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# Similar expression of through-and-through fluid movement along orthograde apical plugs of MTA Bio™ and white Portland cement

**G. De-Deus[1], C. Audi[2], C. Murad[2], S. Fidel[2] & R. Fidel[2]**

[1]Department of Endodontics, Veiga de Almeida (UVA), Rio de Janeiro, Brazil; and [2]Department of Endodontics, Rio de Janeiro State University (UERJ), Rio de Janeiro, Brazil

## Abstract

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**Aim** To compare the sealing ability of four hydraulic cements when used as an apical plug in teeth with wide-open apices.

**Methodology** A sample of 70 maxillary central incisors were divided into four groups ($n = 15$) and a further 10 teeth served as controls. An artificial open apex was created in the teeth using Gates Glidden drills numbers 6-1 in a crown-down manner until the size 1 bur passed through the foramen. A divergent open apex was prepared to a size of 1.24 mm at the foramen by retrograde apical transportation using a number 8 (0.60) Profile Series 29 0.4 taper instrument inserted to the length of the cutting blade. In G1, the open apices were repaired with WMTA Angelus whilst in G2, G3 and G4 MTA Bio™, Pro-Root MTA and Portland cement was employed respectively. Each root was assembled in a hermetic cell to allow the evaluation of fluid filtration. Leakage was measured by the movement of an air bubble travelling within a pipette connected to the teeth. Measurements of the air bubble movement were made after 10 min at a constant pressure of 50 cm $H_2O$. The Kruskal–Wallis *H*-test was applied to the fluid flow data to detect differences between the experimental groups ($P < 0.05$).

**Results** Fluid movement occurred in every sample but was variable in all the experimental groups, ranging from 0.61 to 2.45 μL $min^{-1}$. There was no significant difference in mean fluid flow between the experimental groups ($P > 0.05$).

**Conclusions** Fluid movement through teeth with open apices and filled with four hydraulic cements was similar. All cements allowed fluid movement.

**Keywords:** apical barrier, leakage, MTA, Portland cement, through-and-through fluid movement.

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## Introduction

One of the main challenges in performing root canal treatment in immature teeth with necrotic pulps and wide-open apices is obtaining a seal within the root canal system. The wide-open foramen results in a large volume of filling material and the potential for voids and gaps between the material and canal wall; consequently, a compromised seal may result (Rafter 2005).

Apexification with calcium hydroxide is the most commonly used therapy (Steiner *et al.* 1968, Van Hassel & Natkin 1970, Felippe *et al.* 2005, Ballesio *et al.* 2006). Despite its clinical success, it has disadvantages, such as the need for good patient compliance and multiple appointments extending over a long period of time (from 3 to 24 months) (Frank 1966). In addition, Andreasen *et al.* (2002) reported the

Correspondence: Prof. Gustavo De-Deus, R. Desembargador Renato Tavares, 11, ap.102, Ipanema, Rio de Janeiro, RJ 22411-060, Brazil (Fax: +55 21 2247 6061; e-mail: endogus@gmail.com).

strength of immature teeth was reduced by long-term calcium hydroxide treatment.

A feasible alternative for the multi-appointment $Ca(OH)_2$ apexification procedure is a single-step approach using an apical barrier (Coviello & Brilliant 1979, Schumacher & Rutledge 1993). The one-visit treatment, in its traditional sense, is not a new idea (Roberts & Brilliant 1975) and has been described in the literature as the nonsurgical compaction of a biocompatible material into the apical end of the root canal, thus creating an apical stop, enabling the immediate filling of the root canal (Steinig *et al.* 2003).

The use of MTA to create an apical plug at the end of the root canals with open apices has been developed. This approach was first introduced by Shabahang & Torabinejad (2000) and has been well documented by others (Witherspoon & Ham 2001, Giuliani *et al.* 2002, Linsuwanont 2003, Maroto *et al.* 2003, Steinig *et al.* 2003, Hayashi *et al.* 2004) as a alterative to apexification with $Ca(OH)_2$. According to several case reports, MTA has been used successfully as an apical barrier (Shabahang & Torabinejad 2000, Maroto *et al.* 2003, Steinig *et al.* 2003, Al-Kahtani *et al.* 2005).

It has been confirmed that MTA is a Portland cement plus bismuth oxide to make the mix radiopaque (Song *et al.* 2006, Martin *et al.* 2007). This fact has created interest in the development of Portland cement as a low-cost alternative to MTA and recent studies have compared MTA with Portland cement. In brief, MTA and Portland cement have demonstrated comparable physical and biological properties (De-Deus *et al.* 2005, 2006, 2007). The sealing ability of MTA as an apical plug was already highlighted by earlier studies (Shabahang & Torabinejad 2000, Maroto *et al.* 2003, Steinig *et al.* 2003, Al-Kahtani *et al.* 2005). Alternatively, the sealing ability of Portland cement remains poorly evaluated; however, a recent case report showed excellent periapical healing using Portland cement as an apical plug in a tooth with a wide-open apex (De-Deus & Coutinho-Filho 2007).

A problem regarding the clinical application of the water-cements is the amount of leachable arsenic and lead present in the material (Duarte *et al.* 2005). 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. Aiming to avoid the presence of arsenic and lead, an experimental water-based cement, MTA Bio™, has been developed by a Brazilian dental company (Angelus, Londrina, PR, Brazil). In a recent investigation, MTA Bio™, white MTA Angelus and Portland cement have displayed a similar ability to prevented fluid movement through a repaired furcal perforation (De-Deus *et al.* 2007).

Therefore, the present study was designed to test the sealing ability of MTA Bio™ and white Portland cement when used as an apical plug. Both white MTA Angelus and white Pro-Root MTA were used for comparison. A fluid transport model was used to assess the sealing ability. The null hypothesis is that there is no difference in the through-and-through fluid movement pattern amongst the materials tested used as an apical plug in teeth with wide-open apices.

## 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 70 well-preserved human maxillary central incisors was selected from the tooth bank of Rio de Janeiro State University. The criteria for tooth selection were: single-rooted teeth; complete root formation; no root caries and no fracture line. To improve specimen standardization, the teeth selected were required to have a length varying from 22 to 24 mm. The teeth were autoclaved and kept in 0.2% sodium azide for no longer than 7 days.

### Tooth instrumentation

Standard access cavities were prepared and the canal orifices located. The patency of each canal was confirmed by inserting a size 15 file through the apical foramen prior to root canal preparation. The crowns were then removed at the cemento-enamel junction with a number 4138 diamond bur (KG Sorensen; Zenith Dental ApS, Agerskov, Denmark). The root tips were removed in the same way, leaving roots 12 mm in length. Two millimetres of the apical tip of each root was removed with a number 4138 diamond bur to remove apical deltas and to standardize the canal exit to the centre of the tooth, leaving roots 10 mm in length (Hachmeister *et al.* 2002).

### Open apex procedures

Artificial open apices were created following the protocol described by Hachmeister *et al.* (2002). The root canals were prepared with Gates Glidden drills sizes 6-1 (Dentsply Maillefer, Ballaigues, Switzerland) in a crown-down manner until the size 1 size bur could pass through the apex. The canals were irrigated between each file with 1 mL of freshly prepared 5.25% NaOCl using a disposable syringe and 27-gauge needle. The canals were dried with paper points (Dentsply Maillefer).

A divergent open apices was prepared to a size of 1.24 mm at the foramen by retrograde apical transportation using a number 8 (0.60) Profile Series 29 0.4 taper (Denstply Tulsa Dental, Tulsa, OK, USA) inserted to the length of the cutting blade. The root canal was dried with paper points, and the integrity and shape of apical foramen were verified microscopically (Dental F. Vasconcelos; M900 – X25, São Paulo, Brazil).

## Open-apex filling procedures

The specimens were randomly subdivided into four groups of 15, plus 10 control specimens. Five teeths with intact crowns were also used as a negative control and five teeths that were not filled served as positive controls. In G1, 1 g of white MTA Angelus (WMTA Angelus) was mixed with 0.35 mL of distilled water, according to manufacturer recommendations. The WMTA was placed as close to the apex as possible using an Endogun (Medidenta Int. Inc., Woodside, NY, USA), under microscopic vision (10×) and, compacted with Schilder pluggers (Hu Friedy, Chicago, IL, USA). Radiographs were taken to check the filling has 3 mm in thickness. Paper points moistened with a saline solution were placed into the root canal, against the WMTA to assist the setting of the cements.

In G2 and G3, the same procedures of G1 were performed, but the open apexes were repaired with MTA Bio$^{TM}$ (Angelus) and Pro-Root MTA (Denstply Tulsa Dental) respectively.

In G4, 1 g 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 placement procedures were the same as described for the other groups. All the samples were stored at 100% humidity for 72 h to allow the cement to set.

## Hermetic cell and flow rate measuring

The teeth were placed into a device designed to measure fluid movement, as described previously (Wu *et al.* 1993a, 1994). The crown of each tooth (Fig. 1d)

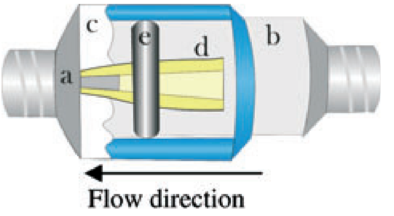


**Figure 1** Schematic illustrating the modified hermetic cell (assembled double chamber).

was placed inside an O-ring (Ø 0.8 cm) (Fig. 1e). All teeth were embedded in a two-component paste/paste epoxy resin cylinder (Fig 1c), in a mould prepared from the end part of a 20-mL Luer-type disposable syringe (Fig. 1a). Coronal and apical openings of the embedded tooth were maintained free of 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 1b). Subsequently, the margins adjoining the two disposable syringes were filled with a blue-fluid epoxy resin (Arazyn 1.0, Ara Química, SP, Brazil) (Fig. 1f). This assembly produced a sealed assembled hermetic cell (a double chamber) made with two partial disposable Luer-type syringes. The blue colour of the fluid resin allowed the no-leakage verification at the syringe-resin joints.

A general view of the fluid flow device is shown in Fig. 2. Compressed air was used to generate a constant pressure of 50 cm $H_2O$. A compressed air source of 2 atm (Fig. 2, n. 1) was connection through a fine pressure regulator (Fig. 2, n. 3) (Dover; Metal Work Pneumática do Brazil Ltda., São Leopoldo, RS, Brazil) to a manifold built from connectors, quick-connects couplings, pressure hoses and valves. A second high-fine pressure regulator (Dover) (Fig. 2, n. 6) was responsible for the fine-tuning of the pressure. A pressurized water reservoir (Fig. 2, n. 7) was connected using a 6-cm polyethylene pressure hose to a manometer device (Fig. 2, n. 8) with a measuring capacity of up to 150 cm $H_2O$. The manometer allowed monitoring a constant pressure of 50 cm $H_2O$ and the measurements of the air bubble movement were made after 10 min.

The hermetic cell outlet (Fig. 2, n. 15) was connected using a 6-cm polyethylene pressure hose (Dover) to the water reservoir through a 6-cm quick-connect coupling (Dover). The hose was connected to a three-way valve (Fig. 2, n. 12) through a quick-connect coupling (Fig. 2, n. 9). The three-way valve was connected to a 200 μL glass pipette, of uniform bore (Ø 0.25 mm) and 300 mm length (Fig. 3, n. 13)

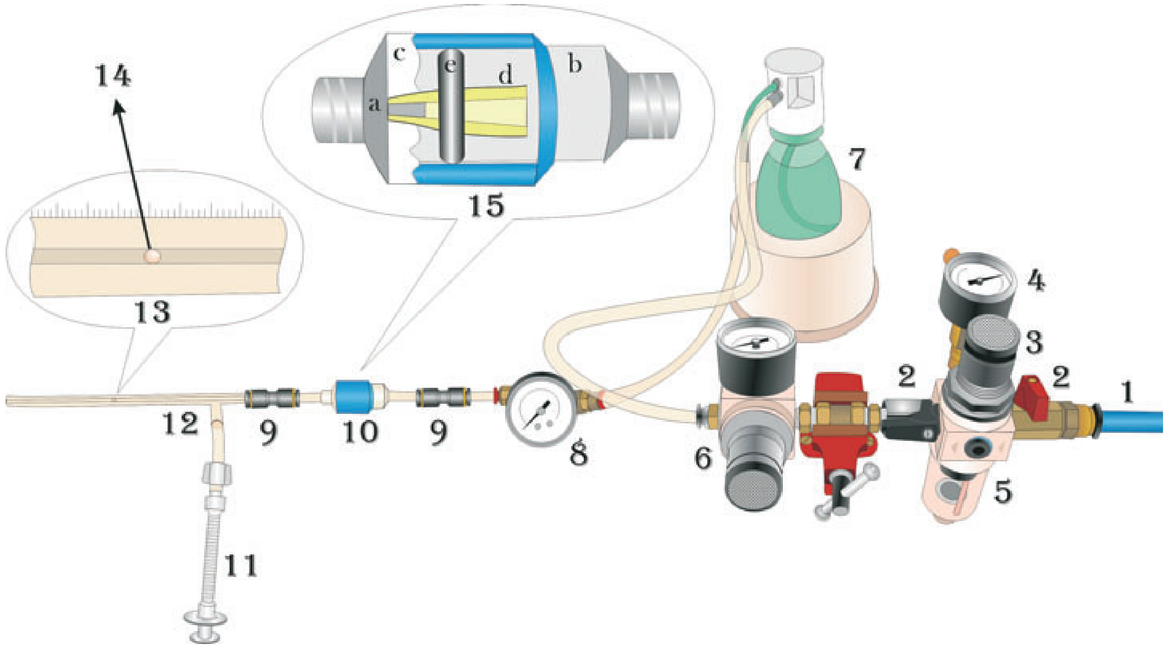


**Figure 2** Flow rate-measuring system set-up.

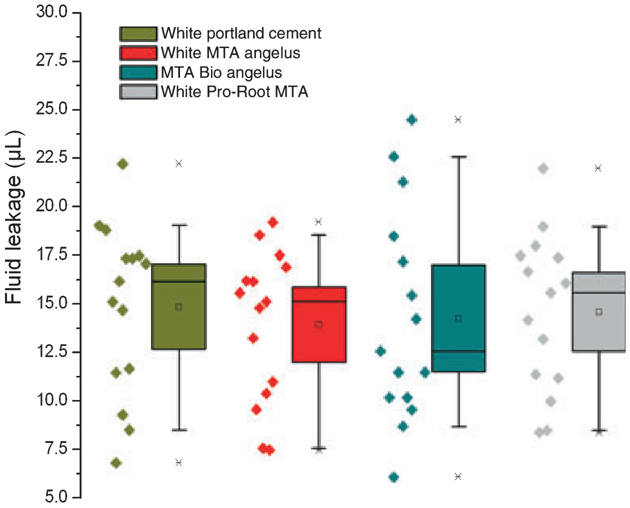


**Figure 3** Box plots of the leakage measures, which illustrate the median traces, minimal and maximal fluid flow traces as well as the variance in each experimental group.

and to a microsyringe (Fig. 3, n. 11). All the connections were glued with cyanoacrylate glue.

Before beginning the experiment, the seals were checked under water by submitting the system to air pressure from the free end of the pipette (Wu *et al.* 1994). Prior to the activation of the system, all of the air was removed from the system and it was filled with bi-distilled water using a syringe adapted to the three-way valve. A small air bubble was then introduced into the system with a microsyringe.

The assembly of the fluid filtration device (hermetic cell and the samples), as well as all of the measurements, was carried out at 24°±1 °C. Once the system was activated, a 10 min stabilization period was allowed for each tooth.

The fluid flow through the apical plug was measured by the movement of the air bubble travelling within the pipette. The direction of filtration was always from the cervical to apical. The water was forced through the full-length voids present in the apical plug, displacing the air bubble in the pipette. The displacement of the air bubble within the capillary tube was measured with a digital micrometer, accurate to 0.01. The negative control measurements were repeated before starting every measurement session.

### Data presentation and statistical analysis

The data were presented as $\mu L\ min^{-1}$. The preliminary analysis of the pooled data from the experimental groups did not follow a Gaussian bell-shaped distribution (normal data) – Kolmogorov–Smirnov test. Further statistical analysis was performed with nonparametric methods, using the Kruskal–Wallis *H*-test. The level of significance was set at $P < 0.05$. SPSS for Windows (Version 11.0, SPSS Inc., Chicago, IL, USA) and Origin 6.0 (Microcal Software, Inc., Northampton, MA, USA) were used as statistical tools.

## Results

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

Fluid movement occurred in every sample and, overall, was variable in the four experimental groups, ranging from 0.61 to 2.45 $\mu L\ min^{-1}$, as can be observed in the box plots in Fig. 3, illustrating the median traces, minimal and maximal fluid flow traces as well as the variability in each experimental group. There were no significant differences amongst the fluid flow data of the experimental groups ($P > .05$).

## Discussion

The current data showed that all four materials displayed a similar capability to prevent through-and-through fluid movement. Therefore, the null hypothesis tested was accepted. In agreement with the results of the present study, previous reports have demonstrated that MTA and Portland cement have a comparable ability to prevent fluid movement (De-Deus *et al.* 2006, 2007).

Water-based cements have demonstrated good performance in producing a seal in a wide variability of clinical and experimental situations (Shabahang & Torabinejad 2000, De-Deus *et al.* 2006, 2007, De-Deus & Coutinho-Filho 2007). The objective of placing an apical plug is to produce a fluid-tight seal to prevent further ingress of tissue fluid, bacteria and bacteria by-products (Steinig *et al.* 2003). Nonetheless, the present results reflects the difficulty of producing a fluid-tight seal in teeth with wide-open apices, which is in agreement with others studies in which the sealing ability of the water-based cements was tested (De-Deus *et al.* 2006, 2007). This is reasonable, because of the high level of through-and-through fluid movement shown in the present results. The present results are in agreement with the longitudinal evaluation of Wu *et al.* (1998a) that found gross leakage in 55% of the MTA samples at 24 h. However, the sealing ability of MTA was greatly improved after the first 3 months and this improved seal was maintained until the end of the experiment. Hachmeister *et al.* (2002) also reported severe leakage when MTA was used as an apical plug. This leakage could be attributed to the inferior technique of delivering MTA to the apical third of the root canal. On the other hand, Al-Kahtani *et al.* (2005) showed that a 5 mm plug of MTA at the apex provided an absolute seal against microleakage of *Actinomyces viscosus*. This is in agreement with Lawley *et al.* (2004), who found that 4 mm of MTA placed ultrasonically provided a good seal. Moreover, Leimburg *et al.* (2004), using a highly sensitive molecular method, showed that an orthograde apical plug of MTA provided an adequate seal against infiltration by *Enterococcus faecalis*. The authors also concluded that leakage may be caused by the intracanal delivery technique rather than by the MTA itself.

These conflicting results might have occurred because of the different experimental designs, such as the fluid transport devices, the apex diameter, the number of samples and the different observation periods, as well as differences in the assembly of the samples and other laboratory conditions. In conclusion, the overall view of the current literature demonstrates that the water-based cements have a better sealing performance than other traditional materials but do not create a fluid-tight seal.

The fluid filtration model was chosen because it is both reproducible and more sensitive than dye penetration (Wu & Wesselink 1993, Wu *et al.* 1994). The fluid filtration method can provide both qualitative and quantitative information about the sealing ability of a material. The quantitative data is provided by the movement of the air bubble through the micropipette (fluid flow) whilst the qualitative data is 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.* (2005) 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 fluid movement at different time intervals over extended periods and superimpose other methods employing the same samples. Fluid filtration is capable of measuring a wide range of fluid flow rates with precise results, as low flow rates can be recorded. Moreover, Wu *et al.* (1998b) demonstrated that MTA can discolour methylene blue dye; as a result the method is invalid.

Several approaches had already been used to find a hermetic connection between tooth margins and the fluid filtration device. Nevertheless, in the pilot assay, the model described by Abramovitz *et al.* (2001) was the most functional and effective. Even so, a modification to the removable hermetic cell (assembled double chamber) described by Abramovitz *et al.* (2001) 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.

It is worth mentioning that, although the favourable sealing results of the water-based cements when used as an apical plug in teeth with wide-open apices has been documented (Shabahang & Torabinejad 2000, Maroto *et al.* 2003, Steinig *et al.* 2003, Al-Kahtani *et al.* 2005, Martin *et al.* 2007), the recent statement of Martin *et al.* (2007) represents a critical point: 'the results obtained with the fluid filtration technique cannot be used to predict clinical success of MTA apexification procedures because they represent only how well the MTA material adapts to the root canal. Whether that MTA apexification achieves clinical success depends on many additional variables'.

## Conclusions

Under the conditions of the present *in vitro* evaluation, the following conclusions can be drawn: (i) no cement was capable of producing a fluid-tight seal and (ii) the sealing ability promoted by all four cements was similar.

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