Comparative evaluation of push-out bond strength of ProRoot MTA, Biodentine, and MTA Plus in furcation perforation repair

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Abstract
Purpose: Few studies have comparatively evaluated the push-out bond strength of different calcium silicate–based materials (CSMs) used in furcal perforation repair. The objective of this in vitro study was to comparatively evaluate the push-out bond strength of commercially available CSMs used as furcation repair materials, in the presence of blood contamination.

Materials and Methods: Furcal perforations were made in 120 molars and were divided on the basis of the repair material used (ProRoot MTA, Biodentine, and MTA Plus), blood contamination, and duration of setting time (24 h vs. 7 days). Push-out bond strength was measured and analyzed by three-way analysis of variance (ANOVA) test.

Results: Push-out bond strength increased with time. The 24-h push-out strength of MTA was less than that of Biodentine. Blood contamination affected the push-out bond strength of MTA Plus irrespective of the setting time.

Conclusion: Caution should be taken while condensing restorative materials over furcation repair materials.

Keywords: Furcation perforation; Proroot MTA; push-out bond strength; repair materials

Introduction
Successful management of furcation perforations poses a challenge for a clinician.[1-2] The perforation can result from iatrogenic causes, caries, or resorption.[1-3] It is advisable to repair the perforation as soon as it is identified, since any delay will allow the bacterial ingress leading to complicated endodontic–periodontal lesion.[4,5] An ideal perforation repair material should provide an adequate seal, be biocompatible, dimensionally stable, insoluble, radiopaque, and allow easy manipulation and placement.[4,5] Mineral trioxide aggregate, which is a calcium silicate–based material (CSM), is currently the choice of material in perforation repair.[1,5-7] Various case series, with a long-term follow-up, have successfully demonstrated the ability of ProRoot MTA to repair strip, lateral and furcal perforations.[7,8] Holland et al.[5] evaluated the healing process of intentional lateral root perforation repaired with ProRoot MTA and Sealapex. The histological analysis showed no inflammation and deposition of cementum over ProRoot MTA in the majority of the specimens repaired with ProRoot MTA. ProRoot MTA primarily contains dicalcium and tricalcium silicate with bismuth oxide as radiopacifier.[9-11] It contains less gypsum than Portland cement, which prolongs its working time, and has very few toxic heavy metal ions as compared to Portland cement.[11] ProRoot MTA powder consists of fine hydrophilic particles which, upon hydration, form a colloidal gel that solidifies by crystallization of hydrates. Dammaschke et al.[12] reported that the amount of surface sulfur and potassium increases 3 times than the powder form of ProRoot MTA. The authors suggested that this layer forms a passive trisulfate layer, preventing further hydration and increasing the setting time. The long setting time of ProRoot MTA is a major shortcoming of the material, apart from difficult handling characteristics, discoloration potential (gray MTA), low washout resistance, and high material cost.[12-14] Recently, various new CSMs have been introduced including Biodentine (Septodont, Saint-Maur-des-Fossés, France), MTA Bio (Angelus, Londrina, PR, Brazil), BioAggregate (BA; Innovative BioCeramix, Vancouver, Canada), MTA Angelus (Angelus), and MTA plus (Prevest Denpro Limited, Jammu city, India). Biodentine has been promoted as a dentin substitute which can also be used as an endodontic
repair material.[15] The powder component mainly consists of tricalcium silicate, with the addition to the powder of CaCO3 and ZrO2.[15] The liquid component has calcium chloride (CaCl2), as setting accelerator, in a water reducing agent.[15] MTA plus is another CSM-based material consisting of tricalcium and dicalcium silicate, bismuth oxide, calcium sulfate, and silica.[14] The manufacturers claim that MTA plus has finer particle size that improves its handling and placement characteristics. MTA plus kit has an optional gel as the mixing vehicle to improve its washout resistance.

Nonsurgical intracanal placement of CSM materials is the preferred method of furcal perforation repair.[1] Since the teeth are unavoidably subjected to masticatory forces, dislodgement resistance of the repair material plays an important role on the time of placement of permanent coronal restoration.[16] Sluyk et al.[17] reported that the displacement resistance of furcal repair with ProRoot MTA was significantly higher at 72 h than at 24 h. VanderWeele[18] et al. evaluated furcal perforations repaired with and without blood contamination utilizing ProRoot MTA mixed with either ProRoot MTA liquid (sterile water), lidocaine, or saline. The displacement resistance increased with time. The authors suggested allowing ProRoot MTA to set undisturbed for 72 h or longer prior to placement of a coronal restoration to prevent ProRoot MTA displacement in furcation perforation repairs. There are very few studies evaluating the dislodgement resistance of different repair materials sealing the furcal perforations. The purpose of this in vitro study was to comparatively evaluate the push-out bond strength of ProRoot MTA, Biodentine, and MTA plus in repairing furcal perforations utilizing an internal matrix, when subjected to blood contamination.

**MATERIALS AND METHODS**

One hundred and twenty freshly extracted mandibular molars with no/minimal caries and non-fused, diverging roots were used in this study. An informed consent was taken from the patients regarding the use of their teeth in the present study. The teeth were visually inspected using magnification loupes. Teeth with cracks, open apices, root caries, or fused roots were discarded. The teeth were cleaned of debris and stored in normal saline till use. A standard endodotic access cavity was prepared in each tooth. The teeth were decoronated 5 mm above the pulpal floor and the roots were amputated 5 mm below the furcation using a water-cooled diamond disk. A perforation was made in the furcation area from the external surface using a high-speed long shank round bur #4. Caution was taken to centralize the perforation between the roots. The samples were embedded in a saline-soaked sponge placed in a plastic cylinder [Figure 1]. A small amount of cold-cure resin was applied to stabilize the root in place in the cylinder. An internal matrix of collagen was placed and compacted beyond the perforation using hand pluggers. The samples were divided into three major experimental groups on the basis of type of perforation repair material. Each group was further subdivided into four subgroups (n = 10) on the basis of setting time and blood contamination status [Table 1].

Two subgroups from each experimental group (1b, 1d, 2b, 2d, 3b, 3d) were contaminated with freshly drawn human blood, immediately before the placement of repair material. The perforation site was filled with blood. The excess blood was absorbed with a damp cotton pellet. No other special attempts were made to clean the blood from the perforation walls [Figure 1a-d]. The remaining subgroups were not contaminated. All samples were repaired using the respective perforation repair materials. Group 1 was repaired using white MTA (ProRoot, Dentsply/Tulsa Dental, Tulsa, OK, USA). MTA powder was mixed with the manufacturer’s supplied liquid until a thick consistency was obtained. The material was packed into the perforation site without any ultrasonic activation. Group 2 was...
repaired using Biodentine (Septodont). The material was mixed according to manufacturer’s recommendations. The liquid from single ampule was emptied in the capsule and the capsule was triturated for 30 sec. The freshly mixed Biodentine had a putty-like consistency and was packed in the perforations using a plastic filling instrument. The samples in group 3 were repaired using MTA Plus (Prevest Denpro Limited). Powder was mixed with manufacturer’s supplied “gel” in a 3:1 ratio. The material was packed in the perforations in a putty-like consistency. Wet cotton pellet was placed over the perforations and the specimens were stored in 100% humidity at 37°C.

After 24 h, samples from groups 1a, 1b, 2a, 2b, 3a, and 3b were subjected to push-out bond strength measurement. A 1-mm-thick cylindrical stylus was attached to the testing apparatus of Universal Instron testing machine (Zwick GmbH, Memmingen, Germany). The stylus was placed over the perforation repair material and an apico-coronal force was applied. The samples were stressed to failure at a crosshead speed of 0.5 mm/min. The push-out bond strength measurement was based on the methodology described in previously published studies. The remaining samples were subjected to push-out bond strength measurements after 7 days. The values of push-out bond strength were recorded for statistical evaluation using SPSS 11.5 for Windows (SPSS Inc., Chicago, IL, USA). The data were statistically analyzed using three-way analysis of variance (ANOVA) test and the level of significance was kept as 5%.

RESULTS

The push-out bond strength of all the groups is presented in Figure 2. There was a significant increase in the push-out bond strength of samples with increase of setting time (from 24 h to 7 days), irrespective of the repair material and contamination status. Blood contamination affected the MTA samples with a setting time of 7 days, but had no significant effect on 24-h samples. In the MTA Plus group, blood contamination significantly decreased the strength both in 24-h and 7-days samples. Blood contamination had no effect on the perforations repaired with Biodentine. In 24-h samples, MTA had significantly less push-out bond strength than Biodentine and MTA Plus (uncontaminated samples). In 7-days group, MTA Plus had significantly less push-out strength than the other repair materials.

**DISCUSSION**

A perforation, irrespective of location or etiology, hampers the prognosis of endodontic therapy. This mechanical/pathological communication between root canal system and external tooth surface should be sealed with a biocompatible material as soon as possible. The perforation repair material could be subjected to tooth function as well as mechanical forces of condensation of restorative materials over the perforation repair site. Lussi et al. investigated the condensation pressure applied by practicing clinicians during amalgam placement. Using a strain gauze, the authors found that average condensation pressures of 3.7 ± 1.3 MPa and 2.2 ± 0.9 MPa were applied during amalgam condensation with a small (1.09 mm² surface area) and a large (2.72 mm²) amalgam plugger, respectively, with a maximum condensation pressure of 8.9 ± 2.4 MPa and 5.5 ± 1.8 MPa. In order to prevent dislodgement from the repair site, a perforation repair material should have sufficient amount of push-out bond strength with dentinal walls.

In the present study, the uncontaminated samples of MTA had a push-out bond strength of 5.2 ± 0.4 MPa after a setting time of 24 h. The strength significantly increased to 9.0 ± 0.9 MPa after the samples were allowed to set for 7 days. Hashem and Wanees Amin reported a push-out bond strength of 8.49 ± 1.75 MPa when MTA was allowed to set for 4 days in contact with phosphate-buffered saline. Saghiri et al. demonstrated that pH has an effect on the push-out bond strength of MTA in the lumen of root slices, and reported a mean push-out bond strength of 9.46 ± 0.63 MPa when the samples were stored at a pH of 8.4 for 3 days. Various authors evaluating dislodgement resistance of MTA in furcation perforation repair have reported that there is an increase in dislodgement resistance at 72 h as compared to 24 h. In the present study, the dislodgement resistance of MTA was less than in other groups at 24 h setting time. This could be attributed to a prolonged maturation process because of the formation of passivating trisulfate layer over hydrating crystals of MTA. To simulate a bad clinical situation, the perforations were contaminated with blood before placement of the repair material. The blood-contaminated MTA samples had a push-out bond strength of 4.8 ± 0.56 MPa and 9.2 ± 0.72 MPa at 24 h and 7 days respectively, with no difference from the uncontaminated samples. VanderWeele et al.
reported that during 0.2 mm initial dislodgement, the effect of blood contamination was significant only in samples mixed with saline. After 7 days, samples restored after blood contamination had significantly less dislodgement resistance.

MTA has a long setting time of 165 ± 5 min. Addition of CaCl₂ has shown to decrease its setting time. Some authors have shown that addition of CaCl₂ has a negative effect on the compressive strength of MTA. Biodentine is a CSM-based material that has polycarboxylate-based hydrophilic polymer system described as “water reducing agent” to reduce the overall water content of the mix, along with CaCl₂, as a setting accelerator. The combined effect reduces the setting time to 12 min and increases the compressive strength. Because of its high compressive strength, manufacturers recommend Biodentine to be used as an interim restoration or as dentine substitute under composite restorations, apart from other endodontic uses. In the present study, Biodentine had a significantly higher push-out bond strength than MTA after 24 h setting time. After 7 days, MTA and Biodentine had similar push-out bond strength in uncontaminated samples. Blood contamination had no effect on the push-out bond strength of Biodentine, irrespective of the duration of setting time. Another repair material tested in the present study was MTA Plus. MTA Plus has a fine particle size, which improves its handling characteristics and may increase the speed of hydration process. The mixing liquid has a salt-free polymer gel. The dislodgement resistance of MTA Plus was higher than MTA after 24 h setting time, which could be attributed to its comparatively short setting time than ProRoot MTA.

All samples, irrespective of setting time or contamination status, had shown a dislodgement resistance more than the average force recorded by Lussi et al. during amalgam condensation (3.7 ± 1.3 MPa). An important point to be noted is that the materials were tested after their setting, which is not the real clinical scenario where the tooth is immediately subjected to masticatory stresses.

REFERENCES


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