Comparative Study of Pulpal Responses to Pulpotomy with ProRoot MTA, RetroMTA, and TheraCal in Dogs' Teeth

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Abstract

Introduction: This study was conducted to evaluate and compare pulpal responses to ProRoot MTA (Dentsply Tulsa Dental, Tulsa, OK), RetroMTA (BioMTA, Seoul, Korea), and TheraCal (Bisco Inc, Schamburg, IL) in dog partial pulpotomy models. **Methods:** Partial pulpotomies were performed on 60 beagle teeth. The exposed pulp tissues were randomly capped with either ProRoot MTA ($n = 15$), RetroMTA ($n = 15$), TheraCal ($n = 15$), or interim restorative material as a negative control ($n = 15$). After 4 weeks, the teeth were extracted and processed for histologic and immunohistochemical examinations using osteocalcin and dentin sialoprotein. Calcific barrier formation, inflammatory reaction, and the odontoblastic layer were evaluated and scored in a blind manner. The areas of newly formed calcific barriers were measured for each group. **Results:** In most of the ProRoot MTA and RetroMTA specimens, continuous calcific barriers were formed, and the pulps contained palisading patterns in the odontoblastic layer that were free of inflammation. However, the TheraCal specimens had lower quality calcific barrier formation, extensive inflammation, and less favorable odontoblastic layer formation. Overall, areas of newly formed calcific barrier were higher in the ProRoot MTA and RetroMTA specimens than in the TheraCal specimens. Also, immunohistochemistry revealed that osteocalcin and dentin sialoprotein were more clearly visible in the ProRoot MTA and RetroMTA specimens than in the TheraCal specimens. **Conclusions:** RetroMTA could provide an alternative to ProRoot MTA. Both materials produced favorable pulpal responses that were similar in nature, whereas TheraCal produced less favorable pulpal responses. *(J Endod 2015;41:1317–1324)*

Key Words

Calcific barrier, inflammation, mineral trioxide aggregate, odontoblastic layer, partial pulpotomy, pulpal response

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The key factor in vital pulp therapy, such as pulp capping and pulpotomy, is to maintain the pulp vitality by protecting the exposed pulp with a biocompatible material. Ideally, the exposed pulpal surface under the capping agent is enclosed by the formation of a calcific barrier, leaving the apical portion of the pulp free of inflammation.

The classic method of vital pulp therapy is performed with calcium hydroxide ($Ca[OH]_2$). However, using $Ca(OH)_2$ has several limitations, including its high solubility and unpredictable treatment outcomes (1, 2). With the introduction of mineral trioxide aggregate (MTA), a novel pulp treatment agent, the short-term and long-term success rates in vital pulp therapy has increased up to 93% (3) and 85% (1), respectively. MTA has been recognized as a biocompatible material that produces excellent induction of hard-tissue formation (4, 5). However, conventional MTA (ProRoot MTA) has disadvantages, such as a long setting time (4 hours) and tooth discoloration (5, 6), that have led to the development of MTA-like materials with improved physical properties.

Biodentine (Septodont, Saint Maur des Fosses, France) has been introduced as an alternative MTA-like material with a reduced setting time, better physical properties, and ease of handling. Biodentine is compatible with dental pulp cells and stimulated the formation of tertiary dentin *in vitro* (7, 8). It also induced differentiation of cultured pulp cells into odontoblastlike cells (9). An *in vivo* study showed that Biodentine is tissue compatible and promotes calcific barrier formation with comparable morphology and integrity to those produced by ProRoot MTA (10). Similar results are being achieved with other MTA materials such as Angelus MTA (Angelus, Londrina, PR, Brazil), Bioaggregate (Innovative BioCeramix, Vancouver, Canada), and MM-MTA (Micromega, Besançon, France).

RetroMTA (BioMTA, Seoul, Korea) consists of a hydraulic calcium zirconia complex that has a setting time of 150 seconds. According to the manufacturer, RetroMTA consists of calcium carbonate (60%–80% by weight [wt%]), silicon dioxide (5–15 wt %), aluminum oxide (5–10 wt%), and calcium zirconia complex (20–30 wt%) (11). An *in vitro* study showed that RetroMTA has similar biocompatibility and angiogenic effects as ProRoot MTA (12). Despite the increase in the use of RetroMTA as a vital pulp therapy agent, there is limited information about RetroMTA in the literature.

TheraCal (Bisco Inc, Schamburg, IL) is a light-cured, resin-modified calcium silicate filled liner designed for use in various vital pulp therapies (13). TheraCal consists of type III Portland cement (45 wt%), radiopacific material (10 wt%), fumed silica (5 wt%), and resin (40 wt%) (14). According to an *in vitro* study on resin-based liners, TheraCal has been introduced as a low cytopathic light-cured liner (15). Moreover, TheraCal has been reported to have higher calcium release, less alkaline pH, and lower solubility when compared with ProRoot MTA or Dycal (Dentsply Caulk, Milford, DE) (13). Likewise, in a previous *in vivo* study, hard tissue formation in TheraCal has been reported to be comparable with pure Portland cement and better than Dycal or glass ionomer cement without significant pulpal inflammation (16).

This study was conducted to evaluate and compare calcific barrier formation, inflammation, and odontoblastic layer formation of ProRoot MTA, RetroMTA, and TheraCal in dog pulpotomy models.

Materials and Methods

Animal Model

Five male beagle dogs were chosen for this study. Each animal weighed ~12 kg and was 18 months old. The animals had intact dentition and a healthy periodontium. Animal selection, management, surgical protocol, and preparation were performed according to routine procedures approved by the Institutional Animal Care and Use Committee, Yonsei Medical Center, Seoul, Korea (certification #2013-0153).

Surgical Protocol

The surgical procedures were performed under general anesthesia in a sterile operating room. The animals received a preanesthetic intravascular injection of tramadol (1 mg/kg; Kwangmyung Pharmaceutical Co, Seoul, Korea) and an intramuscular injection of xylazine (0.2 mg/kg; Rompun, Bayer Korea, Seoul, Korea) and zoletil (5 mg/kg; Ketalar, Yuhan, Seoul, Korea). Isoflurane (Gerolan; Choongwae Pharmaceutical Co, Seoul, Korea) was administered as inhalation anesthesia. To prevent infection, a subcutaneous injection of enrofloxacin (5 mg/kg) was given just before and after treatment, and intraoral amoxicillin clavulanate (12.5 mg/kg) was given for 5 to 7 days postoperatively.

Partial Pulpotomy Procedure

After disinfection of the surgical site using 0.2% chlorhexidine gluconate, infiltration anesthesia was administered using lidocaine (2% lidocaine hydrochloride with epinephrine 1:100,000, Kwangmyung Pharmaceutical Co). Sixty teeth, including incisors, canines, and premolars, of each animal were allocated randomly to 4 pulpotomy treatment groups (n = 15 per group): ProRoot MTA, RetroMTA, TheraCal, and interim restorative material (IRM) (Dentsply Tulsa Dental, Tulsa, OK). Initially, the coronal pulp was removed after occlusal reduction in each root canal system using a high-speed carbide bur no. 330 (H7 314 008; Brasseler, Lemgo, Germany) and distilled water spray. The exposure was then rinsed with sterile saline, and hemostasis was achieved by placing a cotton pellet moistened with normal saline over the exposure site for 2 minutes. ProRoot MTA, RetroMTA, and IRM were each mixed according to the manufacturer's recommendations and placed over the exposure. TheraCal was placed over the exposure in 0.5- to 1-mm thickness and light cured for 20 seconds. The remainder of the cavity preparation was restored with Ketac Molar (3M ESPE, St Paul, MN), a self-curing glass ionomer cement. The dogs were sacrificed 4 weeks after surgery.

Histologic Analysis

The teeth were removed using extraction forceps, and the apical third of each root was sectioned with a high-speed bur to facilitate fixation in 10% buffered formalin (Sigma-Aldrich, St Louis, MO) for 1 day. After fixation, the teeth were decalcified with

TABLE 1. Scores Used during Histologic Analysis of Calcific Barriers and Dental Pulp

Scores	Calcific barrier continuity
1	Complete dentin bridge formation
2	Partial/incomplete dentin bridge formation extending to more than one half of the exposure site but not completely closing the exposure site
3	Initial dentin bridge formation extending to not more than one half of the exposure site
4	No dentin bridge formation
Scores	**Calcific barrier morphology**
1	Dentin or dentin associated with irregular hard tissue
2	Only irregular hard tissue deposition
3	Only a thin layer of hard tissue deposition
4	No hard tissue deposition
Scores	**Tubules in calcific barrier**
1	No tubules present
2	Mild (tubules present in <30% of calcific barrier)
3	Moderate to severe (tubules present in >30% of calcific barrier)
Scores	**Inflammation intensity**
1	Absent or very few inflammatory cells
2	Mild (an average of <10 inflammatory cells)
3	Moderate (an average of 10–25 inflammatory cells)
4	Severe (an average >25 inflammatory cells)
Scores	**Inflammation extensity**
1	Absent
2	Mild (inflammatory cells next to dentin bridge or area of pulp exposure only)
3	Moderate (inflammatory cells observed in one third or more of the coronal pulp or in the midpulp)
4	Severe (all of the coronal pulp is infiltrated or necrotic)
Scores	**Inflammation type**
1	No inflammation
2	Chronic inflammation
3	Acute and chronic inflammation
4	Acute inflammation
Scores	**Dental pulp congestion**
1	No congestion
2	Mild (enlarged blood vessels next to dentin bridge or area of pulp exposure only)
3	Moderate (enlarged blood vessels observed in one third or more of the coronal pulp or in the midpulp)
4	Severe (all of the coronal pulp is infiltrated with blood cells)
Scores	**Odontoblastic cell layer**
1	Palisade pattern of cells
2	Presence of odontoblast cells and odontoblastlike cells
3	Presence of odontoblastlike cells only
4	Absent