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Original Article

Push-out bond strength of different types of mineral trioxide aggregate in root dentin

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ABSTRACT

Objective: The objective of this study was to measure the push-out bond strength of three types of mineral trioxide aggregate (MTA) materials in root dentin.

Methods: The study was carried out at the College of Dentistry, Imam Abdulrahman Bin Faisal University from March 2014 to January 2015. Thirty extracted maxillary central incisors were selected, instrumented, irrigated, and randomly assigned into three groups ($n = 10$): Group 1 - Ortho MTA; Group 2 - MTA Angelus; and Group 3 - ProRoot MTA. Materials were mixed following the manufacturers' recommendations and canals were filled. Teeth were stored in distilled water for 6 months. The push-out bond strength was evaluated using 2-mm thick coronal root sections. The data were analyzed with one-way ANOVA and Tukey-Kramer multiple comparison tests statistically significant at $P < 0.05$.

Results: The mean bond strength values were 68.69 ± 29.63 MPa for Ortho MTA, 42.54 ± 32.78 MPa for MTA Angelus, and 72.75 ± 26.27 MPa for ProRoot MTA groups. There were no significant differences between the bond strengths of tested materials ($P > 0.05$).

Conclusion: Ortho MTA, MTA Angelus, and ProRoot MTA materials showed similar push-out bond strength values in root dentin.

Keywords: Bond strength, mineral trioxide aggregate, push-out test, root dentin

Introduction

Mineral trioxide aggregate (MTA) was manufactured to seal the undesirable pathways between the root canal system and periodontal tissues because of its unique properties.[1] MTA has been researched extensively for its use in clinical applications such as retrograde filling,[2] pulp capping, repair of root resorption, apexification,[3] and as an endodontic sealer.[4] The new application trend is to fill the root canal system completely with MTA such as in cases of apexification,[5] strip perforation of the C-shaped root canals,[6] internal and external root resorption,[7] reimplanted teeth,[8] and retained primary teeth.[9] An ideal material to be used in endodontics is expected to withstand the dislodgment forces produced during tooth function or operative procedures.[10]

Different types of MTA materials have been introduced into the market by different manufacturers. ProRoot MTA (Dentsply Maillefer, Ballaigues, Switzerland), MTA Angelus (Angelus, Londrina, PR, Brazil), and Ortho MTA (BioMTA, Seoul, Republic of Korea) are some of the examples [Table 1]. These materials demonstrate slight differences in their composition. ProRoot MTA consists of 75% Portland cement, 20% bismuth oxide, and 5% calcium sulfate dihydrate.[11] MTA Angelus contains 80% Portland cement and 20% bismuth oxide, with no calcium sulfate, to reduce the setting time.[12] Ortho MTA was introduced with lesser heavy metal content than ProRoot MTA.[13]

Bond strength of endodontic materials to root dentin is an important factor to consider for long-term clinical success.[14] Adherence of a material to surrounding dentin resists any dislodgment forces applied during function or operative procedures.[15] Tensile shear bond strength and push-out bond strength tests have been used to determine the adhesiveness of a material to its surrounding dentin. However, push-out test has been appraised as a more reliable and practical approach.[16,17] Therefore, this study evaluated the push-out bond strength of mature teeth filled with different types of MTA.

Methods

The *in vitro* cross-sectional study was conducted in conformity with the World Medical Association Declaration of Helsinki. Ethical approval was obtained from the Ethics Committee of Imam Abdulrahman Bin Faisal University (#2013260). Thirty

Table 1: Chemical composition of the three tested materials

Chemical composition	ProRoot MTA	Ortho MTA	MTA angelus
Tricalcium silicate, $(CaO)_3\ SiO_2$	✓	✓	✓
Dicalcium silicate, $(CaO)_2\ SiO_2$	✓	✓	✓
Tricalcium aluminate, $(CaO)_3\ Al_2O_3$	✓	✓	✓
Free calcium oxide, CaO	✓	✓	✓
Bismuth oxide, Bi_2O_3	✓	✓	✓
Tetracalcium aluminoferrite, $(CaO)_4\ Al_2O_3\ Fe_2O_3$	✓	✓	×
Gypsum, $CaSO_4\$_2H_2O$	✓	×	×

MTA: Mineral trioxide aggregate

extracted human maxillary central incisors with mature roots, having approximately similar length and buccolingual diameter, and apical size corresponding to the size 15 K-file were selected for this study. Tooth surfaces were ultrasonically cleaned and examined under a stereomicroscope as well as using mesiodistal and buccolingual radiographs. Teeth with previous root canal treatment, dentin pins, coronal restorations, caries, fractures or cracks, and internal or external resorption were excluded from the study. The teeth were stored in normal saline containing 0.1% sodium azide to inhibit bacterial growth.

Root canal treatment procedure

Standardized access cavities were prepared in all the teeth using a cylindrical diamond bur. The working lengths (WLs) were determined using radiographs of size 15 K-files in the canals. Root canals were instrumented with ProTaper Universal rotary system (Dentsply Maillefer, Ballaigues, Switzerland) up to F5 using crown-down technique. Canals were irrigated with 1 mL of 2.4% sodium hypochlorite solution after using each file. Then, 1 mL of 17% EDTA (Ultradent Dental Products, South Jordan, UT, USA) solution was placed using a plastic syringe and 30-gauge needle (NaviTip, Ultradent Dental Products, South Jordan, UT, USA) at the proximities of the WL for 1 min to remove the smear layer. The residual irrigant was flushed with 5 mL of distilled water and size 40 paper points were used to dry the canals. Teeth were randomly divided into three experimental groups ($n = 10$) and filled with the tested materials. All materials were mixed following the manufacturers' recommendations.

- Group 1: In this group, root canals were filled with Ortho MTA. The powder and distilled water were dispensed into the Eppendorf tube and mixed in an auto-mixer. Once mixed, the material was placed into the canal in increments with a ProRoot MTA delivery gun (Dentsply Maillefer, Ballaigues, Switzerland). Each increment was condensed with a preselected plugger (BioMTA, Seoul, Republic of Korea). The canal was filled coronally up to 1 mm below the cementoenamel junction. Access cavity was cleaned with a wet cotton pellet and the temporization procedure was done by placing a wet cotton pellet in the chamber and the access cavity was restored with a temporary material (Coltosol; Coltene/Whaledent AG, Altstatten, Switzerland).
- Group 2: In this group, root canals were filled with MTA Angelus paste placed into the canals using the similar method described above for Group 1. Access cavity was cleaned and the temporization procedure similar to that of Group 1.
- Group 3: In this group, root canals were filled with white ProRoot MTA paste placed into the canals using the similar method described above for Group 1. Access cavity was cleaned and the temporization procedure similar to that of Group 1.

Mesiodistal and buccolingual radiographs were taken to ensure complete filling of the canals and to evaluate the quality of the filling. Specimens were stored in distilled water at 37°C for 6 months.[18] The distilled water was changed weekly. After 6 months, specimens were reexamined under a stereomicroscope to confirm the integrity of the roots.

Push-out bond strength test

Crown with coronal 3-mm section was removed from the roots and then 2-mm thick sections were obtained from the remaining roots using a low-speed water-cooled diamond saw (Isomet; Buehler, Lake Bluff, NY, USA). The canal area filled with the test material was measured on both the coronal and apical side of the cut sections, and the apical surfaces were marked. Specimens having a diameter of ≈1.2 mm on both sides were selected. The push-out test was performed using a universal testing machine (Instron 8871, Servo Hydraulic System, Merlin 2 software, Instron®, Buckinghamshire, UK). Dentin sections were placed on a custom plate and aligned to the hole in the center of the plate. This allowed the 1-mm thick stainless steel plunger to pass through freely under a constant downward force at a speed of 1 mm/min. The plunger had a flat tip which was positioned to contact the test material only. The force was applied until a total bond failure occurred and recorded in Newton (N). Following formula was used to calculate the bond strength in MPa:

$$\text{Bond Strength}\ (\text{MPa}) = \frac{\text{Debonding force(N)}}{\text{Bonded surface area}\ (\text{mm}^2)}$$

Bonded surface area = $2\pi rh$

Where $\pi = 3.14$ (constant), r is the radius and h is the thickness of dentin section.

Data were analyzed with a statistical package (NCSS 2007, NCSS, LLC, Kaysville, UT, USA). One-way ANOVA followed by Tukey-Kramer multiple comparison tests was used to compare groups at a significance level of $P < 0.05$.

Results

Figure 1 presents the box-and-whisker plot of the bond strength values for the tested groups. The mean values in MPa were 68.69 ± 29.63 for Ortho MTA, 42.54 ± 32.78 for MTA Angelus, and 72.75 ± 26.27 for ProRoot MTA groups. Multiple comparison tests showed no significant differences in the bond strength values of tested materials ($P > 0.05$).

Discussion

The study evaluated the push-out bond strength of different types of MTA. The push-out test is a valid method to estimate the adherence of a material to root dentin, simulating clinical stresses.[19] In this testing procedure, fracture occurs parallel to the cement-dentin interface and represents the true shear bond strength of a material.[14]

This study showed insignificant differences in the bond strength values of tested materials. However, ProRoot- and Ortho- MTA showed higher bond strength values than MTA Angelus. The variations in the composition and particle size of the three cements could be the reason for the different bond strength values observed. Although there is no chemical bonding between MTA and root dentin, it has been reported to form interfacial deposits by interaction between the phosphate in body fluid and the calcium and hydroxyl ions released from MTA.[20] These deposits filled up the gaps between the MTA and root dentin that increased the frictional resistance of MTA.[21] However, in the present study access, cavities were sealed by placing a moist cotton pellet and specimens were stored in distilled water for 6 months.

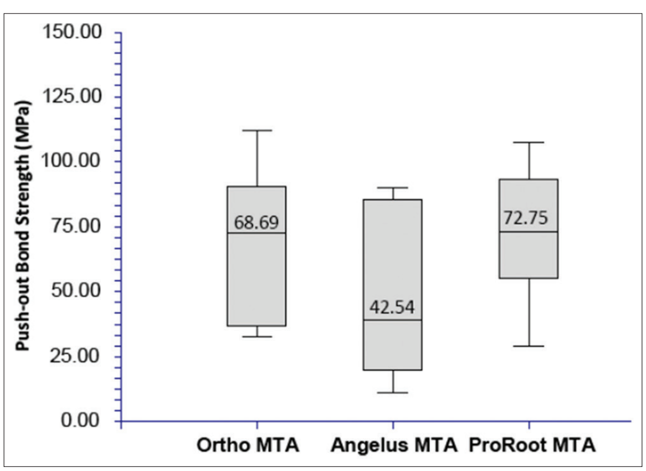

Figure 1: Box-and-Whisker plot for push-out bond strength of all groups. Top and bottom lines indicate the maximum and minimum values in Newton. The box represents 75% of the values, and the line in the box indicates the median value

Clinically, the coronal portion of MTA will be exposed to distilled water or saline to provide moisture or wet environment required for the setting reaction of MTA. During mixing of MTA powder reacts with water and produces calcium silicate hydrate, calcium hydroxide phases, and calcium ions.[22] Calcium ions are continuously released and react with carbon dioxide and water forming deposits of calcium carbonate and calcium hydroxide.[23] Poor solubility of calcium carbonate in water results in the formation of precipitates that improve the sealing ability and thus frictional resistance of MTA.[24] Here, all the root samples were filled with different types of MTA after preparation of the canals. Once the material was set, it acted as a post or primary monoblock.[21,25] This along with increased frictional resistance of MTA might have increased the push-out bond strength of MTA.[21]

As explained above, even in the presence of distilled water, MTA produces calcium carbonate and calcium hydroxide precipitates.[22,23] The longer the storage time, the higher the precipitates.[10] These precipitates fill in the gaps between the material and the root dentin and deposit in dentinal tubules. This increases the resistance of the material to any dislodgement forces applied.[24] Gancedo-Caravia and Garcia-Barbero[10] reported that moisture was important for the setting of the MTA, especially during the first 3 days to resist dislodgment forces and bond strength increased, as the time for specimens to be kept under wet conditions was increased. Aggarwal *et al*.[26] showed a significant increase in the bond strength values of canals filled with MTA and allowed to set for 7 days compared to those tested after 1 day of storage. Nikhade *et al*.[14] also demonstrated that bond strength for calcium silicate-based materials was significantly increased when incubation times were increased. Ertas *et al*.[27] compared the bond strengths of three commercial MTA products and reported that ProRoot MTA had the highest bond strength values compared to MTA angelus and calcium enriched mixture cement. Another study comparing three calcium silicate-based materials also reported that biodentine and ProRoot MTA demonstrated similar but significantly higher bond strength values compared to BioAggregate material in root dentin samples.[28]

Conclusions

Ortho MTA, MTA Angelus, and ProRoot MTA showed similar push-out bond strength values. Although MTA Angelus showed relatively lower bond strength values, difference was not statistically significant compared to other tested materials.

Acknowledgments

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