Comparison of Quick-Set and Mineral Trioxide Aggregate Root-end Fillings for the Regeneration of Apical Tissues in Dogs

George D. Kohout, DDS,* Jianing He, DMD, PbD,* Carolyn M. Primus, PbD,† Lynne A. Opperman, PbD,‡ and Karl F. Woodmansey, DDS* 

Abstract

Introduction: Quick-Set (Avalon Biomed Inc, Bradenton, FL) is a calcium aluminosilicate cement that is a potential alternative to mineral trioxide aggregate (MTA) with greater acid resistance and faster setting. The purpose of this study was to compare the regeneration of apical tissues after root-end surgery when the apical tissues were exposed to Quick-Set or White ProRoot MTA (Dentsply Tulsa Dental Specialties, Tulsa, OK) by root-end resection. Methods: The root canals of 42 mandibular premolars in 7 beagle dogs were accessed, cleaned, and shaped, and obturated with Quick-Set or white MTA. Osteotomies and root-end resections were performed immediately. The dogs were sacrificed at 90 days, and the teeth and surrounding tissues were removed and prepared for histologic analysis. The sections of the apical areas were scored for inflammation, new cementum formation, periodontal ligament formation, and bone quality. Results: At 90 days, both materials supported some degree of cementum formation on the surface of the material, periodontal ligament regeneration, and excellent bone quality. The only significant difference was greater inflammation found in the Quick-Set group. Conclusions: Quick-Set and White ProRoot MTA had a similar effect on bone quality, cementum formation, and periodontal ligament formation after root-end surgery in dogs. Quick-Set was associated with greater inflammation. (J Endod 2014;■:1–5)

Key Words

Calcium aluminosilicate cement, endodontics, mineral trioxide aggregate, Quick-Set, root-end surgery, tricalcium silicate cement

Since its introduction in 1993, mineral trioxide aggregate (MTA) has become a popular root-end filling material. Numerous in vitro and animal studies have shown its biocompatibility (1, 2), high pH (3), osteogenic/odontogenic potential (4), and excellent sealing ability (5, 6). A recent meta-analysis of human studies concluded that MTA is associated with a higher success rate in periapical surgery compared with other materials (7). However, MTA has several characteristics that limit its usefulness. It has a long setting time (3), can be washed out during placement, is difficult to handle, and can cause staining of the tooth structure (8, 9). Despite these negative attributes, MTA has become the gold standard against which novel root-end filling materials are compared.

Quick-Set (Avalon Biomed Inc, Bradenton, FL) is a new material designed to maintain the positive qualities of MTA while improving on some of its shortcomings. Quick-Set is a calcium aluminosilicate cement composed of a fine ceramic powder containing monocalcium aluminate and other proprietary components mixed with a water-based gel. A forerunner of Quick-Set was a similar experimental material named Capasio (Primus Consulting, Bradenton, FL). Capasio had a cationic surfactant in the liquid component, whereas Quick-Set does not. Quick-Set has a working time of 9 minutes and a setting time as short as 12 minutes depending on the powder-to-liquid ratio. The Quick-Set gel increases resistance to washout after placement (unpublished observation by Avalon Biomed Inc).

Several studies evaluating Capasio or Quick-Set have been published. Porter et al (10) tested the physical properties of Capasio and white ProRoot MTA (WMTA) (Dentsply Tulsa Dental Specialties, Tulsa, OK). They found that Capasio had a greater washout resistance, a lower pH (10.3), a similar setting time, and improved acid resistance compared with WMTA (10). Capasio has shown greater dentinal tubule penetration compared with WMTA (11). When immersed in simulated tissue fluid, Capasio and WMTA formed similar apatite crystals on their exposed surfaces, which may facilitate bone and cementum deposition (11). More recently, the cytotoxicity and osteogenic properties of WMTA and Quick-Set were compared using murine odontoblastlike cells. These in vitro studies showed that Quick-Set and WMTA had similar cytotoxic and osteogenic/dentinogenic properties (12, 13).

Although promising results have been found in vitro, Quick-Set has not been studied in vivo as a root-end filling material. The purpose of this study was to compare the histologic response of periapical tissues in dogs when exposed to Quick-Set or WMTA after apicoectomy. The null hypothesis was that there would be no difference in the histologic response to Quick-Set or WMTA.

Methods

The study was approved by the Institutional Animal Care and Use Committee, Texas A&M University Baylor College of Dentistry, Dallas, TX. Forty-two mandibular premolar teeth were treated in 7 beagle dogs to test healing of periapical tissues after apicoectomy in canals filled with either Quick-Set or WMTA. Three teeth in each dog were filled with Quick-Set, and the other 3 teeth were filled with WMTA. The teeth assigned to each
material were randomized by a combination of coin flipping for the material and random drawing for the tooth. Before every procedure, 11 mg/kg clindamycin was injected intramuscularly 1 hour preoperatively; 2.2 mg/kg ketamine and 0.22 mg/kg xylazine-100 were delivered intramuscularly to induce general anesthesia. The dogs were then intubated, and 1 L/min 1%–2% isoflurane in oxygen was used as an inhalation anesthetic throughout the procedure. Local anesthesia was performed with 1.8 mL 2% lidocaine with 1:100,000 epinephrine (Novocol Pharmaceutical, Cambridge, Ontario, Canada). Preoperative radiographs of the mandibular premolars were made. At each treatment visit, teeth were first cleaned of debris using an ultrasonic scaler (NSK Dental, Chicago, IL), disinfected with 0.12% chlorhexidine (Patterson Dental, Southlake, TX), and isolated with a dental dam during nonsurgical root canal treatment.

Nonsurgical treatment was initiated with access to the coronal pulp chamber using high-speed carbide round burs. Cleaning and shaping procedures were performed in the presence of 6% sodium hypochlorite. Gates Glidden drills were used for orifice shaping, and EndoSequence .06 taper nickel-titanium instruments (Brasseler USA Dental, Savannah, GA) were used for preparation of the canal. The working lengths were determined by tactile sense of the apical delta, and shaping was completed to that point. The final irrigation included 6% sodium hypochlorite. After drying with paper points, the canals were completely obturated with either Quick-Set or WMTA using a lentulo spiral (Dentsply Tulsa Dental Specialties) and indirect ultrasonic compaction with pluggers (Miltex, York, PA) using the NSK Varios 350 (NSK Dental, Chicago, IL). Each material was mixed according to the manufacturer’s directions. No gutta-percha or sealer was used in the obturation. The access cavity was restored with Ketac Nano Light-Curing Glass Ionomer (3M ESPE, St Paul, MN).

The surgical phase of the study was performed immediately after the nonsurgical root canal treatment and obturation. An additional 1.8–3.6 mL 2% lidocaine with 1:50,000 epinephrine (Novocol Pharmaceutical) was injected adjacent to the apices of teeth planned for resection for hemostasis. A buccal, full-thickness, mucoperiosteal flap was reflected, and osteotomies approximately 5 mm in diameter were made using a Lindemann bone bur (Hu-Friedy, Chicago, IL) at the apex of each distal root. Approximately 3-mm root-end resections were performed to expose the root filling materials to the periapical tissues (Fig. 1). Saline irrigation was used continuously during the osteotomy and root-end resection. Flaps were reaproximated and closed with 4-0 Vicryl sutures (Ethicon, Somerville, NJ). The dogs were placed on a soft diet for 2 days postoperatively; 1 mg/kg nalbuphine was given subcutaneously immediately postoperatively and as needed every 12 hours for pain control. Postoperative care included intramuscular injection of 2.0 mg/kg ketoprofen once daily for a minimum of 2 days postoperatively.

The dogs were sacrificed 90 days after surgery in accordance with the recommendations of the Panel on Euthanasia of the American Veterinary Medical Association using 2.2 mg/kg ketamine intramuscularly, 0.22 mg/kg xylazine-100 intramuscularly, and 2 mL Beuthanasia-D (Merck Animal Health, Millsboro, MI). One liter of normal saline was used to flush the blood from the head followed by perfusion with 1 L 70% ethanol. Block sections were dissected out and placed in a container of 70% ethanol for further fixation. The resected blocks were demineralized in 0.5 mol/L ethylenediaminetetraacetic acid and embedded in paraffin, and 0.5-μm serial sections were made in a buccolingual orientation. The sections were stained with hematoxylin-eosin.

Histologic sections were evaluated using light microscopy by 2 calibrated examiners. The examiners were blinded to the type of material used in each sample. The sections were scored for inflammation, cementum deposition on the surface of the root filling, periodontal ligament formation, and bone quality (Table 1). If a discrepancy in scoring occurred, the examiners came to a consensus on the score for that aspect of the sample. One to 7 sections were available for each tooth. After scoring, the median scores for each tooth were determined.

### TABLE 1. Grading Scale for Apical Histologic Samples

<table>
<thead>
<tr>
<th>Grade</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>None</td>
</tr>
<tr>
<td>1</td>
<td>Mild</td>
</tr>
<tr>
<td>2</td>
<td>Moderate</td>
</tr>
<tr>
<td>3</td>
<td>Severe</td>
</tr>
<tr>
<td>0</td>
<td>Lack of bone formation; resorption</td>
</tr>
<tr>
<td>1</td>
<td>Normal bone formation; concomitant</td>
</tr>
<tr>
<td>2</td>
<td>Lack of bone formation; no resorption</td>
</tr>
<tr>
<td>3</td>
<td>Normal bone formation; no resorption</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Apical periodontal ligament formation</th>
<th>0</th>
<th>&lt;25%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>&gt;25% but &lt;50%</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>&gt;50% but &lt;75%</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>&gt;75%</td>
</tr>
</tbody>
</table>

**Figure 1. (A) Radiograph of mandibular premolars after obturation and resection of distal roots. (B) Radiograph taken perimortem shows complete or near complete healing of osteotomy sites.**
and statistical analysis was performed using the Mann-Whitney $U$ test with a significance level of $P = .05$.

**Results**

Histologic samples were prepared from 27 randomly selected teeth. Twenty-two of those teeth were able to be scored with 1 to 7 sections available per tooth and a total of 81 sections. Sections that were damaged during processing or did not include the necessary anatomy for scoring were excluded. Nine of the scored teeth were treated with WMTA and 13 with Quick-Set.

Radiographs taken after surgery showed complete filling of the canals by both Quick-Set and WMTA and radiolucency at the apices of the resected roots (Fig. 1A). Radiographs taken at the time of sacrifice showed reduced radiolucency at the apices in the presence of both Quick-Set and WMTA (Fig. 1B). No evidence of periradicular bone loss was noted.

All histologic sections showed complete or nearly complete healing of the osteotomy site with woven bone (Fig. 24 and B). The only defects in bone occurred directly adjacent to the root filling and extended no farther than 500 $\mu$m from the surface of the material. These defects were typically associated with inflammation, which was present at the resected surface of 8 of 13 teeth filled with Quick-Set and 1 of 9 teeth filled with WMTA. The inflammatory infiltrate was entirely neutrophilic and adjacent to the root filling. Some sections had cementum or bone between the root filling and focus of inflammation. When inflammation was absent, the periodontal ligament had formed between the bone and cementum or along the root filling. The periodontal ligament along parts of the root that were not resected showed no evidence of inflammation. Both materials were associated with cementum regeneration. Five of 13 teeth filled with Quick-Set and 6 of 9 teeth filled with WMTA had cementum forming on the surface of the material.

The median inflammation score was significantly lower for WMTA than Quick-Set (Fig. 3). Eight of 9 WMTA samples had no inflammation,
and only 1 sample had mild inflammation. Scores for inflammation with Quick-Set ranged from none to severe, but the median score was associated with mild inflammatory infiltrate. The results for cementum coverage trended toward a significant difference but did not reach the \( p = .05 \) level. WMTA was associated with cementum formation covering greater than 25% but less than 50% of the exposed filling material. The median score for Quick-Set was associated with less than 25% coverage. Periodontal ligament formation and bone quality were not significantly different between the 2 materials.

**Discussion**

Before this study, there had been no *in vitro* evaluation of Quick-Set as a root-end filling material. Therefore, the purpose of this study was to evaluate the periapical response of dogs after apical surgery and exposure to Quick-Set. WMTA was used as the control material. In this study, WMTA was associated with little or no inflammation, excellent bone quality, and frequent cementum and periodontal ligament formation along the surface of the material. The results of the WMTA group were similar to previously published outcomes in animal studies (14–17).

The main result of this study was that WMTA and Quick-Set had a similar effect on the healing of apical tissues after root-end surgery. Both materials supported regeneration of the periapical tissues. The only significant difference was greater inflammation with Quick-Set. WMTA was associated with almost no inflammation, whereas Quick-set was associated with mild inflammatory infiltrate. Where inflammation was present, it was limited to a small area adjacent to the filling material. Super EBA (Bosworth Co, Skokie, IL) is another root-end filling material that has been compared with MTA. Biocompatibility studies in animals have shown that Super EBA is associated with a mild to moderate inflammatory response that is significantly greater than that associated with MTA (17, 18). Despite the difference in inflammation, clinical studies in humans have shown that retrofitting with Super EBA can result in a high success rate (19, 20). However, another human study comparing the 2 materials showed that MTA was associated with a significantly higher success rate than Super EBA (21). These conflicting results show that it is unclear what effect slightly higher inflammation at the histologic level may have on clinical success rates in humans.

The difference in cementum formation between Quick-Set and WMTA can possibly be attributed to the difference in the composition of the materials. WMTA is a hydraulic silicate cement composed of tricalcium silicate, dicalcium silicate, bismuth oxide tricalcium aluminate, tetracalcium aluminaferrite, and calcium sulfate (3). Many of the components of Quick-Set are proprietary; however, the known constituents are a fine ceramic powder of calcium aluminosilicate and a water-based gel. As a result of the different compositions, WMTA has a higher pH than Quick-Set. The pH of WMTA is 12.6, whereas Quick-Set has a pH of 10.3 (10).

One of the limitations of this study was the small sample size per group. Sections from 9 teeth treated with WMTA and 13 teeth treated with Quick-Set were scored. Although this sample size was adequate to determine a significant difference in inflammation, no significant differences were found among other factors. Cementum deposition trended toward a significant difference in favor of WMTA; however, the \( P \) value was .08. There may still be a difference in cementum deposition adjacent to each material. Because of the sample size, this study may have been underpowered to detect the difference (22). Another limitation may have been the duration before sacrifice. All of the dogs were sacrificed at 90 days after root-end surgery. Because both materials appeared capable of supporting regeneration of apical tissues, longer time points may have found other similarities or differences between Quick-Set and WMTA.

The design of this study differed from other similar studies because apical periodontitis was not induced before root canal treatment of the teeth. The purpose of using this model was to minimize the confounding effect that apical periodontitis may have in evaluating the biocompatibility of Quick-Set. For example, if treatment failure occurred in a tooth with apical periodontitis, it would be difficult to assign the cause of failure to the material or some other cause.

The materials in this study were used to obturate the entire canal in the nonsurgical phase before resection in the surgical phase. The purpose of this methodology was to limit the number of materials in the canal that could exert a biological effect on the apical tissues. A previous study found that the resection of MTA did not affect its ability to seal the canal system (23). Apaydin et al (24) studied hard tissue healing associated with either fresh or set MTA used as root-end filling materials and found no difference in the quantity of cementum or osseous healing in dogs. The results of the WMTA group in this study were similar to those found in other studies that placed a fresh retrofitting after root-end resection (15, 17). At this time, it is unknown whether the resection of Quick-Set has any effect on its sealing ability or other properties that can affect the outcome of treatment.

Calcium aluminosilicate cements have been studied recently *in vitro* and in 1 animal study (12, 13, 25). The results of this study add to the favorable results associated with this type of material. As a root-end filling, Quick-Set showed similar overall results to WMTA. Despite its association with a slightly higher inflammation score, Quick-Set may serve as a promising alternative to MTA when a faster setting time or resistance to washout may be needed. Further research on the clinical applications of Quick-Set is recommended.
Acknowledgments

The authors thank Gerald Hill and Connie Tillberg for their technical support.

Supported by a grant from the NIH/NIDCR (grant no. R43DE020204-01A1).

Dr Primus is the owner/CEO of Avalon Biomed, Inc., Bradenton, Florida.

The authors deny any conflicts of interest related to this study.

References


