Evaluation of Compressive Strength of Hydraulic Silicate-based Root-end Filling Materials

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Abstract

Introduction: Hydraulic silicate cements such as mineral trioxide aggregate (MTA) have many clinical advantages. Newer hydraulic silicate materials have been developed that improve on the limitations of mineral trioxide aggregate such as the long setting time and difficult handling characteristics. The purpose of this study was to examine the effect of saline and fetal bovine serum (FBS) on the setting and compressive strength of the following hydraulic silicate cements: ProRoot MTA (white WMTA; Dentsply International, Tulsa Dental Specialties, Johnson City, TN), EndoSequence Root Repair Material (Brasseler USA, Savannah, GA), MTA Plus (MTAP; Avalon Biomed Inc, Bradenton, FL), and QuickSet (QS; Avalon Biomed Inc, Bradenton, FL). **Methods:** Samples of root-end filling materials were compacted into polyethylene molds. Samples were exposed to FBS or saline for 7 days. A universal testing machine was used to determine the compressive strengths. **Results:** QS had significantly lower compressive strength than all other materials ($P < .001$). White MTA and MTAP mixed with liquid had lower compressive strengths after exposure to FBS compared with saline ($P = .003$). ERRM, MTAP mixed with gel, and QS were not affected by the exposure to FBS. **Conclusions:** New silicate-based root-end filling materials, other than QS, have compressive strength similar to MTA. Within the limits of this study, premixed materials and those mixed with antiwashout gel maintain their compressive strength when exposed to biological fluids. *(J Endod 2014;40:969–972)*

Key Words

Compressive strength, hydraulic silicate cement, MTA, root-end filling

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The goal of endodontic surgery is to resolve periapical pathosis when orthograde endodontic treatment is no longer an option (1). The root-end filling material must possess adequate sealing properties, dimensional stability, radiopacity, and biocompatibility (1, 2). Many materials have been advocated for root-end fillings, but today hydraulic silicate cements are commonly used. ProRoot MTA (white mineral trioxide aggregate [WMTA]) (Dentsply International, Tulsa Dental Specialties, Johnson City, TN) is a commonly used hydraulic cement (3). These materials have also been recommended for apexification of immature teeth, perforation repair, and vital pulp therapy (4).

Hydraulic silicate cements set in contact with moisture via a hydration reaction (3, 5, 6). Clinically, both the manufacturer's liquid and biological fluids at the surgical site provide moisture for the setting of the material. These bodily fluids have been reported to affect the set of WMTA (7–9). Torabinejad et al (10) evaluated the effect of blood exposure on dye leakage, and they showed that blood has no effect on the sealing properties of gray mineral trioxide aggregate (MTA). Nekoofar et al (7) found that exposing WMTA to blood altered the physical properties and decreased the compressive strength of the material. Tingey et al (9) exposed WMTA samples to fetal bovine serum (FBS) and saline to evaluate any change in the surface microstructure. They found that exposing WMTA to blood significantly altered the surface morphology of the WMTA samples.

WMTA has many desirable properties and continues to be the gold standard for root-end filling materials (3, 11, 12). Newer hydraulic silicate cements have recently been introduced to the marketplace to improve on the limitations of MTA such as the long setting time and difficult handling characteristics. One of these newer cements is MTA Plus (MTAP) (Avalon Biomed Inc, Bradenton, FL). MTAP is a tricalcium and dicalcium silicate–based cement that can be mixed with a liquid or a gel. The gel improves handling properties and washout resistance of the material (13). MTAP also has the benefit of decreased setting time of approximately 75 minutes compared with WMTA (14). Similarly, QuickSet (QS) (Avalon Biomed Inc, Bradenton, FL) is an experimental calcium aluminosilicate material that has a comparatively reduced setting time (15). When mixed with antiwashout gel, QS exhibits improved handling properties (16). Both MTAP and QS have shown similar biocompatibility to WMTA (15, 16). Another calcium silicate–based hydraulic cement is EndoSequence Root Repair Material (ERRM) (Brasseler USA, Savannah, GA). Unlike other products, it comes premixed in a ready-to-use container. ERRM is a calcium phosphate silicate material with a bioceramic component. It has similar biocompatibility compared with MTA and other calcium silicate–based materials (17–19). ERRM also overcomes the basic handling difficulties associated with MTA (19).

Compressive strength is a measure of multiple material properties including the hydration reaction that is critical to the setting of hydraulic silicate cements (4, 20, 21). Compressive strength is an indirect measure of material setting (20, 21). Although dimensional stability and adequate sealing are of great importance to the clinician when choosing a root-end filling material, compressive strength is also an important property that may affect the clinical performance of the material (2). Compared with MTA, little research has been done involving the setting of these newer materials, and no study has compared the compressive strengths of these hydraulic silicate cements. This study evaluates and compares the compressive strengths of WMTA, MTAP, QS, and ERRM after exposure to saline and FBS.

Materials and Methods

Four hydraulic silicate cements were evaluated: WMTA, ERRM, MTAP, and QS. Cylindrical polyethylene molds with double open ends (length = 5 mm and diameter = 4.17 mm) were used to make samples with standardized size and shape. ERRM was removed from the container and placed directly into the mold. WMTA powder was mixed according to the manufacturer directions with the liquid from the provided ampoules. QS and MTAP powder were mixed with the antiwashout gel according to the manufacturer's directions. In an additional group, MTAP was mixed with the liquid provided from the manufacturer. A single operator mixed all samples. All materials were mixed in a 3:1 powder:liquid/gel ratio by weight as recommended by the manufacturers. Freshly mixed materials were compacted into the molds using an amalgam plugger. Forty samples of each material were then divided into 2 groups: saline (0.9% Sodium Chloride Irrigation USP; B Braun Medical Inc, Irvine, CA) or FBS (Gibco, Life Technologies, Grand Island, NY). The filled molds were placed into floral foam soaked with either saline or FBS and maintained at 37°C at 100% humidity for 7 days.

After 7 days, the ends of the hardened samples were sanded with fresh 400-grit sandpaper to remove any material flash from the ends of the molds. The samples were released from the mold with a Hu-Friedy PLG 1/2 NS amalgam plugger (Hu-Friedy, Chicago, IL). The compressive strengths of the samples were evaluated using a universal testing machine (The Mechanical Tester; TestResources Inc, Shakopee, MN). The machine measured the minimum force in N/mm^2 required to break the samples at a speed of 1 mm/s. The minimum force required to fracture the samples was recorded using MTestWr software version R 1.3.6 (TestResources Inc, Shakopee, MN).

The means and standard deviations were calculated. Statistical analysis included 2-way analysis of variance and Tukey multiple comparison post hoc with a significance level set at $P < .05$.

Results

The results for mean compressive strength are displayed in Figure 1. All samples were completely set and able to be evaluated for compressive strength. QS had significantly lower compressive strength among all the other materials exposed to either saline or FBS ($P < .001$). MTAP with gel and ERRM had significantly higher mean compressive strength than WMTA and QS ($P = .01$). ERRM was not significantly different in mean compressive strength from MTAP with gel or liquid ($P = .669$ and .306).

WMTA was not significantly different in compressive strength from MTAP mixed with water ($P = .671$). MTAP mixed with gel had significantly higher mean compressive strength than MTAP with liquid ($P < .05$).

The condition the materials were exposed to had a statistically significant impact on compressive strength ($P = .003$). Tukey post hoc test showed that WMTA and MTAP mixed with water had significantly lower compressive strength after the exposure to FBS compared with saline.

Discussion

This study was the first to evaluate compressive strength of novel hydraulic silicate cements, and it replicated a clinical scenario in which serum and saline are present at the surgical site. Other studies have shown that MTA and related materials both have a decreased setting time and compressive strength in the presence of blood and blood components (7, 8). The current study confirmed the earlier findings and reports that WMTA was significantly affected by exposure to FBS. MTAP mixed with the liquid had lower compressive strength after exposure to FBS. This finding was similar to the WMTA group and earlier findings by Nekoofar et al (7).

The current study mixed MTAP with both the proprietary liquid and gel. The data indicate that the MTAP mixed with gel was not negatively affected by the exposure to FBS. MTAP and QS mixed with gel maintained constant compressive strength when exposed to both saline and FBS. Gel products had more consistent compressive strength. It is possible that the gel provides some surface protection to the hydraulic cements that guards them from detrimental surface defects induced by the serum. It is also plausible that the liquid was less able to hydrate all molecules of the sample. This could result in a decreased hydration reaction and overall decreased compressive strength noted in the samples.

The compressive strength of premixed ERRM was minimally affected by exposure to FBS. ERRM was premixed by the manufacturer, and it may have a more homogenous mixture. Products that require chairside mixing may have inconsistencies within the material because of variations in operator mixing.

QS had lower compressive strength than any of the materials evaluated. The level of compressive strength required for root-end filling materials is unknown based on our current literature. Although QS has lower compressive strength, it may still be clinically sufficient. The accelerated setting time may be a more desirable property than compressive strength in clinical scenarios that cannot afford the longer setting times of other hydraulic silicates such as WMTA. Overall, the

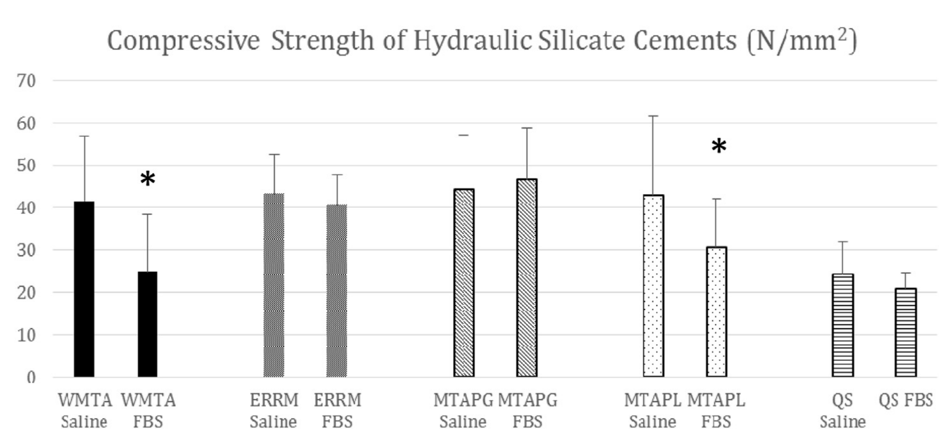

Figure 1. Mean compressive strength values (N/mm^2) with standard deviations. MTAPG and MTAPL are MTAP mixed with gel or liquid, respectively. *Statistically significant difference ($P < .05$).

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