Original Article

Microleakage evaluation of CAAC, WOLCA, and MTA cements by fluid filtration

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Abstract

Introduction: Root-end filling materials used in endodontic surgeries should maintain an adequate seal and prevent apical microleakage. The aim of this study was to compare apical microleakage between two new endodontic cements as root-end filling materials and MTA Angelus using fluid filtration system. Materials and methods: A total of 65 extracted single-rooted human anterior teeth were selected in this study. Canal preparation was carried out manually by step-back technique, following which the canals were obturated. The samples were divided into three experimental groups, each containing 19 samples, and two control groups, including four positive and four negative samples. The apical end of each root was resected, root-end preparation was done, and canals were filled with Calcium Aluminate α-Aluminate Cement (CAAC), a mixture of Wollastonite and CAAC (WOLCA), and MTA Angelus. Then, the samples were placed in the fluid filtration system to measure the amount of microleakage. Data were analyzed by SPSS (Version 19) using Analysis of Variance (ANOVA). P-values < 0.05 were considered significant. Results: Mean microleakage at all times was lowest in MTA Angelus and highest in CAAC cement. There was no significant difference between MTA Angelus and WOLCA cement in the amount of microleakage (P<0.001, Post-hoc Tukey). However; There was a statistically significant difference between MTA Angelus and CAAC cement (p<0.001, Post-hoc Tukey). Conclusion: Given the similarity between the microleakage of WOLCA cement and MTA Angelus, WOLCA is recommended for further clinical and experimental evaluations.

Keywords: Dental leakage. Filtration. Mineral trioxide aggregate. Root Canal Filling Materials

Introduction

When the root canal treatment fails, non-surgical re-treatment is recommended. When the root canal cannot be sealed properly by a non-surgical technique or treatment cannot be performed, endodontic surgery is performed to achieve an adequate apical seal and maintain the tooth [1]. When endodontic surgery is administrated, placement of an appropriate root-end filling material may affect the endodontic surgery and is has a significantly better outcome than gutta-percha [2].

An ideal root-end filling material should be non-toxic, non-absorbable, insoluble in tissue fluids, biocompatible, radiopaque, easy to use, and have dimensional stability [3, 4] So far, different materials such as amalgams, zinc oxide eugenol cement, glass ionomer cement, composite resins, and hybrid glass ionomers have been introduced as root-end filling materials [1]. Calcium silicate-based cements such as mineral trioxide aggregate (MTA) are also used as root-end filling materials [5, 6].

Since a major factor in the success of periapical surgery is to obtain an appropriate seal between the tooth and the root-end filling material [7], the root-end filling material should completely seal the contents of the root canal system and prevent the microleakage of the microorganisms and their products [8]. So far, several methods such as dye penetration, bacterial leakage, radioactive detectors, and electrochemical and fluid filtration methods have been used to evaluate the microleakage of materials [9].

So far, no material has been reported to have all of the properties of an ideal root-end filling material [8], and efforts have been continually made to achieve new compounds and materials that are usable in endodontic surgeries. In 2012, the Dental Research Center of Isfahan University of Medical

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Sciences, Isfahan, Iran introduced Calcium Aluminate α-Aluminate Cement (CAAC), which contains calcium aluminates, alpha aluminate, and a mixture of Wollastonite and CAAC (WOLCA) as endodontic cements [10]. The aim of the present study was to evaluate and compare the microleakage of CAAC and WOLCA as root-end filling materials with that of MTA Angelus by fluid filtration method.

Methods and Materials

Regional Bioethics Affiliated to Isfahan University of Medical Sciences approved the present study protocol (IR.MUI.REC.1395.3.915). In this experimental study, 65 extracted single-rooted human anterior teeth with closed apex and no decay, dilaceration, root fracture, and internal or external absorption were selected. The external surface of the roots was mechanically cleaned by a periodontal scaler (Dentafix, Camberley, United Kingdom) and disinfected with 5.25% sodium hypochlorite solution (Chloraxid, CERKAMED, Stalowa Wola, Poland) for 1 hour. Canal number was verified by radiographic examination in mesiodistal and faciolingual directions [11].

The crown of samples was sectioned at a 90 ° angle to the root longitudinal axis by a diamond disc (Stoddard, Hertfordshire, United Kingdom) in the presence of a water cooling system to obtain a standardized length of 15 mm. The working length of each root canal was determined visually as 1 mm short of the apical foramen by inserting a #10k file (MANI inc, Utsunomiya, Japan) [8]. Then, the canals were manually prepared by K-files up to #40 using the step-back technique. In order to enlarge the coronal two-third of the roots, Gates Glidden Drills #2, #3 and #4 (MANI inc, Utsunomiya, Japan) were used in the step-back technique. Irrigation was done with 5.25% sodium hypochlorite solution [12].

Gutta-percha cone (META BIOMED CO, Chungcheongbuk-do, Republic of Korea) was inserted into the canals using cold lateral condensation method without a sealer. The roots were resected at a distance of 3 mm from the apex by a diamond disc and water cooling system at 90° angle to the longitudinal axis of the root. Then, a cavity with a depth of 3 mm and a diameter of 1 mm was prepared at the end of each sample by a diamond straight fissure bur (Hager & Meisinger GmbH, Neuss, Germany). The dimensions of the cavities were checked by a periodontal probe (Williams , Hu-Friedy, Chicago, IL) rinsed with distilled water for 5 seconds and finally dried with paper points (META BIOMED CO, Chungcheongbuk-do, Republic of Korea) [8].

Then, the samples were randomly divided into three experimental groups (n=19 teeth) based on the root-end filling materials CAAC, WOLCA and MTA Angelus (Angelus Science and Technology, Londrina, Brazil) and two control groups (n=4 teeth). The positive and negative control groups were prepared to the same as other samples with no obturation material. However, the external surface of the negative control group was sealed with two layers of nail polish [12].

The cements were mixed and prepared with a 1:3 ratio of powder to distilled water for 1 minute, were then placed in the cavities by an MTA carrier (Dentsplay Maillefer, Ballaigues, Switzerland), and packed by a plugger (Dentsplay Maillefer, Ballaigues, Switzerland). The density of obturation was evaluated by radiography. To complete the setting process of root-end filling materials, the samples were incubated at 100% humidity and 37°C for 24 hours. After removing the samples from the incubator, the gutta-percha was pulled out of the orifice, and the external surface of the roots, except for the apical region, was covered with two layers of nail polish [8].

Then, the samples were fixed in a fluid filtration system. Air bubbles were injected at 0.5 atm pressure. After a 30-second period, the air bubble movements were recorded by a digital camera (Powershot Elph 100 HS, 12 Megapixel, Canon, Japan) at two-minute intervals for 8 min (at minutes 2, 4, 6, and 8) [8]. The bubble movements indicated the microleakage (microliter per minute).

Data were analyzed by SPSS (IBM SPSS Statistics for Windows, Version 19.0. Armonk, NY: IBM Corp.) Analysis of variance (ANOVA) was used to determine statistical differences in microleakage between the experimental groups. P-values < 0.05 were considered significant.

Results

The microleakage analysis of control groups revealed that although there was no microleakage (zero μL/min) in the negative control group within 8 minutes, the bubbles were out of the system in less than one second in the positive control group. In the experimental groups, the lowest means of microleakage were seen in the MTA Angelus group at all times and the highest ones were observed in CAAC cement group (P-value=0.048, ANAVA) (Table 1).

In addition, although there was a statistically significant difference between the microleakage means of MTA Angelus and CAAC cements ($P<0.001$, Post-hoc Tukey) in all periods, no statistically significant difference was found between the microleakage means of MTA Angelus and WOLCA cements ($P>0.005$, Post-hoc Tukey) (Table 1).

Discussion

Microleakage may be clinically indistinguishable, which is considered an important risk factor for the failure of treatment and apical periodontitis [13]. The most important factor involved in the success of endodontic surgeries is achievement of an ideal seal between the teeth and the root-end filling material [7]. So far, no materials have been found to possess all the properties of an ideal filling material [8]. Therefore, attempts have always been made to improve the properties of the materials available and to obtain an ideal substance. In the present study, the microleakage of two types of cement designed in the Dental Research Center of Isfahan University was evaluated by the fluid filtration method.

So far, many techniques such as bacterial infiltration, air pressure, radioactive detectors, electrochemistry, metal solution, and dye penetration have been used to measure microleakage [13]. Fluid filtration method was developed by Derkson, Pashley, and Derkson [14] and was modified by Wu *et al.* [15] for use in root canal study. Fluid filtration is a simple and time-saving method that is able to make precise microleakage evaluation [16]. The samples are not degraded, and it is possible to measure microleakage at intervals over a period of time [17].

Until now, many new calcium silicate-based cements have been evaluated as root-end filling materials. Yet, MTA has remained the gold standard, with which the new materials should be compared [2]. In the present study, the microleakage of WOLCA was comparable with that of MTA Angelus and the sealing ability of CAAC was lower than that of MTA Angelus. Hence, WOLCA can be considered a substitute for MTA Angelus as a retro-filling material. However, more clinical studies are recommended to be conducted in this regard. WOLCA is a mixture of CAAC cement and wollastonite in 1:1 ratio. Wollastonite is considered a natural calcium silicate with a composition comprising of CaO and SiO [10]. It seems that adding this proportion of wollastonite is appropriate to enhance the sealing ability.

Fluid filtration model is used for various purposes. In a study, three resin-based sealers including AH Plus, Diaket, and EndoREZ were used in combination with cold lateral condensation method, and the apical leakage was evaluated by computerized fluid filtration technique. They concluded that Diaket group showed less apical leakage [17]. Another fluid filtration study evaluated the effect of 2% chlorhexidine on the sealing ability of Biodentine as a root-end filling material and indicated that chlorhexidine improved the sealing ability of Biodentine [8]. Fluid filtration method was also used to determine the effect of master cone size on the apical seal in the curved root canals. The findings showed increasing the master cone size up to #30 did not influence the apical microleakage [11]. Another fluid filtration study assessed the microleakage of gutta-percha and Resilon as root canal filling materials. The findings showed that Resilon increased the apical seal and might be a suitable replacement for gutta-percha [12]. Moreover, a study explored the effect of two different solutions, including phosphate buffer and distilled water on the microleakage of CEM cement as a root-end filling material. The results showed the storage media affected the sealing ability of CEM cement, CEM cement being found to have a better sealing ability in the phosphate buffer solution [18].

It should be noted that the results of fluid filtration model may not be similar to those of other leakage measurement methods. Further, several factors may affect the results of microleakage studies. Type of teeth (bovine or human) [4], environment [18], irrigation [8], and thickness of root-end martials [4] may affect the results of leakage measurement in the fluid infiltration method. Hence, the results of the present should be compared carefully with those of similar studies.

Before the clinical application of retro-filling materials, they should be studied well in the laboratory. Besides the microleakage studied in the present study, radiopacity [19], biocompatibility [10], genotoxicity [20], and cytotoxicity [21] of CAAC and WOLCA cements have been examined in previous studies. The biocompatibility of both types of cement was comparable to that of MTA with respect to inflammatory scores [10]. However, while CCA showed similar DNA damage as MTA did, WOLCA induced more damage [20]. Both types of cement showed acceptable cytotoxicity at low concentrations [21]. Therefore, other prerequisites of root-end filling materials such as solubility, dimensional stability, anti-bacterial activity and bioactivity [3] are recommended to be evaluated for these cements.

Limitations

This study was conducted in laboratory environment under controlled conditions, which might have yielded very different results compared with the clinical studies. Furthermore, the calcium-based cements may interact with substances in the environment over time, so evaluating the long-term sealing ability of root-end filling materials is recommended to be investigated in the future studies.

Conclusion

One of the prerequisites of root-end filling materials is their sealing ability, which can be evaluated by microleakage analysis. Since the microleakage of WOLCA and MTA Angelus cements were similar, the WOLCA cement might be used as a root-end filling material. However, further experimental and clinical studies are needed to be carried out in this regard.

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Table 1. Mean (SD) of microleakage (μL/min) for three cements based on different times.

Cements		**Time (Minute)**			
		2	4	6	8
CCA	Mean (SD)	11.1(3.6)[b]	11.4(4.2)[b]	11(4.2)[b]	9.9(3.8)[b]
WOLCA	Mean (SD)	5.4(2.9)[a]	4.5(3.2)[a]	3.6(1.9)[a]	3.3(1.5)[a]
MTA Angelus	Mean (SD)	3.1(2.3)[a]	2.9(1.8)[a]	2.7(1.7)[a]	2.3(1.7)[a]

In the same column, different letters with lowercase indicate statistically significant differences ($p<0.05$)