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The effect of smear layer on the push-out bond strength of root canal calcium silicate cements

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ABSTRACT

Introduction. The aim of this study was to evaluate the effect of smear layer removal on the push-out bond strength between radicular dentin and three calcium silicate cements (CSC) in comparison with gutta percha and sealer.
Methods. Eighty human anterior extracted teeth were decoronated, cleaned and shaped to size 50/0.05 apically and randomly divided into 2 major groups: (A) smear layer preserved, and (B) smear layer removed using irrigation with 17% EDTA. Roots within each major group were further divided into 4 subgroups according to the obturation material used: (1) ProRoot MTA, (2) Biodentine, (3) Harvard MTA, (4) Gutta percha and AH-plus sealer. Obturated roots were stored in synthetic tissue fluid for 7 days to allow maximum setting of the root filling materials. Three 2-mm-thick slices were obtained from each root at different section levels (coronal, middle, apical). The canal diameters and slice thickness were measured, and the adhesion surface area for each slice was calculated. Push-out bond strength test was carried out using a universal testing machine. The bond failure mode was assessed under an optical microscope at 40×.
Results. The mean push-out bond strength in groups 1A, 2A and 3A were 7.54 (±1.11), 7.64 (±1.08) and 8.79 (±1.55) MPa respectively, while those for groups 1B, 2B and 3B were 6.58 (±1.13), 6.47 (±1.08), 7.71 (±1.81) MPa, respectively. In the gutta percha and sealer groups the push-out bond strength means were: 1.98 (±0.48) and 2.09 (±0.51) MPa in the preserved and removed smear layer groups respectively. The push-out strength values were significantly reduced when the smear layer was removed in the CSC groups ($P < 0.05$) while no significant difference was detected in the gutta percha and sealer groups.
Conclusions. Based on the conditions of this ex vivo study, it can be concluded that smear layer removal is detrimental to the bond strength between calcium silicate cements and dentin.

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1. Introduction

The aim of obturation of the root canal space is to provide a tight seal against the ingress of microbes and fluids into the disinfected root canal space [1]. Ideally, obturation materials should form a strong bond with the canal wall and resist dislodgement during function.

Mineral trioxide aggregate (MTA) was first developed at Loma Linda University in 1993 [2]. It was initially proposed as a perforation repair and retrograde filling material in surgical endodontics. Since then, other products with similar chemical constituents have been developed and are available commercially under different brand names. It has been proposed that a generic name be used for this class of materials [3]. “Hydraulic silicate cements” [3] and “calcium silicate cements” [4] are the most common of those proposed. Calcium silicate cements (CSC) possess several desirable properties such as superior sealing ability, bioactivity, and the ability to set in the presence of fluids [5]. Clinical studies demonstrated satisfactory outcomes of different clinical applications of CSCs [6], and recently they were used for obturation of the entire root canal space [7].

ProRoot MTA (Dentsply Maillefer, Ballaigues, Switzerland) is composed of a hydrophilic powder made of calcium silicates, which reacts with water and sets into a hard structure through a hydration reaction forming calcium hydroxide and calcium silicate hydrates [8]. Biodentine (Septodont, Saint Maur des Fosses, France) is a calcium silicate-based cement composed of a powder (in a capsule) and liquid (in a pipette). The powder consists of tricalcium and dicalcium silicate, calcium carbonate, and zirconium oxide, while the liquid contains calcium chloride as an accelerator and a water reducing agent [9]. Biodentine sets in 10 min [9] and it is promoted as a good dentin substitute in direct and indirect pulp capping procedures. Harvard MTA (Harvard Dental International GmbH, Hoppegarten, Germany) is a new encapsulated CSC with a predetermined powder: liquid ratio. The capsule is activated, mixed in an amalgamator, and the content is ejected with its corresponding gun. Harvard MTA has a working time of 2 min and sets in 40 min (manufacturer’s material safety sheet).

Theoretically, CSC could be used for obturation, but details regarding the optimum conditions are not known. It has not been clearly demonstrated, for example, whether smear layer should be removed prior to obturation with these cements. The aim of this study was to determine the effect of smear layer removal on the push-out bond strength between different CSCs and dentin in comparison with that between gutta percha and sealer and dentin. The null hypotheses are: (a) there is no difference in the push-out bond strength between dentin and different obturation materials. (b) Smear layer removal does not affect the push-out bond strength between the obturation material and dentin.

2. Materials and methods

Eighty extracted human teeth with single canals and curvatures less than 5° [10] were used in this study. The crowns were removed using a water-cooled diamond wheel saw leaving 13 ± 1 mm long roots. After determining the working length and establishing a glide path, root canals were cleaned and shaped with a series of ProTaper files (S_1–F_5) (Dentsply, Maillefer, Ballaigues, Switzerland) to size 50/05 apically. Irrigation between each file was carried out with copious irrigation with 1% NaOCl using a 27-gauge monoject needle with a notched tip (Monoject, Kendall, Covidien, Mansfield, Massachusetts, USA) inserted to 1 mm short of the working length. Prepared roots were randomly divided into two major groups ($n = 40$). In group A, no attempt at removal of the smear layer was carried out. In group B, the smear layer was removed by irrigation with 1 ml of 17% EDTA (PULPDENT, Watertown, MA, USA) for one minute as recommended by Teixeira et al. [11] using the same irrigation needle as for NaOCl. To eliminate the EDTA action, irrigation with 2 ml of NaOCl was carried out followed by a final flush with 5 ml of sterile water. Within each major group, roots were further divided into four subgroups ($n = 10$) according to the obturation material used (Table 1). ProRoot MTA (subgroups 1A and 1B), Harvard MTA (subgroups 2A and 2B) and Biodentine (subgroups 3A and 3B) were used to obturate the root canals in their respective groups using a manual compaction technique with hand pluggers as described by EL-Ma’aita et al. [12]. In groups 4A and 4B (control groups), gutta percha and AH-plus sealer were used as the control groups. The gutta percha was applied into the canals in a thermoplastic injection technique (Obtura Spartan, Algonquin, IL, USA) to allow for standardization of the technique between the three thirds of the canals. The coronal 2 mm of each root were sealed with a glass ionomer filling (AquaCem, DENTSPLY, Surrey, UK). Obturated roots were radiographed in 2 directions; bucco-lingual and mesio-distal, to ensure the canals were densely obturated. The samples were stored at 37° C in synthetic tissue fluid (STF) for 7 days to allow for maximum setting of the materials.

Following the storage period, each root was sectioned horizontally at three different levels (namely: coronal, middle and apical) to obtain three slices 2 ± 0.1 mm in thickness (Fig. 1). The greater and lesser root canal diameters and the thickness of each slice were recorded to the nearest 0.01 mm using a digital caliper. The adhesion surface area was calculated by the following equation:

$$\text{Adhesion surface area}\,(\text{mm}^2) = \left(\frac{D_1 + D_2}{2}\right) \times \pi \times h$$

where D_1 and D_2 are the greater and lesser canal diameters respectively, π is the constant 3.14 and h is the thickness of the obturated root slice.

The force required to dislodge the obturation material from the root slice was measured using a Universal Testing Machine (Roell Z020, Zwick GmbH & Co. KG, Germany). Each sample was attached to a metal jig with the coronal side facing downwards. The metal jig had an adjustable central hole which was made slightly bigger than the greater canal diameter to provide support for the root slice and to allow for unrestricted movement of the dislodged obturation material (Fig. 2). Compressive force was applied to the obturation material through a flat metal rod (0.5, 0.7 and 1.0 mm in diameter for the apical, middle and coronal slices respectively) attached to a load cell and moving downwards at a crosshead speed of 1 mm/min. The metal rod had a clearance of at least 0.2 mm from the