MTA versus Portland cement as repair material for furcal perforations: a laboratory study using a polymicrobial leakage model

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Abstract

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Aim To compare the ability of Portland cement and mineral trioxide aggregate (MTA) to prevent coronal leakage through repaired furcal perforations in molar teeth.

Methodology The pulp chambers of 36 human mandibular molar teeth were accessed and the root canal orifices were located. The roots were horizontally sectioned in the middle third. Composite resin was used to fill the root canal orifices and the apical end of the roots. Perforations were created in the centre of the pulp chamber floor using a size 3 round bur. Thirty teeth were divided into two groups ($n = 15$) and a further six teeth served as controls. In G1, all 15 perforation defects were repaired with MTA while in G2, Portland cement was used. Each tooth was inserted in a silicone tube (bacterial reservoir) with the region containing the perforation protruding through the end. The system was sterilized and placed in a glass flask containing sterile brain heart infusion medium (BHI). The reservoirs were filled with human saliva mixed in BHI and system was incubated at 37 °C and checked daily for the appearance of turbidity in the BHI broth during the following 50 days. The leakage data were analysed statistically by a log-rank test ($P < 0.05$).

Results Eight (53%) of the 15 samples of the MTA group (G1) and nine (60%) of the 15 samples of the Portland cement group (G2) were fully contaminated at 50 days. There was no statistically significant difference between the two groups ($P > 0.05$).

Conclusion Portland cement and MTA demonstrated a similar ability to seal furcal perforations.

Keywords: bacterial leakage, furcal perforations, mineral trioxide aggregate, Portland cement.

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Introduction

Root perforations can occur pathologically as a result of resorption and caries or iatrogenically during root canal treatment. Factors that affect the prognosis of perforation repair include: the location of the perforation, time delay prior to perforation repair, previous contamination by microorganisms (Nicholls 1962, Sinai 1977) and the biological and physical characteristics of the restorative material (Sluyk *et al.* 1998, Abdullah *et al.* 2002).

A variety of materials have been suggested for the nonsurgical repair of furcation perforations including: amalgam, IRM, gutta-percha, dentine chips, calcium hydroxide, Cavit, tricalcium phosphate, hydroxyapatite, glass–ionomer cement, Super EBA and, more recently, mineral trioxide aggregate (MTA; Abdullah *et al.* 2002).

Mineral trioxide aggregate is a new class of restorative material that is a derivative of Portland cement

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(Torabinejad *et al.* 1993, Abdullah *et al.* 2002). The material was developed as a root-end filling material, but it has been suggested as a viable alternative material for various clinical applications such as pulp capping, root-end closure as well as for the repair of furcal perforations (Torabinejad *et al.* 1993, Torabinejad & Chivian 1999). Underlying these applications are the properties of MTA that include biocompatibility (De-Deus *et al.* 2005), good sealing ability (Torabinejad *et al.* 1993) and the ability to promote dental pulp (Menezes *et al.* 2004) and periradicular tissue regeneration (Torabinejad & Chivian 1999). Nakata *et al.* (1998) reported that MTA was significantly better than amalgam in preventing leakage of *Fusobacterium nucleatum* through furcal perforation repairs. Main *et al.* (2004) evaluated the success rate of root perforation repairs using MTA and concluded that MTA provided an effective seal for root perforations and showed promise in improving the prognosis of perforated teeth that would otherwise be compromised. Yildirim *et al.* (2005) investigated the histologic response to MTA or Super EBA when used for the repair of furcation perforations in the teeth of dogs. The authors concluded that MTA created less inflammation than Super EBA; MTA specimens demonstrated healing with new cementum formation in the perforation area, whereas Super EBA specimens in which no inflammation was seen showed connective tissue healing.

Recently the chemical, physical and biological properties of Portland cement have been analysed. Wucherpfenning & Green (1999) reported that MTA and Portland cement were almost identical macroscopically, microscopically and when evaluated by X-ray diffraction analysis. They also reported apposition of reparative dentine when the material was used for direct pulp capping in the teeth of rats. Estrela *et al.* (2000) reported that Portland cement contained the same principal chemical elements as MTA, except for bismuth oxide. Saidon *et al.* (2003) also reported that MTA and Portland cement had similar properties. De-Deus *et al.* (2005) reported that the two brands of MTA they analysed, as well as Portland cement, initially showed an elevated cytotoxic effect that decreased gradually with time allowing the cell culture to repair. Furthermore, they reported that the cell reaction patterns were similar for Pro-Root MTA® (Dentsply, Tulsa Dental, Tulsa, USA), MTA Angelus® (Angelus, Curitiba, Paraná, Brazil) and Portland cement (Mauá CP32-TYPO II, Lafarge, Rio de Janeiro, Brazil) at all experimental time periods. The authors concluded that the positive biological results achieved with Portland cement were encouraging for its use as an endodontic restorative material with lower cost. Ribeiro *et al.* (2005) demonstrated that MTA and Portland cement had no cytotoxic effects in mouse lymphoma cells and they reported that these results might be an additional argument to support the use of MTA and Portland cement in dental practice.

The present paper aims to compare the ability of Portland cement and MTA to seal furcal perforations in extracted human molar teeth using a polymicrobial leakage model.

Materials and methods

Tooth 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 36 human mandibular left and right first molar teeth free from cracks and with similar anatomical characteristics was selected from the tooth bank of Rio de Janeiro State University. The teeth were autoclaved and kept in 0.5% sodium hypoclorite (NaOCl) for no longer than 7 days.

Standard access cavities were prepared and the root 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 in all specimens were etched with 37% phosphoric acid gel (Scotchbond; 3M ESPE Dental Products, St Paul, MN, USA) for 30 s. The Single Bond adhesive system (Scotchbond) was then applied in two consecutive coats and photopolymerized for 10 s with an 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 min with an LED source. The root canal orifices and the apical ends of the roots were then sealed with cyanoacrylate adhesive (Loctite 496; Henkel Ltd, São Paulo, Brazil) in an attempt to increase the marginal seal.

Perforations were created in the centre of the pulp chamber floor using a size 3 round bur (100 ISO size; Dentsply Maillefer, Ballaigues, Switzerland) in a low-speed handpiece. The teeth were rinsed with water and dried with oil-free air. A silicone impression material (President Jet® Coltène AG, Cuyahoga Falls, OH, USA) was mixed to provide a matrix that simulated the bony socket. Teeth were placed into the unset the silicone and then removed when polymerization had occurred.

Thirty teeth were randomly divided into two groups of 15 teeth each (G1 and G2) and a further six teeth served as controls. The teeth were replaced in their silicon impression and the perforations air dried.

Repair of the perforations

In G1, 1 g of MTA (Pro-Root MTA®) was mixed according to the manufacturer's instructions, with 0.35 mL of distilled water to produce a homogeneous paste. In all, 15 perforation defects were repaired with MTA. The MTA was placed in the perforation with an Endogun (Medidenta Int. Inc., Woodside, NY, USA) and compacted with Schilder pluggers (Hu Friedy, Chicago, IL, USA). A cotton pellet moistened with saline was placed in the pulp chamber against the MTA.

In G2, 1 g of Portland cement (Mauá CP32-Kind II, Lafarge) was sterilized with ethylene oxide and then mixed with 0.35 mL of distilled water to produce a homogeneous paste; the Portland cement was mixed to a consistency similar to the Pro-Root MTA. Fifteen perforation defects were repaired with Portland cement. The Portland cement was placed in perforation with an Endogun and compacted with Schilder pluggers. A cotton pellet moistened with saline was placed in the pulp chamber against the Portland cement.

Three teeth that were perforated but not repaired served as positive controls. Another three teeth that were not perforated served as negative controls. All the samples were stored at 100% humidity for 72 h.

Preparation of samples

Two coats of nail varnish were applied on the external surface of all teeth, except 2 mm around the perforation area, in order to prevent bacterial leakage through lateral canals or other discontinuities in the cementum.

The apparatus used in this study was modified from that described previously (Imura *et al.* 1997) and shown in Fig. 1. The teeth were inserted individually in a silicone tube (0.5 × 1.5 mm) with the region containing the perforation protruding through the end. The silicone tube was used to create the bacterial reservoir. The interface between the crown and the silicone hose was sealed with cyanoacrylate adhesive. The system was sterilized overnight using ethylene oxide gas and placed in a 25-mL glass flask containing 6 mL of sterile brain heart infusion medium (BHI; Oxoid Ltd, Basingstoke, UK). The interface between the silicone hose and the flask glass was sealed with cyanoacrylate adhesive. To verify sterilization, the apparatus was incubated at 37 °C for 4 days.

To verify the efficiency of the cyanoacrylate seal, 2 mL of 1% sterile methylene blue dye was placed into the tube leading to the coronal portion of each sample (Malone & Donnelly 1997). If the medium became blue,

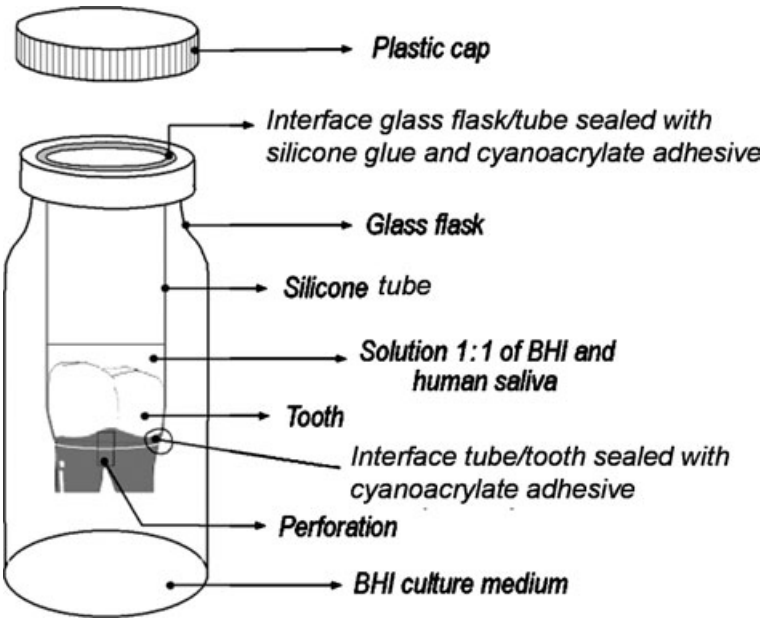

Figure 1 Setup of the experimental model.

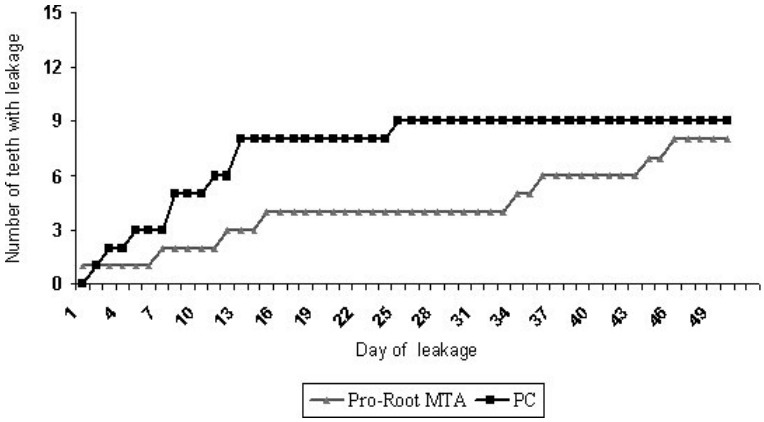

Figure 2 Number of specimens in each group with leakage over a period of 50 days.

this meant the seal was defective and the specimen was discarded. The whole apparatus was incubated at 37 °C for 4 days to ensure sterilization.

Polymicrobial leakage

The reservoirs were filled with human saliva (20 mL) mixed in BHI broth in a 1 : 1 (v/v) ratio (Siqueira *et al.* 1999) and replenished every 3 days. Human saliva was collected from one individual at 9 AM on each day of exposure or solution change. The volunteer did not brush or floss for at least 12 h before collection. A 1-g piece of Parafilm (American National Can, Menasha, WI, USA) was used to stimulate salivary flow (Gomes *et al.* 2003). The system was incubated at 37 °C and was checked daily for the appearance of turbidity in the BHI broth during the following 50 days.

Statistical analysis

All data were organized in a contingency table. A linear regression model (SPSS/PC + Statistics 4.0 software; SPDD International BV, Gorinchem, the Netherlands) was used and leakage data were analysed statistically by a log-rank test. The level of significance was set at $P < 0.05$.

Results

No growth was observed when checking the sterilization of the whole apparatus. All specimens of the positive control group showed broth turbidity within 2 days of incubation. Leakage in experimental samples was first observed at the second day. No evidence of turbidity in the BHI broth occurred in the negative control group during the experimental period. Samples displayed leakage within a range of 2–50 days. Eight (53%) of the 15 samples of the MTA group (G1) were fully contaminated at 50 days. Nine (60%) of the 15 samples of the Portland cement group (G2) were fully contaminated at 50 days. The data obtained were statistically analysed with the log-rank test which showed no statistically significant difference among the two groups ($P > 0.05$). The pattern of leakage in the experimental groups is shown in Fig. 2.

Discussion

Dye leakage studies have been used for many years to evaluate the sealing ability of endodontic materials. However, Wu & Wesselink (1993) suggested that dye penetration studies tend to overestimate leakage as the size of dye molecule is smaller than bacteria. Studies using bacterial cultures or saliva have been used widely to test the leakage resistance of endodontic materials and may be considered to have more biological relevance than dye leakage tests. The use of human saliva is advantageous because it more closely approximates the clinical situation (Siqueira *et al.* 1999, 2000).

Previous reports have demonstrated that MTA and Portland cement are biocompatible (Wucherpfenning & Green 1999, Estrela *et al.* 2000, De-Deus *et al.* 2005). Abdullah *et al.* (2002) described how accelerated Portland cement supported the proliferation of SaOS-2 osteosarcoma line cells *in vitro* and actively stimulated a biological response in these cells through the production of cytokines and a bone-specific protein. Holland *et al.* (2001a) studied the behaviour of the dental pulp in the teeth of dogs after pulpotomy and protection of the remaining tissue with MTA and Portland cement, and reported that both materials had

similar chemical formulations, except for the bismuth oxide in MTA, and the results obtained were the same for MTA and Portland cement. The results observed in biological studies with MTA and Portland cement is supported by Holland *et al.* (2001b) who reported that the mechanism of action of MTA and Portland cement were similar. Both materials contain calcium oxide that forms calcium hydroxide when mixed with water. The reaction of the calcium hydroxide and the carbon dioxide from the pulp tissue produces calcite crystals (Holland *et al.* 2001a). Seux *et al.* (1991) concluded that their findings strongly support the role of calcite crystals and fibronectin as an initiating step in the formation of a hard tissue barrier.

Considering that Portland cement contains the same principal chemical elements as MTA, they probably have a similar mechanism of action and thus the results of biological investigation are similar. It has been suggested that their physical properties could also be similar. Aquilina (1999) supported this opinion when it was demonstrated that accelerated Portland cement had good sealing ability and adequate physical and mechanical properties for a restorative material.

The results of the present study support those described previously (Wucherpfenning & Green 1999, Estrela *et al.* 2000, Holland *et al.* 2001a,b, De-Deus *et al.* 2005) suggesting that MTA and Portland cement are almost similar.

Conclusions

Under the conditions of this laboratory evaluation, the leakage patterns of Pro-Root MTA and Portland cement in furcation repairs were similar over a period of 50 days.

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