Penetration of bioceramic and epoxy-resin endodontic cements into lateral canals

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Abstract: The aim of the present study was to assess the penetration capacity of two endodontic cements, Endosequence BC Sealer and AH Plus, in artificial lateral canals. Twenty-six two-rooted, maxillary first premolars were instrumented to size 40.06 using K3 files. In each root, six lateral canals of two diameters (0.06 and 0.10 mm) were created with a working length of 2, 4, and 6 mm. The specimens were randomly divided into two groups according to the endodontic cement to be used (Endosequence BC Sealer and AH Plus) and obturated by the single-cone technique. The specimens were imaged by digital periapical radiography and scores from 0 to 4 were attributed according to the degree of penetration by sealers into the lateral canals. Data were analyzed statistically by Kruskal-Wallis and Student-Newman-Keuls tests, and a significance level of $p < 0.05$ was adopted. No significant difference was observed between the two endodontic cements used to fill the simulated lateral canals ($p > 0.05$). The diameter of lateral canals only influenced the capacity of the Endosequence BC Sealer in filling the canals, and presented greater penetration in the lateral canals of diameter 0.10 mm ($p < 0.05$). We concluded that the bioceramic endodontic cement Endosequence BC Sealer presented similar ability as AH Plus to fill simulated lateral canals.

Keywords: Root Canal Filling Materials; Root Canal Obturation; Endodontics.

Introduction

The anatomy of the root canal system is very complex because of the presence of isthmus and several ramifications. The incidence of lateral canals is high (range 27.4–99%),[1,2] and they are clinically important because they may host pulp tissue and microorganisms.[3] Previous studies reported a strong correlation between infection inside root canals and the presence of apical periodontitis.[3,4,5] These ramifications complicate the action of instruments and irrigating solutions, and may influence failure after endodontic therapy.[4,6] Irrigating solutions, inter-appointment medication, and endodontic sealers may promote disinfection of these ramifications.[2,3,4,6]

The tri-dimensional obturation is a challenge in clinical practice and aims to avoid gaps that could be conducive for leakage and

microbial development.[7] Root filling materials present certain properties, and antibacterial effectiveness is reported as an important biological characteristic that leads to fewer remnant microorganisms after root canal preparation.[8] Therefore, flowability is another fundamental physical property that allows the penetration of material into small spaces and irregularities.

The properties of bioceramic endodontic sealers have been studied and their clinical performance has been evaluated. These materials present favorable properties of radiopacity[9], flow[9], high calcium ion release,[8,9] alkaline pH,[8,9] low cytotoxicity and genotoxicity,[10,11] and adequate antibacterial effectiveness.[11] Recently, a study demonstrated that the Endosequence BC Sealer indicated bioactivity, as hydroxyapatite was formed after setting of the material.[12] This characteristic is fundamental for its biological and physical-chemical properties.[8-12] AH Plus is an epoxy-based resin endodontic sealer that presents excellent physical-chemical properties including high radiopacity,[9] suitable flow[9], and excellent bond strength with dentin.[12]

Because infected lateral canals are a probable cause of failure of endodontic treatment,[2,4,5,6] the penetration of endodontic sealers into these ramifications may help in disinfection. Currently, limited information about penetration into lateral root canals by bioceramic endodontic sealers is available. Therefore, the aim of the present work was to evaluate the capacity of the Endosequence BC Sealer to fill artificial lateral canals, and compare it with the AH Plus sealer.

Methodology

The present research was approved by the Ethics Committee of Faculty São Leopoldo Mandic, Brazil, under protocol number 903.106.

Twenty-six permanent, two-rooted, maxillary premolars of humans were selected. The teeth had straight roots and completely formed apices with foraminal patency. Periapical radiography was performed for all teeth to identify and exclude those with previous endodontic treatment and internal resorption. The teeth were kept immersed in saline solution until the time of the experiment. The crowns were then cut with a carborundum disk and copious saline irrigation, and had root length of 12 mm.

The foraminal patency was confirmed using #10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) and by viewing beyond the apical foramen using an operatory microscope of 6X magnification (Alliance, São Carlos, Brazil).

An experienced operator performed the root canal preparation using K3 endo-files (Sybron Endo, Orange, USA) and a motor, VDW Silver (VDW, Munich, Germany), operating at 300 rpm and 2.5 N cm torque. All specimens were instrumented using pecking motion in the following sequence: 15.06, 20.06, 25.06, 30.06, 35.06, and 40.06. The working length was established at the previously determined apical foramen. During instrumentation, the specimens were irrigated with 40 mL of 5.25% sodium hypochlorite solution (Fórmula & Ação, São Paulo, Brazil), followed by 5 mL of saline.

The lateral canals were fabricated with a device using a #06 K-file or a #10 K-file (Dentsply Maillefer, Ballaigues, Switzerland), coupled with a light cure resin on the tip of a diamond round bur (1014; Fava Metalúrgica, São Paulo, Brazil). The device was attached in a high-speed and under copious refrigeration. The tip of device was carefully inserted into the external root surface until the desired root canal was formed. Six laterals canals were formed in each specimen, of which, three were made using the #06 K-file and the other three using the #10 K-file on the mesial and distal surfaces, respectively. These canals were made at a distance of 2, 4, and 6 mm from apical foramen. The specimens were observed under a clinical microscope (Alliance, São Carlos, Brazil) (40X magnification) in order to confirm the penetration of the files inside the canal lumen. Additionally, passive ultrasonic irrigation (PUI) with 17% ethylenediaminetetraacetic acid (EDTA; Biodinâmica Química e Farmacêutica LTDA, Ibiporã, Brazil) was performed for three minutes to maintain the patency of the lateral canals. PUI was performed with an Irrisonic tip (Helse Ultrasonic, Santa Rosa de Viterbo, Brazil) mounted on an ultrasonic device (JetSonic; Gnatus, Ribeirão Preto, Brazil) at a frequency of 30 kHz. The device was activated for three cycles of 20 seconds each.

Following this, the specimens were immersed in saline solution until the root canal obturation was to be performed.

The root canals were subsequently dried with absorbent paper points (Dentsply Maillefer, Ballaigues, Switzerland). The roots were inserted in heavy body silicon (Zetaplus, 3M Espe, Saint Paul, USA) in a plastic container to simulate the periodontal ligament. The specimens were covered with silicone up to the coronal third to avoid exposure of the lateral canals.

The teeth were randomly divided into two groups according to the endodontic sealer to be used to fill the root canals: Group 1, Endosequence BC Sealer (Brasseler USA, Savannah, USA); and Group 2, AH Plus (Dentsply Maillefer, Ballaigues, Switzerland). The specimens were obturated using the single-cone technique with the medium gutta-percha cone (Dentsply Maillefer, Ballaigues, Switzerland) calibrated and adapted 1 mm above the apical foramen. The AH Plus sealer was manipulated according to the manufacturer's recommendations, while Endosequence BC Sealer was available in pre-mixed form. The endodontic sealers were inserted in the root canals with a lentulo spiral bur followed by insertion of gutta-percha cones up to the working length. The cones were cut with a warm plugger at the coronal third, and root canal filling materials were vertically compacted using Paiva's condensor.

Radiographs were taken by using a digital radiographic unit (Gnatus XR 6010, Ribeirão Preto, Brazil) operating at 60 kV, 10 mA, with exposure set at 0.3 seconds, and focus-film distance of 30 cm. The images were scanned into the Digora 1.51 software for Windows (Orion Corporation Soredex, Helsinki, Finland).

The images were analyzed by means of ImageJ software (National Institutes of Health, Bethesda, USA). The length of each simulated lateral canal was measured using a caliper (in mm), along with the depth of penetration of the endodontic sealers into the lateral canals. The percentage of penetration into the lateral canals was scored as follows: 0, absence of penetration; 1, 1–25% penetration; 2, 26–50% penetration; 3, 51–75% penetration; and 4, 76-100% penetration.

Data were analyzed statistically with Kruskal-Wallis and Student-Newman-Keuls tests using Graph Prism 7 (GraphPad Software, Inc., La Jolla, USA) at a significance level of $p < 0.05$.

Results

The main root canals of all specimens were adequately filled. Hence, the present analysis was performed only for the fillings of the artificial lateral canals. No significant difference was observed with respect to the filling of the lateral canals between AH Plus and Endosequence BC Sealer ($p = 0.27$).

In both groups, the localization of lateral canals presented no significant influence on the ability of obturation ($p = 0.46$). Endosequence BC Sealer specimens presented greater filling in the coronal third part of the root, while AH Plus presented the best filling in the middle third (Table 1). It was also observed that the apical thirds presented lesser filling of the lateral canals than that of the coronal and middle thirds, but without statistically significant differences ($p > 0.05$).

The diameter of the lateral canals significantly influenced the filling capacity only when the bioceramic Endosequence BC Sealer was used, presenting greater penetration in canals with diameter 0.10 mm than 0.06 mm ($p = 0.02$). In AH Plus sealer specimens, the capacity of penetration was not influenced by the diameter of the simulated lateral canals ($p > 0.05$). Table 2 shows the analysis according to the diameter of the lateral canals.

Table 1. Mean, median, and range of scores (0–4) obtained during analysis of filling of lateral canals, according to location in different radicular thirds ($p = 0.46$).

Variable	AH Plus			BC Sealer		
	Mean	Median	Range	Mean	Median	Range
Coronal	2.63[a]	3.00	0–4	2.98[a]	3.00	0–4
Middle	2.81[a]	3.00	0–4	2.63[a]	4.00	0–4
Apical	2.58[a]	3.00	0–4	2.56[a]	3.00	0–4

Different letters in superscript indicate significant statistical difference ($p < 0.05$).

Table 2. Mean, median, range of scores (0–4) and medium posts obtained during analysis of filling of lateral canals, according to diameter (∅) of artificial lateral canals (p = 0.02).

Variable	∅ 0.06mm				∅ 0.10mm			
	Mean	Median	Range	Medium posts	Mean	Median	Range	Medium posts
AH Plus	2.68	3.00	0–4	152.7372[a]	2.67	3.00	0–4	146.6859[a]
BC Sealer	2.33	3.00	0–4	143.8910[a]	3.11	4.00	0–4	182.6859[b]

Different letters in superscript indicate significant statistical difference (p < 0.05).

Discussion

In the endodontic clinical practice, the anatomical complexity may directly influence the disinfection of the accessory and lateral canals and their sealing.[4,6] The type of cement, its physical-chemical characteristics, and obturation technique are additional factors that could interfere with the filling of the lateral canals.[13,14,15,16,17,20,21]

Several authors have evaluated the ability to fill natural lateral canals in extracted teeth.[13-15] However, due to the difficulty in obtaining human teeth with natural branches for comparison, several other authors have made artificial lateral canals.[16,20,21,22] The mean filling of the lateral canals found in the present study corroborated with previous studies that used only cement for observation.[7,13,21,22,23,24,25,26]

In this study, no significant difference was observed between the fillings of the lateral canals and their position in the roots. DuLac et al.[21] and Reader et al.[22] used acrylic blocks and cured all parts of the root with cement when comparing various obturation techniques. In contrast, Venturi et al.[14] and Fernández et al.[26] found that the coronal third showed greater cement filling in simulated canals than in that of the middle and apical thirds, while the middle third showed greater pre-filling than the apical third, regardless of the type of obturation technique used. In techniques without thermoplasticization, the results were in agreement with the present study, where only the cement penetrated the lateral canals. The absence of statistical difference in the partial compliance between the parts of the roots corroborated with the previous studies.[25,27]

The diameter of the simulated lateral canals (60 µm and 100 µm) used in this study were in accordance with the natural diameters of the lateral canals evaluated by diaphanization and computed microtomography.[2,13,28] In this study, it was observed that the lateral canal diameter had a significant influence only on the use of bioceramic Endosequence BC Sealer, which could be attributed to its greater flowability as compared to the AH Plus cement.[9]

In the present study, an extrarradicular device was used with the intention of reproducing the mechanical barrier of the periodontium during canal filling as per previous studies.[24,25] Thus, the main objective was to prevent the lateral canals from remaining completely open to the external environment, not simulating the real situation, thus facilitating the penetration of the cement into the lateral canals and avoiding possible error in the analysis of the results.

The modified single-cone technique was used because the objective was to evaluate only the penetration capacity of the cement. The warm techniques of gutta-percha not only changed the flow properties of the cements due to the high temperatures, but also facilitated easier entry of the gutta-percha into the alpha phase within the larger lateral canals. This generated a false positive when the radiographic examination was carried out. Furthermore, a recent study demonstrated that single-cone obturation techniques presented similar capacity of filling the root canals as that of warm techniques.[29] Another study observed that bioceramic sealer presented similar filling capacity as that of epoxy-resin, and presented best results when the warm technique was used, thus concurring with the present results.[26]

In this study, most lateral canals were partially filled by the cement. However, an acceptable rate of filling with bioceramic and epoxy-resin sealers was observed in 73.4% and 78% of artificial lateral canals, respectively, and presented superior values than those in the study by Fernández et al.[26] Although there is no

intercurrence sweeping the cement during its passage through the lateral canal, it is suggested that there was dissipation of forces by the conical morphology of the lateral canal. The Endosequence BC Sealer and AH Plus show pseudoplastic behavior, exhibiting viscosity change when a force is applied to them. The higher the force applied, lower is the viscosity and greater the flow. Since the force application is not continuous but punctual, this force is dissipated both by the decrease of the pressure on the walls by the increase of the taper, as well as by the loss of mass of the cement, resulting in the reduction of the flow and incomplete filling of the lateral canals.[26,30,31]

A recent study observed that the Endosequence BC Sealer cement presented adequate penetration capacity in the simulated dentinal tubules, independent of the obturation technique.[32] This is because the particles of this cement measured less than 1 µm, thus easily penetrating the tubules measuring about 2 to 3.2 µm in diameter. It is observed that this penetration could be hampered by some factors, such as the absence of patency of the lateral canal, presence of organic (pulp tissue) or inorganic (dentinal debris) material within the lateral canal, and the lateral canal diameter itself.[4,6]

However, the actual clinical importance of lateral canal sealing, and its influence on the success of endodontic treatment is still debatable. A common misconception among professionals is that teeth with lateral bone rarefaction can only be repaired if the lateral canals are filled. Some studies have shown that the filling of lateral canals may occur incompletely in length as well as in volume of the lateral canal. Radiographically, the canal may be filled, but there may be filling faults due to the maintenance of pulp tissue, dentinal debris, and bacterial colonies.[3,4] Thus, bacteria can still remain active even in cases of radiographically plugged lateral canals. Therefore, the importance of antibacterial activity is detected mainly against microorganisms such as *Enterococcus faecalis* that commonly colonize inaccessible areas.[3,4,5,6] In this respect, previous works have shown that the AH Plus and Endosequence BC Sealer cements present adequate antimicrobial activity.[8,11]

Thus, it may seem appropriate that part of the total bacteria and products were involved and trapped in the sealing materials, and a small part of them were forced against the lateral periodontium. The maintenance of unsealed micro-areas is difficult as they could be contaminated or re-contaminated, and would modify the prognosis of the treatment.[4,6] Thus, the irrigation of the root canal system becomes extremely important in bacterial reduction, so that lateral canals and other branches can be properly filled with endodontic cements.[6]

Another aspect to be considered is the importance of tissue biocompatibility, since it is impossible to control the extravasation of the endodontic cement by the main foramen or any other branch. Bioceramic cements show excellent tissue biocompatibility, mainly because they induce the formation of hydroxyapatite during the setting of the material.[8,11,12] The results obtained in the present study are related to laboratory studies, where conditions were carefully reproduced to simulate the natural environment and the anatomical characteristics of the dental element as much as possible; therefore, precautions should be taken when extending these to clinical settings.

Conclusion

From this study, we can conclude that the Endosequence BC Sealer (bioceramic endodontic cement) presented lateral canal filling capacity similar to that of the epoxy-resin AH Plus in simulated canals. The location of the simulated lateral canals had no significant influence on their filling capacity; however, the diameter of the lateral canals influenced the filling when the Endosequence BC Sealer was used.

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