Human Pulp Responses to Partial Pulpotomy Treatment with TheraCal as Compared with Biodentine and ProRoot MTA: A Clinical Trial

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Abstract

Introduction: Questions exist regarding the efficacy of resin-containing materials such as TheraCal directly applied on the pulp. This study sought to investigate the clinical efficacy of TheraCal as compared with Biodentine and ProRoot mineral trioxide aggregate (MTA) for partial pulpotomy. **Methods:** In this clinical trial, partial pulpotomy was performed for 27 sound human maxillary and mandibular third molars scheduled for extraction. The teeth were randomly divided into 3 groups (n = 9) and underwent partial pulpotomy with TheraCal, Biodentine, and ProRoot MTA. The teeth were then restored with glass ionomer cement. Clinical and electric pulp tests were performed after 1 and 8 weeks. The teeth were radiographed and extracted at 8 weeks. Histologic sections were prepared and analyzed for pulp inflammation and dentinal bridge formation. Data were analyzed by using one-way analysis of variance. **Results:** Clinical examination showed no sensitivity to heat, cold, or palpation in ProRoot MTA and Biodentine groups. Two patients in TheraCal group (20%) reported significant pain at 1 week. Periapical radiographs showed no periapical pathology, and electric pulp test revealed a normal pulp response with no hypersensitivity. Inflammation was absent with all materials at 8 weeks. Normal pulp organization was seen in 33.33% of the teeth in ProRoot MTA, 11.11% in TheraCal, and 66.67% in Biodentine group (P = .06). Biodentine group showed complete dentinal bridge formation in all teeth, whereas this rate was 11% and 56% in TheraCal and ProRoot MTA groups, respectively (P = .001). **Conclusions:** Overall, Biodentine and MTA performed better than TheraCal when used as partial pulpotomy agent and presented the best clinical outcomes. *(J Endod 2017;■:1–6)*

Key Words

Biodentine, partial pulpotomy, ProRoot MTA, TheraCal

Significance

Preservation of pulp vitality is a challenge in immature permanent teeth. Questions exist regarding the efficacy of resin-containing materials. This comparative study between Biodentine, TheraCal, and ProRoot MTA aims to provide a better insight into it. Overall, Biodentine and MTA performed better than TheraCal when used as partial pulpotomy agent and presented the best clinical outcomes.

Preserving pulp vitality after carious or traumatic injuries remains a challenge in immature permanent teeth because this vitality is important for complete root formation (1–3). To this end, vital pulp therapy should be considered in teeth with reversible injury.

ProRoot mineral trioxide aggregate (MTA) is mainly composed of tricalcium silicate, dicalcium silicate, tricalcium aluminate, tetracalcium aluminoferrite, and bismuth oxide (4). When applied directly onto the pulp, MTA as a bioactive material with high sealing ability (3, 5–10) stimulates the formation of dentinal bridge (1, 5–8) and leads to pulp healing, yielding high clinical success rate (6–9). However, MTA has a long setting time (11) and poor handling properties (12) and may lead to tooth discoloration (10, 11).

Biodentine is a tricalcium silicate–based restorative cement used for direct and indirect pulp capping. It has mechanical properties comparable to those of dentin and can be used as a dentin substitute in both the crown and root (3, 13–18). Biodentine is bioactive and nontoxic as tested on human pulp cells (1) and provides marginal sealing by adhering to both dentin and enamel (15, 16). When applied directly onto the pulp in entire tooth cultures, it induced mineralization within the pulp (1) and complete dentinal bridge formation after 6 weeks in human teeth (19). In addition, clinical trials have reported a high clinical success rate of pulpotomy with Biodentine comparable to that of ProRoot MTA (20). Clinical case reports have demonstrated a dentin bridge barrier formation when Biodentine was applied in partial pulpotomy of fractured mature teeth (21).

TheraCal is a new light-cured, resin-modified, calcium silicate–filled base/liner material designed for direct and indirect pulp capping (22). It contains 45 wt% mineral

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(type III Portland cement), 10 wt% radiopaque agent, 5 wt% hydrophilic thickening agent, and 45% resin (22).

Mechanical properties analysis indicates that TheraCal has the greatest compressive and flexural strengths, whereas Biodentine has a higher stiffness and flexural modulus. TheraCal has been reported to be toxic to pulp cells *in vitro* (23). In addition, an extensive inflammatory reaction was observed in 75% of the cases 4 weeks after TheraCal application in dog teeth, whereas a complete dentinal bridge was formed only in 33% of the teeth (24).

A recent study comparing solubility of 6 materials including TheraCal, ProRoot MTA, and Biodentine showed that all 6 materials showed low solubility (25, 26). Both Biodentine and MTA have excellent sealing properties and potential to prevent microleakage (19). However, formation of tunnel defects in reparative dentin underneath the capping material may fail to provide a permanent seal (27). Thus, sealing ability of a material may serve a more prominent role in clinical outcomes than its solubility.

ProRoot MTA is known for its prolonged setting time, which is significantly longer than that of Biodentine (26). It has been shown that TheraCal has a short setting time and releases significantly less calcium ions than Biodentine in aqueous solutions *in vitro* (24).

Because of the lack of clinical studies, questions regarding the safety of applying resin-containing materials such as TheraCal directly onto the pulp remain to be answered. Thus, the aim of this study was to compare the clinical efficacy of TheraCal in partial pulpotomy with that of Biodentine and ProRoot MTA.

Materials and Methods

Inclusion Criteria

Twenty-seven sound human maxillary and mandibular third molars scheduled for extraction were selected in patients between 18 and 32 years of age. Each tooth was radiographically examined to ensure absence of caries and periapical pathology (28).

Operative Procedure

Patients were informed about the experimental rationale, clinical procedures, and possible complications and signed consent forms. All experimental procedures were reviewed and approved by the Ethical Committee of Tehran Dental Branch of Islamic Azad University (code: IR.IAU.Dental.rec.1395,21), and the study was registered in IRCT (ID number: 2015082420004N2). Third molars were then randomly assigned to TheraCal (n = 9), Biodentine (n = 9), and ProRoot MTA (n = 9) groups. Thermal (M + W Dental Müller & Weygandt GmbH, Büdingen, Germany) and electric pulp tests (Sybron Endo, Orange) were performed to assess pulp sensitivity. A standard partial pulpotomy procedure was performed in each experimental group. Before cavity preparation, the teeth were mechanically cleaned and disinfected with 0.2% chlorhexidine solution. After local anesthesia with 2% lidocaine (Daroupakhsh, Tehran, Iran) and rubber dam application, occlusal class I cavities were prepared by using sterile round diamond bur and high-speed handpiece under air-distilled water spray. Pulp chamber was exposed (approximately 2 mm in diameter) with a 10-mm fissure diamond bur (837 L; D + Z GmbH, Frankfurt, Germany) under sterile saline coolant. New burs were used for each preparation. Bleeding was controlled with sterile cotton pellets placed over the pulp exposure site. Partial pulpotomy was performed for the 3 groups as follows.

For ProRoot MTA group, ProRoot MTA (Dentsply, Tulsa Dental, Tulsa, OK) was prepared by gradually mixing 1 mg powder with the liquid within 1 minute according to the manufacturer's instructions until a thick paste with creamy consistency was obtained. After its excision, the pulp was capped with a 2-mm-thick layer of ProRoot MTA, after which a flat, moist cotton pellet was used to shape the material.

For Biodentine group, excised pulps were capped with Biodentine (Septodont, Saint Maur des Fosses, France) per manufacturer's recommendations. The cement was applied as bulk in the cavity with a spatula and a plugger without any conditioning pretreatment.

For TheraCal group, excised pulps were capped with TheraCal (Bisco Inc, Schaumburg, IL) according to the manufacturer's recommendations. A 2-mm-thick layer of TheraCal was placed in the cavity and polymerized for 20 seconds after each 1-mm increment.

After partial pulpotomy, the cavities in all 3 groups were restored with glass ionomer cement (Ketac Molar; 3M ESPE, Seefeld, Germany) (19).

Patients in all groups returned to the clinic for clinical examination after 7 days. One experienced operator performed all the operative procedures.

Clinical Examination

The treatment period was 8 weeks, after which the teeth were extracted for histologic examinations. Radiographs were taken before extraction to determine any signs of periapical pathology. Clinical tests were performed after 1 and 8 weeks. Electric pulp test was performed to assess pulp vitality.

Histologic Examination

After extraction, 1 mm of the apex was cut, and the teeth were fixed with 4% formaldehyde solution and demineralized as previously described (29). Next, 5-μm-thick sections were made of formalin-fixed, paraffin-embedded teeth and stained with hematoxylin-eosin. Finally, the slides were assessed by a pathologist blinded to the patient groups under a light microscope (BX41; Olympus, Tokyo, Japan) by using modified criteria that were based on those of Nowicka et al (19).

Type of Pulp Inflammation

1. No inflammation
2. Chronic
3. Acute and chronic
4. Acute

Intensity of Pulp Inflammation

1. Absent or very few inflammatory cells
2. Mild, <10 inflammatory cells
3. Moderate, 10–25 inflammatory cells
4. Severe, >25 inflammatory cells

Extension of Pulp Inflammation

1. Absent
2. Mild, inflammatory cells only next to pulp exposure site
3. Moderate, inflammatory cells observed in part of coronal pulp
4. Severe, all coronal pulp is infiltrated

Dentin Bridge Thickness

1. >0.25 mm
2. 0.1–0.25 mm
3. <0.1 mm
4. Partial or absent bridge

The thickness of dentinal bridge was measured at the thickest, thinnest, and midmost point areas of the bridge. The average of the 3 values was calculated.

Morphology and Continuity of Dentin Bridge

1. Formation of a complete dentinal bridge
2. Formation of discontinuous incomplete dentin bridge
3. No sign of dentin formation

Pulp Tissue Organization and Morphology

1. Normal pulp morphology
2. Disorganization of pulp beneath the cavity
3. Disorganization of the entire pulp

Data were analyzed by using SPSS version 22 (SPSS Inc, Chicago, IL). Categorical variables are reported as frequency and percentage in each study group. To compare distribution of dependent variables between study groups, Kruskal-Wallis test was performed. *P* values less than .05 were considered as statistically significant.

Results

Clinical Evaluations

Clinical examination showed no sensitivity to heat, cold, or palpation in ProRoot MTA and Biodentine groups. Two patients in TheraCal group (20%) reported significant pain and discomfort at 1 and 8 weeks. Pain management was done by using single dose of nonsteroidal anti-inflammatory drug (ibuprofen 800 mg) (Pfizer Inc, Kings Mountain, NC). Periapical radiographs taken before the extraction of teeth showed no evidence of periapical pathology. Electric pulp test after 1 and 8 weeks revealed normal pulp response with no hypersensitivity.

Histologic Findings

Pulp inflammation was absent with all materials after 8 weeks of treatment except a single case of mild chronic inflammation with TheraCal (Table 1). Pulp organization was normal in 33.33% of the teeth in ProRoot MTA group, 11.11% in TheraCal group, and 66.67% in Biodentine group; this difference was significant ($P = .06$). Local pulp tissue disorganization was observed beneath 6 cases with TheraCal, 3 cases with Biodentine, and 2 cases with MTA. None of the Biodentine-treated teeth showed complete pulp destruction, whereas 22.2% of TheraCal-treated and 44.4% of ProRoot MTA–treated cases showed complete pulp disorganization (Figure 1).

All teeth in Biodentine group showed hard tissue formation in the form of a complete dentin bridge. TheraCal and ProRoot MTA groups showed complete dentin bridge formation in 11% and 56% of the cases, respectively, which was statistically significant ($P = .001$). The frequency of cases showing formation of discontinuous bridge beneath the cavity was significantly different between Biodentine and TheraCal ($P = .01$), whereas Biodentine and ProRoot MTA ($P = .17$) and TheraCal and ProRoot MTA were not significantly different in this respect ($P = 1.00$).

In both ProRoot MTA and Biodentine groups, complete dentin bridge was formed by differentiated odontoblast-like cells, whereas more than half of teeth in TheraCal group had incomplete bridge (Figure 1). Dentin bridge observed with Biodentine was thicker than that with MTA (Table 2).

Discussion

This study compared the use of TheraCal, ProRoot MTA, and Biodentine for partial pulpotomy of sound human third molars. TheraCal treatment resulted in pulp disorganization in 66.67% of the cases beneath the material and in the entire pulp in 22.2% of the cases. Similarly, dispersed mineralization in the form of a discontinuous dentinal bridge was noted in most cases treated with TheraCal. Evaluation of pulp tissue disorganization extent is important because it reflects the consequence of initial pulp inflammation, which in the case of TheraCal led to dispersed mineralization. By contrast, complete dentinal bridge was formed in all Biodentine-treated teeth, which had normal pulp morphology. In 56% of ProRoot MTA cases, dental pulp had either a normal morphology or disorganization right beneath the material. Comparison of dentin-pulp complex response in human teeth after partial pulpotomy with Biodentine, MTA, and TheraCal indicated that there were significant differences among the 3 experimental groups during the observation period. Overall, Biodentine performed better than TheraCal when used as partial pulpotomy agent and presented the best clinical outcomes.

The setting reaction of tricalcium silicate is a hydration reaction, which increases over time producing calcium hydroxide as a hydration by-product (30), and calcium ions release, which are involved in dentin bridge formation (23, 31). Our histologic findings indicated formation of an organized dentinal bridge in ProRoot MTA and Biodentine compared with TheraCal. Considering higher calcium release of TheraCal compared with ProRoot MTA (25), it can be concluded that dentinal bridge formation is more related to other factors.

First, hydration of TheraCal as compared with Biodentine in entire tooth culture model demonstrated that even after 2 weeks of its application onto the pulp, TheraCal hydration was incomplete, whereas that of Biodentine was complete (22). Second, the hydration of Biodentine, but not that of TheraCal, was associated with calcium hydroxide formation. Third, incubation of pulp cells with extracts of Biodentine, ProRoot

TABLE 1. Intensity and Type of Pulp Inflammation after Partial Pulpotomy with 3 Materials at 8 Weeks

Materials		TheraCal	Biodentine	ProRoot MTA
	Index	*N* (%)	*N* (%)	*N* (%)
Intensity of pulp inflammation	Absent	9 (100.0)	8 (88.9)	9 (100.0)
	Mild	0 (0.0)	1 (11.1)	0 (0.0)
	Moderate	0 (0.0)	0 (0.0)	0 (0.0)
	Severe	0 (0.0)	0 (0.0)	0 (0.0)
Type of pulp inflammation	No inflammation	9 (100.0)	8 (88.9)	9 (100.0)
	Chronic	0 (0.0)	1 (11.1)	0 (0.0)
	Chronic and acute	0 (0.0)	0 (0.0)	0 (0.0)
	Acute	0 (0.0)	0 (0.0)	0 (0.0)
Extension of pulp inflammation	Absent	9 (100.0)	8 (88.9)	9 (100.0)
	Mild	0 (0.0)	1 (11.1)	0 (0.0)
	Moderate	0 (0.0)	0 (0.0)	0 (0.0)
	Severe	0 (0.0)	0 (0.0)	0 (0.0)

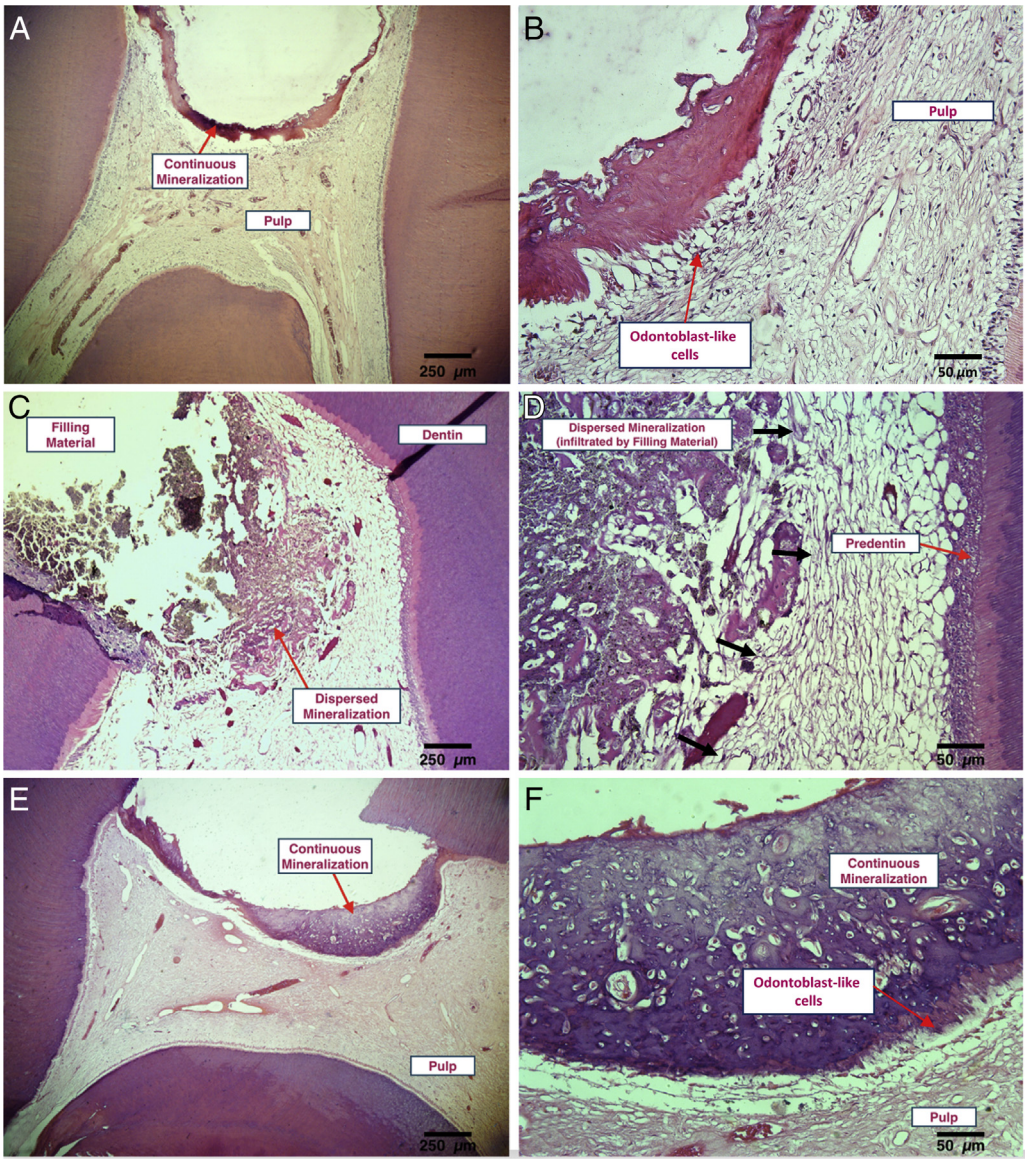

Figure 1. (*A*) Partial pulpotomy with ProRoot MTA shows formation of continuous dentinal bridge (original magnification, ×40). (*B*) Dentinal bridge exhibits cell inclusions and differentiation of new odontoblasts (original magnification, ×200). (*C*) Partial pulpotomy with TheraCal shows non-continuous bridge formation and disorganized mineralization (original magnification, ×40). (*D*) Disorganized pulp tissue is observed under the material (*black arrows*) (original magnification, ×200). (*E*) Partial pulpotomy with Biodentine shows formation of continuous dentin bridge (original magnification, ×40). (*F*) At higher magnification, the bridge exhibits cell inclusions and odontoblast-like cell differentiation (original magnification, ×200).

MTA, and calcium hydroxide led to release of transforming growth factor β1, which decreased only in presence of Xeno III adhesive extract (Dentsply). This factor is involved in recruitment of pulp stem cells and their odontoblastic differentiation (1, 32, 33).

The absence of complete dentinal bridge in 66.67% of TheraCal cases may be explained by the presence of resin in its composition. It has been reported that up to 50% of methacrylate monomer double-bonds remain unreacted in resin polymers (34). The non-polymerized monomers in the composite represent a significant risk when they leach out from the composite and reach dental pulp (35). This indicates that it is impossible to obtain complete polymerization, particularly if the material is applied in a humid environment as in direct pulp capping. Similarly, resin components of TheraCal including HEMA, BisGMA, TEGDMA, and UDMA may remain non-polymerized after contact with pulp tissue, and these are known to be cytotoxic for pulp fibroblasts (36). Thus, incomplete dentinal bridge formation may be due to monomers leaching from the material. Indeed, it has been demonstrated that nontoxic concentrations of monomers inhibit the secretion of dentin sialoproteins and osteonectin and their accumulation in endoplasmic reticulum (37). Because these proteins are involved in the mineralization process, inhibition of their secretion may explain decreased mineralization in TheraCal group compared with MTA and Biodentine groups. This also explains incomplete dentinal bridge after 4 weeks of its application in partial pulpotomy of dog teeth (24).

Microleakage prevention is a determinant factor for partial pulpotomy success. Although this may be provided by the material itself (6–8, 10, 38–40), the long-term success of partial pulpotomy depends on continuous bridge formation, which provides additional pulp protection. In our study, the dentin bridge at the site of injury was uniform and homogenous with Biodentine, followed by ProRoot

TABLE 2. Hard and Soft Tissue Formation Based on Histologic Analysis

Materials	TheraCal *N* (%)	Biodentine *N* (%)	ProRoot MTA *N* (%)
Soft tissue formation			
Pulp tissue organization and morphology			
Normal or almost normal pulp tissue morphology	1 (11.1)	6 (66.7)	3 (33.3)
Disorganization of pulp tissue beneath the cavity	6 (66.7)	3 (33.3)	2 (22.2)
Disorganization of entire pulp tissue	2 (22.2)	0 (0.0)	4 (44.4)
Hard tissue formation			
Dentinal bridge morphology and continuity			
Formation of hard tissue beneath the cavity in the form of complete dentinal bridge	1 (11.1)	9 (100.0)	5 (55.6)
Formation of discontinuous bridge beneath the cavity (incomplete dentinal bridge)	6 (66.7)	0 (0.0)	4 (44.4)
No signs of dentin formation	2 (22.2)	0 (0.0)	0 (0.0)
Dentinal bridge thickness			
More than 0.25 mm	5 (55.6)	5 (55.6)	1 (11.1)
Between 0.1 and 0.25 mm	2 (22.2)	4 (44.4)	8 (88.9)
Less than 0.1 mm	2 (22.2)	0 (0.0)	0 (0.0)

MTA. Therefore, Biodentine and ProRoot MTA are more reliable for long-term protection of dental pulp than TheraCal. Taken together, our data did not support the use of TheraCal in partial pulpotomy. By contrast, the obtained results confirmed that Biodentine and MTA are suitable for this clinical indication. This result supports previous findings regarding induction of dentinal bridge formation in rat molars by Biodentine and MTA application (2, 19, 41) and absence of significant differences between the 2 materials after direct application onto human pulps (19).

Our protocol had some minor limitations. We used sound teeth with no signs of inflammation. Although this adds to the reliability of the protocol, our study could not provide information about the effects of these pulp-capping materials on carious teeth with different levels of inflammation. Hence, it is highly recommended to perform a well-designed long-term study on inflamed teeth with pulpitis. There are numerous examples of endodontic procedures evaluating new tissue formation in young patients (28, 42) and the relationship of age and regeneration *in vivo* (43), all reporting better results in younger patients. Selection of patients in a specific age range was strength of our study because we provided evidence of regeneration in an age group not usually expected.

Acknowledgments

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

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