The Ability of Portland Cement, MTA, and MTA Bio to Prevent Through-and-Through Fluid Movement in Repaired Furcal Perforations

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Abstract

This study assessed the ability of Portland cement, white Angelus–mineral trioxide aggregate (MTA), and MTA Bio to seal furcal perforations in extracted human molar teeth. Fifty-five human mandibular molar teeth were accessed, and the canal orifices were located. The roots were horizontally sectioned in the middle third. Resin composite was used to fill the root canal orifices and the apical end of the root. Perforations were created in the center of the pulp chamber floor by using a size 3 round bur. The teeth were divided into 3 groups ($n = 15$), and an additional 10 teeth served as controls. In G1, the perforation defects were repaired with MTA, whereas in G2 and G3, MTA Bio and Portland cement were used, respectively. Each tooth was assembled in a hermetic cell to allow the evaluation of fluid filtration. Leakage was measured by the movement of an air bubble traveling within a pipette connected to the teeth. Measurements of the air bubble movement were made after 10 minutes at a constant pressure of 20 cm H_2O. Kruskal-Wallis H test was applied to the fluid flow data to detect differences between the experimental groups ($P < .05$). Leakage existed in every sample and was very variable in all the experimental groups, ranging from 0.098–0.51 μL/min. Kruskal-Wallis H-test results showed that there was no significant difference in mean fluid flow between the experimental groups ($P = .874$). The sealing ability promoted by the 3 cements was similar; no cement was able to produce a fluid-tight seal. *(J Endod 2007;33:1374–1377)*

Key Words

Fluid movement, furcal perforations, MTA, MTA Bio, Portland cement

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0099-2399/$0 - see front matter

doi:10.1016/j.joen.2007.07.024

Currently, mineral trioxide aggregate (MTA) is the main material for repairing furcal perforations (1–3). The reasons for this are MTA's favorable properties, including biocompatibility (4), good sealing ability (3, 5), and the ability to promote dental pulp and periradicular tissue regeneration (1, 6).

During the past few years, it has been confirmed that MTA is Portland cement plus bismuth oxide to make the mix radiopaque (7). This has generated scientific interest in the evaluation of Portland cement as a low-cost alternative to MTA, with recent studies comparing MTA with Portland cement. Both materials have been demonstrating comparable physical and biologic properties as well as clinical outcomes (3, 6–11). However, there are disadvantages when using both MTA and Portland cement, such as the extended setting time and the difficulty of handling (12).

A major concern regarding the use of water-based cements is the amount of leachable arsenic and lead present in the material (13). Arsenic and lead are impurities of limestone, which is used in manufacturing Portland cement. High concentrations of arsenic and lead have been found in the cement dust, an alkaline by-product of cement manufacturing. With the aim of avoiding the presence of arsenic and lead, an experimental water-based cement, labeled as MTA Bio, has been developed by a Brazilian dental company (Angelus, Londrina, PR, Brazil). MTA Bio is fully synthesized in a laboratory under controlled, clean, and segregated conditions to ensure that the final product is free of contamination. The goal is to produce a cement with the pro-analysis (P.A.) designation, guaranteeing the customer that the product is of the highest analytical quality. The extensive specifications of the P.A. designation extend beyond those specifications of the American Chemical Society or similar requirements and enable the product to apply for the safety designation (14). According to the manufacturer, as a consequence of the high-quality control of the cement production, the final cement was free of undesirable contaminant substances, in particular, arsenic (13). Furthermore, it has been stated that the handling properties, as well as the setting time, were improved.

The sealing ability of MTA when used as a furcal repair material was already highlighted by earlier studies (1, 2, 15, 16). Alternatively, the sealing ability of Portland cement still remains poorly evaluated. To date (May 2007), an English Pub Med Database search for "MTA" and "sealing ability" produced more than 30 articles published since 1995. On the other hand, when "Portland cement" was included as a key word, an English Pub Med Database search displayed just 3 studies.

Therefore, the present study was designed to compare the ability of Portland cement, white Angelus-MTA, and MTA Bio to seal furcal perforations in extracted human molar teeth. A fluid filtration model was used for leakage assessment. The null hypothesis was that there was no difference in the fluid filtration patterns among the materials when placed in furcation perforations.

Materials and Methods

Selection of Teeth and Specimen Preparation

This study was revised and approved by the Ethics Committee, Nucleus of Collective Health Studies of Rio de Janeiro State University, Brazil. A sample of 55 human mandibular left and right first molar teeth was selected from the tooth bank of the Rio de Janeiro State University. The criteria for tooth selection were tri-rooted teeth; complete

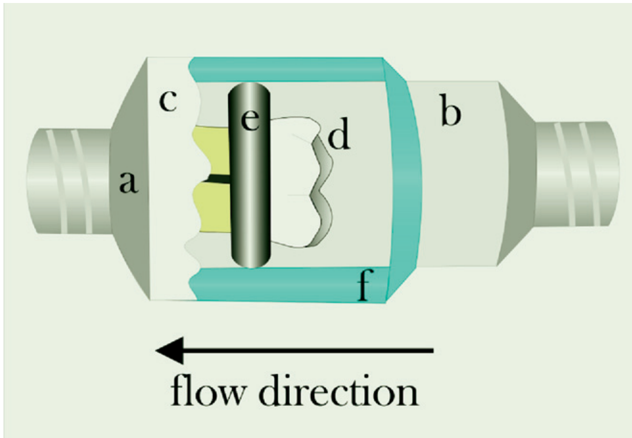

Figure 1. Schematic illustrating the modified hermetic cell (assembled double-chamber).

root formation; no root caries, and no fracture line. To improve specimen standardization, the teeth selected were required to have a dentin thickness at the furcation varying from 2.2–2.5 mm.

The teeth were autoclaved and kept in 0.2% sodium azide for no longer than 7 days.

Tooth Preparation

Standard access cavities were prepared, and the canal orifices were located. The roots were horizontally sectioned in the middle third to facilitate their manipulation. The canal orifices and the apical end of each root were etched with 37% phosphoric acid gel (Scotchbond; 3M ESPE Dental Products, St Paul, MN) for 30 seconds. Then the Single Bond adhesive system (Scotchbond) was applied in 2 consecutive coats and photopolymerized for 10 seconds with a LED source (Ultrablue II; DMC Equipments, São Paulo, SP, Brazil). A resin composite, Z100 (3M ESPE Dental Products), was then used to fill the root canal orifices and the apical end of the root. The resin composite was photopolymerized for 2 minutes with a LED source. Subsequently, the root canal orifice and the apical end of the root were sealed with cyanoacrylate adhesive (Loctite 496; Henkel Ltda, São Paulo, Brazil) in an attempt to improve the seal.

Creation of the Artificial Perforations

A silicone impression material (President Jet; Coltène AG, Cuyahoga Falls, OH) was mixed to provide a matrix that simulated the bony socket. Teeth were placed into the unset silicone and then removed when polymerization had occurred.

Artificial perforations were created in the center of the pulp chamber floor by using a size 3 round diamond bur (100 ISO size; Dentsply-Maillefer, Ballaigues, Switzerland) in a low-speed handpiece.

Forty-five teeth were randomly divided into 3 groups of 15 teeth each (G1, G2, and G3). Ten additional teeth served as controls. Five teeth were perforated but not repaired to serve as a positive control. Another 5 teeth were not accessed to serve as negative controls.

Repair of the Perforations

In G1, one gram of white MTA Angelus (WMTA) was mixed with 0.35 mL of distilled water according to manufacturer's recommendations. The WMTA was placed in the perforation by using an Endogun (Medidenta Int Inc, Woodside, NY) and compacted with Schilder pluggers (Hu Friedy, Chicago, IL). A cotton pellet moistened with a saline solution was placed in the pulp chamber against the WMTA.

In G2, the same procedures of G1 were performed, but the perforations were repaired with MTA Bio (Angelus).

In G3, one gram of Portland cement type IV (Irajazinho TYPO II; Votorantim Cimentos, Rio Branco, SP, Brazil) was mixed with 0.35 mL of distilled water to produce a homogeneous paste; the Portland cement was mixed to a consistency similar to the WMTA. The placing procedures were the same as described for G1 and G2.

All the samples were stored at 100% humidity for 72 hours to allow the cement to set.

Hermetic Cell and Flow Rate Measuring

The teeth were placed into a device designed to measure leakage by fluid filtration (17). In the pilot assay, a little modification in the removable hermetic cell (assembled double-chamber) described earlier by Abramovitz et al (18) was made. In this way, the hermetic cell allowed easy connection, measurement, disconnection, and reconnection of the root to the fluid transport device for each tooth.

The crown of each tooth (Fig. 1*D*) was placed inside an O-ring (Ø 2.5 cm) (Fig. 1*E*). All teeth were embedded in a 2-component paste/paste epoxy resin cylinder (Fig. 1*C*), formed in a mold consisting of the end part of a 20-mL Luer-type disposable syringe (Fig. 1*A*). Coronal and furcal openings of the embedded tooth were kept free of the epoxy resin. A second hollow cylinder, cut from a 5-mL Luer-type disposable syringe, was adapted to the first cylinder before setting of the epoxy resin (Fig. 1*B*). Subsequently, the margins adjoining the 2 disposable syringes were filled with a blue-fluid epoxy resin (Arazyn 1.0; Ara Química, São Paulo, SP, Brazil) (Fig. 1*F*). This assembly produced a sealed assembled hermetic cell (a double-chamber) made with 2 partial disposable Luer-type syringes. The blue color of the fluid resin allowed the no-leakage verification in the syringes-resin joint.

Compressed air was used to generate a constant pressure of 20 cm H_2O. A general view of the fluid flow device is shown in Fig. 2. A small air bubble was then introduced into the system with the microsyringe, and the fluid flow through the repaired furcal was measured by the movement of the bubble traveling within the pipette. Measurements of the air bubble movement were made at 2-minute intervals for 10 minutes.

Statistical Analysis

The preliminary analysis of the pooled data from the experimental groups (SPSS for Windows, Version 8.0; SPSS Inc, Chicago, IL) did not show normal distribution (Kolmogorov-Smirnov test). Further statistical analysis was performed with nonparametric test methods by using the Kruskal-Wallis H-test with Bonferroni correction. The fluid flow was used as a factor, and the level of significance was set at $P < .05$.

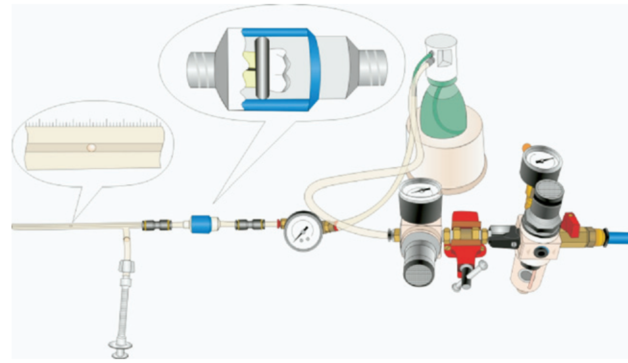

Figure 2. Flow rate measuring system set-up.

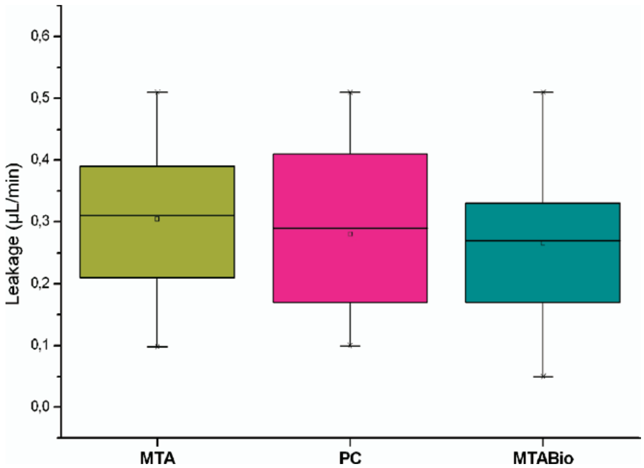

Figure 3. Box plots of the leakage measures, which illustrate the median traces, minimal and maximal fluid flow traces, as well as the variance in each experimental group.

Results

No leakage was recorded for the 5 negative controls, whereas the air bubble moved too quickly to be measured in the positive control, indicating very high fluid flow.

Overall, leakage was very variable in the 3 experimental groups, ranging from 0.098–0.51 μL/min. That point can be clearly observed in the box plots in Fig. 3, which illustrates the median traces, minimal and maximal fluid flow traces, as well as variance in each experimental group.

Leakage existed in every sample. However, Kruskal-Wallis H-test results showed that there were no significant differences among the fluid flow data of the experimental groups ($P = .874$).

Discussion

Fig. 3 illustrates that all 3 materials displayed similar capability to prevent through-and-through fluid movement in the repaired furcal perforations. Therefore, the null hypothesis tested was accepted.

It is worth mentioning that the MTA Bio was qualitatively superior to handle than both MTA and Portland cement. Likewise, the setting time of MTA Bio was clearly faster. The previous statements, as well as the absence of leachable arsenic and lead in MTA Bio, however, should be addressed in future experiments before any conclusive statements can be made.

Water-based cements have been demonstrating good performance to seal furcal perforations when compared with other materials (2, 5). It has been reported that MTA showed a significantly better ability in preventing leakage of *Fusobacterium nucleatum* past furcal perforation repairs than amalgam (19). The objective of placing a repair furcal material is to produce a fluid-tight seal to prevent further ingress of tissue fluid, bacteria, and bacteria by-products (20). Nonetheless, the present results demonstrate a difficulty in producing a fluid-tight seal in repaired furcal perforations. This is reasonable because of the high level of fluid filtration shown in the present results. In agreement, Yildirim et al (21) stated that most of the materials used for furcation perforation repair exhibit slight to severe leakage. However, Weldon et al (2) determined that MTA produced a good seal to fluid flow at a physiologic pressure of 20 cm H_2O. Conversely, in the present study under the same pressure, all the repaired samples showed some amount of fluid filtration. These conflicting results might be because of the different experimental designs, such as the fluid transport devices, the diameter of perforations, the number of samples, and the different observation periods, as well as differences in the assembly of the samples and other laboratory conditions.

The fluid flow values of the present results were of the same order of magnitude as those obtained from other studies in which the fluid transport model was used to assess the ability of the cements to seal furcal perforations and root-end filings (22). In agreement with the results of the present study, previous reports have demonstrated that MTA and Portland cement have comparable sealing ability (3, 23). However, to the best of the authors' knowledge, there is no study that has assessed the sealing ability of the Portland cement with the fluid transport model until now. In the present study, the fluid filtration model was chosen because it is both reproducible and more sensitive than dye penetration (24, 25). The fluid filtration method can provide both qualitative and quantitative information about the seal quality. The quantitative data are provided by the movement of the air bubble through the micropipette (fluid flow), whereas the qualitative data are obtained by the percentage of samples in which fluid flow was detected. Therefore, any fluid filtration represents the detection of a serious fault, the so-called through-and-through voids. As van der Sluis et al (25) stated, very small through-and-through voids, invisible on radiographs or in cross-sections, can be detected by the fluid filtration method. In addition, this method does not destroy the samples, meaning that it is possible to assess leakage at different time intervals during extended periods and superimpose other methods with the same sample. Fluid filtration is capable of measuring a wide range of fluid flow rates with precise results, because low flow rates can be recorded.

Under the conditions of the present ex vivo evaluation, the following conclusions can be drawn: (1) neither cement was capable of producing a fluid-tight seal; (2) the sealing ability promoted by all 3 cements was similar; and (3) the present results suggest that Portland cement has the potential to be developed as a furcal repair material, but more studies are necessary before warranting unlimited clinical use.

Acknowledgments

The authors wish to thank Prof Matthias Zehnder, University of Zürich Center for Dental Medicine, Zürich, Switzerland, for his essential help in reviewing the manuscript.

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