari et al showed that PDA incorporated self-etch and total etch adhesives resulted in higher degree of conversion, bond strength and durability due to its biomimetic remineralization and MMP inhibition activity (36). This can be attributed to the effective resin-dentin bond in both the coronal and middle thirds of the root.

On SEM analysis, the most common type of failure observed was mixed. In general, considering the post-cement-dentin interface, mixed failure is considered more favourable when compared to adhesive failure. The relationship between surface treatment and failure modes agrees with previous studies (26, 30).This could be due to various factors such as incompatibility between the adhesive and resin, inadequate mechanical properties of EFP or cementation protocol. PDA group showed more percentage of mixed failure than SCA group. Also, SEM images confirmed the presence of an irregular and rough surface accounting for better micro-mechanical retention thereby enhancing the better bond with resin cement.

PDA functionalization on EFP also causes random orientation of fibers which can provide an isotropic reinforcement effect on post system (37). On the other hand, SCA treated post samples showed comparatively smoother surface, which might be the cause for more adhesive failures. Control group also showed comparatively more mixed failures with much smoother surface on SEM findings. This could be the reason for the debonding failure seen in fiber post system.

The limitations of the study include high-

er immersion time in PDA affecting the clinical simulation, and a mild staining of the PDA treated EFP surface from opaque to light brown compromising aesthetic requirement (32). Hence, further evaluation on the effect of PDA on long term resin dentin bond strength after aging protocol and longevity of EFP system can also be evaluated in future studies . Moreover, it has been demonstrated in various studies that PDA produces bactericidal action against both Gram-positive and Gram-negative bacteria so which antibacterial studies can also be analysed for long term durability of EFP systems (38, 39).

Conclusions

Within the limitations of this study, it can be concluded that PDA surface pre-treatment resulted in significantly higher PBS values than SCA on the middle third of the root. SEM images also revealed good homogenization and surface deposition of PDA on the EFP surface causing random orientation of the E-glass fibers. Hence, PDA can be an effective surface pre-treatment strategy to prevent the debonding of flexible fiber post systems thereby improving the success rate of post endodontic restoration.

Clinical Relevance

The surface treatment with PDA on flexible fiber post systems can prevent debonding of post thereby improving the success rate of post-endodontic restoration.

Conflict of Interest

No potential conflict of interest was reported by the author(s).

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All the authors have equally contributed to conception, design, data acquisition and interpretation, drafted and critically revised the manuscript. All authors gave their final approval and agree to be accountable for all aspects of the work.
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ORIGINAL ARTICLE

Response of non-differentiated pulp cells (OD-21) to a novel bioceramic for dental pulp capping

ABSTRACT

Aim: *To evaluate an experimental bioceramic (QCP5) effect on undifferentiated pulp cells (OD-21 cell lineage).*
Methodology: *Cells were divided into three groups: control (untreated cells), QCP5 (cells in indirect contact with biomimetic ceramic (QCP5), and Mineral Trioxide Aggregate (cells in indirect contact with [MTA]). Cell viability, biochemical ALP activity, fast red* in situ, *and mineralization were evaluated. The proteins Alp, Col1A1 and DMP1 were detected by immunofluorescence. The data were analyzed by a variance analysis with 5% significance level.*
Results: *The cell viability test at 3 and 7 days was similar between the groups, but at 10 days there was a significant increase in both the MTA and the QCP5 groups. It was observed that at 3 and 10 days there was no significant difference in ALP activity, but at 7 days the expression of ALP was greater in the control group compared with QCP5 and MTA exposure groups. The fast red technique at 3 and 10 days showed no significant difference, but at 7 days it was significantly lower for the control group compared with QCP5 (P = 0.0477) and MTA (P = 0.0217). Mineralization was significantly higher in the control group (P = ≤0.0001). ALP protein marking was similar in all three groups, Col1a1 presence was significantly decreased in the MTA group, and DMP1 was more marked in the QCP5 group.*
Conclusion: *The bioceramic QCP5 promoted cell viability, expression of ALP, mineralization and expression of proteins ALP, Col1a1, and Dmp1. Similar behavior was observed with cells exposed to MTA.*

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Introduction

Vital pulp therapy (VPT) has been proposed to preserve and promote integrity of the mineralized tissue barrier of the pulp vitality of deciduous or young permanent teeth with immature roots affected by caries and without evidence of radicular pathology. Nowadays, treatment options of VPT are represented by indirect pulp treatment (namely indirect pulp capping), direct pulp capping and pulpotomy. In addition, the success of this technique would avoid pulpectomy and subsequent root canal obturation by several materials, that, in turn, could prevent the radicular resorption of the primary molars and alter the development of the permanent teeth (1).

Properties like cytocompatibility are expected from the biomaterials used for such purpose, meaning that when placed in direct contact with the cellular component of vital tissues, these will express physiological levels of proliferation, migration, and survival. In addition, the materials used in VPT should exhibit bioactive properties, i.e., induce the formation of a mineralized hydroxyapatite-like attachment to the dentine substrate through the ionic interchange with tissue fluids in the process of biomineralization. Lastly, biomaterials placed in contact with the dentin–pulp complex should ideally influence cell plasticity, inducing the osteo/odontogenic differentiation of local human dental pulp stem cells (HDPSCs) and, consequently, promote the process of tissue repair upon damage (2).

The most frequently used agents for VTP are calcium hydroxide (CH), di- and tricalcium silicates (mineral trioxide aggregate (MTA), Biodentine (BD) (1) and calcium phosphates with silicon dioxide, tricalcium phosphate (TCP) Cement®, Bioglass® or phosphates without silica. CH was one of the first materials with bioactive characteristics (introduced in the 1920s) used to promote the formation of a dentinal bridge on exposed pulp tissue (3), although CH has been successfully used for its biological and antimicrobial properties, its disadvantages include low mechanical properties, cytotoxicity, poor sealing, lack of adhesion to substrate, microfiltration and high solubility (4-9). The above mentioned materials arose as an alternative to CH because it is a biocompatible material with antibacterial properties, excellent sealing over time, and formation of a thick and homogeneous dentinal bridge that is not reabsorbed. However, these cementitious materials also exhibit several drawbacks such as being difficult to manipulate, long setting time, high cost, difficult storage, uncorrectable discoloring effect associated to the iron ion, and their cytotoxicity by the presence of metallic ions such as Al^{+3} y $Bi^{+3, +5}$ (5, 7, 10-15).

Currently, ceramic materials based on calcium phosphates are popular among dental practitioners because they are biomimetic, biocompatible, bioinductive, and have better physical and mechanical properties than MTA. Bioceramics have a composition similar to the human mineral component (16), and they are able to stimulate components of the extracellular matrix and induce odontoblastic differentiation (17) and hydroxyapatite formation (5). QCP5 is a ceramic material made from eggshell comprising several phases, and several alkaline phosphates, like apatites and tricalcium phosphate (TCP) suitable for inducing rapid mineralization.

Recent advances in tissue and cell engineering have been contributing to repair injured tissues by using mesenchymal stem cells, which have been known to foster self-renewing properties (i.e., proliferation without a change in phenotype) and the capacity to differentiate into one or many different specialized cell types (i.e., changing into a new phenotype). In the Dentistry field, stem cells derived from dental pulp have been isolated and investigated as possible sources for regeneration of injured tissues. Immortalized murine pulp cells (OD-21) are undifferentiated mesenchymal stem cells derived from fetal molar papillae. It has been suggested that OD-21 lineage has potentiality to differentiate into odontoblast-like cells, under appropriate conditions, which might be a favorable source for pulp therapy (18).

The objective of our study was to evaluate the effect of the experimental biomimetic ceramic, QCP5, on OD-21 cells. The null hypothesis was that the QCP5 doesn't promote cell viability, alkaline phosphatase (ALP) expression, formation of mineralization nodules, or protein expression to reach a statistical significance greater than the MTA group.

Materials and Methods

This project was approved by the Ethics Committee B-CIEFO 178-17 of the School of Dentistry of the Universidad Nacional de Colombia-Sede Bogotá.

Preparation of QCP5
Calcium phosphate was biomimetically synthesized from chicken eggshells dried at 140°C in an oven without affecting the structure or stoichiometry and was then used to manufacture QCP5.
The dried eggshell material was fired in a furnace to obtain basic calcium oxide, which was then subjected to aqueous ortho-phosphoric acid solution to produce calcium phosphates. The detailed procedure and the instrumental characterization as well as the results are described in reference (19). The starting material and final product were controlled by X-ray diffraction (The X-ray diffraction (XRD) patterns were obtained using an X'Pert Pro MPD® (PANalytical) diffractometer with CuKα radiation (λ=1.5406 nm), produced at 40 mA and 45 kV. Scans were performed between 2θ values of 5º and 60º with an angular step of 0.0042º, and 5.08 s counting time per step); infrared spectra were obtained using a FT/IR Nicolet iS10 spectrometer (Thermo Fisher Scientific ®) and collected between 600 to 4000 cm^{-1} in absorbance mode, 124 scans at 1 cm^{-1} resolution) (20) and SEM-EDS data were obtained with a Tescan Vega 3 scanning electron microscope at 15,0 KV. The product was packed in transparent pharmaceutical glass vials, marked, sealed with pharmaceutical quality rubber stoppers and aluminum flip-off caps, and then exposed to 25 kGy of gamma radiation for 55 minutes for sterilization.

Preparation of materials
ProRoot MTA (Dentsply®) and QCP5 material were prepared in a laminar flow booth following the manufacturer's instructions.

Cell culture (OD-21 lineage)
The undifferentiated pulp cells, derived from the dental papilla of first molars of lab mice (OD-21 lineage) (21), were seeded by Prof. Jaques Eduardo Nor, of the School of Dentistry in the University of Michigan, USA. Cells were cultivated in 75 cm^3 vials with 10 mL of D-MEM culture medium, bovine fetal serum (10%), penicillin (100 UI/mL), streptomycin (100 µg/mL) and plasmocin (5 µg/mL). Then cells were cultured in 24-well plates at a density of 1 × 10^4 cells per well. Next, 50 µg of ascorbic acid was added to the culture medium, to favor the formation of collagen and extracellular matrix (22) and 2 mM of beta-glycerolphosphate was added last (23). The cells were immediately exposed to the materials using transwell inserts with 0.4 µm pores in the following groups:
-Control (-): OD-21 cells without material (n=5).
-QCP5: OD-21 cells with QCP5 (n=5).
-Control (+): MTA OD-cells with MTA (n=5).

Cell viability
After 3, 7, and 10 days of culture cell viability was evaluated by means of the MTT colorimetric assay ([3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium] bromide) (Sigma). Aliquots of 150 µL were transferred to a plate of 96 wells for spectrophotometer reading (µQuant, Bio-tek Instruments Inc., Winooski, VT, USA) at a wavelength of 570 nm (24).

ALP activity
The detection of ALP at 3, 7, and 10 days was determined by the release of thymolphthalein by hydrolysis of the thymolphthalein monophosphate substrate, using the Labtest commercial kit (Diagnostica SA, Lagoa Santa, MG, Brazil) and following the manufacturer's instructions. Absorbance was determined in the spectrophotometer (Bio-Tek) with a wavelength of 590

nm. ALP activity data were normalized with total protein content.

In situ *ALP analysis by fast red*
The analysis was performed at 3, 7, and 10 days, after removing the culture medium the wells were washed twice with phosphate-capped saline (PBS) at 37ºC. A solution was prepared with trizma (Sigma-Aldrich), dimethylformamide (Merck), naphthol (Sigma-Aldrich) and nuclear fast red reagent (Sigma-Aldrich). 1 mL of this final solution was placed in each well for 30 min. When the time had expired, photographic documentation and quantitative analysis was performed with the Image J® program.

Detection and quantification of mineralized matrix
After 14 days, the wells were washed three times with PBS (Gibco) at 37 ºC. 2 mL of 10% formalin was added for fixation and then the solution was stored at 4 ºC for 24 hours. Formalin was removed from the wells and then dehydrated at room temperature with alcohols (30º, 50º, 70º, and 100º). After drying, the wells were stained with alizarin red 2%, pH 4.2 (Sigma). The protocol of Gregory et al. was followed to quantify mineralization nodules (25).

Immunofluorescence
After 5 days, the cells cultured in the wells were fixed in paraformaldehyde at 4%, pH 7.2. The cells were processed for indirect immunofluorescence. Three separate antibodies were used: monoclonal ALP antibodies (Sigma-Aldrich, USA) type I and Dmp1 collagen (Larry Fisher, USA), followed by secondary antibodies such as fluoride 594 for red fluorescence, and phalloidine 488 for green fluorescence (Molecular Probes, USA). The cells' nuclei were marked with 4,6-diamidine-2-phenylindole, dihydrochloride (DAPI, Molecular Probes). The images were examined under a fluorescence microscope attached to a camera (Leica, Germany).

Statistical analysis
The variance analysis was performed using

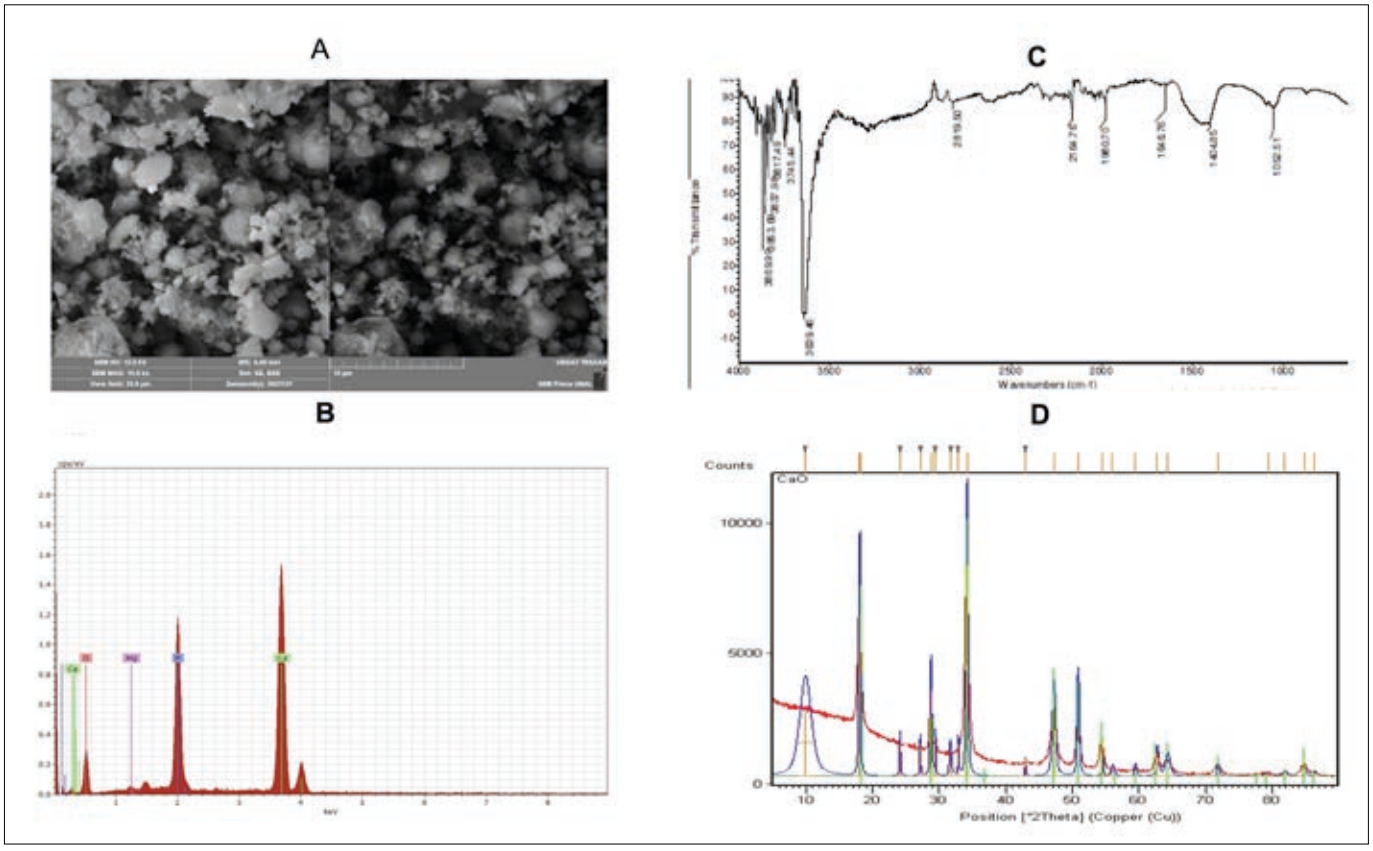

Figure 1
QCP5 Characterization: **(A** and **B)** SEM-EDS, **(C)** FTIR and **(D)** Diffractogram.

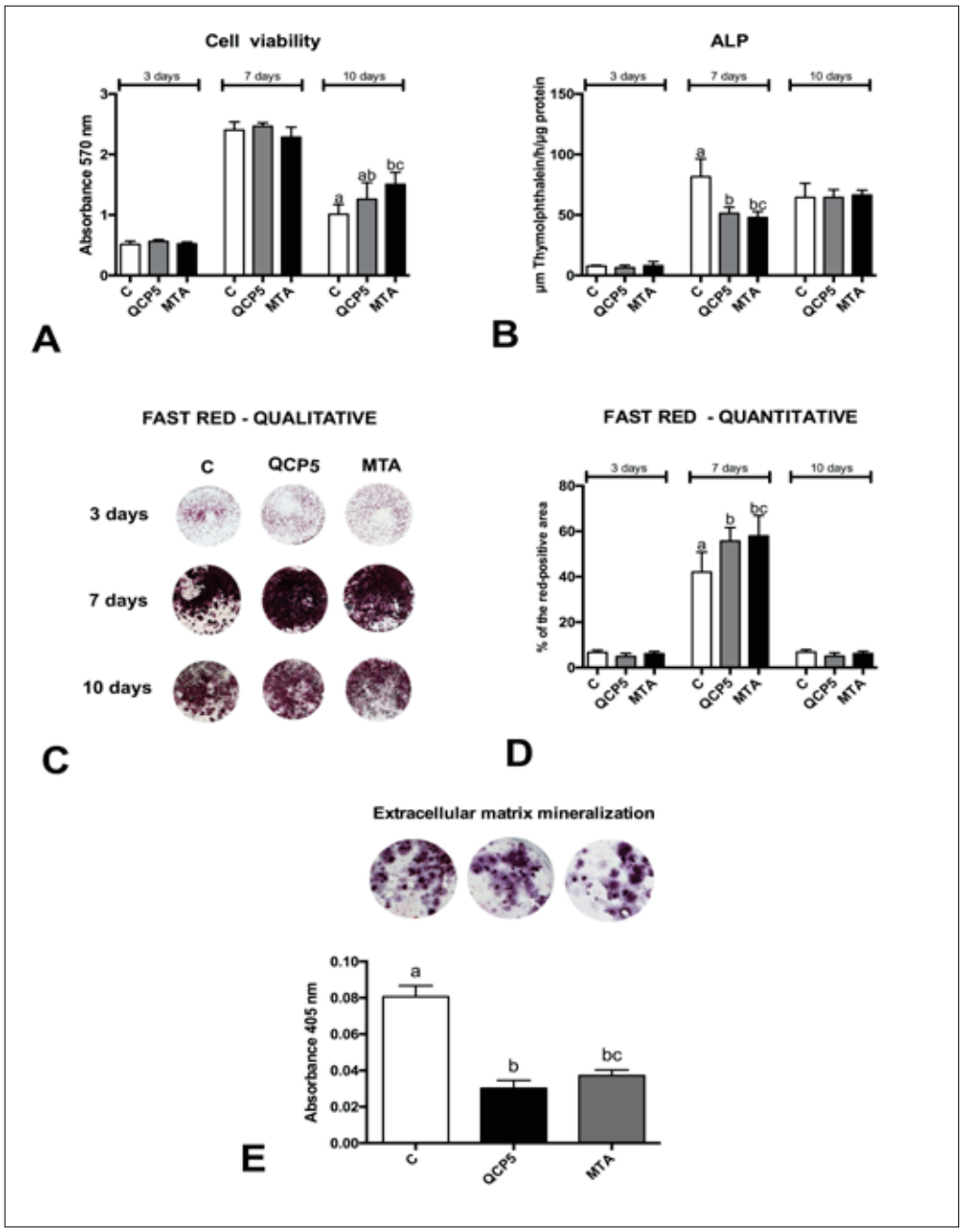

Figure 2
(A) Cell viability assessed by MTT assay at 3, 7, and 10 days of cell culture. **(B)** Activity of alkaline phosphatase through the release of thymolphthalein by hydrolysis of the thymolphthalein monophosphate substrate. **(C)** Qualitative detection of alkaline phosphatase by nuclear fast red *in situ* technique. **(D)** Quantitative detection of alkaline phosphatase by nuclear fast red *in situ* technique. **(E)** Qualitative and quantitative extracellular matrix mineralization. Control group, QCP5 (experimental ceramics), MTA (conventional material). Different letters represent statistical differences.

GraphPad Prism 6.0e software (Graph Pad software, Inc., San Diego, CA). The established significance level was 5%.

Results

Physicochemical characterization
Particles shown in the SEM-EDS figures are amorphous, round-edges, of multidisperse sizes composed of a submicrometric fraction but also a range of small particles aggregates of sizes up to 5 µm and large amorphous particles of around 5-10 µm figure 1A and 1B.
The following observations refer to figure number 1C containing the FTIR in which the band located at 3.642 cm^{-1} originates in the water OH stretch. The wide band at 3.433 cm^{-1} depicts adsorbed humidity water. At 1424 cm^{-1} the absorption is due to υ_3 the A-type substitution on carbonate anion. The 1.044 cm^{-1} strong absorption

peak is the bending mode of the PO_4^{-3} and the small shoulders are librations υ_1 and υ_3 of the same anion. The sharp weak absorption at 874 cm^{-1} comes from a calcium-deficient apatite (26), also from original phosphates anions substituted by carbonate B-type position after the research by Berzina-Cimdina (20) or from HPO_4^{-2} (27). All three sources seemingly different express the same structural finding. The peaks at 602 y 561 cm^{-1} arise from the $\upsilon_1 PO_4^{-1}$ libration or may also stem from the β-TCP following the findings reported by Elliot (26) fact to be taken into account since TCP is added to the QCP5. These findings are somewhat logical and compatible with the composition of the studied powder because the synthesis was conducted in air without excluding atmospheric CO_2 and the product was also kept in air and therefore there are B and A substitutions for carbonate. As indicated in the paper Berzina-Cimdina et al, these peak assignments are subjected to position and strength changes caused by synthesis route, chemicals employed, thermal treatments, treatment duration, particle size, crystallinity and final composition (20). This material coming from eggshell contains magnesiuem and therefore besides TCP it may contain some true whitlockite that may also exert an effect on the FTIR results.

In the diffractogram there are several medium to strong peaks originated in calcium hydroxide, it must be remembered that there is no direct relation between the counts per second or peak intensity and the concentration of two or more compounds since the instrumental sensitivity for each compound is different. Some other peaks such as those at 26, 32, 33, 47 and 49.5 belonging to different types of apatites. Some smaller peaks correspond to beta TCP and other phosphate phases (figure 1D).

Cell viability

At 3 and 7 days there was no statistically significant difference between the groups (P=0.1585, P=0.1202 respectively), while at 10 days there was a significant increase in cell viability in the MTA group in comparison to the control group (P=0.0099); however, there was no difference between the QCP5 group in comparison to the control group (P=0.2180) or MTA group (P=0.2126) (Figure 2A).

Analysis of ALP

At 3 days there was no significant difference between all three groups (P=0.5337). At 7 days the expression of ALP was higher in the control group in comparison to the other groups QCP5 (P=0.0008) and MTA (P=0.0003), however, no difference was observed between the latter two (P=0.8324). At 10 days there was no statistical difference between all three groups (P=0.9102) (Figure 2B).

In situ *ALP analysis by nuclear fast red*

Both qualitatively (Figure 2C) and quantitatively (Figure 2D) it was observed that at 3 days there was no significant difference between the groups (P=0.5337), and at 7 days the expression of ALP was significantly lower for the control group compared to the QCP5 (P=0.0477) and MTA (P=0.0217) groups, and between the latter two there was no difference (P=0.8991). At 10 days there was no statistical difference between all the groups (P=0.0910).

Detection and quantification of mineralized matrix

Figure 2E shows qualitatively and quantitatively that mineralized matrix deposits at 14 days of culture were similar between the QCP5 and MTA groups (P=0.0845). The control group showed a significantly elevated presence of mineralization nodules compared to the QCP5 and MTA groups (P=0.0001).

Immunofluorescence

Figure 3 shows the 3-day immunolocation of Alp, Col1a1, and DMP1 proteins in the control, QCP5, and MTA groups. Cell contour and/or cytoskeleton is evidenced by green coloration (phalloidine marking), blue nucleus (DAPI marking), and red protein presence (antibody marking). In the first row we can observe that the Alp protein was marked in a similar way for the three groups; it was present in the

cytoplasm and adjacent to the nucleus. The presence of Col1a1 is noticeably diminished in the MTA group; the opposite occurs in the cells of the control group and QCP5, which present a similar expression. However the immunolocation of DMP1 is more highlighted in the QCP5 group compared to the other groups.

Discussion

The cell viability results of this paper show that at 3 and 7 days there is no significant difference between the groups (control, QCP5, MTA) while at 10 days there was an increase in cell viability in the MTA and also the QCP5 groups in comparison to the control group; however, the QCP5 viability fell in between the control and the MTA groups showing non meaningful difference between the QCP5 group in comparison to the control group or MTA group. This result seems to indicate that MTA and QCP5 provide a good environment for cell survival, possibly due to bioavailability of mineral ions in concentrations larger than those of the control group. One of the most important proteins for the formation of a mineralized matrix is ALP, this must present a gradual increase in the initial phase of odontoblastic differentiation and indicates the potential for cell differentiation (28, 29). Therefore, the evaluation of this enzyme determines the bioactivity of the material and its potential to promote the onset of repair with the formation of mineralized tissue (8). The ALP biochemical method outcome shown in figure 2B displays a similar response at 3 days in all groups. At 7 days there is a net difference between the control group and the QCP5 and MTA groups. In a sense, the control group largely outperformed the two synthetic materials. A possible reason behind this odd behavior is probably once again the bioavailability of mineral ions. The ions in the culture broth are dissolved and readily available while the ion stock in both QCP5 and MTA are solid and must dissolve and diffuse a certain distance through the well bottom. This explanation is supported by the observation that at 10 days, the bioactivity of all three treatments is equivalent because the ion availability has overcome the solubilization and diffusion barriers. In figure 2C and 2D nucle-

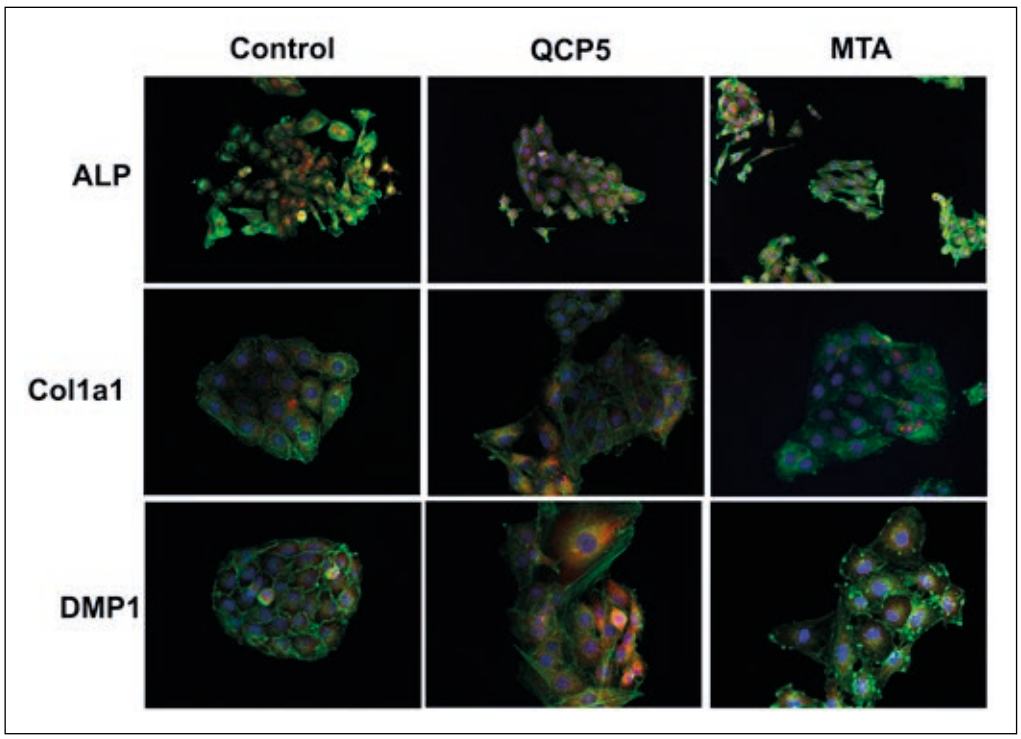

Figure 3
Immunolocation of Alp, Col1a1, and DMP1 proteins in OD-21 cells placed in indirect contact with QCP5 and MTA. Actin filaments marked in green (phalloidin), cell nucleus marked in blue (DAPI), and protein marked in red (antibody).

ar fast red quantitative results show that the three groups express differently at 7 days. At this time point, the QCP5 and MTA groups are clearly superior to the control group and QCP5 performs better than the MTA group as shown in figure 2C.
Experimental tests with alizarin red shows that the QCP5 promotes the formation of mineral nodules in a similar way to MTA; this implies that an intracellular deposition of calcium occurs and is subsequently released into the extracellular space. The control group showed a significantly elevated presence of mineralization nodules compared to the QCP5 and MTA groups probably because the cells in their natural state tend to mineralize.
The images obtained from the immunofluorescence assay showed similar expression of ALP in the three groups. The qualitative results at the three experimental times indicated that the MTA and QCP5 behave similarly. These results echo those found in a study with murine cells exposed to Biodentine, which found no significant differences between the groups treated with Biodentine and the control, favoring the odontoblastic pathway and the association with an intense secretory activity of the cell (17, 30).
The biological response depends on calcium which is the main component of ceramics and is related to bioactivity, osteoblastic survival, modulation of osteopontine levels, bone morphogenetic protein-2, and activation of ATP, which is important in the mineralization process (14, 31-33). Odontoblastic differentiation and the formation of mineralized tissues is regulated by the expression of proteins such as Col1a1 and Dmp1 (28) in the images obtained from our immunolocation observations, the presence of Col1a1 is notably diminished in the MTA group, and DMP1, is more marked in the QCP5 group compared to the other groups. This shows that proteins play a role in intracellular signaling which leads to the differentiation of mesenchymal cells as nucleating proteins in the extracellular matrix, and aids in the orientation and reinforcement of nanocrystals, which are essential properties for dentin regeneration (34).

Conclusions

Based on our results, we conclude that the bioceramic QCP5 promoted cell viability, the expression of ALP, Col1a1, and DMP1 and the formation of mineralization nodules. This indicates it is a promising material for dental pulp capping to conserve vital dental pulp tissue and, by extension, the natural tooth structure surrounding it.

Clinical Relevance

In office practice dental pulp injuries are treated with calcium hydroxide, calcium tri/disilicate and polymers. These materials differ largely from enamel composition (calcium phosphates). The ceramic QCP is mainly based on biomimetic calcium phosphates that closely emulate enamel electrolytes composition (Mg, chlorides, carbonates), it is biocompatible and has better physical and chemical properties. Its composition is like the human mineral component precursors. This paper presents some assays that demonstrate the QCP performance and usefulness.

Conflicts of Interest

The authors have no conflicts of interest to report.

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ORIGINAL ARTICLE

Is it safe to use YouTube™ to learn about root canal preparation? Analysis of content and quality of videos

ABSTRACT

Aim: *This study assessed the quality, educational content, and demographics of root canal preparation videos on YouTube™.*
Methodology: *The study was performed for root canal preparation using the keywords "root canal shaping," "root canal preparation," and "root canal instrumentation" on YouTube™. In total, 108 English language videos shorter than 15 minutes were acquired. After evaluating the demographic characteristics, the viewing rates of the videos were estimated. The quality of the videos was assessed using DISCERN, the Global Quality Scale (GQS), and the Video Power Index (VPI). Statistical analyses of the evaluated results were performed.*
Results: *Endodontists uploaded the most videos (32%), mainly shot on the teeth of patients (30%). The number of views and the VPI were significantly higher for the videos uploaded by commercial companies than by endodontists ($p<0.05$), with no significant difference between videos uploaded by dentists or endodontists. As the DISCERN (reliability) value increased, the number of views/likes and the VPI increased, even though these values were not statistically significant ($p>0.05$). While a positive and meaningful relationship was found between DISCERN and the GQS ($p<0.05$), a negative and significant association was found between the VPI and the interaction index ($p<0.05$). When dentists, commercial companies, and others were considered as a single group and compared with endodontists, no significant difference was found between the two groups in terms of GQS and DISCERN ($p>0.05$).*
Conclusion: *It was highlighted that a high-quality contribution from uploaders is needed for videos posted on YouTube™ about root canal preparation. It is crucial to refer to high-quality sources of information.*

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Introduction

Shaping the root canals is one of the most critical procedures for a more successful treatment outcome (1). For long years, stainless-steel K and H hand files have been used for root canal shaping. Unfortunately, shaping the root canal is difficult with hand files, especially in curved canals. Nickel-titanium (NiTi) file systems have steadily increased among endodontists and general dentists for shaping root canals (2). It has been stated that there are many advantages of using NiTi systems in root canal shapings, such as fewer procedural errors (3), a shorter treatment time (4), and potentially better clinical outcomes (5). Because of these advantages, with the support of technology, Gavini et al. stated that more than 160 NiTi file systems were available in 2018 (6). For this reason, dentists should follow up-to-date information to use the new NiTi systems in the clinic successfully. Recently, surveys have been conducted on attitudes towards root canal treatment procedures and adopting new technologies in general dental practice. The results show differences between general daily practice and academic teaching (7); therefore, dentists need continuous professional development to update and expand their knowledge and skills (8). Additionally, many dental students find endodontic procedures difficult and stressful. They also lack confidence while performing endodontic procedures (9, 10). Because of the risk of transmission of coronavirus disease 2019 (Covid-19), social media and websites may be valuable in providing new educational opportunities (11).

YouTube™ is one of the largest video-based sharing platforms. Monthly, more than a billion hours of video are watched by people internationally (12). It enables easy access to information, collaborative content creation and storage, sharing, and visualization. Because the visualization of learning via learning materials is a significant input for educational development, the YouTube™ platform also aims to provide information to educators with the help of videos (13) and to be considered a learning tool by learners (14). Despite many advantages of YouTube, unrelated commercials, some opprobrious content, long videos, and lack of uncertainty are among the main disadvantages of YouTube™ videos (15). In a survey study conducted among third- and fourth-year dental students in the USA, endodontics was found to be one of the most preferred disciplines in terms of YouTube™ use (16), and, although education was not the primary purpose for using YouTube™, these students were likely to use it as a resource to learn and prepare for clinical dental procedures. This situation draws attention to the importance of the content and quality of the videos shared on YouTube™.

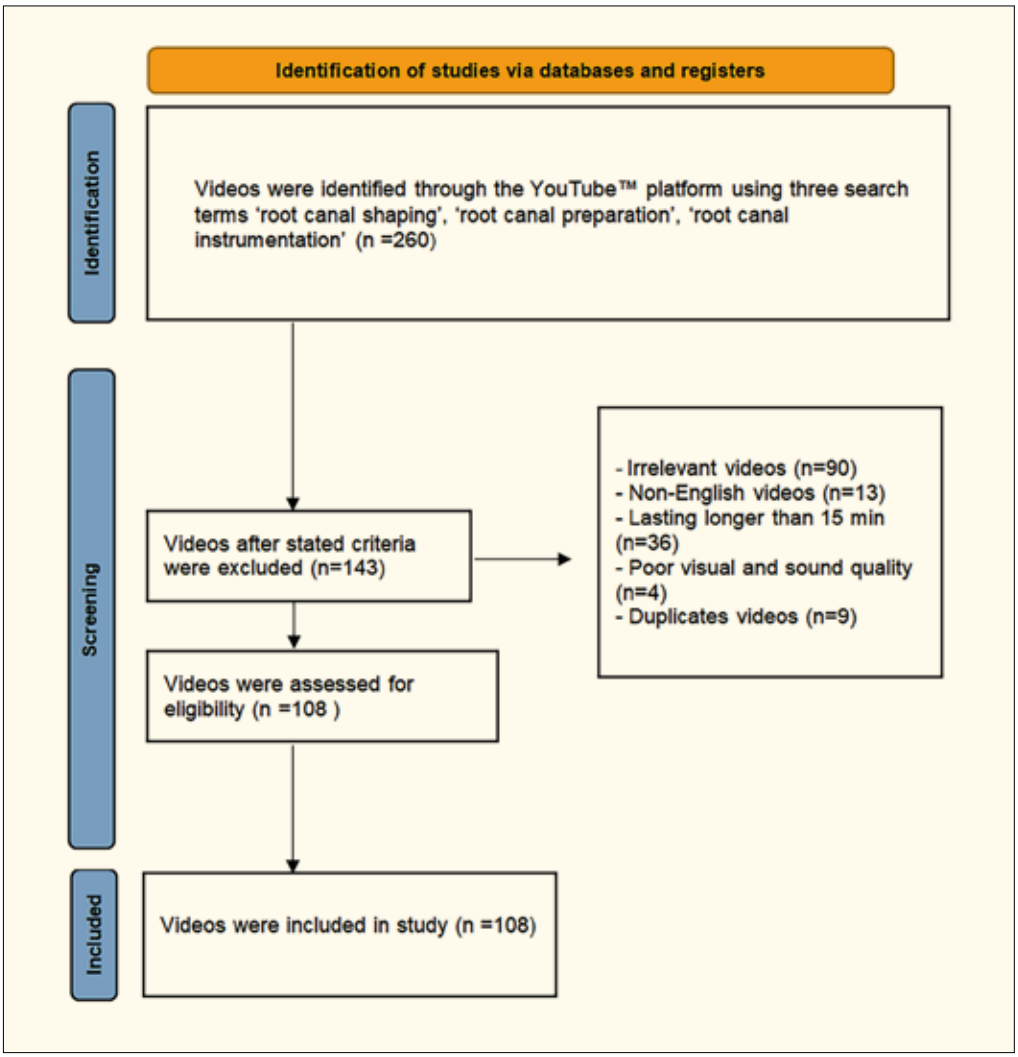
Although the quality and precision of YouTube™ videos have been researched on different topics in endodontics (12, 17-20), no data is available on inspecting YouTube™ videos as inquiries for root canal preparation. Thus, this study aimed to evaluate the quality and content of the information videos available on YouTube™ regarding root canal preparation. The alternative hypothesis of this study was that most of the relevant videos evaluated contained low educational quality or incomplete information.

Materials and Methods

Publicly available data were used in this study, and ethical approval was not obtained from the research ethics committee as any material collected from humans or animals was not included in the study.

The authors followed the PRISMA flow diagram for the video selection process in the present study (21) (Figure 1). The keywords "root canal shaping," "root canal preparation," and "root canal instrumentation" were searched, and "sort by relevance" was used as the default filter. A total of 260 videos were analyzed by two researchers who were specialists in endodontics. Of these videos, 152 were excluded: non-English language videos, videos longer than 15 minutes; videos with poor visual and sound quality; videos irrelevant to the search terms; and duplicated videos. The remaining 108 videos meeting the

Figure 1
PRISMA flow diagram for the video selection process.



inclusion criteria were analyzed further. Each video's demographics, duration (s), number of views, viewer rating (likes and dislikes) and timespan (day) were evaluated. The source of the videos was classified as a dentist, endodontist, commerical company, or other. The tooth/model (extracted human tooth, artificial tooth model, patient's tooth, topic description, no model), instrumentation file (hand file, NiTi file systems, hand and NiTi file systems), and preparation technique were determined for content classification. The reliability of the content in the videos was

Table 1
The DISCERN index consists of five questions

DISCERN - Reliability of information (1 point for every Yes, 0 points for No)
Are the objectives clear and achieved?
Are reliable sources of information used?
Is the information presented balanced and unbiased? Is there any reference to other treatment choices?
Are additional sources of information listed for patient reference?
Are areas of uncertainty mentioned?

Table 2
Demographic features of videos [Frequency (n) and percent (%)]

Parameter	n	%
Uploader		
Dentist	21	19
Endodontist	35	32
Commercial company	23	21
Other	29	27
The used tooth/model		
Extrated human tooth	6	6
Artificial tooth model	16	15
Patient's tooth	32	30
Topic description	29	27
No model	21	19
Topic		
Hand file	5	5
NiTi file systems	73	68
Hand and NiTi file systems	2	2
Preparation technique	28	26

Table 3
Descriptive statistics of videos [Mean ± Standard Deviation (SD), Median (Minimum-Maximum)]

Parameter	Mean ± SD	Median (Min - Max)
Duration (sec)	337±193	309 (40-884)
View	60.291±325.303	3.025 (5-3.253.704)
Like	440±1.605	27(1-15.000)
Video timespan (day)	1.295± 04	1.003 (7-3.692)
DISCERN	1±1	1 (0-4)
VPI	6.320±46.944	283 (1-487.812)
Interaction index	3±6	2 (0-50)

DISCERN, Quality Criteria for Consumer Health Information; VPI, video power index.

evaluated using DISCERN (22) and where the answers were scored as "yes" or "no", 1 point was given for the "yes" answer and 0 points for the "no" answer. DISCERN consists of five questions, the answer to each of which was determined between 1 and 5 points as a result of the evaluation (Table 1). The quality of video information was evaluated using the Global Quality Scale (GQS), which is based on the quality of information available and evaluates the extent to which the observed video is helpful (23). The GQS scores are given in Table 2. The Video Power Index (VPI) was used to evaluate the popularity/preference rate of the videos: [(View Ratio × Like Ratio)/100], where View Ratio = views/day and Like Ratio = [(Likes × 100)/(Likes + Dislikes)] (24, 25).

Statistical analysis

SPSS software package version 20 (IBM Corp, Armonk, IL) was used for statistical analysis. Descriptive statistics (mean, standard deviation, median, frequency, percentage, median, minimum and maximum) were obtained, and the data distribution was calculated using the Shapiro-Wilk and Kolmogorov-Smirnov tests. The Kruskal-Wallis test was used to compare three or more non-normally distributed quantitative data groups, and the Mann-Whitney U test was used to compare two non-normally distributed groups. Spearman's test was performed for the correlation of data. Significance was evaluated at the $p<0.05$ level.

Results

The kappa test results indicated no statistically significant differences between inter-examiner values for scoring the GQS and DISCERN (kappa= 0.923 and 0.930, respectively).

Table 2 shows the topic described in the video, the video's uploader, and the tooth or model used. Table 3 shows the duration time, views, likes, video timespan, and video scale/index (DISCERN, VPI, interaction index). In terms of

Table 4
Distribution of videos by global quality scale (GQS) [Frequency (n) and percent (%)]

GQS	n	%
1 (Poor quality, poor flow of the video, most information missing, not at all useful for patients)	68	63
2 (Poor quality, poor flow of the video, most information missing, not at all useful for patients)	28	26
3 (Moderate quality, suboptimal flow, some important information is adequately discussed but others poorly discussed, somewhat useful for patients)	11	10
4 (Good quality and generally good flow. Most of the relevant information is listed, but some topics not covered, useful for patients)	1	1
5 (Excellent quality and flow; very useful for patients)	0	0

GQS, global quality scale.

video uploaders, endodontists uploaded the most videos (*n*=35; 32%), mainly shot on the teeth of patients (*n*=32; 30%). NiTi file systems were the most mentioned (*n*=73; 68%). In terms of quality, most of the videos were of low quality and unlikely to be useful to clinicians because many important topics were not discussed in their content (*n*=68; 63%). In the videos uploaded by the commercial company, brief information was given about the files' kinematics, cross-sections and size. According to the overall GQS score, none of the 108 videos evaluated were in the "excellent quality and flow" category (Table 4).

In Table 5, there was no significant difference between video uploaders in terms of video duration, number of likes or the DISCERN score. The number of views and the VPI were significantly higher for the videos uploaded by commercial companies than by endodontists (p=0.005, p=0.026), respectively. There was no significant difference between dentists and endodontists concerning the number of views and the VPI parameters (p=0.177, p=0,199), respectively. The commercial companies'

Table 5
Analysis of variables by video uploader

	Dentist	Endodontist	Commercial company	Other
Duration (sec)	456 (64-705)	230 (56-884)	279 (75-593)	374 (40-767)
View	3881 (30-3.253.704) [ab]	953 (5-803.778)[b]	10.282 (8-485.294)[a]	3350 (8-335.580)[ab]
Like	53 (1-15.000)	16 (1-1.600)	32 (1-1.900)	22 (1-4.200)
Video timespan (day)	790 (144 2.986)[a]	834 (43 - 3359)[ab]	1819 (467-3.285)[b]	855 (7-3.692)[ab]
VPI	588 (4-487.812)[ab]	166 (1-25.476)[b]	615 (1-16.757)[a]	179 (1-18.645)[ab]
Interaction index	2 (0-7)[a]	2 (0-20)[a]	1 (0-13)[b]	1 (0-50)[a]

VPI, video power index.
[a-b]There is no difference between the values expressed with the same letters in the same row.
Kruskal Wallis H test

Table 6
Reliability-based comparison of popularity and visibility

Parameter	DISCERN (0-1) n=76	DISCERN (2-5) n=32
View	2728 (8-204.168)	7086 (5-3.253.704)
Like	24 (1-2.600)	47 (1-15.000)
GQS*	1 (1-2)	2 (1-4)
VPI	249 (1-18.645)	646 (1-487.812)
Interaction Index	2 (0-50)	1 (0-20)

*Mann Whitney U test, *p<0,05*
DISCERN, (Quality Criteria for Consumer Health Information); GQS, global quality scale; VPI, video power index.

Table 7
Comparison of GQS and DISCERN values of three uploaders with those of endodontists

Uploader	Endodontist (n=35)		Dentist - Company - Other (n=73)	
	Mean ± SD	Median (Min-Max)	Mean ± SD	Median (Min-Max)
GQS	1.51±0,61	1 (1-3)	1.48±0,77	1 (1-4)
DISCERN	1.34±0,68	1 (0-3)	1.19±0,84	1 (0-4)

DISCERN, Quality Criteria for Consumer Health Information; GQS, global quality scale.
Mann Whitney U test

videos were a significantly longer video timespan than those uploaded by dentists (p=0.031). There was no significant difference between dentists, endodontists, and other uploaders concerning video timespan (p>0.05).
The interaction index of the commerical companies was significantly lower than the other three uploaders (p=0.001). There was no statistically significant difference in interaction index value between the other three uploader types (p>0.05).
As the DISCERN (reliability) value increased, the number of views/likes and the VPI increased even though they were not statistically significant (p>0.05). There were no dislikes in our searching. Furthermore, as the DISCERN score increased, the GQS value increased significantly (p=0.001). In other words, the reliability and quality of the videos were better. Also, as the DISCERN score increased, the interaction index decreased significantly (p<0.05) (Table 6).
Regarding the educational aim of videos, for evaluating DISCERN and GQS, dentists, commercial companies, and others were considered a single group and compared with endodontists. No significant difference was found between the two groups in terms of GQS and DISCERN (p>0.05) (Table 7).
Table 8 shows a positive and significant relationship between duration time, number of views/likes, and the VPI (p<0.001). While there was a positive and significant relationship between the views/likes, video timespan, and the VPI, a significant negative correlation was found with the interaction index (p<0.001). A positive and significant relationship was found between the number of likes and the VPI (p<0.001), but a negative and significant relationship was found between the video timespan and the interaction index (p<0.001). Furthermore, a positive and significant relationship was found between DISCERN and the GQS (p<0.001), but a negative and significant relationship was found between the VPI and the interaction index (p<0.001).

Discussion

The current study highlighted the quality and content of the information videos available on YouTube™ regarding root canal shaping. The alternative hypothesis of this study was accepted because the videos were mainly of poor quality and unlikely to be helpful to clinicans as many important topics were not discussed in their content (63%). Furthermore, most of the content was incomplete or irrelevant, as professionals did not review the uploaded videos, and the quality was checked only by those who watched the videos.
Some study reports suggested that YouTube™ could be considered the power of e-learning because of its visual demonstration of clinical procedures (26-28). Burns et al. performed a survey study on the use of YouTube™ among dental students for learning clinical procedures: 95% of respondents rated YouTube™ videos on

Table 8
Correlation analysis between parameters

Parameter		Duration (sec)	View	Like	Video Timespan (day)	DISCERN	VPI	Interaction Index	GQS
Duration (sec)	r	1							
	p	-							
View	r	0.339	1						
	p	<0.001*	-						
Like	r	0.35	0.826	1					
	p	<0.001*	<0.001*	-					
Video Timespan (day)	r	0.01	0.398	0.125	1				
	p	0.918	<0.001*	0.198	-				
DISCERN	r	-0.084	0.055	-0.001	0.026	1			
	p	0.389	0.57	0.995	0.787	-			
VPI	r	0.349	0.927	0.847	0.076	0.085	1		
	p	<0.001*	<0.001*	<0.001*	0.433	0.384	-		
Interaction Index	r	-0.06	-0.483	-0.055	-0.585	-0.055	-0.294**	1	
	p	0.538	<0.001*	0.568	<0.001*	0.568	<0.001*	-	
GQS	r	0.01	0.161	0.113	0.114	0.729	0.166	-0.144	1
	p	0.919	0.096	0.246	0.241	<0.001*	0.086	0.136	-

*Spearman's correlation test, *p<0.05.*
DISCERN, (Quality Criteria for Consumer Health Information); GQS ,global quality scale; VPI, video power index.

clinical guidelines as a helpful learning tool, and 89% requested dental schools to post informative videos on YouTube™/ social media (16). Some research also highlighted the positive aspects of YouTube™ users, like encouraging discussion and critical analysis (26, 29). Among dental students, YouTube™ was often used to learn about different ways to clinical procedural techniques and improve the visualization and understanding of abstract concepts (16). However, it is also a fact that YouTube™ is not a substitute for first-hand experience.

One of the challenges with easily accessible information is that the content of the videos may lack certainty about the quality and veracity (26, 29). Findings from this study supported the uncertainty of the quality of readily accessible information on YouTube™ regarding root canal preparation. Regarding video content, mainly the following were not disclosed: procedural errors, estimated frequency of file separation in the root canal, what to do to avoid file separation, and treatments that would be applied after the complications. It is essential to consider that low prior knowledge of the subject, especially among dental students, may negatively affect the video search process on YouTube™ (30). A survey study by Fu et al. (28) reported that not all feedback was positive concerning YouTube™ as a learning tool for clinical

endodontics, stating a lack of understanding of the techniques and the procedural information to be followed after possible complications during root canal treatment.

The findings of the present study also support these results. Information sharing about the problems that preparation procedures clinicians may encounter was lacking. Studies in the literature suggest that few faculties recommend YouTube™ as a learning procedures tool for clinical dentistry (16) and that faculty recommendation or validation is an essential factor influencing students' perception of the reliability of external resources (31).

In this study, there was no significant difference between video uploaders in terms of video duration, number of likes, and DISCERN, and the number of views and the VPI were significantly higher for the videos uploaded by commercial companies than those uploaded by endodontists. There was no significant difference between dentists and endodontists for these two parameters. Also, the videos were mostly shot on the teeth of patients. Uploaded videos could enhance the fame of the owner/brand of the videos. In addition, Cuddy et al. (32) reported that the videos could be intended for uploaders' commercial purposes rather than educational content. The results of this study also support this conclusion.

Endodontists uploaded more videos about root canal preparation that met the inclusion criteria on YouTube™ in this study. In this study, when dentists, commercial companies, and others were considered as a single group and compared with endodontists, no significant difference was found between them in terms of GQS and DISCERN. However, this may be because the number of endodontists uploading videos was about half the others. Although not statistically significant, the mean values of endodontists were higher. Therefore, it can be concluded that GQS and DISCERN will increase as the number of endodontists uploading videos increases. In addition, as the DISCERN score increased, the GQS value increased significantly. This result supports the data in the literature that professionals and communities supply more credible health information (12, 17, 20, 33). With higher DISCERN scores, the veracity and content quality of the videos were considered to be almost high (33). As the length of the video increases, it may provide more detailed information to the viewer, but it may also cause a loss of concentration in the subject. In the present study, there was a significant relationship between duration time, number of views/likes, and the VPI, in agreement with the results of the previous study (12). The instructional purpose is essential in determining the length of a video intended to be used as a teaching tool. It has been stated that the shorter the video, the higher its impact on the subject (34). However, the subject's content and complexity can affect the video's length to impart the correct information to the target viewer productively (35). Therefore, for all videos rated by their viewers, there were many "likes" and no "dislikes," suggesting that viewers generally view videos as helpful. The videos evaluated here did not have "dislikes." Such video rating is unscientific and subjective but could be used to show that the viewer approves of the video and thus attracts more viewers in the future (20).

The methodology of this study had some limitations. Uploaders can modify and edit videos, comments, and delineative data on YouTube™. Such tampering with the videos may lead to different search results in different time zones (33). Moreover, while endodontic treatment is widely performed worldwide, only English videos were evaluated. Thus, our findings are limited as English is not the primary language in most countries.

Conclusion

Within the limitations of this study, the content of the videos on YouTube about root canal preparation was not reliable and sufficient. However, videos with high content and quality that professionals prepare for educational purposes may help to reduce incomplete information intake over the Internet.

Clinical Revelance

In light of these findings, it is essential for dentists and dental students to be aware of

current and critical information, to direct endodontists to appropriate resources (professional or commercial) and to obtain accurate and up-to-date information.

Conflict of Interest

All authors declare no conflicts of interest.

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ORIGINAL ARTICLE

Effect of smear layer removal using different chelators on push-out bond strength of bioceramic sealer

ABSTRACT

Aim: *The aim of this study was to evaluate the effects of phytic acid (IP6), ethylenediaminetetraacetic acid (EDTA) and glycolic acid (GA) used as a final irrigation solution on the push-out bond strength (POBS) of a bioceramic-based root canal sealer.*
Methodology: *The study included 60 single-root human mandibular premolars. After the teeth were decoronated, they were cleaned and shaped using the #25.08 Reciproc R25 single file system. Throughout preparation, each canal was irrigated using 20 ml 5.25% sodium hypochlorite (NaOCl). The teeth were divided into 4 group, each consisting of 15 (n=15) according to the final irrigation agent [1% IP6, 10% CI, 17% EDTA, and distilled water (DW)]. The final irrigation protocol consisted of application of 5 ml chelating agent for 1 minute followed by 5 ml 5.25% NaOCl application. Root canals were filled using Well Root ST canal sealer and Reciproc R25 gutta-percha, based on the single-cone technique. A 2-mm section was extracted from the middle part of the roots to test for POBS. Values were recorded in MPa and fracture types were examined. Groups were compared using one-way ANOVA (Welch's) test.*
Results: *The GA, EDTA, and IP6 groups showed no significant intergroup differences ($p>0.05$). EDTA and GA groups had significantly higher POBS than the DW group ($p<0.05$). No significant difference was observed between IP6 and DW groups ($p>0.05$).*
Conclusion: *GA increased the bond strength of the bioceramic-based canal sealer to the root canal dentin at least as much as EDTA; IP6 exhibited similar strength to these chelators, it was not better than DW.*

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Introduction

Root canal sealers are used to provide a bond between the root canal wall and the core filling material. A strong and long-lasting bond between the root canal wall and the filling material is an important factor in preventing root canal infection caused by proliferation of microorganisms or reinfection owing to coronal/apical leakage (1, 2). Push-out bond strength (POBS) is considered a prognostic factor relevant to assess the bond provided by a root canal sealer between the canal wall and core filling material (3).

Root canal instrumentation causes the formation of a smear layer (SL), which contains organic and inorganic components that occlude the orifices of dentinal tubule and remarkably prevent irrigants and medications from reaching the dentin surface (4). Furthermore, SL creates an interface between the filling material and dentin, preventing the sealer from adhering to the dentin (5). Chelating agents are recommended for use during root canal treatment to improve chemo-mechanical preparation by removing SL and demineralized and softened dentin from the root canal. To some extent, this procedure exposes a large number of dentinal tubules, which increases the contact zone and provides stronger bonding between the sealer and root canal dentin (6). Removal of SL using this procedure may improve the adhesion of sealers to dentin. An effective chelating agent should remove SL by acting only on the superficial dentin without damaging the interior region of the root dentin. Ethylenediaminetetraacetic acid (EDTA) has good SL-removal capacity, but (7) has some undesirable effects when used for more than 3 minutes, including denaturation of collagen fibrils (8), and erosion of peritubular and intertubular dentin (7). This resulted in a need for searching alternative irrigants that are biocompatible and effective in removing SL without damaging the structure and properties of the root dentin to ensure a successful root canal treatment. Phytic acid (inositol hexaphosphate-IP6), recognized in the endodontic literature as an alternative to EDTA, is a chelating agent that is biocompatible with osteoblasts, able to remove SL and release TGF Beta in regeneration (9, 10). Glycolic acid ($C_2H_4O_3$ -GA) is an organic chelator that is highly soluble in water and that induces collagen and fibroblast proliferation. Furthermore, this acid is suggested as a substitute for phosphoric acid, which is abrasive on enamel and dentin (11). Additionally, GA is relatively less toxic than EDTA and readily biodegradable (12).

However, various chelating agents may cause different superficial dentin modifications (removing different parts of major inorganic elements such as calcium [Ca^{++}] (13, 14) and this may give rise to variable interference with the bonding of calcium silicate-based sealers to dentin. Against this background, the aim of this study was to evaluate the effect of IP6, EDTA and GA used as chelating agents on the bonding strength of calcium silicate-based root canal sealer (Well Root ST) to root canal dentin. The DW group was used as the reference agent for comparison purposes. The null hypothesis tested was that various chelating agents would not affect the bonding strength of the calcium silicate-based root canal sealer.

Materials and Methods

This study received approval from Ethical Committee of Dicle University, Faculty of Dentistry, Diyarbakır, Türkiye (no: 2021-39).

Calculating the sample size

The sample size was calculated based on a previous study (15). According to this study, the minimum sample size for each group was found to be 6 observations. In the present study, we used 15 teeth per group and 60 teeth in total.

A total of 60 single-root mandibular premolar teeth were used; these teeth had completed their apical development, had been extracted for periodontal or orthodontic reasons, and had no fractures or cracks on them. The teeth were decoronated to a root length of 15±1 mm using a

diamond disk under water cooling. Then, working length was determined using a 15 K-type (VDW, Munich, Germany) hand file for standardization. The working length was determined such that it would be 1 mm short of the file going beyond the apical foramen. Root canal preparation was performed using a Reciproc R25 (VDW, Munich, Germany) single file system in accordance with the manufacturer's instructions. Irrigation was performed using 30 gauge irrigation needles (Dentsply Sirona, Maillefer, Ballaigues, Switzerland) with two lateral vents. Throughout the preparation, each canal was irrigated using 20 ml 5.25% NaOCl (Promida, Eskişehir, Turkey). Following enlargement, the teeth were randomly divided into 4 groups for final irrigation (n=60). The groups were as follows:

EDTA Group (n=15): The root canals were irrigated with 5 mL 17% EDTA (Promida, Eskişehir, Turkey) (1 minute) and 5 ml 5.25% NaOCl.

GA Group (n=15): The root canals were irrigated with 5 mL 10% GA (Sigma Aldrich Co. LLC, St Louis, MO, USA) (1 minute) and 5 ml 5.25% NaOCl.

IP6 Group (n=15): The root canals were irrigated with 5 mL IP6 (Sigma Aldrich Co. LLC, St Louis, MO, USA) (1 minute) and 5 ml 5.25% NaOCl.

DW Group (n=15): The root canals were irrigated with 5 mL DW (1 minute) and 5 ml 5.25% NaOCl.

After final irrigation procedures were performed according to the irrigation regimen for each group, all teeth were rinsed using 5 ml DW and dried with paper points. Root canals were filled with bioceramic-based Well Root ST (Vericom, Gangwon-Do, South Korea) sealer using Reciproc R25 gutta-percha cones based on the single-cone technique. The coronal chamber was obturated using a temporary restorative material. The teeth were embedded in square silicone molds filled with cold-curing acrylic (Imicyl, Konya, Türkiye). After acrylic polymerization, the samples were stored at 37 °C and 100% humidity for 7 days to ensure that the canal sealer was fully cured.

The acrylic was marked with an acetate pen 4 and 6 mm above the apical section. Then, samples were cut using the ISOMET device (Isomet, Buehler, Lake Bluff, IL, USA), with a blade rotating at 200 rpm (ATM GmbH, Mammelzen, Germany) under water cooling to obtain a sample of approximately 2 mm from the middle 1/3 of each sample. Section thickness was measured with a digital caliper (Mitutoyo Corp, Tokyo, Japan) with 0.01 mm precision. The push-out bonding strength of the samples was tested using the Instron device (Instron 3382, Instron Corp., Memmingen, Germany). A stainless-steel cylindrical tip with a diameter of 0.75 mm was mounted on the device and positioned to touch only the canal filling. The prepared device was used to apply a load at a constant speed of 1 mm/min until debonding of the root canal filling and dentin was achieved. Owing to the increasing taper of the sections in the apico-coronal direction, the load was applied to the canal filling material in the apico-coronal direction. Fracture strength values were recorded in Newton (N) and converted to Megapascals (MPa) to calculate the bond strength. After the bond strength test, samples were examined to identify their fracture types (Figure 1). Adhesive failure is the type of failure that occurs at the interface between the filling material and dentin, whereas a cohesive failure is the failure that occurs within the filling material itself. Mixed failure indicates frac-

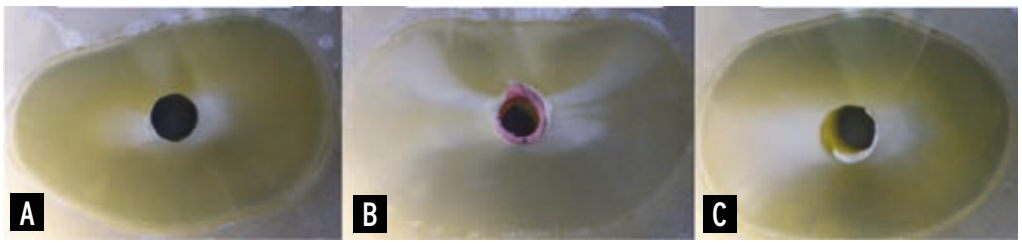

Figure 1
Visualization of failure types after POBS testing under a stereo microscope **A)** Adhesive failure, **B)** Ccohesive failure, **C)** mixed failure.

ture both at the filling material-dentin interface and within the filling material.

Statistical analysis
Data were analyzed using SPSS 21.0 Software (IBM Corp, Armonk, NY) and were normally distributed according to the Shapiro-Wilk test. The variances were not found to be homogeneous according to Levene's test, and the data were compared using the one-way ANOVA (Welch's) test. Multiple comparisons were performed using Tamhane's test. Inter-rater agreement was calculated using Cohen's Kappa statistic. The alpha type error was set at 0.05.

Results

Descriptive statistics of the push-out test are given in Table 1. No significant difference was observed between the IP6 and EDTA groups, and these two groups exhibited significantly higher bond strength than the DW group. Although the IP6 group showed lower bond strength than the GA and EDTA groups, this difference was not statistically significant. No significant difference was observed between the IP6 group and the DW group.
The graph of intragroup values by type of failure is given in Figure 2. Kappa test results showed statistically high inter-rater agreement in determining types of failure after bond strength test in each group (Kappa value=0.824). Mixed failure was more common in the IP6 group (53.3%), while cohesive failure was more common in the EDTA group (46.7%). The rate of adhesive failure was higher in the GA group (40%) and DW group (66.7%).

Discussion

Removing the inorganic component of SL using EDTA and the organic component using NaOCl is generally considered a standard clinical practice. However, this combined irrigation protocol causes abrasion on the dentin surface (16). Furthermore, prolonged exposure of the root dentin to EDTA can reduce dentin's modulus of elasticity and flexural strength (17). Therefore, there is a search for alternative chelating agents with less or no harmful effect on root dentin. The effect of chelating agents is generally not limited to SL; these agents also change the ratio of Ca^{++}/phosphate present in the dentinal walls (18). Furthermore, they expose collagen fibers and reduce dentin hardness (19). These changes may affect the bonding between dentin to calcium silicate-based sealers, which use Ca^{++} ions in dentin for biomineralization. The results showed no significant difference in the bond strength of the Well Root ST bioceramic sealer to root dentin after removal of SL with different chelation solutions, therefore, the null hypothesis of the study was accepted. Compared to the samples treated with chelating agents, DW-treated (control) samples had significantly lower bond

Table 1
Descriptive statistical values for push-out bond strength in groups

Group	n	Mean ± SD	Median (Min-Max)	p
GA	15	3.9±1.19^{A}	4.31 (1.71-5.56)	0,004*
EDTA	15	4.12±1.45^{A}	4.13 (1.79-6.73)	
IP6	15	3.39±1.19^{AB}	3.17 (1.95-5.71)	
DW	15	2.83±0.59^{B}	3.02 (1.72-3.54)	

$^{A-B}$*Groups with the same letter have no significant difference between them.]*

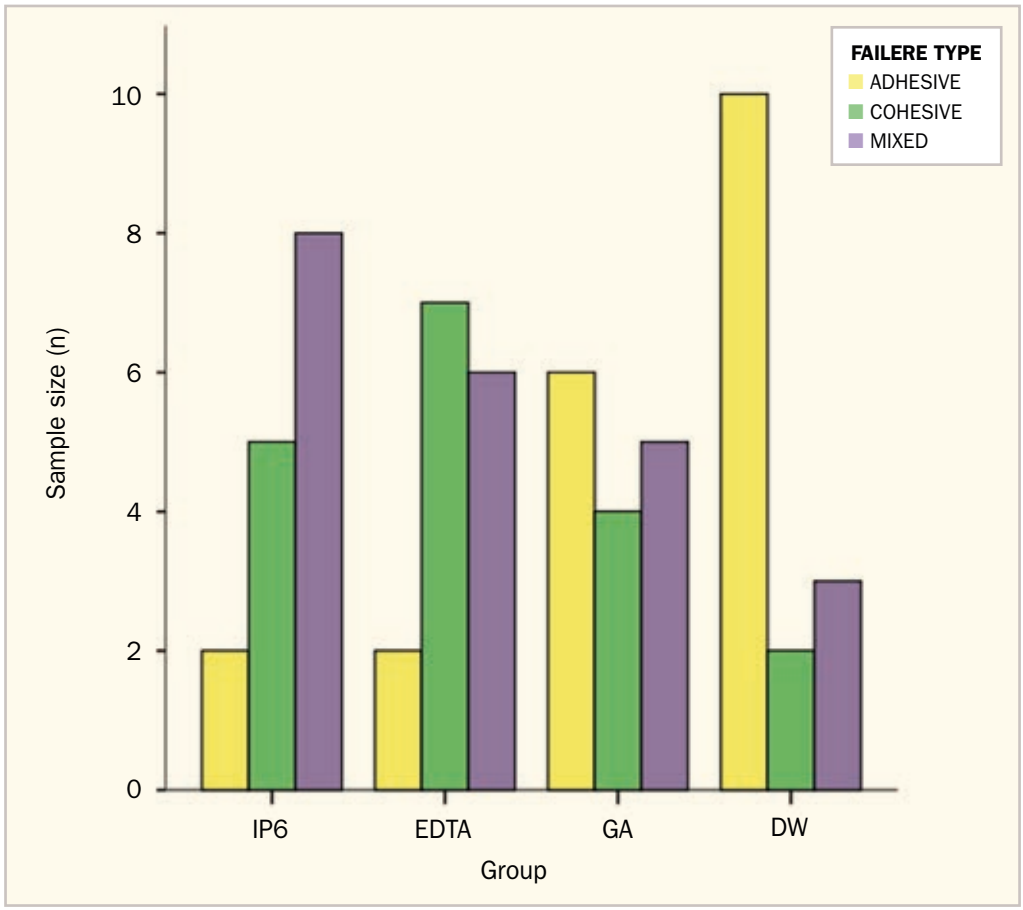

Figure 2
Intergroup and intragroup comparison of failure types.

strength values. This finding strongly suggests that the presence of SL has a negative effect on adhesion between dentin and the Well Root ST. The increase in surface roughness caused by removal of SL may be clinically beneficial because retention is achieved by the micromechanical interaction of the sealer with the dentinal tubules (20). The fact that the bonding between bioceramic sealer and radicular dentin is reportedly brought about by mechanical interlocking of the sealer plug in the dentinal tubules rather than chemical interaction (21). All chelating agents used were kept in the canal for 1 minute. 1 minute of EDTA application has been reported to be effective in removing SL (22). A longer contact time may result in excessive peritubular and intertubular erosion and destruction of root dentin (22, 23).

In this study, the highest POBS value was observed in the GA and EDTA groups. This may be owing to the fact that GA at 10% concentration has an SL-removal ability similar to EDTA at 17% concentration. In addition, its acidic pH (2.36 and 2.18) reportedly causes demineralization of dentin, and this may result in increased surface roughness, which has a clinical benefit in micromechanical bonding of adhesive materials (24). The results of our study are in line with that of a POBS evaluation by Veeramachaneni et al. (25) conducted with a similar method. This study evaluated the POBS of bioceramic (Bio C sealer) and epoxy resin (Dia-Proseal) sealers after using a variety of final irrigants and found that both sealers exhibited higher push-out bond strength after treatment with GA with no significant difference between 5% and 17% GA has been demonstrated. Furthermore, bioceramic sealer with GA as final irrigant showed higher bond strength than epoxy resin. Our study only used bioceramic-based

Well Root ST sealer, and could not make any comparison with other sealers.

IP6 contributes to various cellular functions, has multiple negative charges, making it an effective chelator of polyvalent cations such as Ca++, magnesium and iron (26). Studies have found IP6 to be effective in removing SL (10, 27). A confocal laser scanning microscopy study by Eskander et al. (28) found deeper sealer penetration with 17% EDTA, compared to 1% IP6 and reported that the IP6 group had moderate tubular penetration. In contrast, Nassar et al.(10) reported that both IP6 and EDTA removed SL, but the 1% IP6 group exhibited cleaner surfaces. This study found no significant difference between the IP6 group and the other groups, including the control group. We think that the discrepancy in the findings is due to the different amounts of irrigants used and the size of contact with the dentin surface. There is no other study with a similar methodology that investigated the effect of IP6 on the POBS of bioceramic sealer.

Well Root ST is a tricalcium silicate-based, premixed and injectable bioceramic sealer. The zirconium oxide, calcium silicate, filler and hydrophilic thickeners it contains initiate the setting reaction by using the moisture in the canal (29). A study with a similar methodology to ours investigated the effect of 17% EDTA, 18% etidronic acid (HEPB) and 0.2% chitosan on the POBS of AH Plus and Well Root ST sealer and found that the bond strength of Well Root ST sealer was affected by chelating agents (15). Our study achieved a similar result in that the POBS of Well Root ST sealer did not differ significantly with three different chelators. A study by Kaki and Genç Şen (15) mostly observed adhesive failure in all experimental groups, this study achieved a different result. The control group using DW exhibited mostly adhesive failure (66.7%), the samples using chelator had 42.22% mixed failure. According to the authors of the study, the greater proportion of adhesive failure in the DW group may be the result of insufficient sealer-dentin bonding. The greater proportion of mixed failure in the samples using chelators compared to the control group can be attributed to the fact that sealer-dentin bonding has an effect comparable to sealer-gutta-percha bond (30). There was no significant relationship between the effect of different chelating agents and the types of fracture.

Using sealer without a core filling material is not an appropriate representation of actual clinical conditions and the absence of gutta-percha in the root canal filling may affect the results of the POBS test (31). The bond between gutta-percha and sealer is weak, and this low adhesion reduces the mechanical properties of root canal filling materials compared to the use of endodontic sealers alone and exhibits low resistance to elastic deformation (32). Concerning obturation techniques, lateral condensation and warm filling techniques can have an impact on POBS and are less reproducible than the single-cone technique (33, 34). Therefore, in this study, obturation was performed using gutta-percha cones suitable for the enlarged canals, based on the single-cone technique. Because standardization of the POBS test is important to investigate bonding issues in the sealer-dentin interface (35). This study investigated the effect of three different chelating agents on the bonding between bioceramic sealer and dentin, and therefore, the use of core material should be considered invariant.

POBS test determines dislocation resistance of materials and thus provides an effective and reliable measure of adhesion of sealers to root canal walls (36). The density of dentinal tubules and the strength of sealer bonding to dentin decrease along the root from the coronal to the apical third (37). Therefore, this study only used sections obtained from the middle third of each root for POBS testing. One of the limitations of this study is thus the use of sections from only the middle third of the roots, instead of the coronal or apical third.

Conclusion

GA exhibited a POBS that was significantly higher than DW and similar to EDTA. IP6, on the other hand, exhibited a POBS similar to GA, but had no significant dif-

ference with DW, which is unable to remove SL. Therefore, GA, as an alternative chelator, can increase the POBS of bioceramic-based Well Root ST root canal sealer. Further studies are needed to investigate the chelating effect of IP6.

Clinical Relevance

The knowledge about the influence of the chelator on POBS of bioceramic-based root canal sealers is essential. Also, GA, an organic chelator, increased POBS as much as EDTA.

Conflict of Interest

All authors declare no conflicts of interest.

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ORIGINAL ARTICLE

Effects of different irrigation solutions on the accuracy of electronic apex locators in curved and straight root canals

ABSTRACT

Aim: *To evaluate the effects of different irrigation solutions on the accuracy of 4 different electronic apex locators (Propex II, Propex-Pixi, Dentaport ZX, DTE Dpex V) (EALs) in curved and straight root canals.*
Methods: *A total of 20 extracted human teeth; 10 maxillary incisors with straight root canals and 10 mandibular molars with curved root canals, of which the curvature angles were between 30-50 degrees were selected. A #10 K-type file was advanced under a stereomicroscope at X15 magnification until the file was seen apically and the measured value was recorded as actual length (AL). Then, electronic length (EL) was determined using the selected EALs in different irrigation solutions. Group 1 was the control group. 1% NaOCl, 2.5% NaOCl, 5% NaOCl, 2% CHX, 17% EDTA and EDTA gel was used for groups 2-7, respectively. After each measurement, the roots were washed with 5 mL of distilled water and dried with a paper point before the same teeth were used in the next group. The difference was calculated by subtracting each tooth's AL from EL.*
Results: *When EALs accuracy was compared, there was a significant difference for Propex-Pixi and DTE Dpex V. When EALs' accuracy was compared in presence of different irrigation solutions, there was a significant difference in the Control group and Group 5.*
Conclusions: *All EALs performed more successfully in straight canals than in curved canals. Electronic measurements of molars with curved root canals were affected in the presence of CHX and when the root canals were dry.*

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Introduction

The establishment of correct working length (WL) has a critical role and can affect the success of root canal treatment (RCT). Appropriate shaping, disinfection, and filling of root canal could not complete without an accurate WL (1). Cemento-dentinal junction (CDJ) is a histologic landmark that determines where the pulp tissue ends and periodontal tissue begins (1). However, studies showed that most of the time CDJ and apical foramen are not at the same location (2, 3). The location of CDJ is accepted as 0.5-0.75 mm coronally to the apical foramen (4).

All the pulp tissue, necrotic materials, and microorganisms should be removed from entire root canal surfaces (4). Preparation and filling of root canal system at shorter than CDJ can increase undisinfected bacterial area causing failure of RCT. On the other hand, over-instrumentation beyond the WL damages apical constriction, making filling of the root canal system difficult jeopardize the apical seal (1).

While determining the WL operator can use radiographic methods, tactile sensation, and electronic apex locators (EALs) (5). Manual tactile sensation depends on the operator's skills, age of the patient and teeth type (6). The radiographic apex can be seen on the radiograph and identifies as anatomical end of the root (7). The distance between anatomical apex and radiographic apex distance can vary due to secondary dentin deposition. Disadvantages of using radiographs for determining WL are difficulty to set proper projection, radiation exposure and lack of possibility to reflect correct length of root. Both these methods are not objective and highly repeatable (8). For these purposes EALs, that use the resistance of electronic current passing, designed many years ago (9).

In the world of modern endodontics, EALs consider as valuable additions to determine WL (5). The development of EALs has helped to obtain more accurate WL and this method is highly predictable when combined with radiographs (10).

In 1918, Cluster suggested that the root canal length can be assess by using electrical conductance (11). In 1942, Suzuki reported a device that can measure electrical resistance between oral mucosa and periodontal ligaments (12). He discovered electrical resistance between file in the root canal and electrode positioned on the oral mucosa recorded a consist value of 6.5 kΩ. Later on, Sunada performed extensive experiments on patients and discovered that the electrical resistance between mucous membrane and periodontium was stable regardless of patients age, shape, or type of teeth (9).

First generation EALs, use resistance method for determining WL. Initially alternating current was 150 Hz sine wave and patients often felt pain due to this high current (7). Second generation EALs identify as single frequency impedance, that use impedance measurements instead of resistance. However, the impedance depends on vary factors and their biggest disadvantage was the need of constant calibration between each root (13). Third generation EALs use multiple frequency impedance different than second generation, it measures the impedance difference between 2 frequencies (7). Fourth generation EALs use multiple frequencies (2-5 frequencies), utilize resistance and capacitance measurements at the same time and allow more accurate measurement of WL different than third generation (14).

Propex II, and Propex-Pixi are the fifth generation EALs, Dentaport ZX is a third generation EAL, and Dpex V is a sixth generation EAL, all of which were used in this study. Propex II measures the capacitance and resistance seperately, Propex Pixi measures the square root of the impedances, Dentaport ZX uses two different frequencies simultaneously and calculate the ratio of impedance and DTE Dpex V has multi-frequency apical position technology for accurate measurement.

In addition, irrigation solutions are essential for disinfecting the root canal system (15). Usage of these solutions provide lubrication, debridement and dissolution of tissues. However, presence of any kind of electrolytes can affect determination of WL of EALs (16). In particular, presence of

electroconductive solutions such as sodium hypochloride (NaOCl) reduces impadence, resulted in determining shorter WL (17).
Although there are limited studies in the literature showing the accuracy of EALs in teeth with curved roots, no study has been found investigating the comparison of the accuracy of different EALs in determination of WL in straight and curved root canal (10, 18).
The aim of this *in vitro* study was to evaluate the effects of different irrigation solutions on the determination of WL using with 4 different EALs (Propex II, Propex-Pixi, Dentaport ZX, DTE Dpex V) in teeth with straight and curved root canals were evaluated. The null hypothesis tested was that the irrigation solutions and canal curvatures do not affect the accuracy of different generation EAL measurements.

Materials and Methods

The Clinical Research Ethics Committee of Akdeniz University, Turkey reviewed and approved the study design with decision number KAEK-475. G*Power 3.1.9.7 program was used to the determine sample size. When the minimum clinical significant difference between success rate by EALs for each solution is predict to be 30%, the minimum number of samples to be included in this study with a .05 alpha value and 80% power is 41 for each EAL. A total of 20 extracted human teeth; 10 maxillary incisors with straight root canals and 10 mandibular molars (mesial roots) with curved root canals, of which the curvature angles were between 30-50 degrees were used.
After the teeth were examined under the operating stereomicroscope (Zeiss Stemi, CarlZeiss, Germany), teeth with cracks or fracture lines, or RCT were excluded from the study. Radiographs were taken in buccolingual direction from the mandibular molar teeth, and the angle of curvature of the root canal was determined according to the Schneider's method (19). Teeth with the curvature angles were between 30-50 degrees were selected.
Hard and soft tissue residues on the teeth were cleaned with a scaler. During the study to prevent the teeth from drying out, the teeth were stored in saline solution. The endodontic access cavities were prepared in all teeth. After checking the apical patency with the #8 K-file, the teeth with the #10 K-file stuck apically were selected. To create a stable and reliable coronal reference point incisal edges and cusps of included teeth were flattened.

Determination of Actual Length (AL)
#10 K-type file advanced under a stereomicroscope (Zeiss Stemi, CarlZeiss, Germany) at X15 magnification until it can be seen apically. The rubber stopper was fixed to the incisal edge at the first moment when the file was seen apically, and then the distance between the rubber stopper, which was removed from the canal, and the tip of the file, was measured with an endometer. This process was repeated 3 times by the same operatör for each tooth to prevent operator failures. The avarage value were calculated and recorded as the actual length (WL).

Determination of Electronic Length (EL)
Alginate was mixed according to the manufacturer's instruction. The lip clip of the EALs remained in the alginate and the teeth were embedded in the alginate model at the enamel-cement margin. Electronic length (EL) was determined using 4 different EALs (Propex II, Propex- Pixi, Dentaport ZX, DTE Dpex V).
The #10 K- file was advanced through the canal until the signs of *'Apex'* for Propex II (Dentsply, Ballaigues, Switzerland), *'0.0'* for Propex Pixi (Dentsply, Ballaigues, Switzerland), *'0.0'* for Dentaport ZX (Morita, Kyoto, Japan) and *'0.0'* for DTE Dpex V (Woodpecker, Guangxi, China) were seen on the screen of EALs.
After seeing these signs remained constant for 5 sec on the screen of the devices, the rubber stopper was fixed. Then the distance between the rubber stopper and file tip was measured with an endometer and the EL was recorded. This procedure was repeated for 7 groups for different irrigation solutions at different days. All measurements were performed by a single op-

erator by repeating 3 consecutive times for each tooth.
The irrigation solutions were freshly prepared and groups were divided according to the irrigation solution to be used. Measurements of ELs were obtained under dry condition and after irrigation with 5 mL of the solutions:
Group 1 (Control Group). In this group, after each teeth were dried with paper-points measurements of EL were recorded using 4 different EALs.
Group 2 (1% NaOCl). 5 mL of 1% NaOCl was used as irrigation solution in this group. EL measurements were recorded for this group using the same electronic measurement method.
Group 3 (2.5% NaOCl). 5 mL of 2.5% NaOCl was used as irrigation solution in this group. EL measurements were recorded for this group using the same electronic measurement method.
Group 4 (5% NaOCl). 5 mL of 5% NaOCl was used as irrigation solution in this group. EL measurements were recorded for this group using the same electronic measurement method.
Group 5 (2% CHX). 5 mL of 2% chlorhexidine (CHX) was used as irrigation solution in this group. EL measurements were recorded for this group using the same electronic measurement method.
Group 6 (17% EDTA solution). 5 mL of 17% EDTA was used as irrigation solution in this group. EL measurements were recorded for this group using the same electronic measurement method.
Group 7 (17% EDTA gel). 5 mL of 17% EDTA gel was used as irrigation solution in this group. EL measurements were recorded for this group using the same electronic measurement method.
After each irrigation solution, the roots were washed with 5 mL of distilled water and dried with a paper point before using the next solution.

Statistical Analysis
The difference was calculated by subtracting the WL from the EL for each tooth.
Negative values (-) indicated a shorter response than recorded value, and positive values (+) indicated a more advanced response from recorded value. In the statistical evaluation, it was investigated how much the differences between recorded value and EALs value and the obtained WL deviated from the resorption area (*0 points) and whether this deviation was significant. The accuracy of WL determination methods was compared within the tolerance range of ±0.5 mm. The possible differences between the percentages of acceptable measurements obtained by EALs was analysed by the chi-square test. In order to control for type 1 error, Bonferroni correction was used in pairwise comparisons using standard statistical software (SPSS 25.0). For all tests, the significance level was set to 5%.

Results

In this study, 10 mandibular molars with mesial root canal curvatures between 30-50 degrees and 10 maxillary incisors with straight root canals were evaluated with 4 different EALs. As shown in Table 1, a total of 70 measurements were recorded for 10 molars and 10 incisors in the presence of 7 different solutions. A significant difference was found for Propex-Pixi and DTE Dpex V. Propex-Pixi and DTE Dpex V were more successful in straight root canals than curved ones (P <0.05). There was no significant difference for Propex II and Dentaport ZX. Propex II and Dentaport ZX had more successful measurements in straight root canals than curved ones, with the success rate of 57.1% and 64.3%, respectively.
When EALs accuracy was compared in 40 measurements in presence of different irrigation solutions, there was a significant difference in the Control group and Group 5 (2% CHX) as is shown in Table 2. In these groups, EALs were found significantly more successful at incisors with straight root canals than at molars with curved canals (P <0.05). In other groups there was no significant difference. For incisor teeth, Group 7 (EDTA gel) had the most successful results with a success rate of 77.5% and Group 2 (1% NaOCl) had the lowest success rate (55%). For molars, Group 7 (EDTA gel) had the most successful results with a

Table 1

Comparison of the accuracy of four different EALs in curved molar and straight incisors in ± 0.5 mm tolerance range (with each device, 70 measurements were made for 10 molars and 10 incisors in the presence of 7 different solutions)

EAL	Molar		Incisor		p-value
	%	n	%	n	
Propex II	41.4%	29[a]	57.1%	40[a]	0.063
Propex-Pixi	54.3%	38[a]	74.3%	52[b]	0.014
Dentaport ZX	55.7%	39[a]	64.3%	45[a]	0.301
DTE Dpex V	48.6%	34[a]	70.0%	49[b]	0.010

**The lowercase letters indicate the difference between the molars and incisors for each EAL.*

Table 2

Comparison of the accuracy of EALs in curved molar and straight incisors in ± 0.5 mm tolerance range according to the presence of different irrigation solutions (in each group, 40 measurements were made for 10 molars and 10 incisors with 4 EALs)

Group	Molar		Incisor		p-value
	%	n	%	n	
Control	42.5%	17[a]	67.5%	27[b]	0.025
1% NaOCl	42.5%	17[a]	55.0%	22[a]	0.263
2.5% NaOCl	57.5%	23[a]	62.5%	25[a]	0.648
5% NaOCl	52.5%	21[a]	57.5%	23[a]	0.653
2% CHX	37.5%	15[a]	75.0%	30[b]	0.001
17% EDTA	52.5%	21[a]	70.0%	28[a]	0.108
EDTA gel	65.0%	26[a]	77.5%	31[a]	0.217

**The lowercase letters indicate the difference between the molars and incisors within each group.*

success rate of 65% and Group 5 (2% CHX) had the lowest success rate (37.5%).

Discussion

Apical constriction is generally a narrowest portion of the root canal system and may vary widely in shape. CDJ, the point where pulp tissue ends and periodontal tissue begins, is the ideal point for working length. However, CDJ and apical constriction could not always coincide. Therefore operators use various methods to obtain an accurate working length such as tactile sense, radiographic methods, or EALs (5). For this reason to evaluate the accuracy of EALs, the ± 0.5 mm tolerance range was accepted. This tolerance range is considered highly accurate and clinically acceptable by previous studies (20-23).
Materials used for the embedding of extracted human teeth should have similar electroconductive and colloidal consistency as the periodontal ligament.

Many studies used agar-agar, gelatin, alginate, or saline solution for *in vitro* EAL studies (16, 18, 34). Alginate models have favored materials because of their firm consistency that prevents intrusion of material, good electroconductive property, inexpensive and easy preparation. Also, the stiffness of alginate prevents fluid movement inside to canal that can cause premature electronic readings (18). Due to these advantages, alginate mold was used in this study to mimic as much as possible the periodontal tissue.

Irrigation solutions take an important role in RCT. However, there are still concerns that solutions may affect EALs accuracy (5, 24-29). NaOCl is the most popular and universally accepted irrigation solution with the capacity for disinfection and dissolution of organic tissue. NaOCl is commonly used in concentrations between 0.5% and 6% (30). On the other hand, CHX is generally used to disinfect the root canals and is commonly used in 0.2-2% concentrations and 17% EDTA is used as a chelator to remove the smear in routine RCT (31). Therefore, the most commonly used irrigation solutions were preferred in this study.

Khattak et al. (24) have reported CHX has a lesser effect than NaOCl on ProPex II. Ozsezer et al. (5) showed that in the presence of CHX solution, closer measurements to AL were obtained with ProPex II than in the presence of NaOCl. In another *in vitro* study by Jain et al. (26) evaluated the efficacy of Root ZX and Propex II in the presence of 1% NaOCl and 2% CHX, CHX had more successful measurements. Also, Khursheed et al. (25) obtained the best results in presence of CHX. In this study, successful measurements were obtained with the presence of CHX solution for incisors with straight root canals as well. However, the lowest success rate was obtained in Group 5 for molar teeth with curved root canals. This inconsistency may be explained by anatomical variation of molars.

In the presence of NaOCl solution, regardless of the concentration of the solution, WL measurements were the least successful. A possible explanation of these short measurements could be the high electroconductive property of NaOCl (27). Previous studies showed that solutions with high electroconductive properties reduce the impedance of EALs and cause a decrease in WL whereas low electroconductive solutions are caused by over-instrumentation (32, 33). Altunbaş et al. (34) have been reported similar results that the percentage of accurate results was found decreased in the presence of NaOCl solution. Kobayashi et al. (35), and Fan et al. (16) reported that high electroconductive solutions such as NaOCl can cause short measurements. On the other hand, previous *in vitro* studies (24, 29) indicated that the accuracy of EALs was not influenced by the concentration of NaOCl which is consistent with the results in this study.

Oliveira et al. (36) tested 5 different EALs including Propex-Pixi and ProPex II and indicated that the best results were obtained when the file reached to apical foramen without passing beyond this point. Therefore, the EL measurement was recorded at the point where the signal to reach the apical foramen was seen on the screen of EALs.

Somma et al. (37) compared the accuracy of Dentaport ZX, Raypex 5, and ProPex II and reported that there was no significant difference among EALs. This result for Dentaport ZX and ProPex II was in accordance with the present study. However, Mancini et al. (38) reported that Dentaport ZX showed less accuracy than ProPex II in the study that evaluated the accuracy of EALs in anterior and posterior teeth. In the present study, there was no significant difference between Dentaport ZX and Propex II. This inconsistency could be explained by the different experimental set-ups and conditions of the root canal system.

Sadeghi et al. (18) reported that successful measurements of actual WL with ± 0.5 mm tolerance range were 70% for straight canals and 35% for curved canals. Also, Wrbas et al. (39) reported that the determination of WL in anterior teeth with ± 0.5 mm tolerance range was 80%. These results are consistent with the present study. The accuracy of EALs decreased in curved posterior teeth. This situation can be clarified by reducing the taper and the diameter of an apical foramen in curved root canals affect the EL measurements.

Mandibular molar teeth are considered to have more apical variations and deltas. Keleş et al. (40) reported that mesial roots of mandibular molar teeth have apical deltas that can reach up to 2 mm. These anatomical variations are difficult to disinfect, later on can cause reinfection of the root canal system and also can affect working length determination of EALs.
In this study, there were statistically different results obtained among the irrigation solutions, canal curvatures, and EAL measurements. Therefore, the null hypothesis was rejected.
This study has some limitations such as the absence of intraoral electroconductive fluids and periodontal ligament due to its *in-vitro* setup. Although teeth had occlusion reduction in order to obtain a reference point, it is challenging to obtain similar WL within each tooth. Other limitations of this study are anatomical variations of extracted teeth and the difficulty of standardization of curvature angles. Even though the curvature angles are standardized with Schneider's method, it is difficult to obtain exactly a 30°-50° angle with extracted teeth.
In literature, there are few studies that focused on the accuracy of EALs on curved and straight root canals. Therefore, the results of this study should be verified by clinical studies.

Conclusions

All EALs used in the present study performed more successfully in straight canals than in curved canals, even though the only significant difference was found for Propex-Pixi and DTE Dpex V. In addition, electronic measurements of molar teeth with curved canals are adversely affected in the presence of CHX and when the root canals are dry.

Clinical Relevance

The accuracy of electronic apex locators is the most commonly used method for determining the working length in endodontic treatments, in the presence of different irrigation solutions and tooth types.

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Conflicts of interest

The authors have no declared financial interests in any company manufacturing the types of products mentioned in this article.

Ethics Approval

The Clinical Research Ethics Committee of Akdeniz University in Antalya, Turkey reviewed and approved the study design (decision number KAEK-475).

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ORIGINAL ARTICLE

Immunohistochemical analysis of Biodentine versus MTA in repair of furcation perforation: an animal study

ABSTRACT

Aim: *This study compared Biodentine (BD) and mineral trioxide aggregate (MTA Angelus) in repair of furcation perforation (FP) in terms of inflammation and new hard tissue formation.*
Methodology: *Ninety-six teeth in six adult mongrel dogs were divided into two equal groups (48 teeth/3 dogs each) according to the time of repair; immediate and delayed repair of the induced FP. These groups were divided into three subgroups (16 teeth each) according to the evaluation period; 1, 2, and 3 months. Each subgroup was further subdivided into four subdivisions according to the FP repair material used; MTA Angelus (6 teeth), BD (6 teeth), negative control (2 teeth) and positive control (2 teeth). Instrumentation, obturation and FP were performed in the experimental and positive control teeth. The perforations were sealed according to the groups and subdivisions. Histopathology and immunohistochemical analysis using Osteonectin antibodies were performed for assessment of the inflammatory cell count and new hard tissue formation. All data were statistically analyzed.*
Results: *In all groups and subgroups, there were no significant differences between MTA and BD in the inflammatory cell count and new hard tissue formation (P>0.05).*
Conclusion: *Compared to MTA Angelus as a FP repair material, Biodentine induces similar degree of inflammation and new hard tissue formation.*

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Introduction

Furcation perforation (FP) may happen during opening an endodontic access as a result of a bad direction of the bur, or at post space preparation and localization of the calcified canals (1).
The prognosis of FP depends mainly upon its size, site, the duration between the defect creation and repair, and the degree of periodontal damage. Therefore, immediate therapy using suitable filling material is essential to avoid the complications, and to enhance favorable prognosis. (2).
The ideal filling material used for treatment of the FP should have an efficient sealing ability and enhance the new hard tissue formation. Numerous filling materials have been used for FP repair. These materials include both manufactured cements such as; MTA, Bioaggregate and Biodentine and natural biological materials such as; platelet rich plasma and platelet rich fibrin (3-6).
MTA is commonly applied FP repair material because it has good biocompatibility and sealing ability as well as low bacterial leakage and cytotoxicity (7). However, MTA has few shortcomings such as delayed setting (3h), less applicability, discoloration and expensiveness (3-6).
Recently, BD has been developed for endodontic repairs like perforations, apexifications, resorptive tissues and retrograde filling cement (8). BD has the same characteristics of MTA, but it has faster setting time and better applicability (5-8).
To improve the physical properties of BD, a modified chemical constitution, addition of setting accelerators and softeners, and a predosed capsule were carried out (8,9). There are scarce studies on BD as a treatment for the FP, mostly *in vitro* studies (6,10). The hypothesis of this study was that Biodentine can alternate MTA for treatment of the FP. Therefore, the present study compared BD and MTA in repair of furcation perforation in dogs in terms of inflammation and new hard tissue formation through histological as well as immunohistochemical evaluations.

Material and Methods

Animal model
This study was accepted by the Ethics Committee at Faculty of Dentistry, Ain Shams University, Egypt (Protocol number 15-12-13-Endo). All international and institutional guidelines for animal use and care were followed up in the current study. Ninety-six premolar and molar teeth in six adult mongrel dogs were selected. These dogs were 2-3 years old, 15-20 kg, and clinically normal. All selected teeth were healthy with complete root development. These dogs were randomly divided according to the time of repair into two groups (48 teeth/three animals each); immediate (group I) and delayed repair (group II). Based on the evaluation periods, the main groups were divided into three subgroups (16 teeth each); one month (subgroup 1), two months (subgroup 2), and three months (subgroup 3). Each subgroup was further subdivided into four subdivisions according to the material used; MTA Angelus (subdivision A, n=six teeth), BD (subdivision B, n=six teeth), negative control (subdivision C, n=two teeth) and positive control (subdivision D, n=two teeth).

Creation of furcation perforations
The dogs were pre-medicated with subcutaneous Atropine sulphate (Atropine sulphate 1%®, ADWIA, Egypt) at a dose of 0.05 mg/kg and intramuscular Xylazine HCl (Xylaject 2%®, ADWIA, Egypt) at a dose of 1mg/kg. The anesthesia was induced by intravenous Ketamine HCl (Keiran®, EIMC Pharmaceuticals Co., Egypt) at a dose of 5mg/kg. The anesthesia was then maintained by intravenous Thiopental sodium 2.5% solution (Thiopental sodium®, EPICO, Egypt) at a dose of 25 mg/kg (dose to effect). Access cavity and exposure of the pulp chamber were carried out in both experimental and positive control teeth by using a #4 round bur (Dentsply maillefer, Ballaigues, Switzerlad) with conventional speed hand piece mounted on an electric micromotor. Removal of the pulp tissue by a large spoon excavator and instrumentation of the root canals by hand files and crown down technique were performed. A K-file

#15 (Root ZXII – J Morita – Japan) was placed until the limit of cemento-dentinal junction with watch winding motion and working length was confirmed by apex locator (Dentsply Maillefer, Balaigues, Switzerlad). The mechanical preparation was done by step back technique until master apical file ranging 40-55 according to the size of the initial file. Irrigation of the root canal with normal saline solution was carried out after each file. Master cones were placed. Obturation of the root canal was performed by the cold lateral condensation technique with Gutta percha core and Endo-fill cement as a sealer (Dentsply Maillefer, Balaigues, Switzerlad).
A 1.4 mm-diameter furcation perforation was done by a #4 round bur at low speed hand piece in the center of the pulp chamber floor in both experimental and positive control subgroups until the hemorrhage was noted. The perforation depth was limited to 2 mm into the alveolar bone by a rubber stopper. Hemostasis was performed by irrigation with normal saline solution and drying by the paper points. For confirmation of the furcation perforation, radiographs were taken.
In the group II (delayed repair), the perforation sites were left open for a month to induce bacterial infection and inflammatory lesion in the furcation area (4). The perforation sites were immediately sealed in group I (immediate repair).

Perforation repair

- Subdivision IA

Angelus MTA (Angelus, Londrina, PR, Brazil) was mixed according to the manufacturer's instructions. One part of water was mixed gradually to 3 parts of the powder using MTA mixing plastic stick. The paste was carried out into the perforation sites by a small amalgam carrier and compacted with a suitable size plugger. The access cavity was closed by chemical cured Glass ionomer (Ivoclar vivadent pvt. Ltd., India). Radiographs were taken to confirm the perforation repair.

- Subdivision IB

Biodentine (Septodont, USA) was mixed according to the manufacturer's instructions. The capsule was tapped on a hard surface then, opened and placed on the white capsule holder. Five drops of the liquid were poured into the capsule then; the capsule was closed and placed on the amalgamator at a speed of 4000 rotations/min for 30 seconds to obtain a thick consistency. The material was transferred to the perforation sites by a small amalgam carrier and compacted with a suitable size plugger. The same steps for filling of the access cavity and radiography were carried out as in subdivision IA.

- Subdivisions IIA and IIB

At the end of the infection time, the dogs were re-anesthetized, and radiographs were taken for confirmation of the induced furcal lesion. The perforation site was cleaned by using a small spoon excavator for removal of necrotic and inflamed tissues. Cleaning of the perforation site was carried out with normal saline. After drying the sites with paper points, the perforations were treated with angelus MTA and BD as previously described subdivisions IA and IB.

- Positive control subdivision

The perforations were kept open with no filling.

- Negative control subdivision

Intact teeth were left without perforation to show the normal histology.

Histological evaluation

At the end of each observation time, each dog was sacrificed by anesthetic overdose (20 mL of 5% Thiopental sodium solution). Each experimental and control tooth was sectioned with its surrounding bone for preparation for histological evaluation. Fixation of the blocks was carried out in 10% buffered formalin solution for 2 weeks. After decalcification of the samples in17% EDTA solution for 120 days, the samples were prepared as usual for histopathology. The blocks were cut in buccolingual sections of 6um thickness. These specimens were stained by hematoxylin and eosin dye for assessment of the inflammatory cell count as follows: three representative fields in each slide were evaluated at x200 magnification power. These fields had well-preserved architecture, no artifacts and intense inflammatory cells.

Image analysis software was applied to count the total inflammatory cells.

Immunohistochemical evaluation
Immunohistochemical staining was performed using Osteonectin antibody. Immunohistochemical analysis was applied by using anti-Osteonectin antibody to identify the new hard tissue. The sections were deparaffinized in xylene. Antigen retrieval was carried out using citrate (pH 6.0) in a microwave oven followed by blocking of endogenous peroxidase using a solution of 50% Methyl alcohol and Hydrogen peroxide (1:1). The samples were incubated in bovine serum albumin (BSA) for 1h inside a moist chamber to block nonspecific antigens. Samples were incubated with the primary antibodies (1:400, overnight at the room temperature) followed by incubation with a secondary antibody (Universal LSAB TM Kit, DAKO, Carpinteria, CA, USA) for 30 min. A final incubation was performed using the tertiary complex Streptavidin peroxidase (Universal LSAB TM Kit, DAKO, Carpinteria, CA, USA) for an additional 30 min. The reaction was seen using diaminobenzidine (Universal LSAB TM Kit, DAKO, Carpinteria, CA, USA). Counterstaining was performed using Mayer's hematoxylin, and the specimens were mounted in Permount. The new bone formation was evaluated according to Alhadainy *et al.* (11). Briefly, Scores 0, 1, 2 and 3 represented no, slight, moderate and heavy bone formation, respectively.

Statistical analysis
Numerical data were presented as mean and standard deviation (SD) values. Inflammatory cell count data showed normal (parametric) distribution. One-way ANOVA was applied for comparison between the inflammatory cell counts in the groups, subgroups and subdivisions. Tukey's post-hoc test was applied to pair-wise compare between the groups when ANOVA test was significant.
For non-parametric data, Kruskal-Wallis test was applied for comparison between the groups, subgroups and subdivisions. Mann-Whitney U test was applied for pair-wise comparisons between the groups when Kruskal-Wallis test was significant. Prevalence of new hard tissue formation was presented as frequencies and percentages. The significance level was set at $P<0.05$. The statistical analysis was carried out with SPSS statistics version 20 for windows (IBM Corporation, NY, USA).

Results

Histological findings
The data are presented in table (1) and figure (1). A significant difference was seen in the inflammatory cell count between the group I (immediate repair) and group II (delayed repair) in all subgroups ($P<0.05$).
No significant difference was noticed in the inflammatory cell count between subdivision A (MTA Angelus) and subdivision B (BD) in both groups ($P>0.05$). There was a significant difference in the inflammatory cell count between subgroup 1 (one month), subgroup 2 (two months) and subgroup 3 (three months) in groups I and II ($P<0.05$).
In positive control, there was a significant difference in the inflammatory cell count between subgroup 1 and each of subgroup 2 and subgroup 3 ($P<0.05$). However, no significant difference was found between subgroup 2 and subgroup 3 ($P>0.05$).
In negative control, no significant difference was seen in the inflammatory cell count between subgroup 1, subgroup 2 and subgroup 3 ($P>0.05$).
A significant difference was noticed in the inflammatory cell count between subgroup 1, subgroup 2 and subgroup 3 in both MTA Angelus and BD subdivisions ($P<0.05$).

Immunohistochemical findings
The data are presented in Table (2) and figures (2-4). Both positive and negative control exhibited zero score in the new hard tissue formation. A significant difference was recorded in the new hard tissue formation between group I and group II in both MTA Angelus and BD subdivisions ($P<0.05$).
In group I and group II, no significant differences were reported in the new hard tissue formation between MTA Angelus and BD subdivisions ($P>0.05$).
A significant difference was seen in the

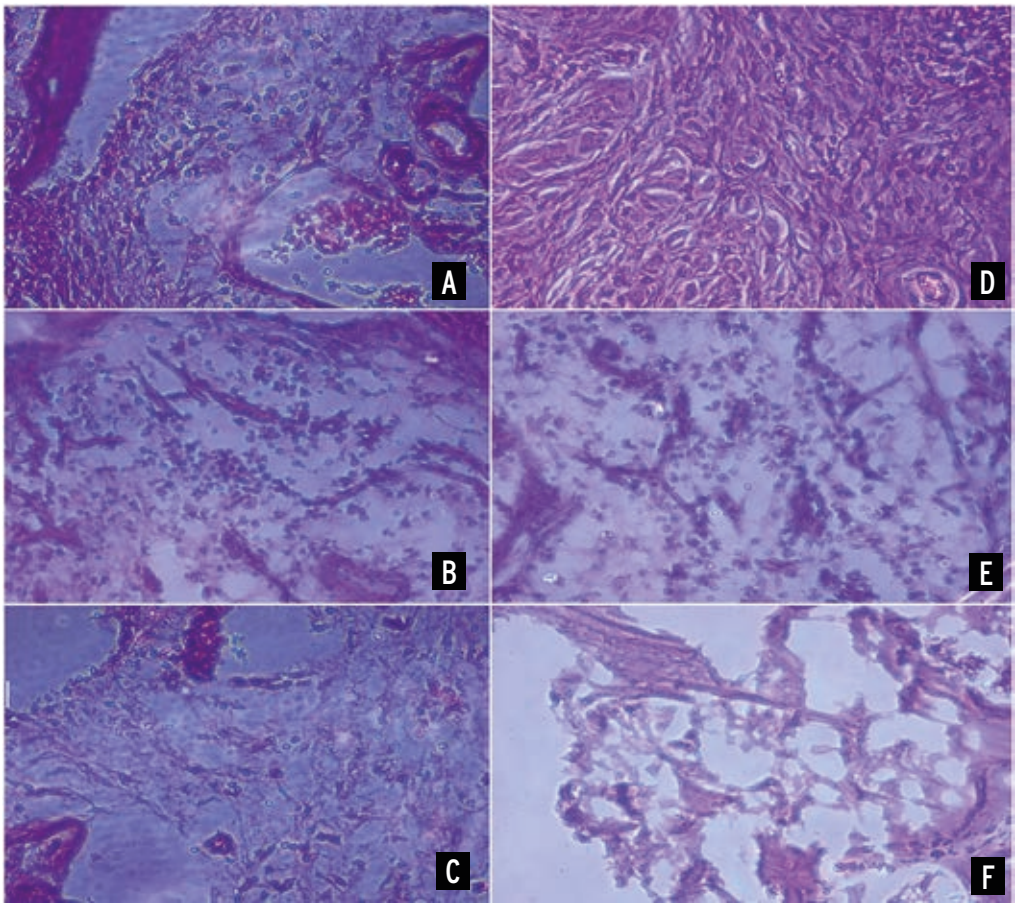

Figure 1
Representative photomicrographs of group II showing mild **(A)**, moderate **(B)** and severe **(C)** inflammatory reaction in the MTA subdivision after 1, 2 and 3 months, respectively. Representative photomicrographs of group II showing mild **(D)**, moderate **(E)** and severe **(F)** inflammatory reaction in the Biodentine subdivision after 1, 2 and 3 months, respectively (H&E, X 200).

Table 1

The mean and standard deviation (SD) values of the inflammatory cell count in different groups, subgroups and subdivisions

Subdivisions	Group I (Immediate sealing)			Group II (Delayed sealing)			P-value
	Subgroup 1 (One month)	Subgroup 2 (2 months)	Subgroup 3 (3 months)	Subgroup 1 (One month)	Subgroup 2 (2 months)	Subgroup 3 (3 months)	
MTA	714.17±7.88^{Ab}	511.67±14.3^{Bb}	296.67±6.41^{Cb}	755.67±10.23^{De}	546.00±10.64^{Ee}	311.67±9.33^{Fe}	≤0.001*
BD	702.50±16.33^{Ab}	504.50±7.89^{Bb}	292.83±8.95^{Cb}	735.17±10.80^{De}	536.17±9.64^{Ee}	317.67±5.20^{Fe}	≤0.001*
Positive	842.50±3.54^{Aa}	922.00±14.14^{Ba}	962.50±3.54^{Ba}	860.50±4.54^{Dd}	945.00±15.14^{Ed}	992.51±3.54^{Ed}	≤0.001*
Negative	61.02±1.42^{Ac}	69.00±1.41^{Ac}	64.03±1.44^{Ac}	65.02±1.62^{Df}	71.00±1.61^{Df}	74.03±1.64^{Df}	≤0.001*
P-value	≤0.001*	≤0.001*	≤0.001*	≤0.001*	≤0.001*	≤0.001*	

Means with different capital letters in the same row indicate significant difference.
Means with different small letters in the same column indicate significant difference.
**Significant at P<0.05.*
NS: non significant.

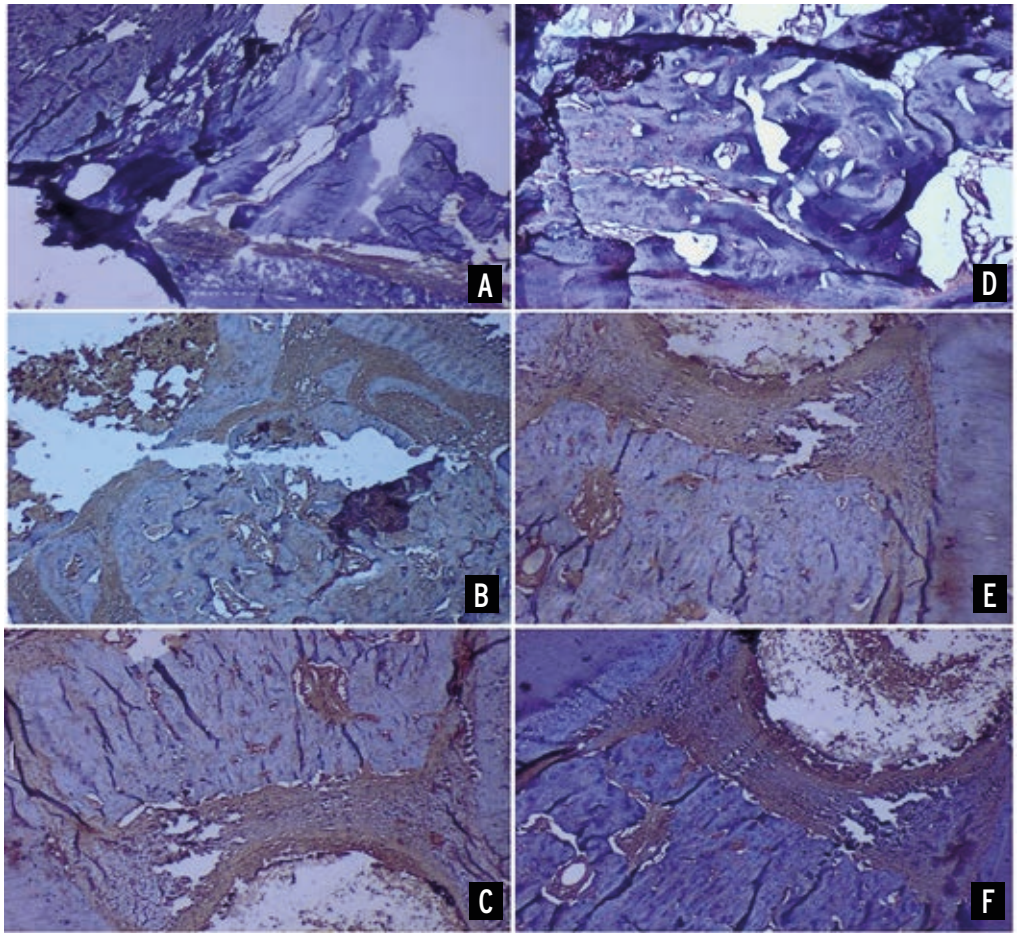

Figure 2
Representative photomicrographs of Osteonectin section of group I showing mild **(A)**, moderate **(B)** and dense **(C)** new bone formation at the FP site in the MTA subdivision after 1, 2 and 3 months, respectively. Representative photomicrographs of Osteonectin section of group I showing mild (**D)**, moderate **(E)** and dense **(F)** new bone formation at the FP site in the Biodentine subdivision after 1, 2 and 3 months, respectively.

Table 2

The mean and standard deviation (SD) values of the new hard tissue formation scores in different groups, subgroups and subdivisions

Subdivisions	Group I (Immediate sealing)			Group II (Delayed sealing)			P-value
	Subgroup 1 (One month)	Subgroup 2 (2 months)	Subgroup 3 (3 months)	Subgroup 1 (One month)	Subgroup 2 (2 months)	Subgroup 3 (3 months)	
MTA	1.67±0.52^{Aa}	2.50±0.55^{Ba}	3.00±0.00^{Ca}	1.00±0.00^{Dd}	1.67±052^{Ed}	2.17±0.41^{Ed}	≤0.001*
BD	1.67±0.52^{Aa}	2.83±0.41^{Ba}	3.00±0.00^{Ba}	1.00±0.00^{Dd}	2.00±0.63^{Ed}	2.33±0.52^{Ed}	≤0.001*
P-value	1 Ns	0.241 Ns	1 Ns	1 Ns	0.336 Ns	0.523 Ns	

Means with different capital letters in the same row indicate significant difference.
Means with different small letters in the same column indicate significant difference.
**Significant at P<0.05).*
Ns: non-significant at P>0.05.

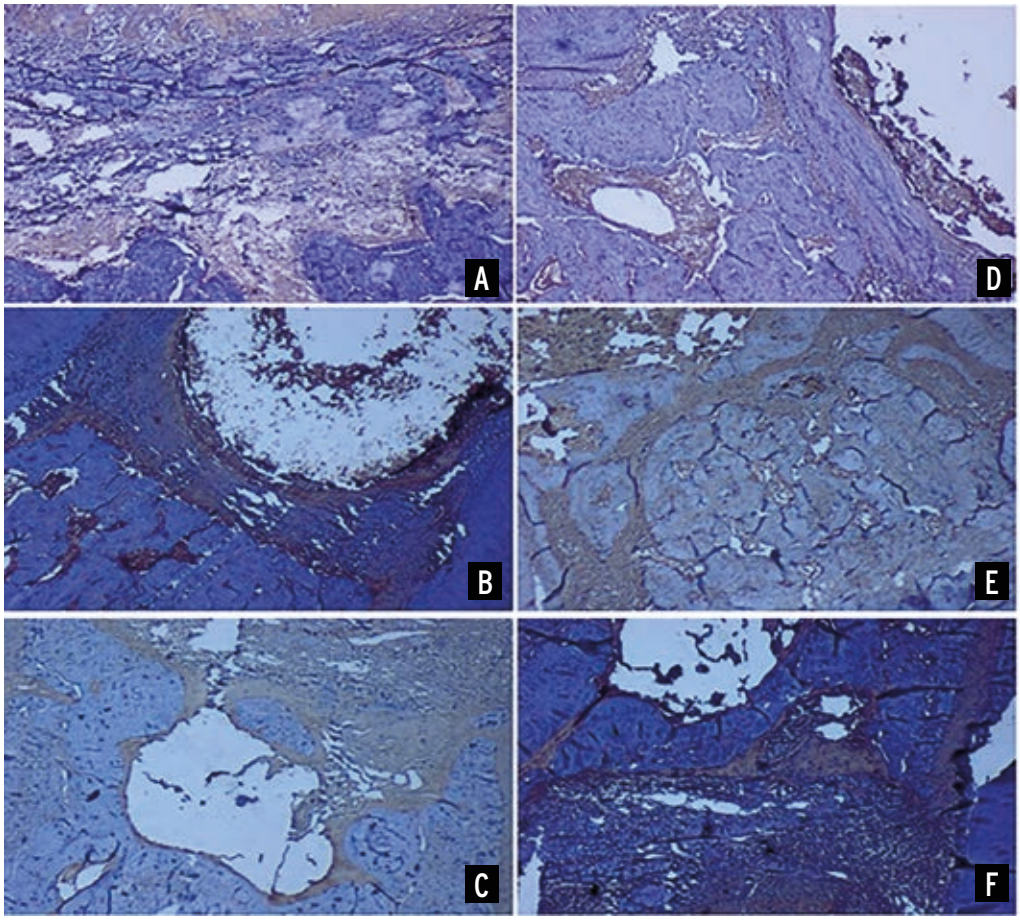

Figure 3
Representative photomicrographs of Osteonectin section of group II showing mild **(A)**, moderate **(B)** and dense **(C)** new bone formation at the FP site in the MTA subdivision after 1, 2 and 3 months, respectively. Representative photomicrographs of Osteonectin section of group II showing mild **(D)**, moderate **(E)** and dense **(F)** new bone formation at the FP site in the Biodentine subdivision after 1, 2 and 3 months, respectively.

new hard tissue formation between subgroup 1, subgroup 2 and subgroup 3 in MTA Angelus subdivision of group I ($P<0.05$). Significant differences were reported between subgroup 1 and subgroup 2 and subgroup 3 in BD subdivision of group I ($P<0.05$). However, no significant difference was noticed between subgroup 2 and subgroup 3 in BD subdivision of group I ($P>0.05$). In group II, significant differences were recorded in the new hard tissue formation between subgroup 1 and subgroup 2 as well as subgroup 3 in both MTA Angelus and BD subdivisions ($P<0.05$). There was no significant difference between subgroup 2 and subgroup 3 in both MTA Angelus and BD subdivisions ($P>0.05$).

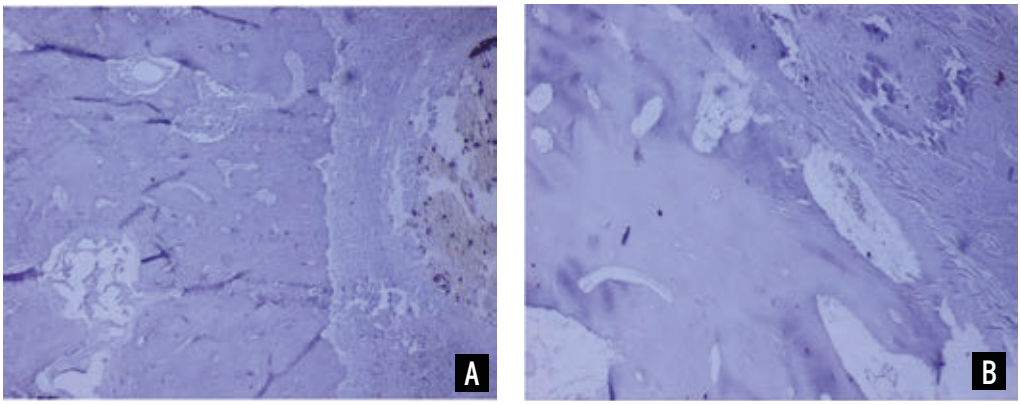

Figure 4
Representative photomicrographs of Osteonectin section showing no bone formation at the FP site in the control positive subdivision in group I **(A)** and group II **(B)**.

Discussion

During treatment of FP, using of an ideal repair material is an important factor for good prognosis. The FP repair material should have the abilities of good sealing and induction of new hard tissue (3, 4). This study compared BD against MTA as a FP repair material. According to the present results, the hypothesis of this study is accepted and BD can alternate MTA in the repair of FP.

In last few years, BD has been simplified the clinical techniques due to its superior mechanical properties and faster setting time compared with other calcium silicate-based materials (12).

MTA is considered as a gold standard material for the FP repair because it has favorable biocompatibility and sealing ability (7). Therefore, we compared BD with MTA in the present study.

The iatrogenic FP is considered as one of the most serious complications of endodontic therapy that may lead to unsuccessful treatment of the root canal. Also, FP may occur pathologically by dental caries or resorption (13). Therefore, the present study assessed both immediate and delayed sealing of the FP to simulate both types of clinical cases.

Biocompatibility and bioactivity of the FP repair materials are major properties that should be taken in consideration because the material is in close contact with the vital tissues during the procedure and can affect the viability of the periradicular cells (10,14). Therefore, this study evaluated the inflammatory cell count and new hard tissue formation induced by both MTA and BD.

The selection of dogs in the present study is based on the facts that the dog has a comparative apical repair mechanism with human in shorter duration and the good accessibility and visibility of their dental roots and roots furcation (15,16). However, the roots furcation is present at 1-2 mm from the cemento-enamel junction (CEJ) in dogs (17). Therefore, any technique produces acceptable outcome in dogs may produce a more acceptable result in humans because the distance from the CEJ to the furcation is more prominent (17).

Similarly to previous studies, the perforation size in this study was standardized at 1.4 mm (3, 4, 18, 19). The alveolar bone was penetrated for 2 mm to induce the inflammatory response. Also, leaving the FP open for one month for saliva contamination was another cause for induction of inter-radicular lesion in the group II (4, 20).

Two evaluation methods (Histological and immunohistochemical methods) were applied in the current study to overcome the shortcomings of each method. These methods showed various degrees of osteoblastic and osteoclastic reactions that indicate a bony reaction to the various treatments. Immunohistochemical analysis was performed using Osteonectin antibody. Osteonectin is a non-collagenous protein of bone that shares in the osteoid maturation and mineralization (21). Therefore, immunohistochemistry with polycolonal Osteonectin antibodies shows a high specific marking of actively matrix-producing osteoblasts (21).

Biodentine has almost similar physicochemical properties of MTA (10, 22, 23). Therefore, it was not surprising that there were no significant differences in the inflammatory cell count and new hard tissue formation between the MTA and BD when used as FP repair materials in the present study. Similar findings were recorded in a recent study (24). MTA was able to repair the FP due to its antimicrobial action and its high pH (12.5) that enhances the cementogenesis and osteogenesis (25).

It was not surprising that no significant difference was recorded between the group I (immediate sealing) and group II (delayed sealing). The time of repair plays an important role in the repair of FP due to the crucial role of infection (3,4).

After one month, both MTA and BD samples exhibited high inflammatory cell count but statistically less significant than that in the positive control. This was explained by the inadequate time for repair of the defect. Similar findings were recorded before in several studies (26, 27).

After two and three months, the positive control samples exhibited significant highest mean of inflammatory cell count com-

pared to MTA and BD samples. This could be attributed to the presence of microorganisms and continued inflammatory reaction in the positive control samples due to direct communication with the oral cavity. On the other hand, MTA and BD samples exhibited a significant lower mean of inflammatory cell count than that of the positive control due to the sealability, biocompatibility, and alkaline pH of the repair materials. This is in agreement with several previous results (24, 28-32). Quantitative field emission gun-scanning electron microscope (FEG-SEM) observations illustrated that there is no significant difference between Biodentine™ and ProRoot MTA in the mean gap at the dentin–furcation repair material interface (29). Moreover, calcium silicate materials have excellent effects on human periodontal ligament stem cells regarding cell adhesion and morphology (33).

The main limitations of this study were the small number of used teeth and relatively short times of evaluation. Therefore, future studies are recommended to evaluate the efficacy of BD as a furcation perforation repair material on a large sample size and for longer duration.

Conclusion

Compared to MTA as a FP repair material, Biodentine induces similar degree of inflammation and new hard tissue formation.

Clinical Relevance

Biodentine is an alternative to MTA when used as a furcal repair material.

Conflict of Interest

There are no conflicts of interest.

Acknowledgments

None.

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ORIGINAL ARTICLE

Hot modified technique: a novel modified obturation technique using biosealers

ABSTRACT

Aim: *This research aimed to test the actual temperature inside the root canal while the obturation phase was ongoing. Specifically, the obturation was done by the proposed heat-based technique with bioselaers.*
Materials and Methods: *This study tested the temperature evaluation. In the experiment, two premolars were utilised, and thermocouples of K-type one for each tooth were used. The Bonferroni method was conducted to compare the data collected from temperature.*
Results: *The experiment results showed that using the new obturation method, the heat did not reach the apical third.*
Conclusions: *Using the proposed modified hot obturation procedure, the temperature will not change the apical area. Consequently, this technique eludes inducing the fast setting for the biosealer.*

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KEYWORDS *obturation technique, biosealer, endodontic space, cleaning, root canal treatment.*

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Introduction

Achieving short and long-term success, the root canal treatment is chiefly founded on good three-dimensional (3D) cleansing of the endodontic system after completing the mechanical shaping. Afterwards, it is crucial to seal the complex endodontic system with complete 3D obturation (1-5).

When the anatomy of the endodontic system is described, it shows anatomical areas that can be accessible for the hand and rotating files (the main root canals) (6, 7). Contrarily, many researchers have shown that the endodontic system contains areas beyond the reach of mechanical tools (lateral canals, loops, ramifications, apical isthmuses, deltas, and dentinal tubules) (8-10). Therefore, more than mechanical shaping is required to reach all zones of the root endodontic system. Moreover, whatever the approach used in shaping the canal, leaving parts of the root canals untreated can occur (11, 12).

Accordingly, it is necessary to perform root canal chemical cleaning to disinfect both the accessible and unreachable spaces) (13, 14). Immediately when the zones mentioned above are cleansed (15-17), they can be obturated with gutta percha and sealer or the recently introduced sealers, the biosealer (18). Certainly, when the biosealers were initially marketed, it was with guidance to be utilised with only the single cone cold technique.

The biosealers can harden immediately when coming in contact with heat, hence, the recommendation mentioned above.

Conversely to the cold technique, the System-B-based approach implies heating to melt the gutta-percha after applying traditional sealer.

Eventually, the melted filling material will flow into the lateral anatomies and fill deeper the complex endodontic space better.

This research aimed to test the actual temperature inside the root canal while the obturation phase was ongoing using a new obturation method: Hot Modified Technique. The technique was developed to avoid causing any risk of chemical alteration of the bioseal. In addition, it aims to show some clinical cases where it is possible to see the difference between the single-cone and the hot-modified techniques.

Materials and Methods

Recently extracted human mandibular premolars (n=2) with intact coronal surfaces were selected for this study.

The selected teeth were extracted for an orthodontic treatment plan and were irrelevant to the current experimentation. The inclusion criteria were patients with age (18-25 years). On the contrary, the exclusion criteria were the existence of any root resorption, incomplete apices, any type of fracture or previous root filling. Before starting the experiment, informed consent was obtained from the patients.

The soft tissues connected to the teeth' exterior surface were pulled utilising a curette. Next, the samples were saved in separate vials containing 5 mL of 10% formalin till usage.

The teeth were prepared for the study by de-coronating them at the level of the cementoenamel junction to get the roots of a standardised length (18 mm). Then, a file size 10 K-type (Coltène/Whaledent, Altstätten, Swiss) was introduced in each root canal till it was visible from the apex.

The final working length was set by deducting 0.5 mm from that measurement. The canals were shaped with nickel-titanium rotating Ni-Ti files (Hyflex files EDM, Coltène/Whaledent, Altstätten, Swiss).

The files used in this study to prepare the canals were 10/0.05, 20/0.05, and 25/0.08 rotary files of Hyflex EDM were used till the full working length. After the final apical instrumentation, the size and taper of the apical area were 25/0.08. During canal instrumentation, irrigation

was performed with 5,25% NaOCl solution (Canal pro, Coltène/Whaledent, Altstätten, Swiss). The irrigation was done with a 30G needle in the syringe type (Canal pro irrigating tips, Coltène/Whaledent, Altstätten, Swiss).
The amount of NaOCl used for each tooth was 5 mL and refreshed each minute.
Later, each canal was flushed using sterile saline and then irrigated with 3 mL of chelating agent 17% of ethylenediaminetetraacetic acid (EDTA) (the canal pro EDTA, Coltène/Altstätten, Swiss); this step lasted for 1 min and aimed to get rid of the formed smear layer. Finally, all canals acquired the last rinse of 3 mL of sterile saline.

The temperature evaluation
Regarding the experimentation of temperature evaluation, two-second mandibular premolars were appointed. Then, two K-type thermocouples (ThermoWorks, Salt Lake City, Utah, US) were used for each tooth.
Regarding the thermocouples' fixation in teeth, the examiner drilled cavities utilising a diamond bur Type 196D.644.110 (Komet Dental, Trophagener Weg 25, 32657 Lemgo, Germany), the preparation was done from the external root surfaces until the root canals. The holes were positioned one at the apical foramen (Ta) and the other at 3 mm away from the apex (T3) (8). After the attachment of the thermocouples, the teeth were mounted using Duralay resin (Henry Schein Dental, Melville, New York, United States) in an aluminium tube. The temperature of the tooth environment was controlled and maintained at 37 °C using a thermally controlled heater (Jiu Tu, Baoan District, Shenzhen, China) supplied with an aluminium block.
To register the signals, the thermocouples were attached to the NI DAC interface (MOD National Instruments Corporation, Austin, TX, USA). The LabView system (National Instruments Corporation) registered the signals at a pace of 10 points per second for 300 s.
After fixing the thermocouples in place, the canal was obturated utilizing the System B appliance (Kavo Dental, Orange, California, United States). The master cone gutta-percha was standardized at the same lengths and size for both premolars (25/0.08 Coltène/Whaledent Altstätten, Swiss).
The biosealer chosen for the current experiment was bioseal (Coltène/Whaledent, Altstätten, Swiss), the bioseal syringe tip was placed 10 mm from the working length, and 2 mm of biosealer was injected in each tooth.
A single cone obturation technique was used in the first premolar (experiment A). The procedure included the insertion of the gutta-percha cone till the working length.
In Experiment B, the second premolar was obturated with the proposed hot modified technique, where the heat carrier tip X-Fine (30/04) (Kerr Dental, Orange, California, United States) at 180 °C was inserted 6 mm shorter than the working length. The time of down packing was of 4 s.

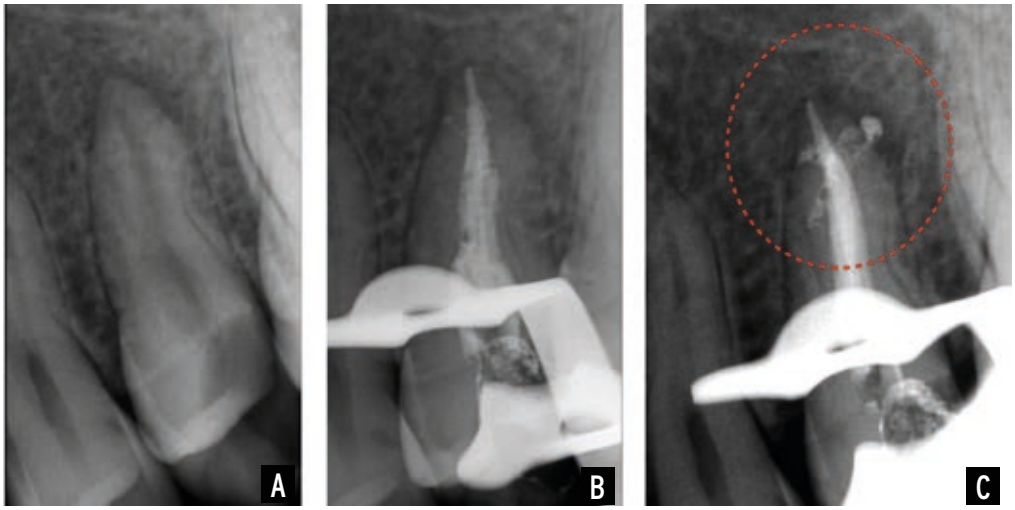
Data were statistically analyzed
Experiment analysis of variants through the OriginLab Pro7 software (Northampton, MA, USA) at a significance level of 0.05 utilizing the Bonferroni method was performed to compare the temperature data.
Some clinical cases done with this new technique are shown in Figures 1, 2 and 3.

Results

Using the novel obturation method, the results demonstrated that no heat reached the final apical 3 mm of the canal. The last apical 3 mm stayed at 37 °C.

Discussion

The current work aimed to compare the impact of the new obturation technique to the single cone method on the existing temperature in the apical region and its penetration in the lateral complexness of the root canal system.
Initially, when the Biosealers were pre-



Cold Singe Cone *Hot Modified Technique*

Figure 1
Endodontic treatment of 2.5 with irreversible pulpitis caused by a distal cavity. **A)** Pre-operative x-ray. **B)** Intra-operative x-ray where the gutta-percha cone was inserted with the biosealer using the single cone technique without heat and pressure. **C)** Hot modified technique, it's possible to see in the apical third, after the new obturation method, how the biosealer reached all the complexity.

sented, they came up with the recommendation to use the single-cone technique (18). Otherwise, the sealer can set faster if it comes in contact with heat.
The newly proposed obturation technique, described as the "hot modified technique", implicates utilising the bioceramics sealers in a 3D manner (19). The purpose was to push the sealer by creating coronal pressure to penetrate deeper than the single cone technique, the lateral anatomies.
Furthermore, the technique was done by first inserting the biosealer and the gutta percha cone inside the root canal. Then, the technique should follow similarly to the system B technique but with some modifications. Specifically, the difference was performing a faster down-packing movement at a decreased temperature of 180° to a maximum penetration depth of 6 mm away from the working length.
Compared to the single cone technique, the proposed hot-modified technique permits a better fill of the biosealer into the lateral anatomies such as lateral canals, isthmuses, loops, or even the dentinal tubules (20, 21). Furthermore, this work established that the heat does not approximate the apical third using the new approach. Thus, no alteration can occur to the biosealer created by the heat.

Conclusions

In conclusion, Bioceramics could lead to greater clinical success thanks to their beneficial characteristics such as

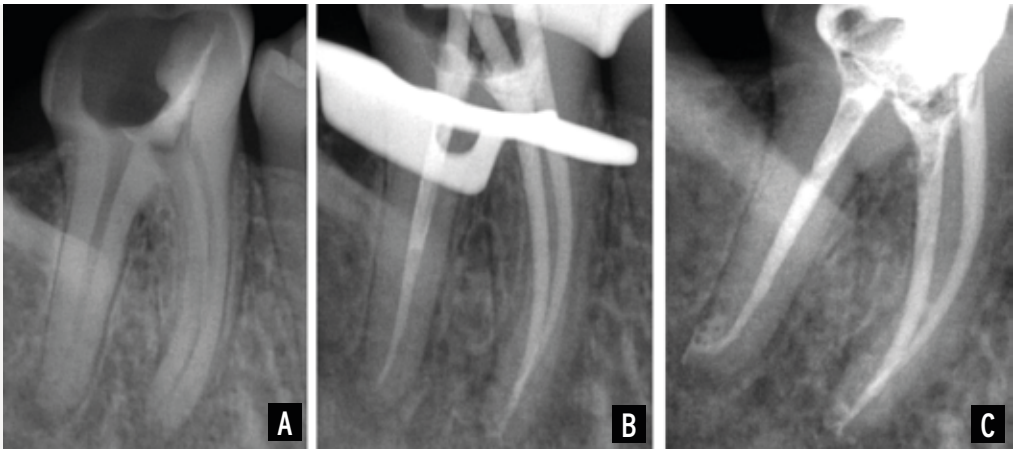


Figure 2
Endodontic treatment of 4.6 with necrosis caused by a deep occlusal cavity. **A)** Pre-operative x-ray. **B)** Intra-operative x-ray where the gutta-percha cone was inserted with the biosealer using the single cone technique without heat and pressure. **C)** Hot modified technique, it's possible to see in the apical thirds, after the new obturation method, how the biosealer reached all the complexity.

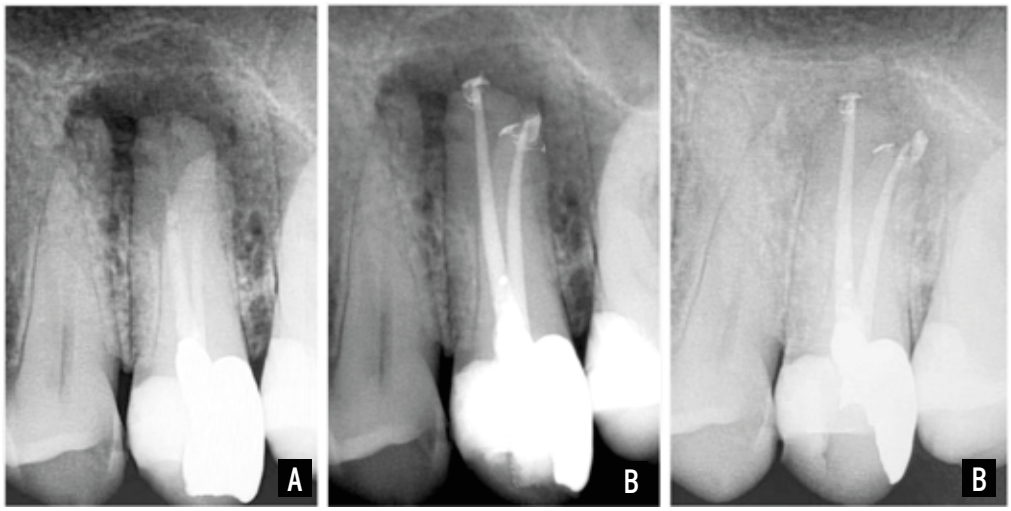


Figure 3
Non-surgical Endodontic Retreatment of 2.5 with periapical lesion.
A) Pre-operative x-ray.
B) Post-operative x-ray where the Hot Modified Technique was used: it's possible to see in the apical thirds, after the new obturation method, how the biosealer reached all the complexity.
C) 2 years follow-up showing good healing.

antibacterial actions, high biocompatibility, and micro-expansion reaching most of the complex endodontic space (18, 19).
Within this study's limits, the three-dimensional penetration of the biosealer in the lateral anatomy was significantly enhanced by employing the new obturation technique compared to the single cone technique.
Furthermore, utilising the heat carrier obturation method, the heat does not reach the apical region, eluding any risk of the immediate setting for the biosealer. Moreover, future investigations with different methods and biosealers can be necessary to verify these results.
Whether the new obturation method provides any significant advantage in improving clinical outcomes is yet to be confirmed.

Clinical Relevance

This technique allows using Bioceramic sealers with heat obturation, creating a three-dimensional seal.

Conflict of Interest

None.

Acknowledgements

None.

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REVIEW ARTICLE

Assessment of irrigation dynamics comparing syringe needle irrigation with various other methods of irrigation using computational fluid dynamics: a systematic review

ABSTRACT

The irrigation dynamics between conventional needle irrigation and other irrigation techniques were evaluated using computational fluid dynamics (CFD) in the current systematic review. Following the inclusion and exclusion criteria, three electronic databases (PubMed, Scopus and Cochrane) were searched until June 2022. Studies comparing conventional needle irrigation with various other techniques of irrigation were included. Two reviewers independently evaluated the retrieved articles. A total of 329 articles were obtained, from which 23 papers were included for full-text review. After exclusion of 18 studies, 5 articles were considered and included in the present systematic review. The risk of bias for in vitro studies was reported following modified JBI criteria and CRISS recommendations. The parameters assessed were shear stress, irrigant replenishment, velocity, turbulence, and apical pressures. It was observed that negative pressure irrigation technique was superior to positive pressure syringe needle irrigation, although the latter provided higher apical pressures.

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Introduction

The success of a root canal therapy largely depends on thorough disinfection. Syringe needles are most frequently used in daily practice for root canal irrigation (1, 2). When root canals are irrigated with traditional syringe needle irrigation, positive pressure is applied inside the canals (3). There are potential risks of irrigant extrusion beyond the periapical tissues in circumstances when an inadvertent breach of the apical foramen occurs, which could result in problems (4, 5)

Evidence from the literature stated that root canal disinfectant might not always reach the apical part of the canal when syringe needle irrigation techniques are employed (6-8). Additionally, studies revealed that the disinfectant solution has a very limited ability to penetrate canal complexities such as isthmus, lateral, and accessory canals (9, 10). Endodontic biofilm within the root canal should also be considered during the root canal treatment (11, 12). Dislodging the biofilm and improving disinfection are both crucial during root canal irrigation. Complete dislocation of the biofilm is impossible with the syringe needle irrigation solely (13). Since irrigation activation devices are negative pressure systems, they have been employed for better canal disinfection (14). Negative pressure irrigation devices improve the effectiveness of antimicrobial activity by enhancing the irrigant penetration into the apical third (15) and improving the biofilm dislodging within the root canal (16, 17). Additionally, studies have revealed that the root canal irrigant can reach the lateral, auxiliary canal, and isthmus by using the activation devices (18).

Although the aforementioned concepts are well accepted and documented in the literature, more studies are still needed to fully understand how different techniques of irrigation affect irrigation dynamics. Apical pressure, wall shear stress, turbulence, irrigant flow pattern, and exchange of irrigating solution are all components of irrigation dynamics (19). The dynamics of irrigation change depending on the type of root canal disinfection technique. Numerous techniques have been used in the literature to evaluate the dynamics of the irrigant, including apical pressure assessment devices (20, 21), dye clearance techniques (22-24), recovery trap devices (25), and computational fluid dynamics (CFD) analysis (26).

The CFD model provides thorough information on the dynamics of irrigant evaluating the various key parametrs (27). Therefore, the current systematic review aimed at assessing positive pressure syringe needle irrigation with other techniques evaluating irrigation dynamics using CFD.

Review

Data collection

The current systematic review was registered in Opensciencefframework (OSF) registry (Identifier: DOI 10.17605/OSF.IO/YHF9X). Mesh terms and keywords were used during the electronic search in PubMed, SCOPUS, and Cochrane databases. The search was carried out until June 2022. To find more papers, a manual search and reference linking were conducted. Keywords used were “extracted teeth”, “simulated root canal model”, “computational fluid dynamics”, “syringe needle irrigation”, “manual root canal irrigation”, “irrigation activation system”, “positive pressure irrigation”, “negative pressure irrigation”, “fluid dynamics”, and “irrigation dynamics”. The review was prepared following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) standards. Basic information about study, characteristics, and assessment methods were all collected by two independent authors. In addition, data on variables such as study design, irrigant type, concentration, depth of needle placement and irrigant inlet flow rate were assessed.

Study questiosn

- Popultaion: studies assessing the sim-

ulated root canal models or extracted human teeth.
- Intervention: positive pressure irrigation systems.
- Comparison: other irrigation delivery methods.
- Outcome: assesment of irrigant dynamics and apical pressures.

Inclusion and exclusion criteria
This comprehensive review considered studies conducted on extracted teeth or simulated root canal models that evaluated irrigation dynamics analysed using CFD. Case reports, case series, review articles, and animal research were not included. The present systematic review was unable to pool data for a meta-analysis due to the heterogeneity of the included articles.

Risk of bias
The Joanna Briggs Institute (JBI) and Checklist for Reporting In-vitro Studies (CRISS) criteria were adapted to analyse the bias for in vitro studies. Different domains were considered to report the risk of bias such as experimental consition, blinding, incomplete data, standardization of specimen, standardization of preparation, reporting data. Based on the aforementioned standards, research was categorised across all fields as "low risk," "moderate concerns," or "high risk."

Search outcomes
Literature search resulted in 239 articles and 17 were excluded because of duplication. The rest of the 222 records were screened for applying eligibility criteria and 199 were excluded. Twenty-three articles were retrieved for full-text analysis according to inclusion and exclusion criteria. Because of no full-text access, 18 articles were not considered for review. Ultimately, five articles were considered for further analysis. The PRISMA flowchart summarizes the article selection process (Figure 3).

Study characteristics
Characteristics of included studies are presented in Table 1. Two studies were in vitro studies (28, 29) and three were ex vivo investigations (30-32). Three research articles evaluated the fluid dynamics in extracted teeth (28, 29, 31), whereas two studies assessed a model with simulated root canals (30, 32). Three studies included extracted teeth with varied morphologies (28-30). The maxillary canine was used in one study (28), mandibular premolars and oval canals of mandibular molars were considered for other studies (29, 31).
Fluid dynamic analysis comparing needle irrigation with various activation methods were assessed within included articles. Negative pressure systems were the majority of the activation devices evaluated in the included studies. Most of the articles used passive ultrasonic activation, v pro safe endo, endovac and aspiration cannula (28-32). Except for one study, which utilised pure water, the rest of papers utilised 1% to 5.25% sodium hypochlorite. The irrigation needle utilised was mostly positioned 1-3 mm from working length. One study has standardised the irrigant's inlet velocity at 6 ml/minute (29). Regarding the evaluation area, two studies (28, 29) analysed the fluid dynamics in the primary canal alone, whereas the apical ramification was assessed in one study (31). Two studies evaluated the irrigation dynamics in the primary, secondary, and isthmus regions (30, 32). Table 2 reports the outcome of the included studies.

Risk of bias
For in vitro research, the risk of bias was evaluated using modified JBI and CRISS criteria. The assessment of each domain was made as high, low, or with some concerns based on the signalling questions. In terms of reporting experimental conditions, four out five papers received a low risk of bias rating. When reporting blinding, all studies revealed a significant bias risk. Three out five studies that evaluated the uniformity of specimen and preparation reported insufficient data. As a result, all included papers had an overall high risk of bias (Figure 1 and 2).
The disinfection of the apical part of

Table 1
Study characteristics

Author and year	Parameters evaluated	Study design	Simulation using CFD (Teeth selection)	Study groups	Needle insertion	An inlet flow rate of needle	Region of assessment	The concentration of the irrigant
Chen et al 2014 (30)	Irrigant velocity, turbulence, Shear wall stress, intensity, overall flow patterns	Ex vivo	Root canal simulation	Group 1: syringe irrigation openended needle, Group 2: syringe irrigation with a side-vented needle, Group 3: Apical negative pressure. EndoVac using the micro-cannula. Group 4: Passive ultrasonic-assisted irrigation.	Group 1 and 2: 3 mm short of apex Group 3: point before binding Group 4: 1 mm from the apical terminus	Groups 1 and 2: 0.15 mL/s-inlet flow rate	Simulation of the primary and secondary canal, isthmus	Distilled water with a density r=998.2 kg m-3 and a constant viscosity m=1.0×10^{-3} kg/m-s.
Dhingra et al 2014 (28)	Turbulence of irrigants. Comparing passive ultrasonic and syringe. Irrigation. Assessment of continuous and intermittent. irrigating methods Removal of dentin debris.	Invitro	75 extracted single-rooted maxillary canines	Group 1: ultrasonic irrigation (3 min continuous flow) Group 2: ultrasonic irrigation (1.5 min continuous flow) Group 3: ultrasonic irrigation (3min intermittent flow) Group 4: 1.5 min intermittent flow ultrasonic irrigation Group 5: needle irrigation for 1 min.	3 mm short of working length	Flow-inlet at 0.1 g/s, and the turbulent intensity was set at 0%	Simulation of primary root canal	2% Sodium hypochlorite with a density equal to 1.04 g/cm^3 and viscosity 0.986×10^{-3}.
Widjiastuti et al 2018 (29)	Fluid dynamics simulation	Invitro	27 extracted-single-root mandibular premolars	Controlgroup: positive pressure irrigation system with side vented (closed-ended) needle. Group 1: positive-pressure irrigation (open-ended needle). Group 2: Negative pressure irrigation system [V pro Endo Save].	Not mentioned	Not mentioned	Simulation of primary root canal	2.5% Sodium hypochlorite
Lorono et al 2020° (32)	Irrigant pressure, Velocity Shear stress	Ex vivo	Root canal simulation	Groups 1: Positive pressure needle. Group 2: negative pressure (aspiration cannula).	Group 1 and 2: 3 mm short of apex	Inlet flow rate 0.18 mL/s	Simulation of primary, secondary canal and isthmus	1% sodium hypochlorite with 1.04 g/cm^3 and 0.9998 Pa-S viscosity
Lorono et al 2020b (31)	Irrigant flow, irrigant velocity, shear wall stress, apical pressure	Ex vivo	Mandibular molar with oval root canal	Group 1: Positive pressure needle Group 2: Negative pressure	Positive pressure: 1 mm from working length Negative pressure: 3 mm from working length	Inlet flow rate 0.1 g/s (6 ml/min)	Apical ramification	5.25% sodium hypochlorite

the root canal system is crucial for the treatment's success (33). It's not optimal to only rely on the conventional needle for root canal irrigation, as the irrigant cannot reach the canal complexities (34). This systematic review compared syringe needle irrigation to other techniques of irrigant activation to evaluate the differences in irrigation dynamics. Different fluid dynamics are elicited by various activation systems, eventually altering the debridement outcome. It's widely known that the use of syringe needle irrigation causes a vapour lock effect, which prevents irrigant penetration (35, 36). On the contrary, reports showed

Table 2
Outcome evaluation

Author and year	Shear wall stress	Irrigant flow	Velocity	Turbulence	Irrigant exchange	Apical pressure	Outcome
Chen et al 2014 (30)	Group 1: 185 Pa Group 2: 425 Pa Group 3: 45 Pa Group 4: 875 Pa	Group 1: 1.5 mm apical to needle tip Group 2: 0.5 mm apical to needle tip Group 3: not mentioned Group 4:reported negligible	Group 1: 7.0 m s-1 at the exit of the needle Group 2: 1.0 m s-1 Group 3: Not mentioned Group 4: Not mentioned	Group 1: 70% Group 2: <10% Group 3: not measurable Group 4: >96%	Parameter not addressed	Parameter not addressed	The needle with an open end had a higher wall shear stress than the needle with a side vent. Passive-ultrasonic irrigation had the highest velocity magnitude and the least amount of wall shear stress compared to the apical negative pressure method of irrigation.
Dhingra et al 2014 (28)	Not addressed	Not addressed	Not addressed	Group 5- Highest turbulence at the apical one-third of the root canal	Parameter not addressed	Parameter not addressed	The needle should be kept loose in the canal and kept short of the working length, as evidenced by the fact that the exit had the highest turbulence.
Widjiastuti et al 2018 (29)	Not addressed	Not addressed	Not addressed	Parameter not addressed	Mean (SD) of the distance between the apical end and the peak of the irrigation solution Control: 2.209 (0.001) Group 1: 0.441 (0.005) Group 2: 0.068 (0.015)	Parameter not addressed	The negative pressure irrigation system can reach the apical end more effectively than positive pressure irrigation
Lorono et al 2020° (32)	FE-1628.44 Pa FEC-1256.87 Pa FEM-1185.69 Pa LE-1298.24 Pa LEC-1355.24 Pa LEM-1261.36 Pa	Parameter not addressed	FE-8.44 FEC-8.59 FEM-8.63 LE-8.48 LEC-8.61 LEM-8.61	Parameter not addressed	Parameter not addressed	FE-131100 Pa FEC-168328 Pa FEM-171748 Pa LE-130893 Pa LEC-144932 Pa LEM-149647 Pa	FE and FEM, showed irrigation flow through the isthmus in the most apical section
Lorono et al 2020b (31)	SV1-4.5 mmHg SV3-0.9 mmHg FV1- 3.8 mmHg FV3-1.1 mmHg N1-0.9 mmHg N3-0.4 mmHg MiC-0.6 mmHg	SV3-flow lower in the most apical area & apical ramification. SV1-generalized fluid flow in the main canal but not near apical ramification. FV3-reduced flow in the apical 2 mm. V1-flow in apical few millimeters of the main root canal and the apical ramification. N3-reduced flow with no evidence in apical area. N1-irrigant reached the main canal but no flow in apical ramification. MiC-irrigant flows the entire canal.	SV1 & 3-the flow velocity is low in an apical ramification FV 3-low velocity in an apical direction FV 1-medium- High velocity last few apical millimeters N3-low velocity in the two most apical millimeters. N1-medium velocity in the main canal. MiC-velocity was low	Parameter not addressed	Parameter not addressed	SV1-12 mmHg SV3-1.5 mmHg FV1-52.5 mmHg FV3-14.3 mmHg N1-19.5 mmHg N3-8.3 mmHg MiC-3.4 mmHg	SV needle- reduced positive pressure and increased shear wall stress. FV1 needle-increased apical pressure. The notched needle showed least irrigant flow at the apical ramification and the reduced shear wall stress was reported with positive pressure needles Microcannula generated better irrigant flow in the ramification with negative apical pressure values but, had reduced shear wall stress and irrigant velocity.

LE-Lateral Exit Needle, FE-frontal exit needle, LEC-Lateral Exit and cannula in the crown, FEC-frontal exit and cannula in the crown, LEM-LE and cannula in middle third, FEM-Frontal exit and cannula in the middle third.
SV1-side vented 1mm from working length, SV3- side vented 3mm from working length, FV1- front vented 1mm from working length, FV3- front vented 1mm from working length, N1- notched needle 1mm from working length, N3- notched needle 3mm from working length, MiC- Microcannula.

Figure 1

Study		Risk of bias						
		D1	D2	D3	D4	D5	D6	OVERALL
	Chen et al 2014	+	×	×	+	+	+	×
	Dhingra et al 2014	+	×	×	+	+	+	×
	Widjiastuti et al 2018	×	×	+	+	+	×	×
	Lorono et al 2020 (31)	+	×	+	+	+	+	×
	Lorono et al 2020 (32)	+	×	×	+	+	×	×
	D1: Experimental condition *D2: Blinding* *D3: Incomplete data*	*D4: Standardization of specimen* *D5: Standardization of preparation* *D6: Reporting data*					Judgement × High + Low	

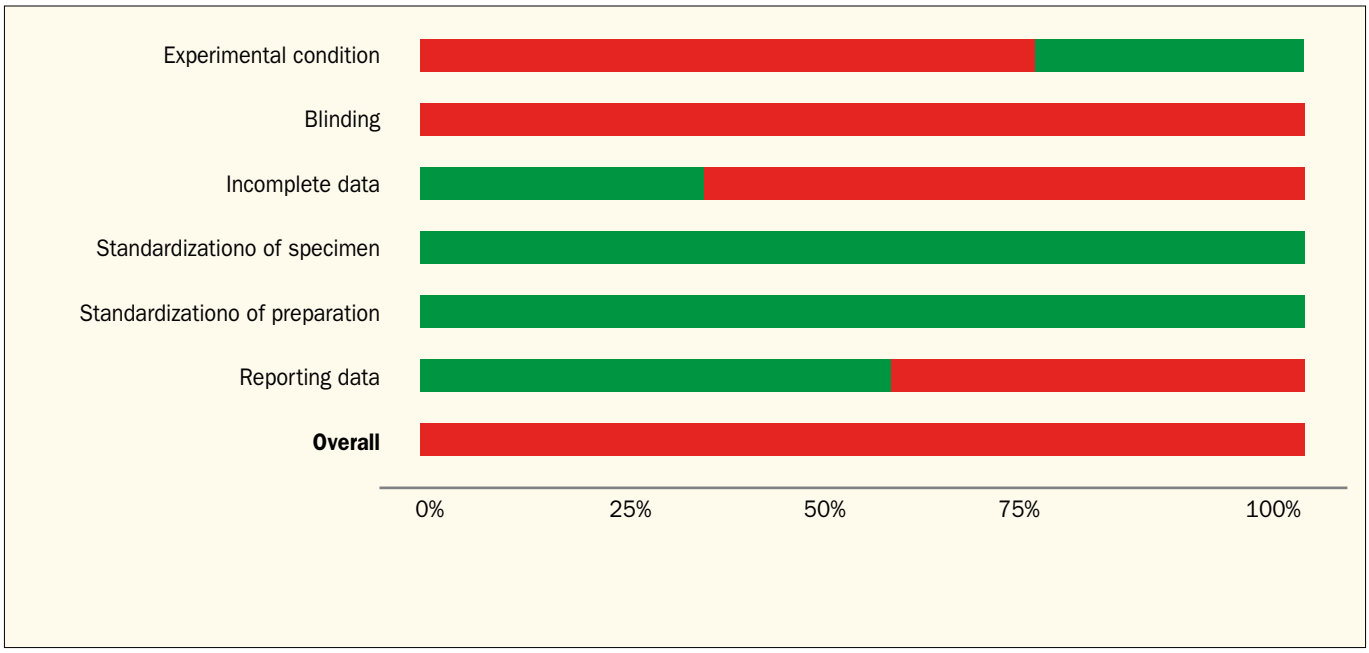

Figure 2

that the use of activation devices eliminates vapour locks (36). Study results showed that dislodging a vapour lock that had formed may be accomplished by irrigating at 0.260 mL/s (35).

Previous researches discussed the significance of wall shear stress (26, 37). The effectiveness of irrigant agitation is inversely proportional to the extent of an irrigant's wall contact (38). Although the pressure created in the canal varies, previous study reported an increased wall shear stress at pressures of -35 mmHg and flow rates of 0.5 to 8 mL/min. According to Lorono et al. (31), passive ultrasonic activation demonstrated a higher apical pressure compared to needle irrigation, whereas micro-cannula showed a reduced value.

The shear wall stress is significantly influenced by the root canal's taper. Studies demonstrated that even a small amount of taper preparation can increase wall shear stress (26, 37). Preavius reports

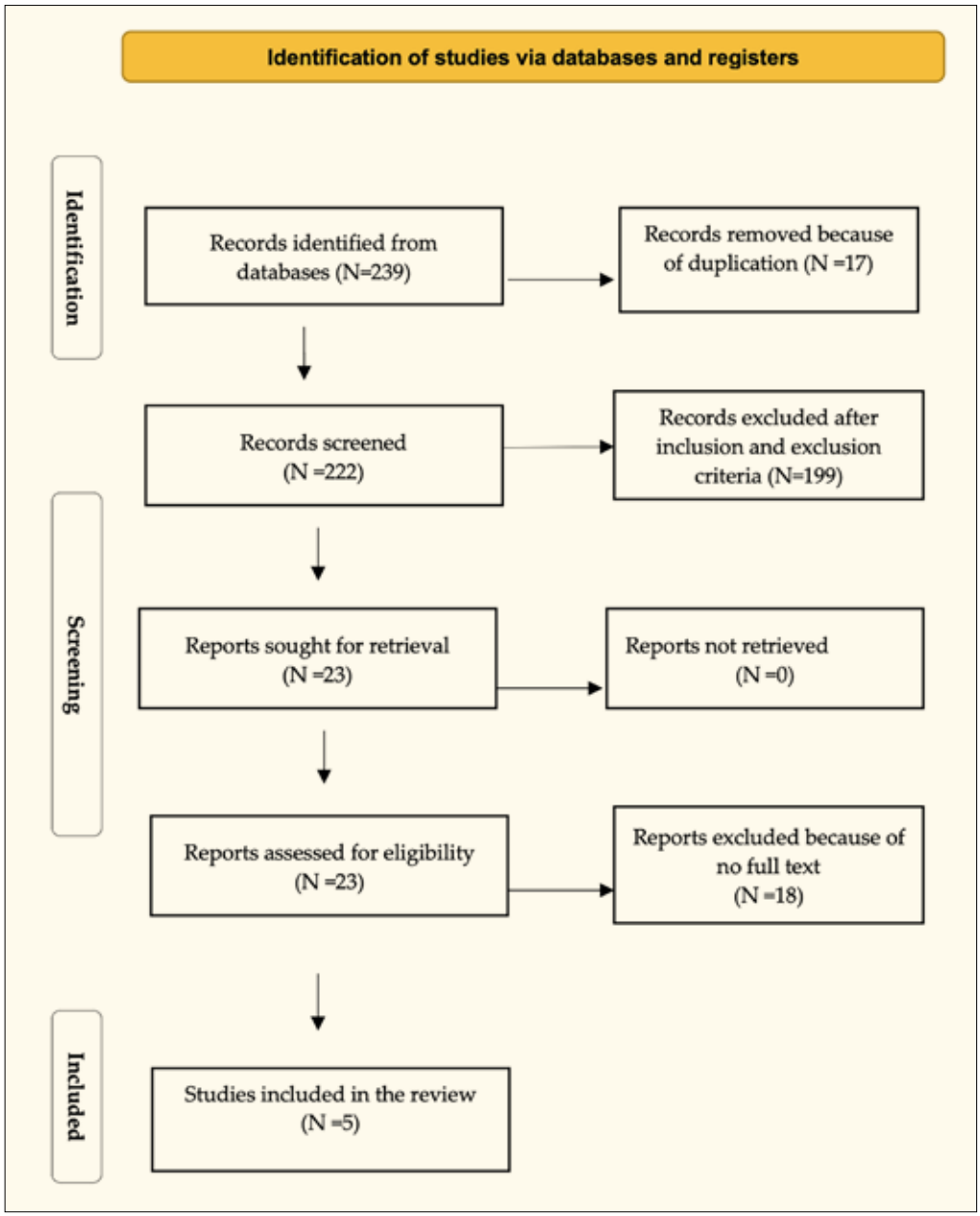

Figure 3
PRISMA 2020 flow diagram for new systematic reviews which included searches of databases and registers only.

indicated that shear wall stress may be generated with a preparation size of 25/04 (26, 37). Three included studies reported canal taper and sizes between 35/06 and 40/06 (28, 29, 31). However, it became clear that larger preparation sizes allowed better irrigant replenishment as compared to 25/06 when evaluating the replacement or exchange of irrigant in the apical third (39-41). Wall shear stress helps in the biofilm detachment from the root canal walls. Whereas in cases of larger canal preparation, the effect is negligible as a result of decreased wall shear stress (42).

It's questionable to maintain the balance with the flowing liquid and created apical pressures during root canal irrigation. Increasing taper to more than 35/06, reduces the apical pressure and wall shear stress. One of the included study showed a reduced shear stress when comparing a negative pressure micro-cannula to a positive pressure syringe needle (31).

In addition, when a negative pressure method was used as opposed to syringe needle irrigation, there was a noticeable increase in shear stress in the isthmus area (32). Endovac showed lesser shear stress compared to passive ultrasonic irrigation while contrasting two negative pressure systems (30). Shear wall stress is elicited better with the side-vented needle types as compared to the open-ended ones (30).

Teeth with increased diameters and tapers reduce irrigation extrusions (43, 44). The apical pressures and irrigant flow are also influenced by the canal's curvature (45) and the root canal's morphology (46). The vent of the needle being utilised typically affects the pressures that are created (21, 47). Compared to a side-vented needle, an open-ended needle generates more apical pressure. It was clear that an open-ended needle could irrigate the apical end more effectively than a closed-ended needle. It's been reported that front-vented needles increased apical pressure as compared to micro-cannula irrigant disinfection (31). In addition, needle with a side vent reported lower apical pressure than one with a front vent (31).

Apical pressure is reported to be directly proportional to the irrigation flow rate. Indeed, a flow rate of 4 ml/min can effectively reach the apex and generate enough apical pressure (23, 26, 48); moreover, the flow rate varies depending on the needle type (49). Only five articles have compared syringe needles to other methods of irrigant activation within the scientific literature.

Another important parameter of irrigation dynamics is the turbulence of the flowing fluid. Clinically various irrigating solutions help in adequate debris removal and canal contents (50, 51). However, the turbulence of flowing liquid helps in enhancing the ability of the disinfectant solution. The inlet velocity has a significant impact on the irrigant's turbulence. The irrigant inlet velocity in three of the included articles was kept at 6 ml/min. Only two articles have compared the turbulence on using syringe needle irrigation with irrigant activation systems (28, 30). Comparing the various syringe designs, open-ended syringes were found to produce more turbulence than side-vented needles. Additionally, it was noted that the irrigant velocity was high with an open-ended needle (7 m/s) and low with a side-vented needle (1 m/s). Endovac had the least turbulence as compared to passive ultrasonic activation (30). It was stated that, to accomplish maximal disinfection, it is imperative to sustain maximum turbulence at the outflow where the needle does not bind the canal. Syringe needle irrigation had the least turbulence, according to Dhingra et al. (28) that assessed the turbulence of fluid in ultrasonic irrigation and syringe irrigation.

Overall the results of the present systematic review showed favourable results in terms of fluid flow with least recorded pressures in negative pressure irrigation systems. The negative pressure irrigation system outperformed the syringe needle irrigation in terms of irrigant replenishment because it allowed adequate irrigant penetration to the apical third.

The main limitation of the current systematic review was represented by the inclusion of in vitro studies that reported a high risk of bias and might have questionable translation on clinical settings. In addition, since multiple factors and parameters were evaluated, a meta-analysis was not possible. Future high quality laboratory researches are more warranted on this topic to get a conclusive evidence.

Conclusions

Negative pressure irrigation technique was superior to positive pressure syringe needle irrigation, mainly in terms of irrigant replacement and enhanced flow, that may reduce the irrigant extrusions. However, higher apical pressures were demonstrated by the positive pressure irrigation systems.

Clinical Relevance

Current systematic review assessed the irrigation dynamics on using various irrigation systems. Negative pressure irrigation system showed better irrigant replacement and enhanced flow. So con-

sidering the clinical scenario, negative pressure irrigation systems shown to reduce the irrigant extrusions with enhanced flow.

Conflict of Interest

None.

Acnowledgements

None.

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CASE REPORT

Extensive external-internal root resorption 22 years after trauma and inadequate endodontic treatment: a case report with 20-year follow-up

ABSTRACT

Aim: *This paper describes the management of an extensive external-internal root resorption (EIRR), 22 years after dental trauma and inadequate endodontic treatment, with a 20-year follow-up.*

Summary: *A 30-year-old Caucasian female patient was referred to evaluate the right maxillary central incisor, which presented a sinus tract with mild suppuration. The tooth had been compromised by a trauma, and it was endodontically treated 22 years before. There was no periodontal involvement, mild pain on vertical percussion and apical palpation, and no response to the cold sensitive test. Radiographic analysis showed poorly performed endodontic treatment, EIRR, and asymptomatic apical periodontitis. After performing root canal filling material removal and chemomechanical preparation, a calcium hydroxide paste was used for 45 days. Then, the apical root canal third, and the resorptive lesion were filled with gutta-percha/sealer and MTA, respectively. Longitudinal follow-ups (2, 9 and 20 years) were conducted, and confirmed the success of the intervention.*

Key learning points:

- *Dental trauma is a relevant public health problem due to its high incidence, mainly in children and adolescents.*
- *One of the main sequelae resulting from more aggressive dental trauma is root resorption. When an external root resorption (ERR) reaches the walls of the pulp cavity, or an internal root resorption (IRR) reaches the root surface, an external-internal root resorption (EIRR) process ensues, and represents one of the most challenging clinical situations faced by the clinician.*
- *In cases of EIRR, MTA allows endodontic treatment and tooth restoration to be completed more quickly, thus contributing to the longevity of teeth.*

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Introduction

Dental trauma is a relevant public health problem due to its high incidence, mainly in children and adolescents. According to Doğramaci et al. (1), the prevalence of traumatic injuries in the permanent dentition of children aged 8 to 14 years ranges from 6.1 to 27.6% (2-4), with a higher incidence at ages 9 to 11 years (5, 6). The most commonly affected teeth are the maxillary central incisors (53.2 to 88.1% of all compromised teeth) (2, 4), especially in male patients (1, 3, 4).
One of the main sequelae resulting from aggressive dental trauma is root resorption, which is basically divided into external and internal. External root resorption (ERR) is characterized by the loss of structure from a mineralized and/or cementless area located on the root surface, and evolves toward the pulp cavity. On the other hand, internal root resorption (IRR) is a less frequent insidious inflammatory process, which can start at any point of the pulp cavity and progress toward the root surface (7). When an ERR reaches the walls of the pulp cavity, or an IRR reaches the root surface, an external-internal root resorption (EIRR) process ensues, and represents one of the most challenging situations faced by clinicians (8).
Teeth affected by EIRR are subjected to root canal treatment to eliminate the factors stimulating bone resorption (microorganisms and bacterial toxins), and interrupt the pathological process. These measures prevent further damage to the root, and recover the integrity of periradicular tissues (9). The use of calcium hydroxide ($Ca(OH)_2$) as an intracanal dressing has been recommended in cases of post-traumatic EIRR, in an effort to dissolve the remaining pulpal debris, alkalinize the dentin complex, control periodontal bleeding (if occurring), enhance the cleaning and disinfection process of the root canal system (RCS), and stimulate the formation and deposition of hard tissue (10).
However, the permanence of $Ca(OH)_2$ inside the root canal for long periods of time has been linked to the occurrence of coronal and/or root cracks or fractures (11), and possible recontamination of the RCS between appointments (12). Therefore, other alternatives have been developed and investigated.
Mineral trioxide aggregate (MTA) has been recommended for several clinical situations, such as pulp capping (13), root-end filling (14), and root canal filling material to induce apexification in open-apex teeth (15), as well as reparative material in cases of root perforation (16) and root resorption (17). Its main advantages are sealing ability, biocompatibility, antimicrobial effect, radiopacity, and modulation of cytokine production (16, 18, 19). Specifically in cases of EIRR, MTA allows endodontic treatment and tooth restoration to be completed more quickly, thus avoiding possible root cracks or fractures and recontamination of the RCS – both associated with the long-term use of $Ca(OH)_2$ – between appointments (12, 20).
Longevity is one of the most important factors related to success in Endodontics, and most case reports published to date about non-surgical management of EIRR have mentioned follow-ups of 6 (21), 12 (22), 13 (9) and 17 months (23), and 2 (24), 3 (25), 5 (26), 6 (27) and 11 years (28). Bearing this mind, the aim of this paper was to describe an approach to treating extensive EIRR 22 years after dental trauma and inadequate endodontic treatment in a right maxillary central incisor, with a 20-year follow-up. Therefore, this is the case report with the longest follow-up period ever recorded after a non-surgical intervention performed to treat a tooth affected by EIRR.

Case report

This case report has been written according to Preferred Reporting Items for Case Reports in Endodontics (PRICE) 2020 guidelines (29). A 30-year-old Caucasian female patient was referred to the clinic of one of the authors (C.M.) to evaluate the right maxillary central incisor endodontically treated 22 years before, which presented a sinus tract with mild suppuration. Her medical history was non-contributory. The following information was

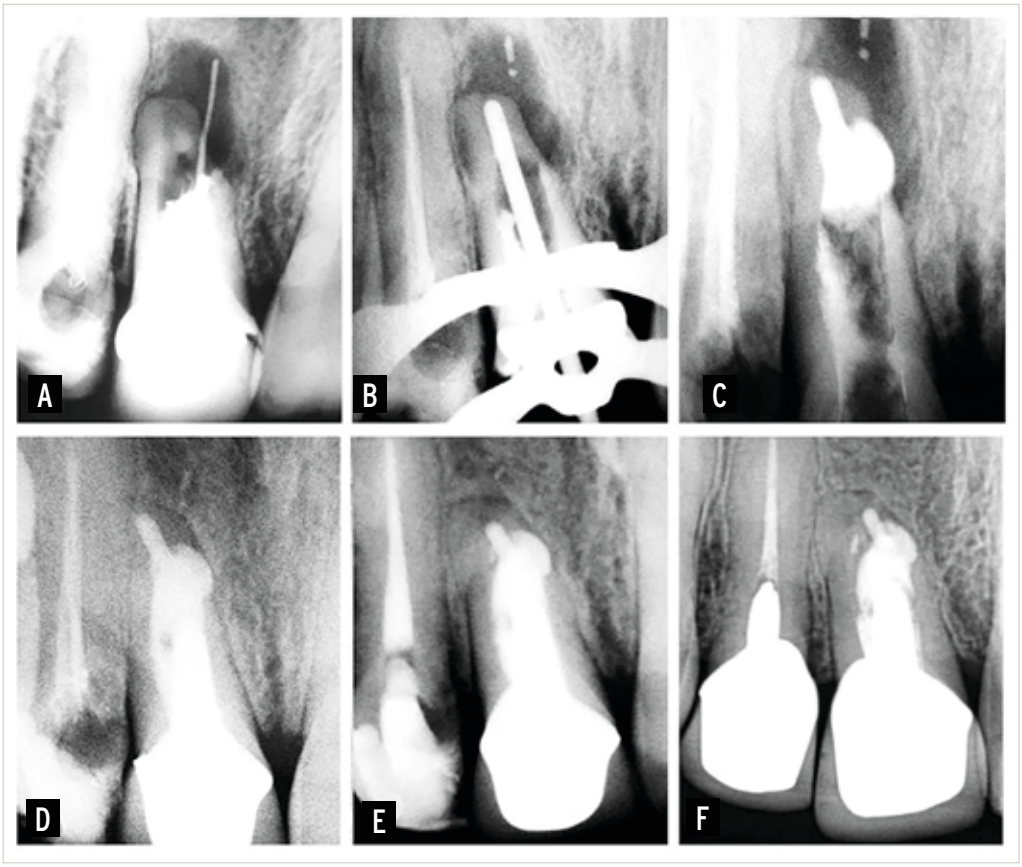

Figure 1
A) Initial radiography of the right maxillary central incisor, which had been poorly endodontically treated, and which was affected by both EIRR and asymptomatic apical periodontitis. **B)** Radiographic analysis of the main gutta-percha cone. **C)** Apical root canal third and resorptive lesion filled with gutta-percha/sealer and MTA, respectively. **D-F)** 2, 9 and 20-years follow-ups, respectively

provided by the patient during anamnesis: the tooth in question had been compromised by a traumatic injury caused by a fall when she was 8 years old. It changed color, and was subjected to root canal treatment a few months later. Some years after, the coronal portion of the tooth was fractured and replaced with a metal-ceramic crown. The clinical exam showed no periodontal involvement, mild pain on vertical percussion and apical palpation, and no response to the cold sensitive test (EndoIce, Coltene/Whaledent, Cuyahoga Falls, OH, USA). Radiographic analysis showed poorly performed endodontic treatment, EIRR, and asymptomatic apical periodontitis (Figure 1A). The patient was given a detailed explanation about the particularities and limitations of her case, she agreed to the proposed endodontic retreatment, and signed an informed consent form.

In the first visit, buccal infiltrative anesthesia (2% mepivacaine with adrenaline - 1:100.000, DFL, Rio de Janeiro/RJ, Brazil) was administered, the crown was flattened, the metal post was removed by ultrasonic energy, and a provisional crown was made. In the next visit, the same anesthetic was given, the provisional crown was removed, a rubber dam was placed, and the operative field was cleaned with 2.5% NaOCl (Biodinâmica, Ibiporá, PR, Brazil). Next, root canal filling material removal was conducted by means of Hedstrom files (Dentsply, Petrópolis, RJ, Brazil). The working length was determined radiographically 1 mm short of the root apex, and minimal instrumentation was performed with manual stainless-steel K-files (Dentsply), by gently brushing the root canal walls. Irrigation was performed with 2.5mL of 1% NaOCl (Biodinâmica) at each file use or change.

A chelating solution (17% EDTA, Herpo Produtos Dentários, Rio de Janeiro, RJ, Brazil) was applied for 3 minutes, after which the root canal was dried with ab-

sorbent paper cones (Tanari Industrial, São Paulo, SP, Brazil), and filled with a $Ca(OH)_2$ paste as an intracanal dressing (Calen – SS White, Rio de Janeiro, RJ, Brazil). The provisional crown was fixed temporarily with Dycal (Dentsply).

After 45 days, the same previous procedures were undertaken, and the intracanal dressing was removed with 2.5ml of 1% NaOCl (Biodinâmica), and the last file was used during the biomechanical preparation. Then, the root canal was flushed with 2.5 mL of 17% EDTA (Herpo Produtos Dentários) for 3 minutes, irrigated with 5 ml of saline solution, and dried with absorbent paper cones (Tanari Industrial). The main gutta-percha cone was inserted into the root canal and checked radiographically for adequate positioning (Figure 1B), after which the apical third was filled using the Schilder technique and Endofill sealer (Dentsply). Afterwards, the MTA (ProRoot, Dentsply-Maillefer) was prepared on a sterile glass plate, and introduced into the root canal with Paiva condensers (Golgran, São Caetano do Sul, SP, Brazil) to completely fill the resorptive lesion (Figure 1C), followed by once again fixing the provisional crown (as previously described). The patient was given a clear explanation of the importance of frequent follow-ups before the definitive prosthetic rehabilitation of the tooth, and was urged not to neglect this advice. The first follow-up could not be conducted before 2 years (Figure 1D). Figures 1E and F show the 9- and 20-year follow-ups, respectively, thus proving the therapy success (absence of pain, swelling and other symptoms, no sinus tract, no loss of function and radiological evidence of a normal periodontal ligament space around the root) (30).

Discussion

One of the main factors for achieving favorable prognosis is early diagnosis followed by adequate treatment, regardless of the type of root resorption. If correct diagnosis and/or treatment are not obtained in a timely manner, potential damage caused by the resorptive process can make the recovery of periradicular tissues unfeasible, and indicate tooth extraction (7). The aim of this paper was to describe the management of extensive EIRR, 22 years after dental trauma and inadequate endodontic treatment of a right maxillary central incisor. The success of the intervention was proven by the longest follow-up ever recorded in the literature – 20 years (Figure 2).

In cases of EIRR, clinical procedures are considered extremely complex because effective disinfection must be performed without causing further damage to the periradicular tissues, which are normally already compromised. Moreover, as much remaining tooth structure as possible should be maintained, and an attempt made not to weaken it even further, hence leaving it at greater risk of coronal and root fracture. In the current case report, cleaning and shaping of the root canal were carefully conducted by manual stainless-steel K-files to cause as little damage to the remaining dentin as possible, and 1% NaOCl was used as the irrigation solution.

The final flushing was undertaken with a chelating solution (17% EDTA) to remove the smear layer, thus increasing the disinfection process through the use of $Ca(OH)_2$ as an intracanal medication. Passive ultrasonic irrigation was not used, because the risks and potential injuries had to be weighed to determine if they outweighed the benefits of the procedure.

The use of $Ca(OH)_2$ as an intracanal dressing has been recommended in cases of EIRR resulting from traumatic injuries, because this substance: i) shows excellent antimicrobial action and ii) acts as a physicochemical barrier to prevent proliferation of residual microorganisms, RCS reinfection, or invagination into the root canal of the granulation tissue present in the resorptive lesion. Furthermore, $Ca(OH)_2$ can promote the necrosis of the resorptive cells located in the Howship's lacunae, thus neutralizing clastic cell acids, preventing the mineral dissolution of the root, and rendering the region unsuitable for acid hydrolases (10). These actions invariably predispose toward a better prognosis (7); however, the time required for $Ca(OH)_2$ to achieve them, whether directly or indirectly, is a controversial issue.

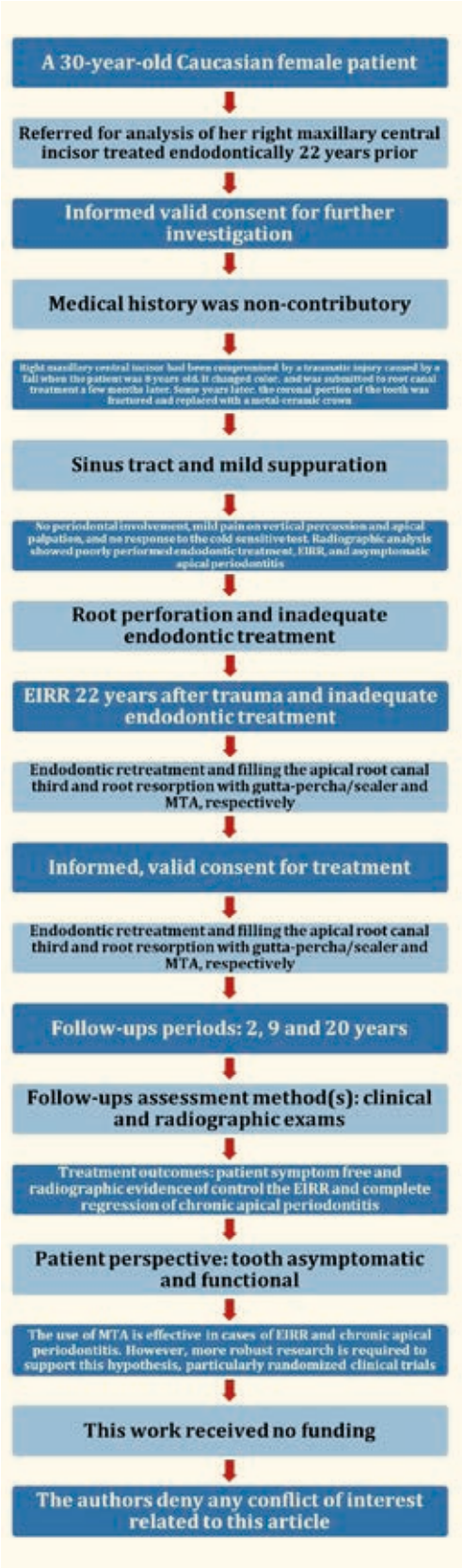

Figure 2
PRICE 2020 flow chart

Studies have reported that $Ca(OH)_2$ can be used from 4 weeks to several months (7, 10). However, some studies have discouraged its long-term use due to the likely occurrence of coronal and/or root cracks or fractures, and possible RCS recontamination between appointments (12, 20). In the present case report, $Ca(OH)_2$ was used for 45 days (3 changes every 15 days), because this was the time required to completely stanch the intracanal bleeding resulting from EIRR. Right after the bleeding stopped, the apical third and resorptive lesion were filled with gutta-percha/sealer and MTA, respectively. In cases of EIRR, MTA has been singled out as the material of choice, owing to its excellent sealing ability and biocompatibility, antimicrobial effects, and radiopacity, as well as its ability to regenerate periodontal attachment, and induce both osteogenesis and cementogenesis (16, 18, 19). The pathological changes that occurred in the periodontal tissues close to the EIRR increased the risk of overfilling. As already mentioned in previous papers, one of the most challenging steps of the present case report was to prevent MTA extravasation to the periradicular tissues (22). However, had this situation occurred, it would not have been so critical as to compromise the prognosis of the treatment, owing to MTA biocompatibility (19).

Conclusions

The findings of the current case report let us infer that MTA is effective in cases of EIRR and asymptomatic apical periodontitis. However, more robust research is required to support this hypothesis, particularly randomized clinical trials.

Clinical relevance

In cases of EIRR, MTA allows endodontic treatment and tooth restoration to be completed more quickly, thus avoiding possible root cracks or fractures and recontamination of the RCS – both associated with the long-term use of $Ca(OH)_2$ – between appointments, and contributing to the longevity of teeth.

Conflict of interest

The authors deny any conflicts of interest related to this study.

Acnowledgments

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CASE REPORT

Combined orthograde 3D navigation microsurgical endodontic retreatment for the management of persistent apical periodontitis in a mandibular molar

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ABSTRACT

Aim: *This case report shows a combined, orthograde and 3D navigation, microsurgical endodontic treatment of an element with persistent apical periodontitis (PAP), due to an inadequate endodontic treatment and a separated instrument beyond apical foramen of the mesio-buccal canal of the tooth 3.6. A targeted minimally invasive ostectomy with 3D navigation system was performed to localize the apex and remove the broken instrument, then completing the root end management and filling.*

Summary: *After previous renewal of the existing restoration and non-surgical retreatment, microsurgery was carried out using the Navident. CBCT dicom data and stl files obtained from intraoral scans were uploaded into the software and matched together. The preoperative digital planning defined the direction and depth of the ostectomy with 5.2 mm cilindrical bone mill drill. On the day of surgery an optic support was placed adhesively at the mandibular level, detected by the Navident camera.*

After the calibration of handpiece and the drill, a mucoperiosteal flap was performed. The bone mill drill was guided by the navigator, conducting a selective osteotomy. The removed bone block was stored in a Hank's buffered salt solution. The root end was resected and removed around the broken instrument. After the removal of the separated instrument, the retrocavity was prepared and filled with RRM fast set putty. A collagen sponge was placed to support the cortical block. The suture was made with 6.0 Vycril. Radiological images demonstrated the healing process. 3D navigation allowed to create a precise and targeted osteotomy. The 3D navigation seems to be predictable in complex cases, requiring accurate execution technique.

Key learning points

- *The use of 3D navigation is a valuable aid in complex cases, in which the proximity to anatomical structures.*
- *This technology allows a selective and rapid ostectomy, even by operators with less clinical experience*

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KEYWORDS *Endodontics, microsurgical endodontics, Navident, persistent apical periodontitis*

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Introduction

Persistent apical periodontitis (PAP) is a chronic inflammation of the periradicular tissues caused by etiological agents of endodontic origin. The main causes of PAP may include complex anatomy, reduced opening of the pulp chamber, forgotten or untreated canals, complications in instrumentation and extrusion of material beyond the apex (1).
The persistence of endodontic lesions after treatment may also be due to biological factors not directly related to the treatment: root infection due to the complexity of the root canal system, extraradicular infection due to actinomycosis, accumulation of cholesterol crystals, cystic lesions and wound healing with scar tissue (1).
Surgical micro-endodontics (EMS) is a highly predictable treatment option for the resolution of cases of endodontically treated teeth with persistent apical periodontitis (2). Retrograde surgical treatment is recommended when orthograde retreatment is not successful or demonstrates an increased risk than the microsurgical approach (3).
In recent years, thanks to the use of new technologies and the development of increasingly performing materials and equipment, we have witnessed a significant increase in the success rate of surgical micro-endodontics (4-6).
The Buffalo Study (5) showed a success rate after surgical micro-endodontic treatment of 94% with intraoral radiographs follow-up and 91% with cone beam CT (5).
Errors during the osteotomy and apicoectomy phases, that compromise the apical seal or the integrity of the support structures, are considered the first cause of failure of microsurgical treatment (5).
A study analyzed the causes of failure of surgical endodontic interventions, correlating the failures to a poor technique of preparation and filling of the retrograde cavity (7); on the contrary, the use of a microsurgical technique and the use of new biocompatible cements allows to obtain 92.9% of success in cases of reoperation (7).
Surgical micro-endodontics involves several phases including flap creation, ostectomy, apical root resection (RER), retrograde cavity preparation (RECP) and retrograde obturation (REF) (2, 3).
Ostectomy and apical resection can sometimes be complicated procedures because of the difficult access to the affected site due to an intact and thick cortex or to the high risk of damage the noble anatomical structures near the operative site.
The anatomical structures to pay particular attention to are the floor of the nasal cavity, the maxillary sinus, the mental foramen and the mandibular canal (2, 3).
Although CBCT allows the operator to identify the precise position of the root apex (8), freehand procedures (FH) are often linked to the operator's dexterity, experience, ability to interpret CBCT images (7).
The introduction of new guided technologies, through the use of digitally created and then 3D printed static guides (7-9) and 3D dynamic navigation (10) have improved the accuracy and efficiency of this therapeutic procedure.
Dynamic navigation systems (3D-DNS) represent an emerging technology that allows the implementation of minimally invasive procedures, increasing accuracy, safety and reducing the possibility of iatrogenic damage (11, 12).
The dynamic navigation system is a computer-based system similar to a satellite guidance system, which uses an optical stereo video camera and optical sensors to align the patient's real anatomical structures to the cone beam CT data, allowing to carry out an operation by navigating in time real through the monitor vision of the patient's CT images during the operating session.
The application protocol requires careful planning by the operator, starting from the CBCT images. This system makes use of optical cameras that track movement and CBCT images for immediate virtual feedback from the operator.
The match of these two technologies allows immediate intraoperative feedback of the surgical maneuvers.
The guided navigation system has found greater use in the implant field for the past

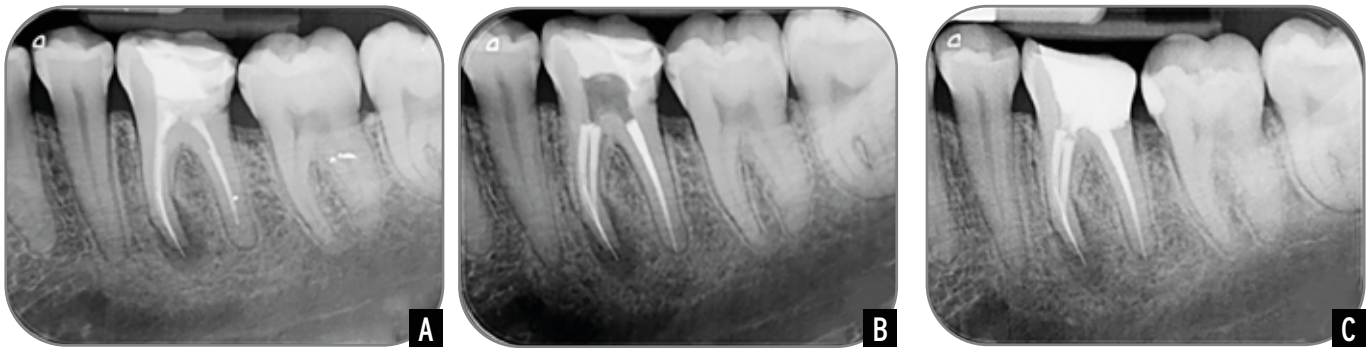

Figure 1
Orthograde retreatment: **A)** initial periapical x-ray, **B)** x-ray after the orthograde retreatment, **C)** long term restauration.

decade (12); this technology has allowed the planning and finalization of implant cases even in unfavorable anatomical conditions, allowing to highlight and avoid noble anatomical structures near the chosen rehabilitation site.
In orthograde endodontics, this system has been used for the localization of calcified canals (8-10), for access cavity planning (15, 16), for the removal of root canal posts (15), for orthograde retreatments (17) and for intraosseous anesthesia (18).
Recently 3D-DNS has been used for surgical micro-endodontics with excellent results, but the literature on this subject is still limited (10-18).
The advantages of this technology are mainly linked to the possibility of carrying out a correct apical resection and with a favorable bevel angle; operating times are shorter, reducing patient and operator discomfort; the operator can also modify his own operating strategy during the operation (17, 18-26).
The objective of this case report is to demonstrate how the use of dynamic navigation technologies in surgical micro-endodontics facilitates the operator in the ostectomy and apicectomy phases even in the vicinity of noble anatomical structures.

Case Report

A 32 years old female patient, with medical history of chemotherapy for breast cancer, was referred for consultation before antiresorptive therapy with oral bisphosphonates in order to reduce the risk of secondary osteoporosis. Chief complaint was pain in chewing and tenderness to percussion on tooth 3.6. Radiological periapical exam evidenced apical periodontitis, secondary caries and inadequate previous endodontic treatment with a separated instrument beyond the apical foramen in the mesial root (Figure 1).
The patient performed a cone beam computer tomography (CBCT) (Morita,Accuitomo) that highlighted the root anatomy, the buccal plate and the relationships with the inferior alveolar nerve.
First and foremost, the orthograde retreatment of the element 3.6 was performed. We carried out the removal of the gutta-percha with solvent (OGNA, Muggiò, Italy) and the canal system was re-shaped with Protaper Next System (Dentsply Maillefer, Baillagues, Switzerland).
The canal system was obtured with warm vertical condensation and the element was filled with a fuji long-term temporary filling (Figure 1).
Dicom data were uploaded on the Navident software to plan the navigated microsurgical endodontic procedures.
Since there are not yet commercially available software dedicated to navigated surgical micro-endodontics, we have planned the ostectomy in correspondence with the mesial root of the element 3.6. For the execution of this operation, we selected the cilindrical bone mill drill with diameter of 5.2 mm which in a single surgical act would have allowed to perform the ostectomy and the apicectomy (Figure 2).
We started with the planning of the surgical approach with the CBCT image data in order to verify the movement of the burs in the three levels of the space.
Trough the registration phase we matched the patient's CBCT images to the patient's anatomical structures.

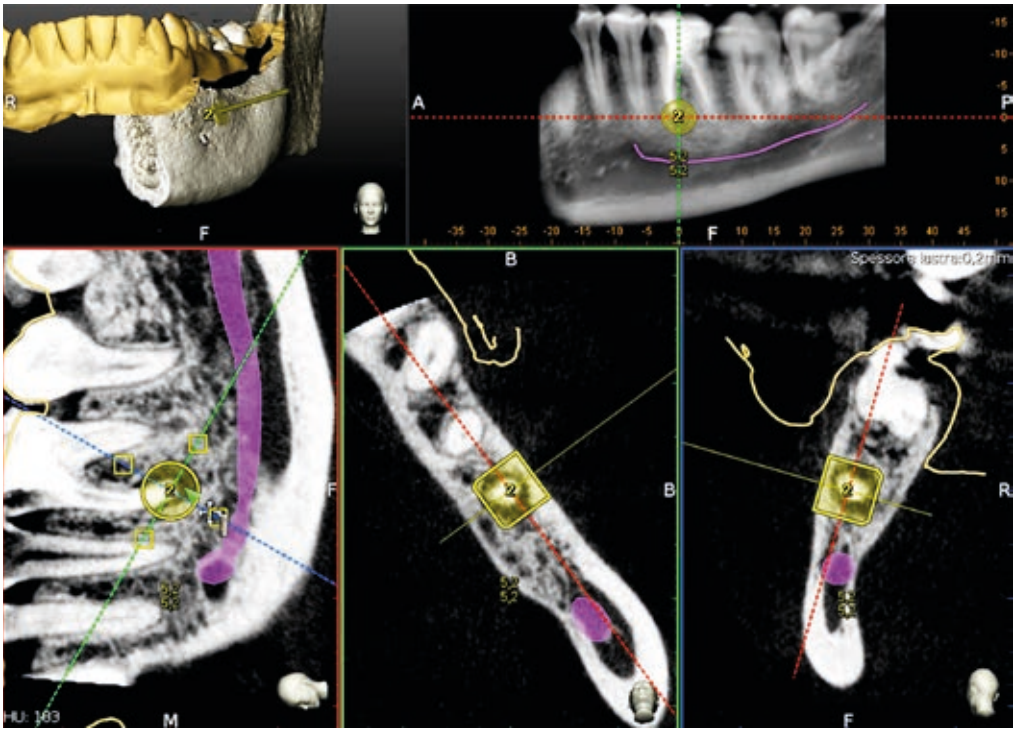

Figure 2
Digital planning with Navident system.

At the mandibular level we blocked a particular recognition tool called "butterfly" with silicone which allowed the stereovideocamera of the Navident system to identify the chosen anatomical site. Subsequently, thanks to the calibration phase, we verified the exact correspondence between the patient's six dental landmarks, chosen on the visualization software, and the same points in the patient's mouth.
The dental handpiece and the burs have been calibrated, through the optical recognition system.
Through the tracing phase we checked that the operator's movements in the three planes of space corresponded to what we were viewing on the screen, checking the degree of accuracy.
We checked that the previously fixed support did not move in any way to avoid losing the calibration.
Two percent mepivacaine with 1:100,000 epinephrine local anesthesia was administered for the inferior alveolar nerve block; a triangular papilla-based mucoperiosteal flap was made from the element 3.7 to the element 3.4 with a medial release incision (Figure 3).
The minimal invasive ostectomy (Ø 5.2 mm) was performed using a round bone-mill (Nobel Biocare, Yorba Linda, CA, USA) mounted on a high-speed handpiece surgical motor Kavo (Biberach, Germany) at 900 rpm. The removed bone block was stored in Hank's buffered salt solution.
Once the ostectomy phase was completed, it was possible to immediately visualize the mesiobuccal root with the fractured instrument beyond the apical foramen.
Hemostasis was obtained with an innovative hemostatic glue, utilized in general surgery (Ifabond™, Peters Surgical®).
We carried out the root resection by consuming the dental tissue around the instrument with a fine grain with a size #4 carbide round bur and a surgical length #702 carbide fissure bur (SS White Dental, Lakewood, NJ, USA) on a high-speed handpiece at 40,000 rpm.
The instrument was removed, after mobilization, with low-power angled ultrasonic tips (Acteon (Acteon Group, Olgiate Alona, Va, Italy).
A conventional 3 mm retrograde preparation was performed and the isthmus were prepared with low-power ultrasonic tips

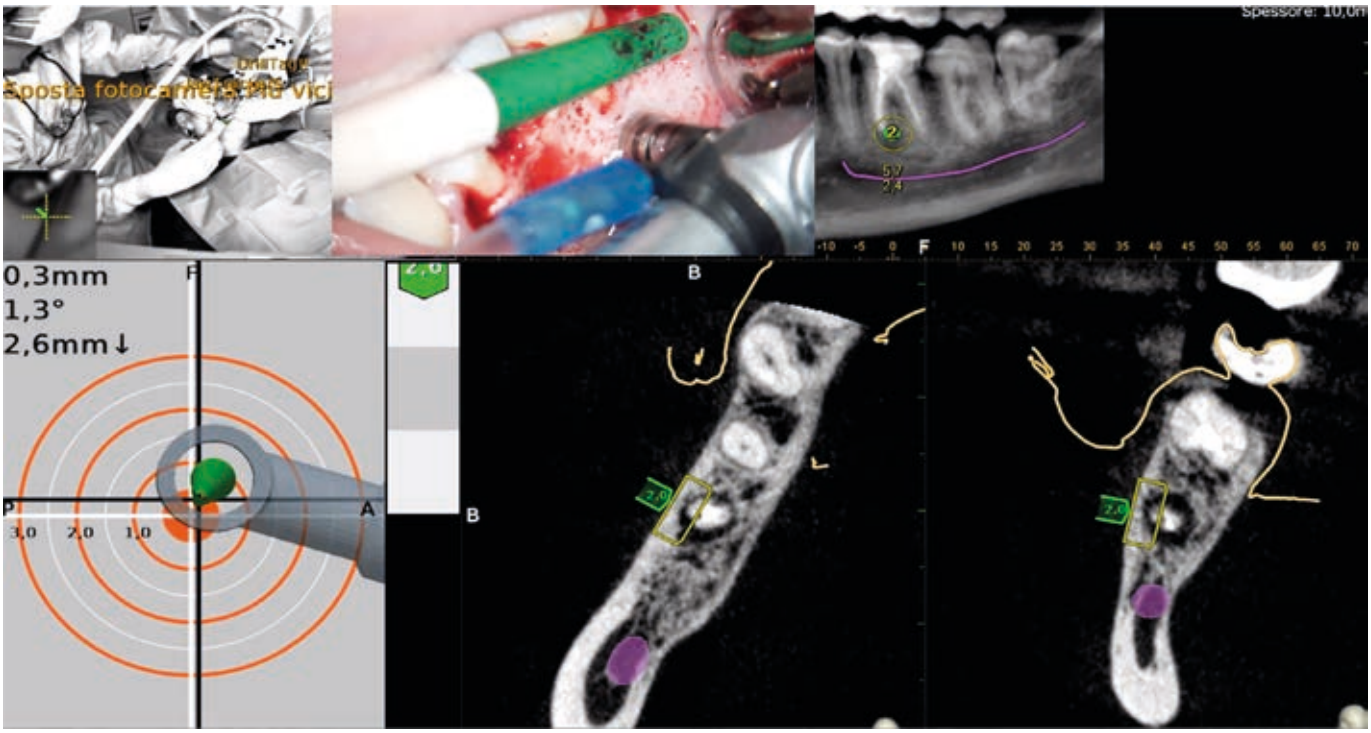

Figure 3
Ostectomy phase with bone mill drill.

(Acteon Group, Olgiate Alona, Va, Italy), using the microscope (ProErgo, Zeiss, Oberkochen, Germany).
The retrograde cavity was filled with Endosequence (Brasseler USA, Savannah, GA) and subsequently finished with diamond burs filled.
After positioning a fibrin sponge as a support, we repositioned the bone block; then the surgical wound was sutured with re-

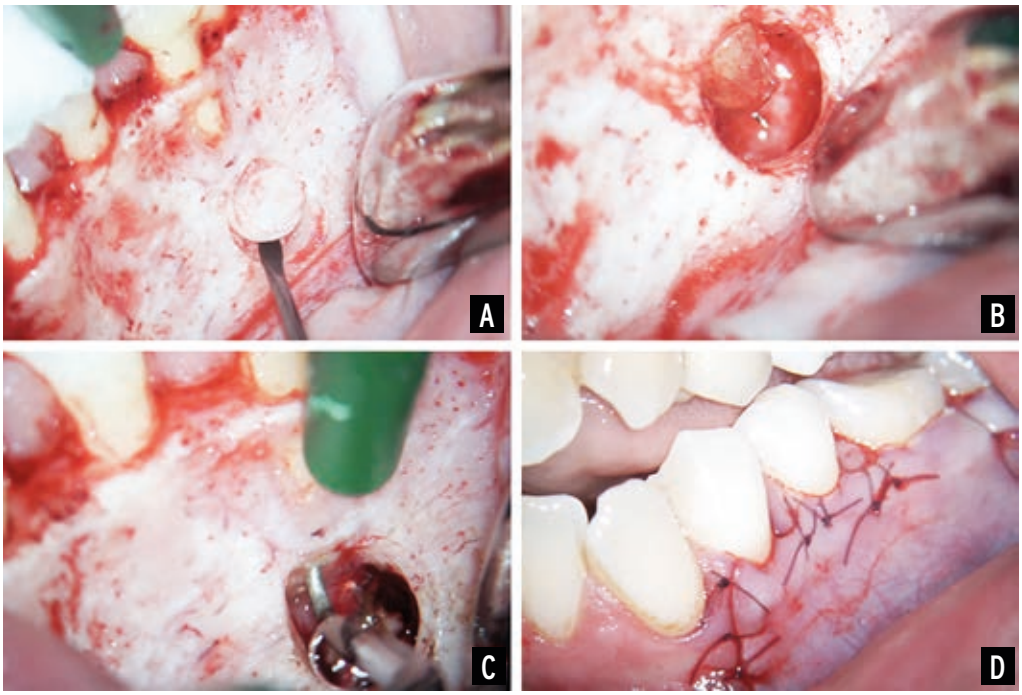

Figure 4
Dinamic microsurgical procedures: **A)** end of the ostectomy, **B)** bone after ostectomy, **C)** retrograde cavity preparation with ultrasound low power tip, **D)** suture with 6.0 Vycril.

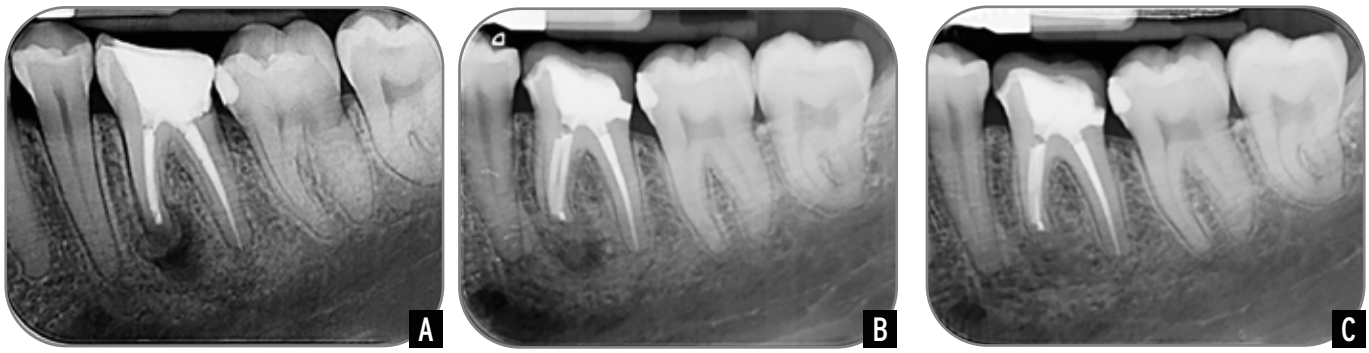

Figure 5
Follow up: **A)** end of the microsurgical endodontics, **B)** 4 months follow up and **C)** 12 months follow up.

sorbable 6.0 Vicryl Plus (Ethicon, J&J Medical, Somerville, NJ) (Figure 4).
The suture at the mesial release incision was removed after 3 days, while the suture at the papillae was removed one week later.
The restorative build up was realized two weeks after surgery. Radiographic assessment was performed at the end of surgery, at 4 months and 12 months after surgery (Figure 5). It is possible to observe that there is a good healing of soft tissue; the lesion is in regression phase (Figure 6). The patient no longer has signs and symptoms.

Discussion

Surgical endodontics represents a valid and decisive technique in cases of teeth presenting persistent apical periodontitis, where the orthograde endodontic retreatment has not allowed to resolve the initial problem (2).
In recent decades, the concept of surgical endodontics has evolved further, through the use of increasingly performing operating techniques dedicated to a minimally invasive approach that respects the initial anatomical situation of the patient, to the point of defining this type of treatment as "microsurgical" (3, 12, 19).
The operating microscope, the micromirrors, the dedicated instrumentation, the ultrasonic tips for root canal preparation and the marketing of new cements for the filling of the retrograde cavity represent the foundations for the success of these interventions.
However, the indications for microsurgical endodontic retreatment have not changed: persistent apical periodontitis with or without symptoms in elements with adequate prosthetic restorations, correction of problems due to extrusion of material or fracture of root canal instruments and the need for histological analysis of the periradicular tissue (20).
However, in some clinical situations, surgical micro-endodontic treatment is complicated by proximity to noble anatomical structures that represent an obstacle for the

Figure 6
Clinical situation 12 months after surgery

clinician: the maxillary sinus, the inferior alveolar nerve, the mental foramen or the floor of the nose.
For this reason, in recent years the use of surgical procedures has spread, similar to those used in guided implantology for the creation of templates dedicated to osteotomic procedures. This procedure is called guided surgical micro-endodontics and has already been described in numerous scientific publications (19-22).
Guided surgical micro-endodontics involves several operating phases; through an intraoral scan of the patient and the execution of a level II radiographic investigation (CBCT), a template is created which presents a dedicated invitation to perform the osteotomy (22).
The operator, by positioning the surgical template, carries out the operation guided by the slot created during the digital planning of the operation (22). This technology, which allows a selective ostectomy, makes the operator's maneuvers safer, preserving the anatomical structures close to the site to be treated (22).
In the last 5 years, however, dynamic navigation systems have been presented and marketed on the dental market.
There are several dynamic navigation systems with decidedly different characteristics and costs; dedicated software often have different fields of application.
Dynamic navigation, through a system of tracking stereo cameras, allows you to perform surgical interventions by following the operator's movements in real time on a dedicated video. The doctor, after an accurate planning phase, can carry out the treatment and eventually modify his therapeutic strategy in progress (13).
These systems are already used in robotic surgery in medicine and find the greatest field of application in orthopedic surgery, otorhinolaryngology, ophthalmology, vascular surgery, neurosurgery and oncological surgery (13).
Their applications in odontostomatology are many and under study. Guided navigation systems are mainly used in implantology, for planning and carrying out operations in safety, in the vicinity of noble anatomical structures.
In orthograde endodontics, guided navigation systems have proved to be useful for finalizing treatment cases of dental elements with calcified canals (10) and for planning and performing intraosseous anesthesia (23). Our clinical experience is in agreement with the literature; dynamic navigation in orthograde endodontics has allowed us to finalize several cases of highly calcified teeth.
The navigation system was recently used for planning and fabricating the pulp chamber opening in a group of extracted maxillary and mandibular incisors previously scanned with a CBCT (REF nr Jain).
In half of the elements the pulp chamber was opened with the free hand method and in half with the 3D-DNS method; subsequently the teeth were subjected to a control CBCT.
The results showed that there are no differences between the two techniques as regards the mandibular incisors, while the openings made with dynamic navigation in the upper incisal group were decidedly more conservative than with the freehand method (15).
The creation of virtual models for the simulation of orthograde dental retreatments with this method has been proposed, defining it as optimal for the retreatments of elements restored with glass fiber posts (12).
The applicability of this system for surgical micro-endodontic operations has recently been applied.
In a case of persistent apical periodontitis in the frontal sector; the treatment was performed by an undergraduate student, under the supervision of an expert operator (17). However, this case was conducted in the frontal sector, where the traditional microsurgical approach could have been used in complete safety.
Some authors have used the dynamic navigation system on anatomical preparations to compare the skills of expert and non-expert operators in surgical micro-endodontic operations, hypothesizing that the method would allow the results to be equalized between operators;

the results obtained from this study refer to a comparison between the operators, highlighting in both groups a high accuracy in the execution of the osteotomy and apicectomy maneuvers, a greater speed of intervention, but highlights the need for a steeper learning curve long, especially for non-expert operators (24). Ex vivo cadaver study design applied this technology on anatomical preparations reaching the conclusion that this method allows an accurate, rapid ostectomy with a lower bone volume removed, defining it as safe and very useful in the posterior mandibular sector (11, 25).
To date, a dedicated software to perform endodontic ostectomies with this navigation system has not yet been patented.

Conclusion

Dynamic navigation technology can be used in areas close to noble anatomical structures, avoiding damage. A more conservative osteotomy allows for faster healing, fewer anesthesias, reduces bleeding; this technology reduces operator and patient fatigue.
Dynamic navigation systems still have a high cost and require a period of training to speed up the learning curve. Further studies are needed to deepen and validate this method.

Clinical Relevance

This new technology can be a valid resource to retreat persistent periapical lesions, allowing the maintenance of tooth in the oral cavity.

Conflict of Interest

The authors deny any conflicts of interest related to this study.

Acknowledgement

None.

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CASE REPORT

Maxillary lateral incisor with Vertucci's type V root canal configuration

ABSTRACT

Aim: *To describe and discuss the procedures adopted during the endodontic treatment of a maxillary lateral incisor with Vertucci's type V root canal configuration.*
Summary: *A 30-year-old Caucasian male patient was referred for analysis of his left maxillary incisors, both compromised by a traumatic injury occurred seven days prior. His medical history was non-contributory. The root of tooth 21 presented a vertical root fracture, thus indicating its extraction. Tooth 22 showed no periodontal involvement or response to the cold sensitive test, but presented mild pain on both vertical percussion and apical palpation. The initial radiographic exam showed asymptomatic apical periodontitis, and suggested apical root fracture or apical root canal bifurcation. A cone-beam computed tomography (CBCT) was requested, and revealed no apical root fracture, but the presence of apical root canal bifurcation. The 12-month clinical and radiographic follow-up evidenced the partial success of the established therapy. Technological resources were relevant to the successful management of the complex case report described herein. However, patience, perseverance and clinical experience were also essential factors.*
Key learning points

- *Vertucci's type V classification is considered one of the rarest and most challenging root canal configurations among the existing anatomical complexities.*
- *This paper describes and discusses the procedures adopted during the endodontic treatment of a maxillary lateral incisor with Vertucci's type V root canal configuration.*
- *Besides the technological resources, patience, perseverance, and clinical experience were essential for performing a predictable endodontic treatment in a tooth affected by a diagnosis posing a great difficulty such as that presented herein.*

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Introduction

The main goal of endodontic treatment is to maintain or restore the health of periapical tissues. In vital teeth, the pulp is removed, and the root canal is emptied, cleaned, shaped, and hermetically filled with biocompatible material. Considering that the inflammation process is restricted to the pulp, and that the periapical tissues have not yet been compromised, the endodontic intervention is performed basically to maintain their integrity. On the other hand, in necrotic teeth, the pulp cells are definitely compromised, thus triggering the microbial colonization of the root canal system (RCS), and the development of apical periodontitis (1). A periapical lesion may be present even without being radiographically visible (2); therefore, endodontic treatment aims to restore the local tissue (1).

Endodontic infection cannot be eliminated, mainly due to the anatomical complexity of the RCS (3, 4). The substantial success rates of endodontic treatment in necrotic and infected teeth – 78,9% (5), 82,64% (6), 84,7% (7) and 86% (8) – are explained by the reduction in the microbial contingent, i.e., infection control (3), achieved mainly by effective chemomechanical preparation (9). Although chemical and mechanical cleaning occur together, it is understood didactically that they are performed by chemical substances and by endodontic instruments in contact with the root canal walls, respectively. Moreover, both are complemented by the physical cleaning mechanism of the irrigation process, performed by the flow and reflux of the irrigant (10). Nevertheless, knowledge of the root canal anatomy is essential for proper chemomechanical preparation (11).

In general, anterior teeth have a single root and canal (12, 13). Nonetheless, in the upper arch, endodontic treatments performed on central (14, 15) and lateral incisors with 2 canals (16, 17), and lateral incisors with 3 (18, 19) and 4 canals (20), have already been reported in the literature. Among the existing anatomical complexities, Vertucci's type V (21) classification is considered one of the rarest and most challenging root canal configurations. The aim of this paper was to describe and discuss the procedures adopted during the endodontic treatment of a maxillary lateral incisor with Vertucci's type V (21) root

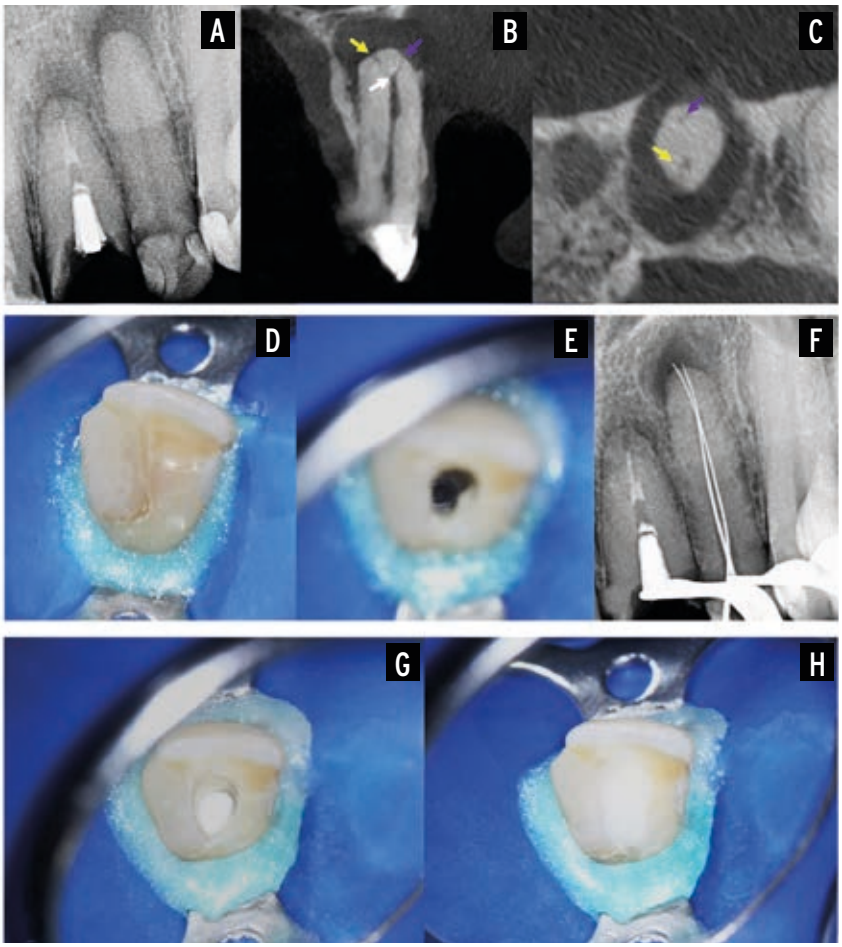

Figure 1
A) Initial periapical radiograph. **B)** and **C)** Sagittal and axial tomographic views, respectively (white arrow: start of bifurcation/purple arrow: buccal canal/yellow arrow: palatal canal). **D)** Initial clinical view. **E)** Coronal opening after initial exploration with #15 K-FlexoFile (Dentsply-Maillefer) and preparation of the root canal orifice and cervical and middle root canal thirds with #2, and #2 and #3 Largo and Gates-Glidden drills (Dentsply-Maillefer), respectively. **F)** Access to the apical bifurcation by using C-Pilot #10 (VDW) precurved files. **G)** Root canal filling with calcium hydroxide paste (Ultracal XS, Ultradent). **H)** Temporary coronary sealing with glass ionomer cement (Ionoseal, VOCO).

canal configuration. The 12-month clinical and radiographic follow-up evidences the partial success (repair in progress) of the established therapy.

Case report

This case report was written according to the Preferred Reporting Items for Case Reports in Endodontics (PRICE) 2020 Guidelines (22). A 30-year-old Caucasian male patient was referred to the clinic of one of the authors (H.B.) for analysis of his left maxillary incisors, both compromised by a traumatic injury caused by his falling from a horse seven days prior. His medical history was non-contributory. The anamnesis and clinical exam revealed that tooth 21 had a metal-ceramic crown that was lost due to the accident. Analysis of the root of this tooth using a dental operating microscope (DOM) showed a vertical root fracture, thus indicating its extraction. Tooth 22 showed no periodontal involvement or response to the cold sensitive test (EndoIce, Coltene/Whaledent, Cuyahoga Falls, OH, USA), but presented mild pain on both vertical percussion and apical palpation. The initial radiographic exam showed asymptomatic apical periodontitis, and suggested apical root fracture or apical root canal bifurcation (Fig. 1A). Therefore, a cone-beam computed tomography (CBCT) was requested, and revealed no apical root fracture, but the presence of apical root canal bifurcation (Fig. 1B and 1C). The patient was given a detailed explanation about the particularities and limitations of his case, and agreed to undergo the proposed endodontic treatment, for which he signed an informed consent form.

In the first visit, the patient received buccal infiltrative anesthesia (2% mepivacaine with adrenaline - 1:100.000, DFL, Rio de Janeiro, RJ, Brazil), and was fitted with a rubber dam. The surgical field was cleaned with 2.5% sodium hypochlorite (NaOCl) (Biodinâmica, Ibiporã, PR, Brazil) (Fig. 1D), and the coronal opening was performed with #1014 and #3083 drills (KG Sorensen, Barueri, SP, Brazil). The root canal orifice and the cervical and middle thirds were explored initially with #15 K-FlexoFile (Dentsply-Maillefer, Konstanz, Germany), and then prepared with #2, and #2 and #3 Largo and Gates-Glidden drills (Dentsply-Maillefer), respectively (Fig. 1E), applying 2.5 mL of 5.25% (Fórmula & Ação, São Paulo, SP, Brazil) after each use or change of file, and a NaviTip needle coupled to a 5 mL plastic syringe (Ultradent, Indaiatuba, SP, Brazil). After numerous attempts, the apical root canal bifurcation was accessed by using several C-Pilot #10 (VDW, Munich, Germany) precurved files (Fig. 1F). Subsequently, the cervical and middle root canal thirds were irrigated with 2.5 mL of a chelating solution (17% EDTA, Biodinâmica) for 3 minutes, dried with sterile absorbent paper points (Endo Points, Manacapuru, AM, Brazil), and filled with calcium hydroxide paste (Ultracal XS, Ultradent) as an intracanal dressing (Fig. 1G). The pulp chamber was obturated with a small sterile sponge, and the coronal opening was sealed with glass ionomer cement (Ionoseal, VOCO, Cuxhaven, Germany) (Fig. 1H).

In the second visit, the patient received buccal infiltrative anesthesia (2% mepivacaine with adrenaline - 1:100.000, DFL), and was fitted with a rubber dam. The surgical field was cleaned with 2.5% NaOCl (Biodinâmica), and after removing the temporary restoration and calcium hydroxide paste with a #1014 drill (KG Sorensen) and 2.5mL of 5.25% NaOCl (Biodinâmica), respectively, an ultrasonic tip (The Finder, Helse, Santa Rosa de Viterbo, SP, Brazil) was used to facilitate access to the apical root canal bifurcation (Fig. 2A and B). Afterward, both canals' working length (WL) was determined with an electronic apex locator (Root ZX II, J. Morita, Kyoto, Japan). Chemomechanical preparation was performed by using manual K-FlexoFiles from #15 to #30 (Dentsply-Maillefer), and applying 2.5 mL of 5.25% NaOCl (Fórmula & Ação) after each use or change of file. Subsequently, 2.5 mL of 5.25% NaOCl and 17% EDTA (Biodinâmica) were activated for 30 seconds by using both passive ultrasonic irrigation (PUI) (Irrisafe, Helse) and Easy Clean (Easy Equipamentos Odontológicos, Belo Horizonte, MG, Brazil), alternately. The root canals were then rinsed

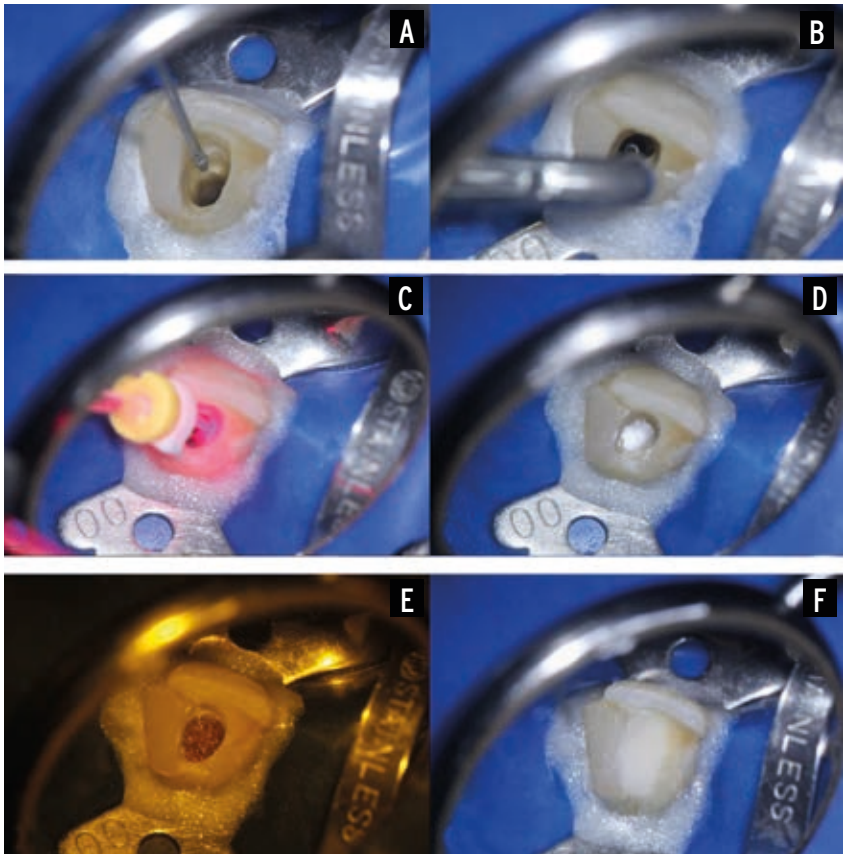

Figure 2
A) and **B)** Ultrasonic tip (The Finder, Helse) used to facilitate access to the apical root canal bifurcation. **C)** Optical fiber (MMOptics) positioned to perform irradiation. **D)** Root canal filling with calcium hydroxide paste (Ultracal XS, Ultradent). **E)** Small sterile sponge filling the pulp chamber. **F)** Temporary coronary sealing with glass ionomer cement (Ionoseal, VOCO).

with 1 mL of 5% sodium thiosulfate and 1 mL of 0.85% saline solution for 60 seconds each, and dried with sterile absorbent paper cones (Endopoints). Next, 0.5 mL of 25 µg mL^{-1} methylene blue (Vetec Quimica, Sigma Aldrich-Merck, Darmstadt, Germany) was injected into the root canals with a NaviTip needle coupled to a plastic syringe (Ultradent) up to the level of the access cavity, and left there 5 min for pre-irradiation. Then, the canals were irradiated with a low-power diode laser (Twin laser, MMOptics, São Carlos, SP, Brazil) through an optical fiber (MMOptics) with a diameter of 0.3 mm. The light was applied for 5 min at a wavelength of 660 nm and power of 40 mW without the optical fiber. The optical fiber was inserted into both root canals up to the WL (Fig. 2C). The root canals were again flushed with 10 mL of sterile 0.85% saline solution to remove the photosensitizer (23), dried with sterile absorbent paper cones (Endopoints), and filled with calcium hydroxide paste (Ultracal, VDW) as an intracanal dressing (Fig. 2D). The pulp chamber was obturated with a small sterile sponge (Fig. 2E), and the coronal opening was sealed with glass ionomer cement (Ionoseal, VOCO) (Fig. 2F). In the last visit, the same initial procedures were performed as described above. Next, the calcium hydroxide paste was removed by using a #30 manual K-FlexoFile, PUI and Easy Clean, as previously described. The root canals were then flushed with 2.5 mL of 17% EDTA (Biodinâmica) for 3 minutes, irrigated with 2.5 mL of saline solution, and dried with sterile absorbent paper cones (Endopoints). The main gutta-percha cones (30/.02) (Endopoints) were placed and checked radiographically for accurate positioning (Fig. 3A), then removed from the canals, labeled with AH Plus sealer, and reinserted. Additionally, 4 B8 accessory gutta-percha cones (Endopoints) were inserted, and #60 gutta-condenser (Dentsply-Maillefer) and #3 Paiva condenser were used to perform the thermomechanical and vertical compactions, respectively (Fig. 3B). The pulp chamber was cleaned with a small sterile sponge moistened with 70% alcohol, and the coronal sealing was performed with SDR bulk-fill resin (Dentsply-Maillefer) (Fig. 3C). Periapical radiography (Fig. 3D) and CBCT (Fig. 3E and F: sagittal and axial tomographic views, respectively) were both performed 12 months after treatment, and showed the healing in progress (Fig. 4).

Discussion

For a long time, diaphanization techniques were the main means used to analyze the root canal anatomy. Currently, other methods are used, such as CBCT and micro-computed tomography (micro-CT), which evidence in greater detail how changes in standard anatomical patterns can affect all the teeth (24). Anterior teeth typically have a single root and canal. Nonetheless, in the upper arch, endodontic treatments in central (14, 15) and lateral incisors with 2 canals (16, 17), and lateral incisors with 3 (18, 19) and 4 canals (20) have already been reported in the literature. Among the existing anatomical complexities, Vertucci's type V (21) classification is considered

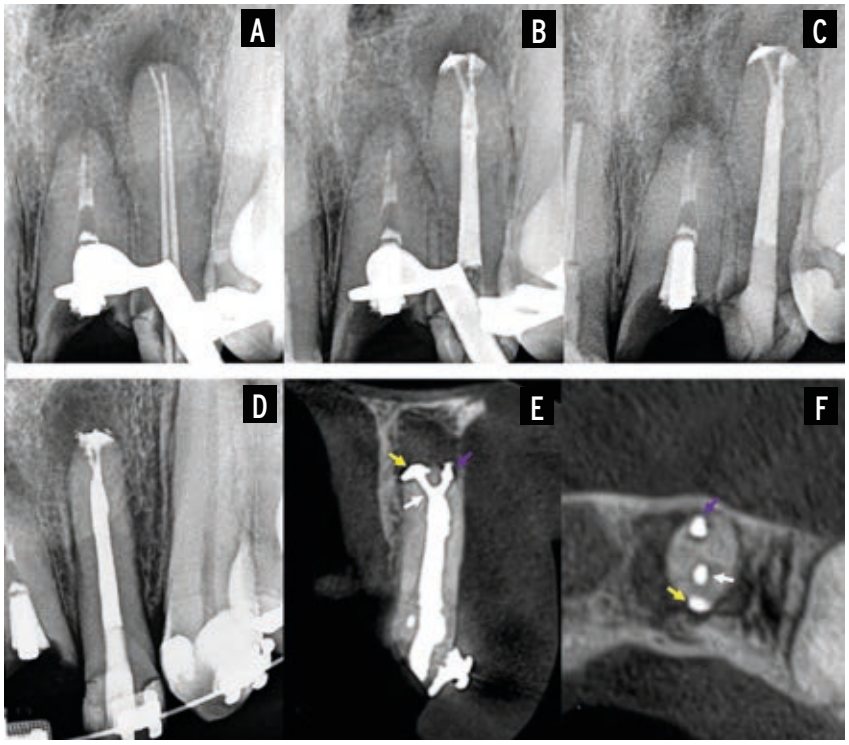

Figure 3
A) Periapical radiograph of the main gutta-percha cones. **B)** Periapical radiograph after thermomechanical and vertical compactions. **C)** Final periapical radiograph after coronal sealing with SDR bulk-fill resin (Dentsply-Maillefer). **D)** Periapical radiograph performed 12 months after the treatment. **E)** and **F)** Sagittal and axial tomographic views, respectively, taken 12 months after the treatment, showing partial success (healing in progress) (white arrow: start of bifurcation/purple arrow: buccal canal/yellow arrow: palatal canal).

one of the rarest and most challenging root canal configurations. The aim of this paper was to describe and discuss the procedures adopted during the endodontic treatment of a maxillary lateral incisor with Vertucci's type V (21) root canal configuration. The 12-month clinical and radiographic follow-up evidences the partial success (repair in progress) of the therapy.

Although the success of endodontic treatment mainly depends on the cleaning and/or disinfection of the RCS (1), it is imperative to be knowledgeable about anatomical complexities, including extra- and intracanal variations (14-20, 25). This understanding is required to accurately identify anatomical landmarks before and during the treatment, associated with normal and aberrant anatomy situations observed in daily clinical practice. Accurate diagnosis and careful analysis of periapical radiographs could provide relevant anatomical information. Should the clinician judge this information not sufficient for conducting the correct endodontic treatment, a CBCT may be useful (13, 14). In the present case report, a CBCT was requested to investigate the presence of both apical root fracture and apical root

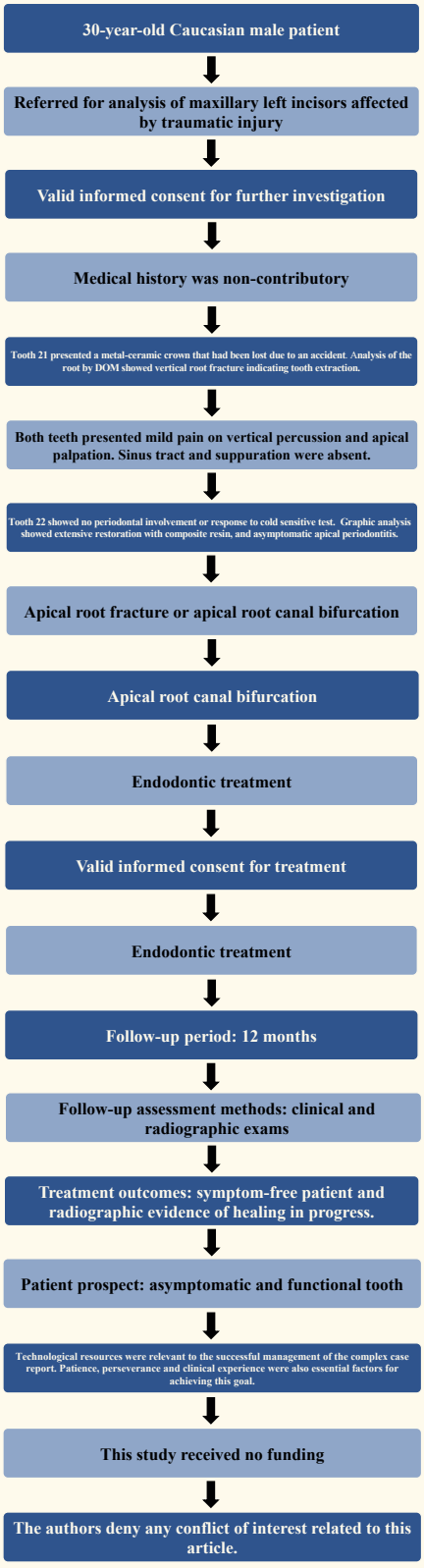

Figure 4
PRICE 2020 flowchart.

canal bifurcation, in a previously traumatized maxillary lateral incisor, following a suspicion established after careful analysis of the initial radiograph.

An adequate initial radiograph can show anatomical complexities directly or indirectly. A sudden break, or the narrowing or change in the radiographic density of the root canal, may indicate the presence of additional canals (25). In the current case report, a sudden break was not clearly visible in the initial radiograph, because of the bifurcation in the last millimeters of the root canal. A CBCT exam clearly revealed the absence of apical root fracture, and the presence of apical root canal bifurcation, thus providing an accurate diagnosis, and enabling more predictable treatment planning.

According to Perrin et al. (26), although complex root canal configuration poses a serious endodontic challenge, visualization of the pulp chamber under DOM (mainly) (27), or loupes, and subsequent exploration help decrease the risk of iatrogenic errors, increase the likelihood of discovering extra canals, and facilitate canal negotiation. Yadav et al. (28), reported that it is important to extend the access opening carefully, particularly over the lingual shoulder, in order to uncover any additional canals. In the present case report, this strategy was not used "for diagnostic purposes", since the bifurcation was identified by CBCT; however, it was important to facilitate the initial negotiation of the canals, and accurately perform the other treatment stages.

A more conservative instrumentation by using manual files was chosen due to the reduced dimensions of the root canals beyond the bifurcation. This strategy could only be performed based on the tactile sensitivity provided by manual instrumentation. Less root wear (i.e. less effective mechanical cleaning) was "compensated" by complementary antimicrobial strategies, such as using calcium hydroxide paste as intracanal dressing and photodynamic therapy, both extensively reported in the literature (23, 29).

Despite the metallurgical revolution experienced by Endodontics in recent decades through the development of new instruments, it is infeasible to complete an endodontic treatment without using manual files. They must be used during the initial exploration of the root canal, the investigation, location, and initial negotiation of extra-canals, especially in cases of high (anatomical) complexity, such as the one presented herein, etc. In addition, it is also important to reiterate that robust scientific evidence has shown that using endodontic instruments in an automated way has provided greater comfort for both patient and clinician and greater dynamism to complete the treatment when possible. However, the prognosis of endodontic treatment was not changed from the automation of biomechanical preparation (30).

Another important issue that must be discussed is the root canal obturation method. Tagger's hybrid technique has been shown to provide promising results in terms of adaptation and adhesiveness of filling materials to the root canal walls (31, 32), and sealer penetration into dentinal tubules (33). This technique was used in the present case report, because of these advantages.

Lastly, it is important to emphasize that all the measures highlighted herein were relevant for the successful management of this complex case report. However, patience, perseverance and clinical experience were also essential factors for achieving this goal (34, 35).

Conclusion

Although most studies indicate the presence of a single root and canal in maxillary lateral incisors, the clinician must be aware that there are anatomical complexities that also affect this dental group. An accurate initial radiograph, and superior diagnostic imaging resources, such as CBCT and DOM, as well as patience, perseverance and clinical experience are essential for performing a predictable endodontic treatment in a tooth affected by a diagnosis posing a high level of difficulty such as that presented herein.

Clinical Relevance

Vertucci's type V classification is considered one of the rarest and most challenging root canal configurations among the existing anatomical complexities. This paper describes and discusses the procedures adopted during the endodontic treatment of a maxillary lateral incisor with Vertucci's type V root canal configuration. The 12-month clinical and radiographic follow-up evidences the partial success (repair in progress) of the established therapy. Besides the technological resources, patience, perseverance, and clinical experience were essential for performing a predictable endodontic treatment in a tooth affected by a diagnosis posing a great difficulty such as that presented herein.

Conflict of Interest

The authors deny any conflicts of interest related to this study.

Acknowledgements

The authors deny any financial affiliations.

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CASE SERIES

Management of necrotic teeth with apical periodontitis using sonically activated irrigation

ABSTRACT

Aim: *To present root canal treatment using sonically activated sodium hypochlorite for cases with necrotic pulp and apical periodontitis.*
Summary: *Four patients were scheduled for root canal treatment diagnosed with periapical pathosis and bone resorption with a periapical index (PAI) score not less than 3. After access cavity preparation and working length determination, the cleaning procedure was performed using sodium hypochlorite (NaOCl) 2.5% irrigation activated by EndoActivator; then, teeth were filled with gutta-percha. After a follow-up period with an average of four years, clinical and radiographic findings showed complete healing and bone reformation.*
Key learning points:

- *Clinicians must appreciate the information gained from scouting about the average root canal size; based on that; we can determine the shaping & disinfection strategy.*
- *Sonically activated irrigation can be a predictable approach for cleaning infected teeth with ample root canal space without apical instrumentation.*
- *Activating irrigation can help to preserve dentine meanwhile achieving a successful outcome.*

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KEYWORDS *Apical periodontitis, non-instrumentation, root canal treatment, apical preparation size, irrigation activation*

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Introduction

Microorganisms and their byproducts are the leading cause of inflammation of the pulp and periapical tissues (1). Therefore, the primary objective of root canal treatment is to eliminate microorganisms and pathologic debris from the pulp space (2) and prevent its reinfection (3).
Optimal apical preparation diameter still has been a subject of controversy (4); some authors suggested a pre-determined size beyond 35 or 40 (5), while others recommended enlarging the canal three sizes larger than the first apical binding file would be adequate (6). On the other hand, others reported that large apical sizes remove more significant amounts of the root dentine that, could weaken the root and lead to fractures (7). Besides, Literature showed that more than half of the root canal walls remain untouched (8).
Previous years have witnessed several developments in the irrigation activation procedures such as sonic or ultrasonic activation, negative pressure, and laser technologies (9). These devices dramatically improve the antimicrobial and cleaning abilities of the irrigants, in addition to preserving the root dentine and maintaining a high fracture resistance (10, 11).
The EndoActivator® (Advanced Endodontics, Santa Barbara, CA) is an electrically driven unit operating at stated frequencies of 33, 100, and 167 Hz (12). It employs polymer tips of different sizes (size 15, .02 taper, size 25, .04 taper, size 35, .04 taper) to activate the irrigants sonically (12).
This report presents a case series in which a root canal cleaning procedure was performed using sonic activation of irrigation without apical instrumentation, leading to a successful radiographic & clinical outcome.

Report

A total number of four male patients with an age range from 15 to 41 years old were scheduled for root canal treatment. Clinical and radiographic examination revealed that all teeth had ne-

Table 1
Preoperative evaluation and Diagnosis

Case no.	Tooth no.	Sex /age	Symptoms	Sinus tract	Swelling	Percussion	Palpation	Mobility	Diagnosis	Preop. PAI score	Initial binding file
1	15	M/15	No	Yes	Intraoral	No	No	Within normal limit	Chronic apical abscess	5	#55
2	24	M/17	Pain	No	Extraoral /intraoral	Yes	Yes	Grade I	Facial cellulitis	3	B #25 P #30
3	41	M/30	No	No	No	No	No	Within normal limit	Asymptomatic apical periodontitis	4	#30
4	12	M/41	No	No	No	No	No	Within normal limit	Asymptomatic apical periodontitis	4	#35

crotic pulp and periapical pathosis with bone resorption. Diagnosis for each case is recorded in Table 1.

All cases had a clinical evaluation of mobility, soft tissue lesions, percussion, and palpation (Table 1). Radiographic evaluation was done by periapical radiograph using a film holder for parallel technique (Rinn Dentsply Sirona, Weybridge, UK). Bone resorption with PAI score (13) not less than 3 was recorded for all cases. The patient's medical and family history was noncontributory. After explaining the treatment procedure, written informed consent was obtained from the patient or guardian. The local anesthetic solution 2% lidocaine containing 1:100,000 epinephrine (Dentsply Sirona, York, PA) was administrated, and all teeth were isolated with a dental dam (Crosstex, New York, USA), followed by removal of caries and defective restorations (if present). Conventional straight-line access cavity preparation after building the missing proximal wall using chemical cure glass ionomer (Dentsply Detrey, Konstanz, Germany). A stainless-steel K file size #10 (Dentsply Maillefer, Ballagues, Switzerland) was used to scout root canals to evaluate internal canal anatomy, dimension, and geometry. Then the canals were irrigated using 5 ccs of NaOCl 2.5% (Chloraxid, Cerkamed, Stalowa Wola, Poland). The size of the scouting file was increased until it binds at the provisional working length. The initial binding file was #25 or larger for all cases.

An electronic apex locator (X-SMART DUAL, Dentsply Sirona, Ballaigues, Switzerland) was used to measure the final working length and confirmed by a periapical radiographic image (Vix-WinTM Platinum, Gendex Dental Systems, Illinois, USA) with parallel technique.

5 ccs of (NaOCl) 2.5% were delivered by needle with gauge 30 (Prorinse Maillefer, Ballaigues, Switzerland) at insertion depth 1 mm from full working length (FWL). The irrigation was activated by Endoactivator tip size (15/.02) at 10000 CPM (cycles per minute) for 1 minute while moving the tip up & down with a vertical amplitude of about 2 mm with maximum insertion of 1 mm from FWL. The irrigation cycle was repeated 3 times for each canal, and the canal was irrigated with 5

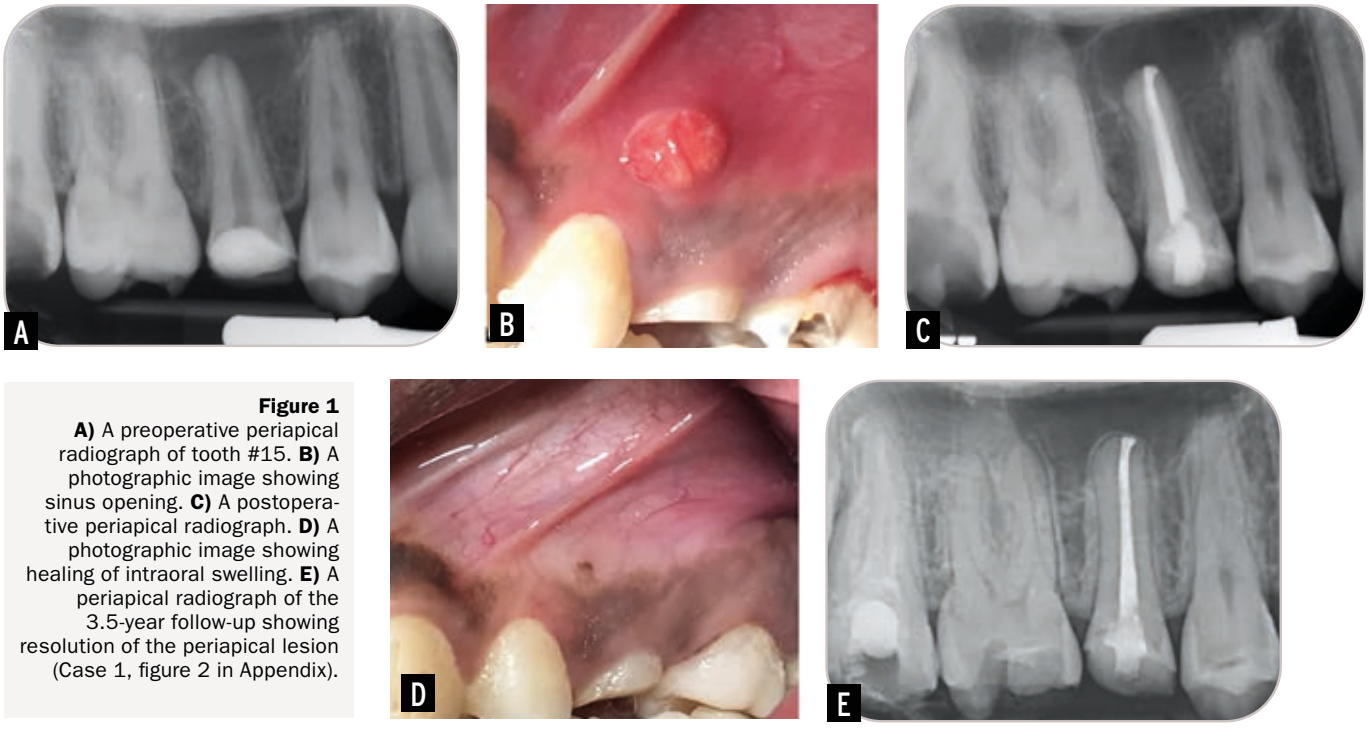

Figure 1
A) A preoperative periapical radiograph of tooth #15. **B)** A photographic image showing sinus opening. **C)** A postoperative periapical radiograph. **D)** A photographic image showing healing of intraoral swelling. **E)** A periapical radiograph of the 3.5-year follow-up showing resolution of the periapical lesion (Case 1, figure 2 in Appendix).

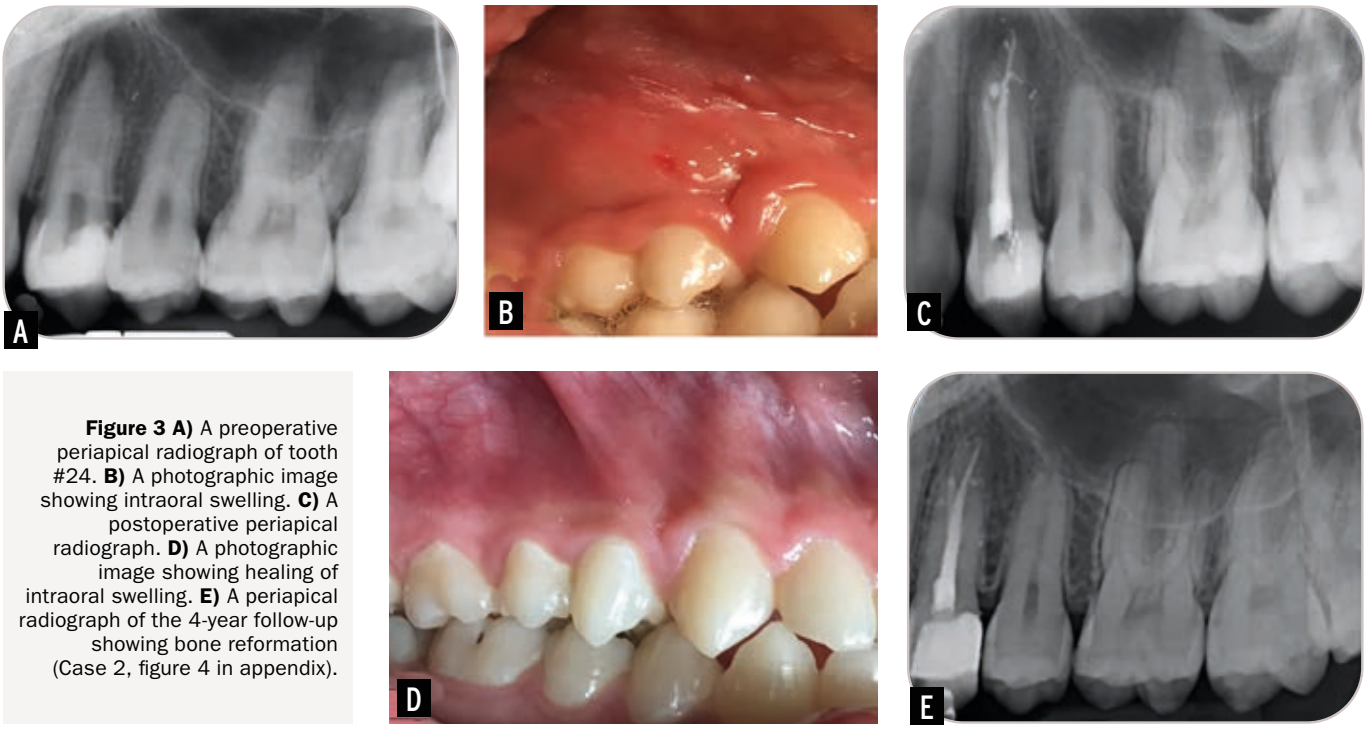

Figure 3 A) A preoperative periapical radiograph of tooth #24. **B)** A photographic image showing intraoral swelling. **C)** A postoperative periapical radiograph. **D)** A photographic image showing healing of intraoral swelling. **E)** A periapical radiograph of the 4-year follow-up showing bone reformation (Case 2, figure 4 in appendix).

ccs of NaOCl 2.5% to replenish the irrigant and flush out debris after each cycle. Antibacterial medication (amoxicillin-clavulanate, 1000 mg twice daily for five days) was given only for one case with facial cellulitis (Table 2).

Based on the initial binding file size master gutta-percha cone was selected. A tug back (resistance while pulling) was felt and confirmed radiographically. In case of no tug back, the cone was trimmed by surgical steel blade #15 (Swann-Morton, Sheffield, England) and gutta-percha gauge (Dentsply Sirona, Ballaigues, Switzerland) till it was achieved. The warm vertical compaction technique was selected for filling root canal space and AH26 silver-free sealer (Dentsply Detrey, Konstanz, Germany). The tooth was restored with glass ionomer (Dentsply Detrey, Konstanz, Germany), then referred to the general dentist for a final restoration.

The patients were evaluated clinically and radiographically in the follow-up visits. The clinical examination assessed mobility, any remaining soft tissue lesions, swelling (if present), percussion, and palpation. The radiographic examination comprises independent (PAI) scoring using periapical radiographic images by parallel technique.

After an average follow-up duration of four years (Table 2), all cases were asymptomatic clinically; furthermore, radiographic examination showed complete healing of peri-radicular radiolucency with a PAI

Table 2
Treatment outcome

Case no.	Tooth no.	Prescribed antibiotic	Postop. PAI score	Years of final review	Outcome
1	15	No	1	3.5	Healed
2	24	Yes	1	4	Healed
3	41	No	1	3.5	Healed
4	12	No	1	4	Healed

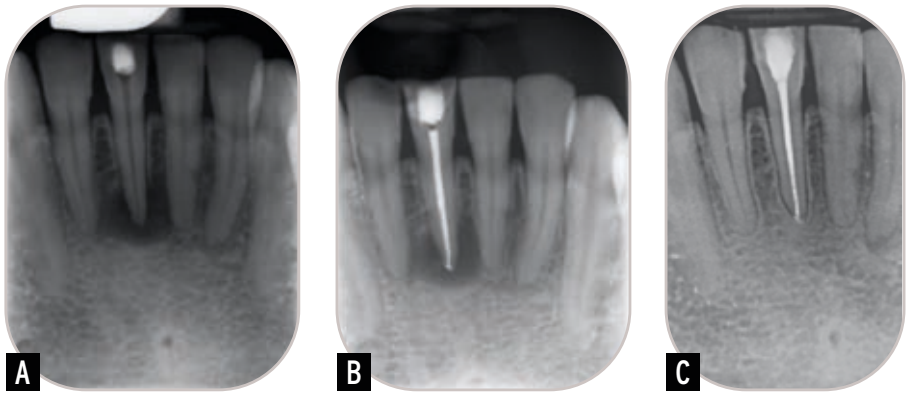

Figure 5
A) A preoperative periapical radiograph of tooth #41. **B)** A postoperative periapical radiograph of tooth #41. **C)** A periapical radiograph of the 3.5-year follow-up showing bone reformation (Case 3, figure 6 in appendix).

score of 1, which is normal. Concerning final restoration, all cases had direct adhesive restoration except one case (case 1, figure 2 in appendix) that did not comply with the recommended treatment.

Discussion

Bacteria is the main reason for pulpal and periapical infection (1, 14, 15), so eliminating microorganisms is the main target of root canal treatment to achieve healing (16). In this report, complete healing of four cases with necrotic pulp & apical periodontitis was achieved by sonic activation of (NaOCl) 2.5% using EndoActivator to disinfect the root canal space. EndoActivator enhances depletion of bacteria and biofilm severance (17-19). The tip oscillation creates a powerful hydrodynamic phenomenon (18), leading to effective cleaning of the root canal space (20). Additionally, irrigant replenishment after each activation cycle increases the antibacterial effect of NaOCl (21).

The conjectural relation between an irrigant or irrigation technique with a clinical outcome is often deficient (22). A well-known drawback in root canal irrigation research is the rareness of clinical studies, mainly those addressing the long-term treatment result. Moreover, depending on laboratory studies to recommend solutions or techniques is considered the lowest evidence level (23). To date there is no clinical study correlated between apical preparation size & clinical outcome. In this way, the present case series is trying to

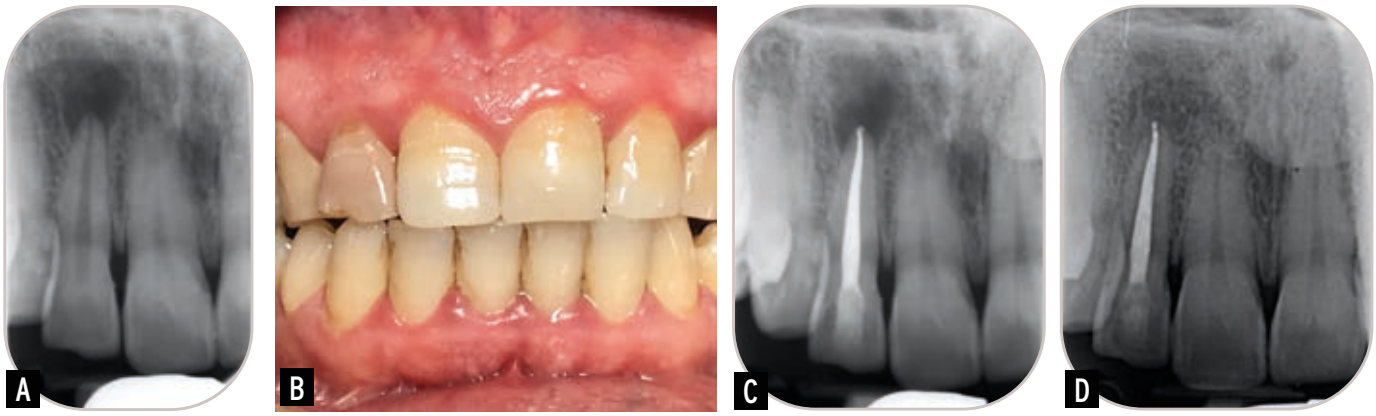

Figure 7
A) Preoperative periapical radiograph for tooth #12. **B)** A photographic image showing a discoloration of tooth #12. **C)** A postoperative periapical radiograph. **D)** A periapical radiograph of the 4-year follow-up showing bone reformation (Case 4, figure 8 in appendix).

bridge the gap between laboratory studies & clinical application by presenting the treatment outcome of cases treated with sonically activated irrigation without apical preparation after an average of 4 years of follow-up. So, we can adopt more conservative approach in root canal treatment based on both research & clinical evidences.

Nowadays, the primary role of instrumentation is to provide a way to the apical third for the irrigants to carry out the main bulk of cleaning and disinfection (24). Accordingly, large canals may not require this shaping action as long as the irrigant could be delivered to the apical third & efficiently activated to remove the remaining pulp tissues and microorganisms (25).

The optimal apical preparation diameter is a never-ending issue and one of the most debatable topics in endodontics, acknowledging the needed balance between microbial reduction and preserving tooth structure (26). Aminoshariae & Kulild recommended enlarging the apical size for patients with necrotic pulps and periapical lesions to increase healing outcome in terms of clinical and radiographic evaluations (27). however, the current case series showed a successful outcome without apical preparation.

Boosting root canal disinfection could be achieved using more effective irrigation activation methods (28). Therefore, it may be recommended to keep the apical size as minimal as possible, provided that sufficient irrigation is feasible (29), and so this will preserve root dentine (30).

The limitation of this case series is the restricted application to large canals with an initial binding file not less than size #25.

Conclusion

In this case series, teeth with necrotic pulp & apical periodontitis were treated with non-instrumentation technique by sonic activation of NaOCl 2.5% showed favorable clinical and radiographic outcome. So, if the average apical diameter is equal to or greater than #25 and irrigation needle can reach easily up to 1 or 2 mm from the full working length, we can adopt more conservative approach like sonic activation of irrigation to achieve efficient disinfection meanwhile preserving the root canal dentine. Further clinical trials focusing on the clinical outcome in relation to the irrigation activation and apical preparation size are recommended.

Clinical Relevance

Clinical and radiographic outcomes were adequate after an average of 4 years of endodontic treatment using activated irrigation. We can rely on the irrigant for cleaning the root canal space if there is sufficient space for proper activation. So, we can successfully treat root canals without or with minimal instrumentation and preserve the root dentine.

Conflict of Interest

The authors deny any conflicts of interest related to this study.

Acknowledgment

Primary Health Corporation, Doha, Qatar, will provide article publication fees if present.

Appendix

Flow charts for all cases follows after references.

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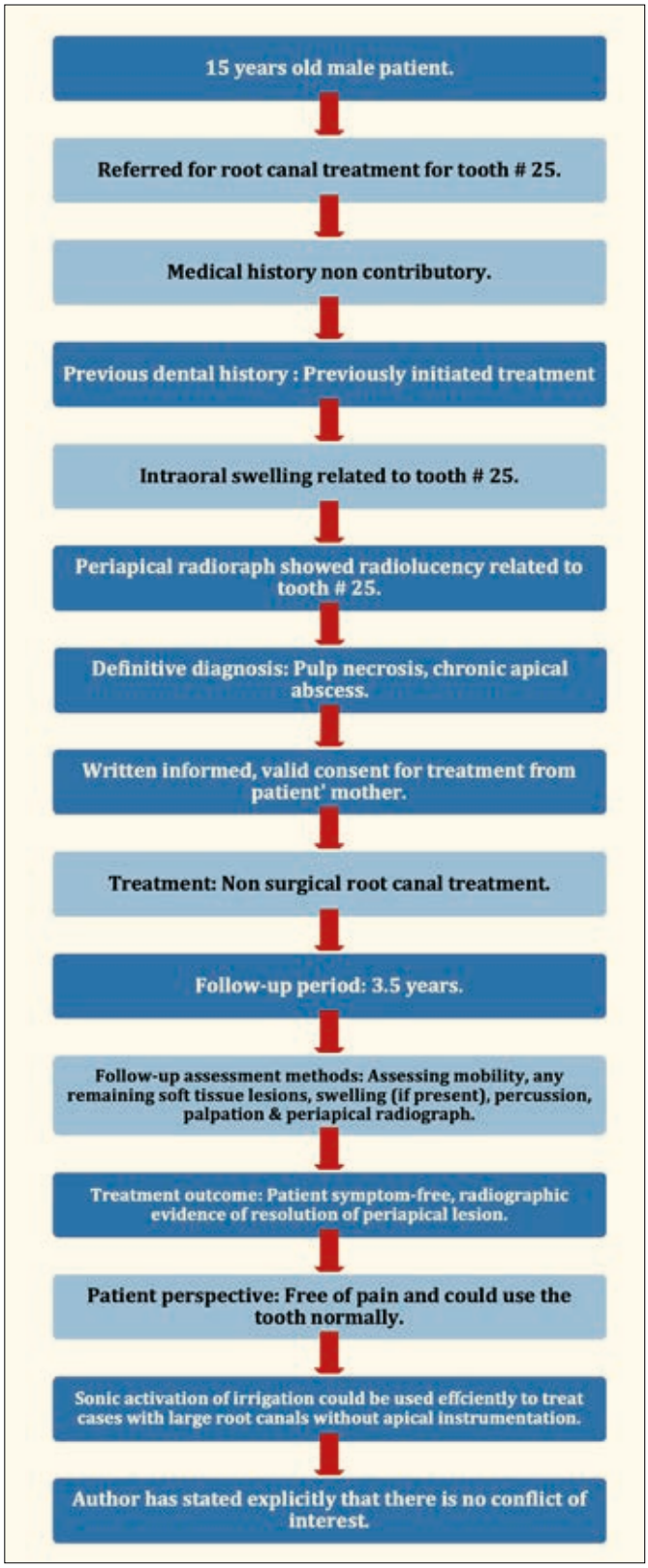

Figure 2
Price 2020 flow chart for case 1.

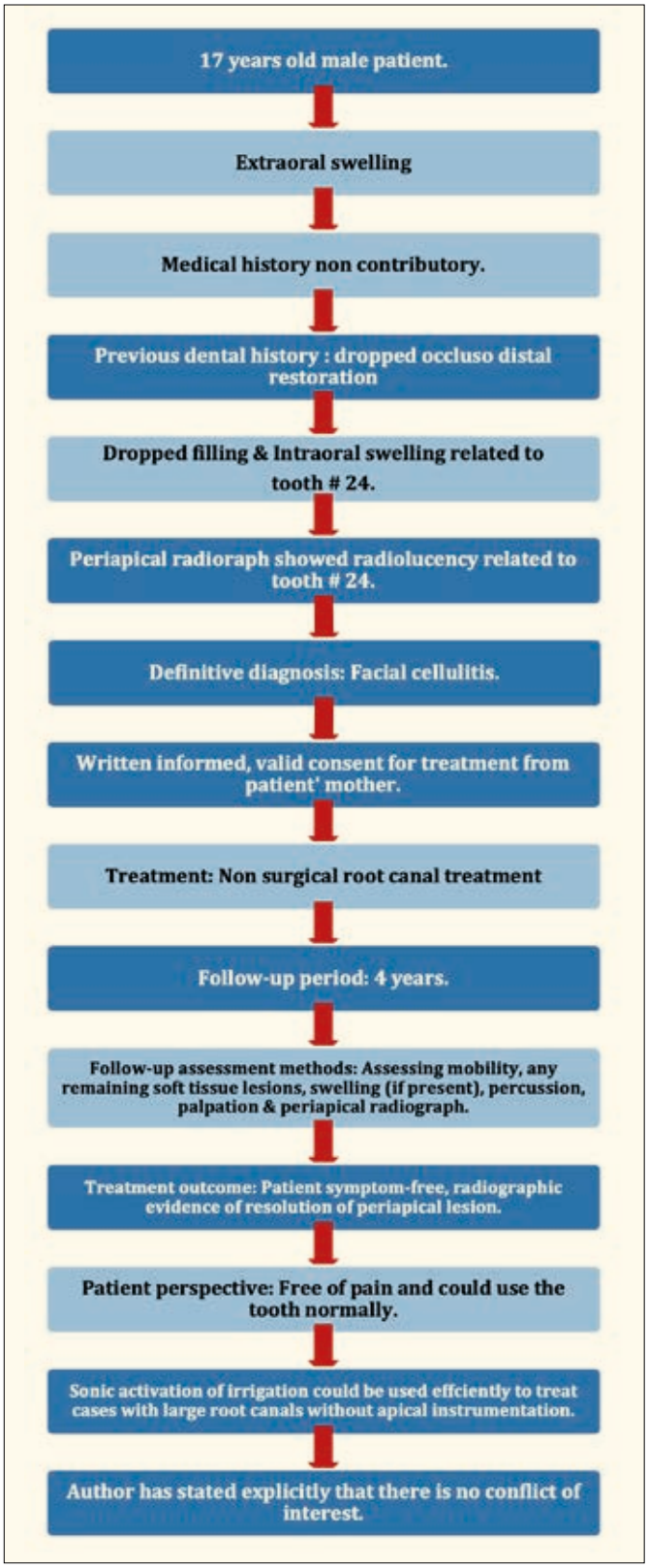

Figure 4
Price 2020 flow chart for case 2.

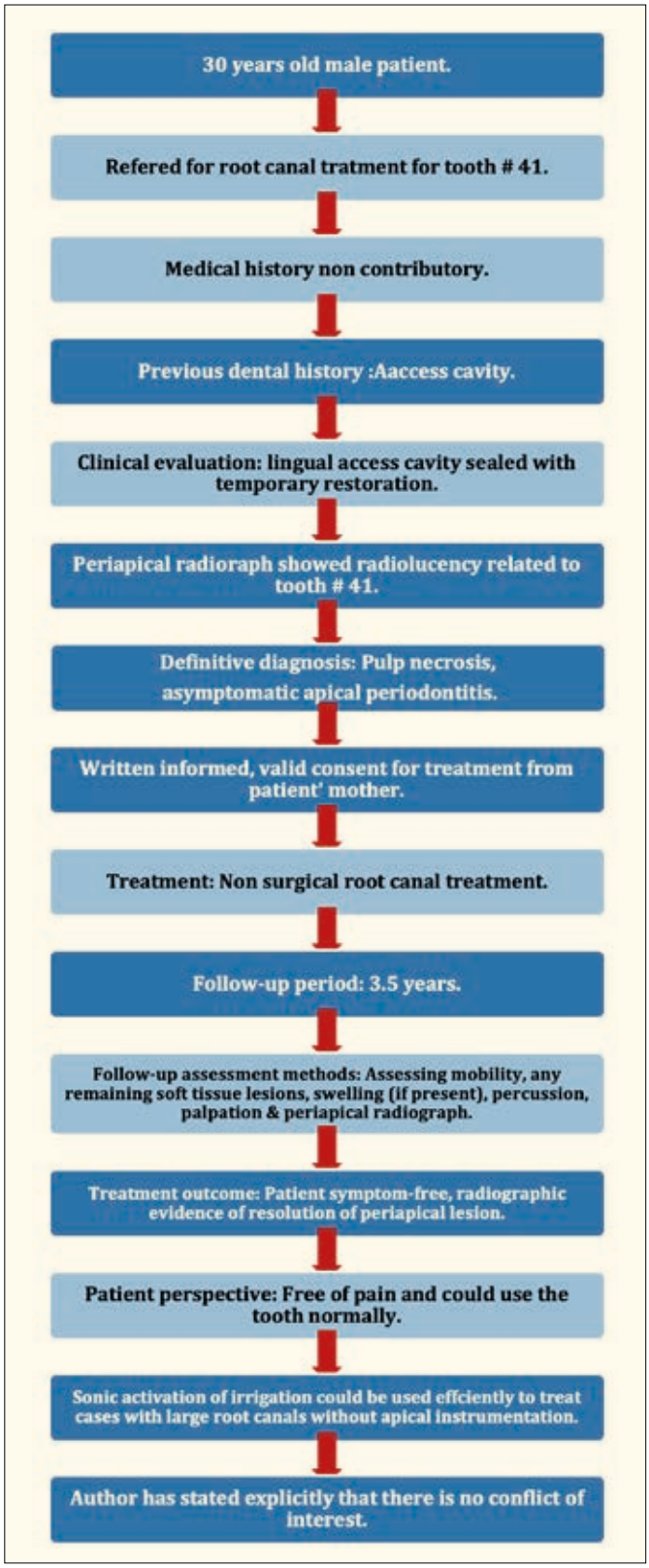

Figure 6
Price 2020 flow chart for case 3.

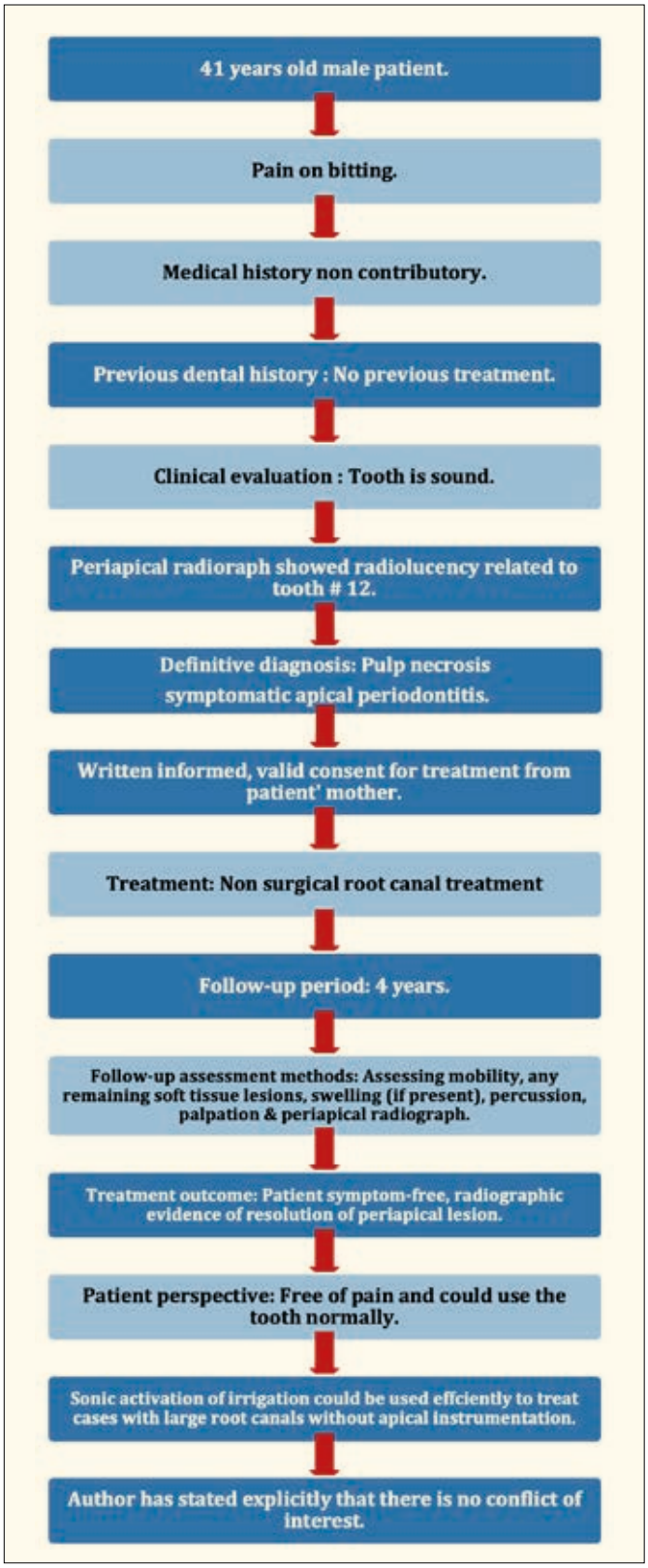

Figure 8
Price 2020 flow chart for case 4.

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Lettera DEL PRESIDENTE

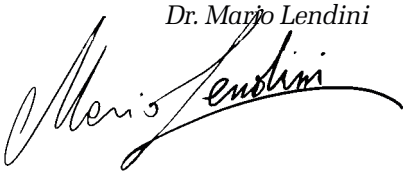
Cari Amici,

siamo finalmente arrivati all'apice del calendario culturale 2023 della Società Italiana di Endodonzia e sono orgoglioso di condividere con Voi il programma del 38° Congresso Nazionale SIE **SMART ENDO - Certezze Vs Innovazioni** che si svolgerà a Bologna il 9, 10 e 11 novembre.
La SIE ha, naturalmente, nel proprio DNA l'Endodonzia che è stata ed è, orgogliosamente unici, l'argomento monotematico dei propri congressi; questo non significa limitare la nostra visione, ma piuttosto ampliarla e approfondirla condividendo le conoscenze e le esperienze di tanti Soci che hanno duramente lavorato nella ricerca clinica e scientifica e che, come Relatori nelle varie sessioni congressuali, possono mettere a disposizione della nostra crescita professionale.
Quando cediamo alla multidisciplinarietà non perdiamo mai il punto di vista endodontico e chiediamo a Relatori di altre Società Scientifiche di creare i giusti link fra la nostra e la loro specialità per offrire il miglior aggiornamento possibile e quindi quella ricaduta reale di capacità clinica che ciascuno di noi vuole portarsi con sé quando partecipa a un evento di aggiornamento specialistico.
Questo congresso in particolare è stato progettato non per essere un evento riservato a un'élite di super specialisti, ma per offrire ai Colleghi che affrontano la professione a 360° e soprattutto ai giovani che sempre di più operano come consulenti, una disamina semplice e lineare ma, come è giusto, di altissima qualità su tecniche, materiali e strumenti di assoluta attualità.
Abbiamo scelto il titolo **SMART ENDO** perché vogliamo condividere una nostra certezza: l'Endodonzia attuale è enormemente più facile e predicibile del passato, anche recente, ma, proprio per questo, l'operatore deve costruire un bagaglio aggiornato di conoscenze su strumenti, apparecchiature e materiali, soprattutto quelli più innovativi, nell'ambiente certificato, controllato e affidabile di una società scientifica come la SIE.
Il sottotitolo rappresenta la filosofia del congresso, ovvero offrire una visione ragionata e approfondita di quali siano le **Certezze Vs Innovazioni**. Quali sono i punti fermi, sotto l'aspetto clinico e scientifico, ormai validati?

Lettera del Presidente

Quali sono le novità sulle quali c'è ancora molta strada da percorrere?
Il tema e il filo conduttore del congresso sono i **materiali bioceramici**, in tutte le loro formulazioni e relative applicazioni cliniche, e le nuove variazioni delle leghe NI-TI che applicate agli strumenti attuali ne hanno cambiato profondamente le caratteristiche tecniche, il modo di utilizzo e la stessa clinica. Le diverse sessioni affronteranno queste tematiche in macro aree cliniche: i Relatori non sono stati chiamati a fare una semplice relazione, ma a confrontarsi in un gruppo di lavoro specialistico per analizzare l'argomento in modo completo ed esaustivo.
Il futuro quindi è già nel nostro presente e il fatto che ancora, magari, non utilizziamo alcune tecnologie non significa che non siano già una realtà affidabile con cui dobbiamo acquisire familiarità. La SIE anticipa i tempi e propone il corso pre-congresso che avrà per tema **Il work-flow digitale in Endodonzia**. Relatori esperti fonderanno sinergicamente conoscenze cliniche, tecnologiche e informatiche per analizzare lo stato dell'arte attuale e darci la possibilità di applicarle immediatamente nel nostro lavoro di tutti i giorni.
Tutti noi sappiamo quanto sia fondamentale anche in Endodonzia un team affiatato e preparato. La SIE ha deciso di dedicare specificamente alle assistenti alla poltrona un'intera sessione di aggiornamento non solo sulle tecniche, i materiali, gli strumenti e le attrezzature endodontiche, ma, soprattutto, sulle modalità e le posizioni di lavoro al microscopio operatorio perché da sempre la nostra filosofia è che **inSIEme** si raggiungono i migliori risultati!
Il Premio Garberoglio per la ricerca scientifica in Endodonzia, il Premio Lavagnoli-Riitano per la clinica, i case report e i case series e il Miglior Poster, offrono a giovani Colleghi e Studenti la possibilità di misurarsi in un contesto di eccellenza per un risultato prestigioso e a noi tutti di valutare quale sia l'evoluzione reale della nostra specialità.
Tutto questo, ma non solo questo… è il Congresso SIE 2023! La possibilità di incontrarci e di confrontarci direttamente, gli eventi sociali, le tavole cliniche SIE e quelle degli Sponsor, che a nome della Società ringrazio per il loro costante, attivo ed insostituibile supporto, lae mostra merceologica per toccare con mano le novità, insieme con un programma scientifico e culturale di altissimo livello costituiscono un mix di opportunità umane e professionali veramente imperdibile.
Benvenuti al 38° Congresso Nazionale della Società Italiana di Endodonzia!

Società Italiana di Endodonzia
Il Presidente
Dr. Mario Lendini



STRUTTURA SOCIETARIA

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Bresciano Dott. Bartolo
Cavalleri Prof. Giacomo
Pecora Prof. Gabriele
Perrini Dott. Nicola
Vignoletti Dott. Gianfranco

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Malky Dott. Maher
Mancini Dott. Roberto
Mancini Dott. Mario
Mancini Dott. Manuele
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Messina Dott. Giovanni
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Tonini Dott. Riccardo
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Vecchi Dott. Stefano
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Veralli Dott. Eduardo
Vittoria Dott. Giorgio
Volpi Dott. Luca Fedele
Zaccheo Dott. Francesco
Zaccheo Dott. Fabrizio
Zerbinati Dott. Massimo
Zilocchi Dott. Franco

SOCI AGGREGATI

Giovinazzo Dott. Luca

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Past President
Fornara Dott. Roberto
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Castro Dott. Davide
Coordinatore della Comunicazione
Polesel Dott. Andrea
Revisore dei Conti
Vecchi Dott. Stefano
Revisore dei Conti
Vittoria Dott. Giorgio

SOCI SCOMPARSI

Ricordiamo con affetto e gratitudine i Soci scomparsi:

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Socio Attivo
Borsotti Prof. Giancarlo
Socio onorario
Castagnola Prof. Luigi
Socio Onorario
De Fazio Prof. Pietro
Socio Attivo
Dolci Prof. Giovanni
Socio Onorario
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Socio Onorario
Spina Dott. Vincenzo
Socio Onorario
Zerosi Prof. Carlo
Socio Onorario

COME DIVENTARE SOCIO ATTIVO/AGGREGATO

Scaricabile dal sito **www.endodonzia.it**

SOCIO AGGREGATO

Per avere lo status di Socio Aggregato si dovrà presentare la documentazione descritta nel sito www.endodonzia.it che sarà valutata dalla Commissione Accettazione Soci. La documentazione che verrà presentata dovrà mostrare con rigore, attraverso casi clinici, l'interessamento del candidato alla disciplina endodontica.
Un meccanismo a punti è stato introdotto per valutare l'ammissibilità del candidato allo "status" di Socio Aggregato: i punti saranno attribuiti in base al tipo di documentazione presentata. Possono accedere alla qualifica di Socio Aggregato tutti i Soci Ordinari della SIE, in regola con le quote associative degli ultimi tre anni, che completino e forniscano la documentazione alla Segreteria Nazionale (Via Pietro Custodi 3, 20136 Milano) entro i termini che verranno indicati all'indirizzo web: www.endodonzia.it.
La domanda dovrà essere firmata da un Socio Attivo, in regola con la quota associativa per l'anno in corso, il quale è responsabile della correttezza clinica e formale della documentazione presentata.

DOCUMENTAZIONE NECESSARIA PER DIVENTARE SOCIO AGGREGATO

Qualsiasi Socio Ordinario, con i requisiti necessari, può presentare la documentazione per ottenere la qualifica di Socio Aggregato. Un meccanismo a punti è stato introdotto per valutare il candidato: un minimo di 80 punti è richiesto per divenire Socio Aggregato.
La documentazione clinica per ottenere la qualifica di Socio Aggregato dovrà presentare almeno sei casi, di cui non più di tre senza lesione visibile nella radiografia preoperatoria e non più di uno di Endodonzia Chirurgica Retrograda.
Nella domanda non potranno essere presentati casi la cui somma superi i 120 punti per la qualifica di Socio Aggregato.
L'aspirante Socio Aggregato potrà presentare la documentazione clinica in più volte, con un minimo di 40 punti per presentazione, in un arco massimo di tre anni. Il mancato rinnovo della quota associativa, anche per un solo anno, annulla l'iter di presentazione dei casi.

SOCIO ATTIVO

Per avere lo status di Socio Attivo si dovrà presentare la documentazione descritta nel sito www.endodonzia.it che sarà valutata dalla Commissione Accettazione Soci. La documentazione che verrà presentata dovrà mostrare con rigore, attraverso documentazione scientifica e casi clinici, l'interessamento del candidato alla disciplina endodontica.
Un meccanismo a punti è stato introdotto per valutare l'ammissibilità del candidato allo status di Socio Attivo: i punti saranno attribuiti in base al tipo di documentazione clinica e scientifica presentata. Possono accedere alla qualifica di Socio Attivo tutti i Soci Ordinari della SIE, in regola con le quote associative degli ultimi tre anni, che completino e forniscano la documentazione alla Segreteria Nazionale (Via Pietro Custodi 3, 20136 Milano) entro i termini che verranno indicati all'indirizzo web: www.endodonzia.it.
La domanda di ammissione allo status di Socio Attivo rivolta al Presidente della SIE dovrà essere firmata da un Socio Attivo in regola con la quota associativa per l'anno in corso, il quale dovrà aver esaminato e approvato la documentazione. Quest'ultimo è responsabile della correttezza clinica e formale della documentazione presentata.

DOCUMENTAZIONE NECESSARIA PER DIVENTARE SOCIO ATTIVO

Qualsiasi Socio Ordinario, con i requisiti necessari, può presentare la documentazione per ottenere la qualifica di Socio Attivo. Il Socio Aggregato che volesse presentare la documentazione scientifica e clinica a integrazione di quella clinica già approvata dalla CAS per lo status di socio Aggregato, potrà farlo già dall'anno successivo all'ottenimento della sua qualifica.
Un meccanismo a punti è stato introdotto per valutare il candidato a Socio Attivo. Un minimo di 200 punti è richiesto per divenire Socio Attivo.
Nella domanda non potranno essere presentati casi la cui somma superi i 240 punti per la qualifica di Socio Attivo.
La documentazione scientifica potrà essere presentata, a completamento della documentazione clinica, solo per la domanda per divenire Socio Attivo e non potrà superare i 80 punti.
La documentazione clinica dovrà presentare un minimo di sei casi, di cui almeno 4 di molari pluriradicolati con delle precise tipologie: tra questi casi almeno uno deve essere un ritrattamento con lesione visibile nella radiografia preoperatoria e dei restanti tre almeno due devono avere una lesione visibile nella radiografia preoperatoria.
La documentazione clinica non deve presentare più di un caso di Endodonzia Chirurgica Retrograda con immagini e non più di uno senza immagini.
La documentazione scientifica non potrà presentare più di due articoli come coautore.

MODALITÀ DI DOCUMENTAZIONE DEI CASI CLINICI

Criteri e modalità per la valutazione dei casi clinici idonei ad accedere alle qualifiche di Socio Aggregato e di Socio Attivo sono espressi nell'apposita sezione del Regolamento

della Società Italiana di Endodonzia (SIE) all'indirizzo web: www.endodonzia.it.

CRITERI DI VALUTAZIONE

I casi clinici verranno valutati nel loro complesso, coerentemente con gli scopi e fini della SIE, e devono essere presentati dai Candidati considerando non solo l'aspetto clinico, ma anche quello formale della documentazione presentata.
La documentazione scientifica verrà valutata considerando la classificazione ANVUR delle Riviste Scientifiche, i documenti scientifici dovranno essere tutti di pertinenza endodontica.

ADEMPIMENTI DEL CANDIDATO

La domanda di ammissione allo status di Socio Aggregato/Attivo, rivolta al Presidente della SIE, dovrà pervenire, insieme alla documentazione di seguito elencata, alla Segretaria della SIE con un anticipo di 20 giorni sulle date di riunione della CAS, sufficiente per poter organizzare il materiale dei candidati. Le date di scadenza saranno rese note sul sito. La domanda dovrà essere firmata da un Socio Attivo in regola con la quota associativa per l'anno in corso, il quale dovrà aver esaminato e approvato la documentazione. Quest'ultimo è responsabile della correttezza clinica e formale della documentazione presentata.

PRESENTAZIONE DEI CASI ALLA COMMISSIONE

La presenza del Candidato è obbligatoria durante la riunione della CAS; è altresì consigliabile la presenza del Socio presentatore.

LA COMMISSIONE ACCETTAZIONE SOCI

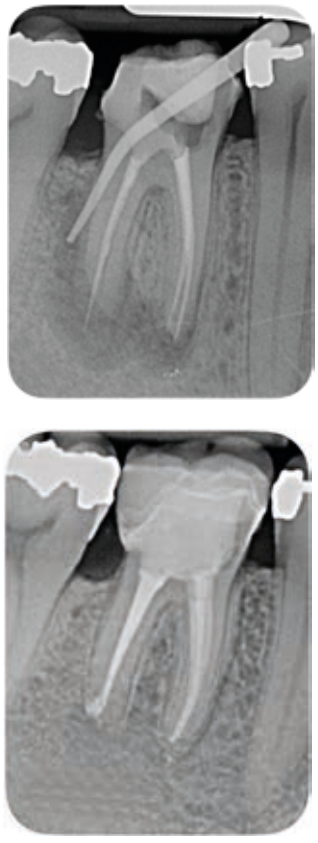
La CAS (Commissione Accettazione Soci) è formata cinque Membri di indiscussa esperienza clinica, quattro Soci Attivi con almeno cinque anni di anzianità in questo ruolo eletti a ogni scadenza elettorale dall'Assemblea dei Soci Attivi e Onorari e uno dei Past President della Società incaricato dal CD a ogni riunione. Compito della CAS è quello di esaminare e valutare la documentazione presentata dagli aspiranti Soci Aggregati e Soci Attivi. Per rispetto del lavoro dei Candidati e per omogeneità di giudizio, in ogni riunione CAS verranno valutati non più di 12 candidati a Socio Attivo; resta libero, invece, il numero dei candidati a Socio Aggregato valutabile in una singola riunione. Il Consiglio Direttivo (CD) incaricando la Commissione Accettazione Soci (CAS) la rende responsabile dell'applicazione delle regole descritte nell'articolo 2 del regolamento. Il giudizio della CAS è insindacabile.

MEMBRI DELLA COMMISSIONE ACCETTAZIONE SOCI BIENNIO 2023-24

Francesco Riccitiello
Maurizio Boschi
Marco Colla
Claudia Dettori
Giuseppe Multari

CeraSeal

Quality and ergonomics for simple and predictable root canal fillings



Courtesy
of Dott. Filippo Cardinali

Role and aims of root canal obturation

Complete filling of the endodontic space combined with an airtight seal of the foramen are essential prerequisites for a quality root canal obturation and represent the goal the clinician must aspire to when performing the obturation.
Pre-mixed bioceramic cements for root canal fillings have been in use in clinical practice for more than 10 years and their use is becoming increasingly popular due to their characteristics. The absence of shrinkage and the interaction with the canal walls during the hardening reaction allow the clinician to achieve the obturation goals using cold gutta-percha techniques, which are easier and faster to perform than hot techniques.

Ceraseal: ergonomics and safety

Ceraseal is a pre-mixed calcium-silicate bioceramic cement that can be easily applied inside the canal with disposable tips: the absence of powder-liquid mixing phases means that the cement components are in the ideal percentages, eliminating the risk of contamination during preparation and insertion of the cement into the canal.
Ceraseal has a high radiopacity that makes it clearly visible on post-operative X-rays. During the setting reaction, high pH values are reached, giving Ceraseal a powerful antibacterial action.

Hermetic Seal

Ceraseal requires moisture to start the setting reaction, which results in a chemical bond between the bioceramic cement and the dentin of the canal parts. This chemical reaction also occurs within the dentinal tubules where Ceraseal can penetrate due to its low particle size, resulting in a high-quality hermetic seal that prevents bacteria from percolating into the canal. The ability to harden in a moist environment makes Ceraseal the cement of choice when complete drying of the endodontic system is not possible for anatomical reasons.

Flowability and Stability

The high fluidity allows Ceraseal to penetrate even unshaped spaces such as isthmuses or lateral canals and fill the endodontic system three-dimensionally. Ceraseal does not contract or expand: this unique stability is the basis for its use with cold gutta-percha techniques such as single cone, not to mention that it can also be used with conventional hot root canal techniques.

Biocompatibility and Bioactivity

Biocompatibility is certainly one of the most important features of Ceraseal: in case of accidental extrusion, Ceraseal does not interfere with the health status of healthy periapical tissues, nor does it interfere with healing processes in case of periapical lesions, promoting instead peri radicular bone regeneration.

sweden & martina

Simit Dental, azienda leader da più di 30 anni nel settore dentale, in occasione di Expodental, presenterà ufficialmente tre novità della linea di sistemi di ingrandimento Orascoptic.

La prima novità è **Dragonfly™**, un innovativo sistema d'ingrandimento con alimentazione a batteria completamente integrata e comandi incorporati per azionare il sistema di illuminazione.

Tutte le componenti elettroniche e le batterie sono completamente contenute all'interno del telaio, quindi non ci sono cavi visibili. Un innovativo design offre comfort per tutto il giorno riducendo al minimo la pressione sul ponte nasale dell'utilizzatore.

Dragonfly™ è disponibile in tre modelli diversi:

- **Dragonfly™ PRO:** il modello premium supporta la linea completa di oculari Orascoptic ed è ricca di funzioni bonus tra cui batterie extra, impostazioni multiple di intensità della luce, finitura estremamente resistente;
- **Il modello RDH:** supporta gli oculari RDH Elite progettati specificamente per igienisti dentali;
- **Il modello NEO:** entry-level è disponibile in un unico colore e supporta i 4 poteri di ingrandimento più popolari.

Dragonfly™ è il sistema integrato per eccellenza che garantisce una performance di livello superiore in totale libertà.

Orascoptic è inoltre da sempre attenta alle nuove esigenze del mercato e alle richieste dei professionisti del settore dentale ed in occasione della fiera principale del settore dentale Simit Dental presenterà due ulteriori novità assolute nella sua gamma di sistemi ingrandenti:

- **Eyezoom Max™** è il sistema della gamma Eyezoom™ ad ingrandimento variabile da 3,5X a 6,5X più potente di sempre. Offre una risoluzione ad alta definizione ed una maggiore acuità visiva.

Le generose dimensioni del campo dell'ingrandimento a 3,5X combinate con la capacità di eseguire procedure impegnative utilizzando l'ingrandimento a 6,5X, creano un'esperienza di ingrandimento versatile per il professionista.

- Linea di sistemi **ingrandenti ergonomici Ergo**: gli occhiale Ergo ad alta definizione consentono di lavorare in tutta comodità, migliorando la postura del professionista senza sacrificare la visione.

La tecnologia Orascoptic utilizza prismi di rifrazione per consentire al professionista di stare seduto in posizione eretta e ridurre l'inclinazione del collo. I sistemi ingrandenti Ergo sono un'opzione ergonomica che offre comfort per tutto il giorno e sono disponibili in due ingrandimenti - RDH Ergo 3X ed HDL Ergo 3,5X.

Tutti i sistemi ottici sono realizzati con lenti in vetro con rivestimenti antigraffio e antiriflesso.

Vieni a provare le novità Orascoptic ad Expodental!

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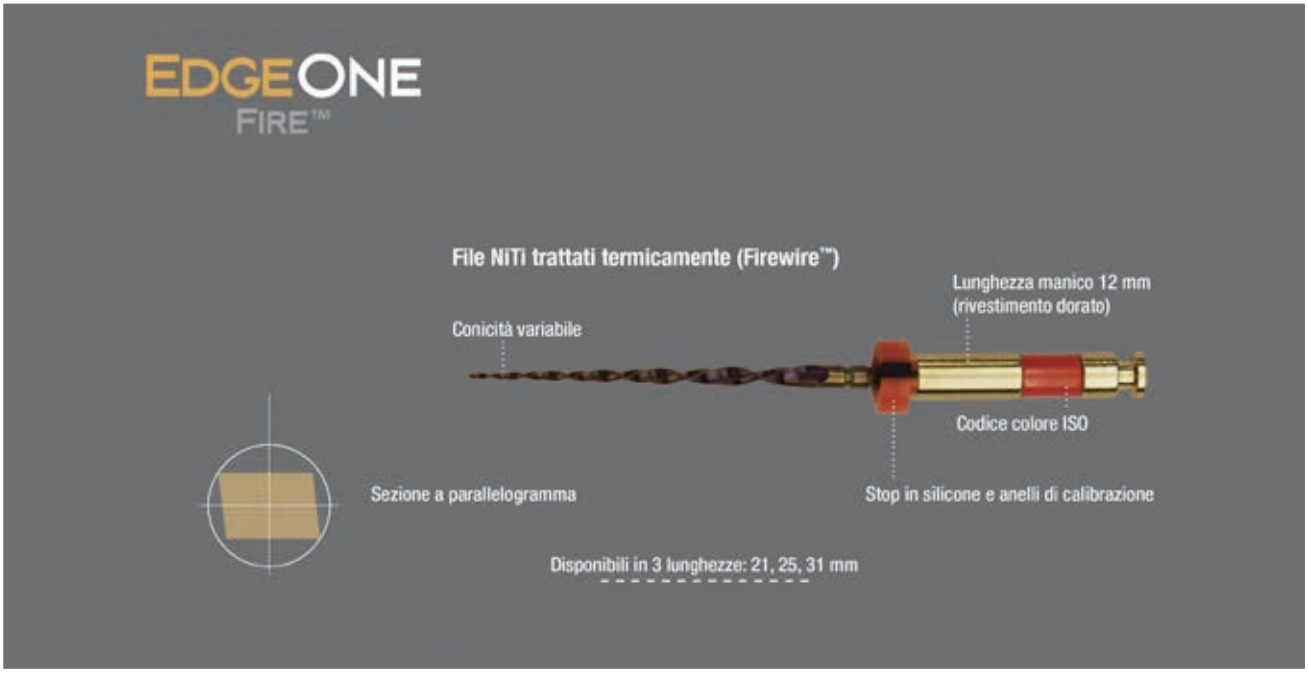

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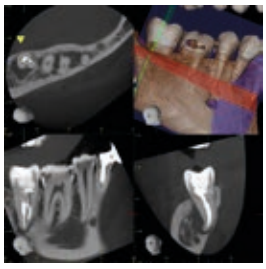

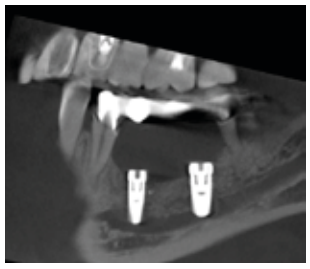

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- Nagendrababu V, Chong BS, McCabe P, Shah PK, Priya E, Jayaraman J, Pulikkotil SJ, Setzer FC, Sunde PT, Dummer PMH. *PRICE 2020 guidelines for reporting case reports in Endodontics: a consensus-based development.* Int Endod J. 2020 Feb 23. Doi: 10.1111/iej.13285. https://onlinelibrary.wiley.com/doi/10.1111/iej.13285.
- Nagendrababu V, Chong BS, McCabe P, Shah PK, Priya E, Jayaraman J, Pulikkotil SJ, Dummer PMH. *PRICE 2020 guidelines for reporting case reports in Endodontics: Explanation and elaboration.* Int Endod J. 2020 Mar 28. Doi: 10.1111/iej.13300. https://onlinelibrary.wiley.com/doi/abs/10.1111/iej.13300.

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- **Results:** give the main results of the study, including the outcome of any statistical analysis.
- **Conclusions:** state the primary conclusions of the study and their implications. Suggest areas for further research, if appropriate.

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Abstract for Mini Review Articles should be non-structured of no more than 250 words, including a clear research question, details of the literature search strategy and clear conclusions.
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THE STRUCTURE

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Material and Methods must contain sufficient detail such that, in combination with the references cited, all clinical trials and experiments reported can be fully reproduced.
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Conclusions should contain a summary of the findings.

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The Introduction section should be focused to place the subject matter in context and to justify the need for the review. The Review section should be divided into logical subsections in order to improve readability and enhance understanding. Search strategies must be described and the use of state-of-the-art evidence-based systematic approaches is expected. The use of tabulated and illustrative material is encouraged. The Conclusion section should reach clear conclusions and/or recommendations on the basis of the evidence presented.

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Standard journal article
(1) Somma F, Cammarota G, Plotino G, Grande NM, Pameijer CH. The effectiveness of manual and mechanical instrumentation for the retreatment of three different root canal filling materials. J Endod 2008;34:466-9.

Corporate author
British Endodontic Society - Guidelines for root canal treatment. Giornale Italiano di Endodonzia 1979;16:192-5.

Journal supplement
Frumin AM, Nussbaum J, Esposito M. Functional asplenia: demonstration of splenic activity by bone marrow scan (Abstract). Blood 1979;54 (Suppl. 1):26a.

Books and other monographs
Personal author(s)
Gutmann J, Harrison JW. Surgical Endodontics, 1st edn Boston, MA, USA: Blackwell Scientific Publications, 1991.

Chapter in a book
Wesselink P. Conventional rootcanal therapy III: root filling. In: Harty FJ, ed. Endodontics in Clinical Practice, (1990), 3rd edn; pp. 186-223. London, UK: Butterworth.

Published proceedings paper
DuPont B. Bone marrow transplantation in severe combined immunodeficiency with an unrelated MLC compatible donor. In: White HJ, Smith R, eds. Proceedings of the Third Annual Meeting of the International Society for Experimental Rematology; (1974), pp. 44-46. Houston, TX, USA: International Society for Experimental Hematology.

Agency publication
Ranofsky AL Surgical Operations in Short-Stay Hospitals: United States-1975 (1978). DHEW publication no. (PHS) 78-1785 (Vital and Health Statistics; Series 13; no. 34.) Hyattsville, MD, USA: National Centre for Health Statistics.

Dissertation or thesis
Saunders EM. In vitro and in vivo investigations into root-canal obturation using thermally softened gutta-percha techniques (PhD Thesis) (1988). Dundee, UK: University of Dundee.

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All manuscripts submitted to our journal are critically assessed by external and/or in-house experts in accordance with the principles of peer review (http://www.icmje.org/#peer), which is fundamental to the scientific publication process and the dissemination of sound science. Each paper is first assigned by the Editors to an appropriate Associate Editor who has knowledge of the field discussed in the manuscript. The first step of manuscript selection takes place entirely in-house and has two major objectives: i) to establish the article appropriateness for our journals readership; ii) to define the manuscript priority ranking relative to other manuscripts under consideration, since the number of papers that the journal receives is much greater than it can publish. If a manuscript does not receive a sufficiently high priority score to warrant publication, the editors will proceed to a quick rejection. The remaining articles are reviewed by at least two different external referees (second step or classical peer review). Manuscripts should be prepared according to the Uniform Requirements established by the International Committee of Medical Journal Editors (ICMJE) (http://www.icmje.org/org/#prepare).