A Randomized Controlled Study of the Use of ProRoot Mineral Trioxide Aggregate and Endocem as Direct Pulp Capping Materials: 3-month versus 1-year Outcomes

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Abstract

Introduction: The purpose of this study was to assess the long-term clinical outcomes of direct pulp capping (DPC) with ProRoot MTA (Dentsply, Tulsa, OK) and Endocem (Maruchi, Wonju, Korea) as pulp capping materials. To this end, the 1-year cumulative successes of both materials were evaluated and compared with those of the 3-month outcomes in a prospective, randomized controlled trial. **Methods:** Patients were recruited from the Department of Conservative Dentistry of the Yonsei University Dental Hospital, Seoul, South Korea, from January to May 2013. Of the 48 teeth that met the inclusion criteria, 46 teeth were randomly allocated to either ProRoot MTA or Endocem groups (n = 23). Direct pulp capping was performed, and clinical and radiographic examinations were conducted over 1 year after the treatment. Survival analyses were conducted to compare the cumulative successes between ProRoot MTA and Endocem and to evaluate other clinical variables. **Results:** Forty-one teeth were recalled 1 year after the treatments (recall rate = 89.13%). There were no significant differences between the cumulative successes of ProRoot MTA and Endocem in either log-rank or Cox proportional hazard regression analyses (P > .05). Among the other clinical variables, cavity type (class I, II, III vs class V) was determined to be significant in both the log-rank test (P = .001) and Cox regression analysis (P = .006). **Conclusions:** Both ProRoot MTA and Endocem exhibited similar cumulative successes as direct pulp capping materials up to 1 year. The teeth restored with class V cavities exhibited significantly lower cumulative success rates after direct pulp capping compared with the teeth restored with other types of cavities. *(J Endod 2015;41:1201–1206)*

Key Words

Direct pulp capping, Endocem, ProRoot MTA, randomized controlled trial, survival analysis

Direct pulp capping (DPC) is a procedure that treats exposed pulp by directly covering it with biocompatible materials (1). By separating the pulp from bacteria and noxious stimulus, DPC aims to maintain the vitality of the pulp rather than removing it. In this regard, the selection of appropriate pulp capping material that provides sufficient sealing and biocompatibility is an important prerequisite to achieving predictable DPC outcomes (2–4).

Calcium hydroxide (CH)-based materials were once widely used in DPC; however, because these materials do not sufficiently satisfy the requirements in terms of sealing and biocompatibility (1, 5–8), their success rates have exhibited wide fluctuations. Moreover, mineral trioxide aggregate (MTA), a calcium silicate–based cement, elicited remarkable improvements in DPC outcomes (1, 5, 8–10) because of its superior biocompatibility and sealing ability relative to other materials (11–13). However, several limitations remain regarding the use of conventional MTA (ProRoot MTA; Dentsply, Tulsa, OK) as capping material including poor manipulability and long setting times (14–16) that restrict the broader application of DPC. For these reasons, a recently introduced fast-setting pozzolan-based MTA (Endocem; Maruchi, Wonju, Korea) is gaining attention as an alternative capping material for its high manipulability, fast setting properties, and acceptable biologic responses (15–18).

However, it should be noted that there is still a lack of clinical evidence to guarantee the performance of Endocem as a capping material. Although our previous study confirmed the clinical outcome of Endocem up to 3 months (19), when considering that the cumulative success of DPC could experience alterations over time (1, 5), a 3-month follow-up period would not be sufficient to guarantee the long-term prognosis of the capping materials. Therefore, more reliable clinical evidence, particularly long-term results of at least 1 year, should be supplemented in the literature to support the clinical use of Endocem in DPC.

In addition, from the perspective of the levels of evidence, there are still few high-quality clinical trials that have investigated DPC in the current endodontic literature (20). Most studies have been conducted with nonrandomized controlled designs (ie, case-controlled studies or retrospective studies) or sample sizes that

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were too small to identify statistical significance (less than 20 subjects) or without consolidated standards (21, 22). Therefore, clinical studies with higher levels of evidence are strongly needed to promote a better understanding on the prognosis of DPC.

The purpose of this study was to assess the long-term clinical outcome of DPC with ProRoot MTA and Endocem as pulp capping materials in relation to the follow-up period after DPC. To accomplish this goal, the 1-year cumulative successes of both materials were evaluated and compared with the preceding 3-month outcomes (19) in a prospective, randomized controlled trial (RCT) based on the survival analysis.

Materials and Methods

This study was approved by Yonsei University Committee for Research on Human Subjects (2-2012-0052) and conducted in accordance with the CONSORT 2010 statement (23). Among the patients who attended the Department of Conservative Dentistry, Yonsei University Dental Hospital, Seoul, Korea, from January to May 2013, 37 patients (48 teeth) met the inclusion and exclusion criteria of this study and were initially assessed for eligibility in this study. The risks, benefits, and alternatives of the treatment were explained, and written informed consent was obtained from each patient with the exception of 2 patients (2 teeth) who declined involvement in this trial. Ultimately, 35 patients (46 teeth) were included and randomly assigned to either the ProRoot MTA or Endocem groups and received the allocated interventions.

Inclusion and Exclusion Criteria

The inclusion criteria were as follows:

1. Patients aged older than 19 years
2. Permanent teeth diagnosed with reversible pulpitis
3. Teeth exhibiting direct pulp exposure from trauma or dental caries

The exclusion criteria were as follows:

1. Patients aged younger than 19 years
2. Primary teeth
3. Teeth diagnosed with irreversible pulpitis or pulp necrosis
4. Teeth exhibiting clinical and/or radiographic signs of chronic periodontitis, cracked teeth, internal/external root resorption, or excessive pulp canal obliteration
5. Teeth showing persistent pulpal hemorrhage after receiving 10 minutes of sodium hypochlorite dressing

To discern the eligibility of each subject based on the previously described criteria, clinical and radiographic examinations were conducted including periapical radiographic assessment, mobility, percussion, bite tests, periodontal probing, and pulp sensibility tests with ice sticks and electric pulp testers (Digitest; Parkell Inc, Farmingdale, NY). The teeth were diagnosed with irreversible pulpitis or pulp necrosis when they exhibited relevant signs and symptoms, such as present or previous history of spontaneous pain, sinus tract, prolonged response or no response to the pulp sensibility test, or apical radiolucency on the periapical radiograph.

Sample Size Calculation

Before patient recruitment, the sample size was calculated by the method of Walters (24) with the assumption of the relatively normal distributions of the sample. With the expectation of a 15% mean difference between the control (ProRoot MTA) and experimental groups (Endocem), the minimum number of subjects needed to induce statistical significance ($P < .05$) was calculated as 38 with a power of 0.80. Considering a maximum of 20% follow-up loss, the sample size required in this study was ultimately estimated to be 46 subjects (23 subjects for each group).

Randomization, Allocation Concealment, and Blinding

By combining the 2 variables of patient age (>40 or ≤40 years) and exposure site (occlusal surface or axial surface), 4 strata (occlusal surface and age >40, occlusal surface and age ≤40, axial surface and age >40, and axial surface and age ≤40) were created for this study. Based on this stratification, an independent research coordinator randomly allocated each patient to either the ProRoot MTA or the Endocem group. Because the capping materials were different in terms of appearance and handling characteristics, allocation concealment and blinding to the clinical practitioners were not possible; therefore, the assignment was blinded only to the patients (single-blinded).

Treatment Protocol

After local anesthetic injection and rubber dam isolation, the tooth surfaces were disinfected by scrubbing with 2% chlorhexidine and 75% isopropyl alcohol before the excavation of the caries. Carious dentin was initially removed with round burs and low-speed handpieces under sterile water spray, and the remaining soft dentin was manually removed with a sterile spoon excavator. After complete caries excavation, the exposed pulp was disinfected with 2.5% sodium hypochlorite irrigation and a soaked cotton pellet. Teeth exhibiting adequate pulpal hemostasis after 10 minutes of sodium hypochlorite dressing were randomly allocated to each material group.

In the ProRoot MTA group, MTA was mixed according to the manufacturer's instructions (1:3 water/powder ratio) and applied on the pulp exposure site via a sterile amalgam carrier. Basically, the capping materials were placed with a thickness of 3 mm, but in several class II or V cavities, which did not provide sufficient cavity depth, every attempt was made to maintain the thicknesses of the capping materials as close as possible to 3 mm. Cotton pellets soaked with sterile saline were placed on top of the MTA, and the cavity was temporarily sealed with intermediate restorative material (IRM; Caulk Dentsply, Milford, DE). One or 2 days after DPC, the cavity was opened, and the setting status of MTA was confirmed. After the confirmation, the remaining cavity was restored with resin-modified glass ionomer (RMGI; GC Fuji II LC, GC Corp, Tokyo, Japan).

In the Endocem group, Endocem was mixed according to the manufacturer's instructions (1:2 water/powder ratio) and placed on the pulp exposure site using a Centrix syringe gun (Centrix, Shelton, CT) and a needle tip (Shinwoo Dental, Gyeonggi-do, Korea). After 5 minutes of Endocem hardening, the remaining cavity was immediately restored with RMGI.

In both groups, the teeth were finally restored with direct resin filling, an inlay/overlay, or a single crown when the pulp vitality was maintained without specific complications 3 months after DPC.

Outcome Assessment

The patients were recalled periodically at 1, 2, 4, and 12 weeks, 6 months, and 1 year after the treatments. To determine the successes and failures of the treatment, clinical and radiographic examinations were conducted at each appointment. Periapical radiographs were blindly evaluated by 2 independent examiners who were not involved in the clinical procedure.

Treatment success was defined by cases in which the tooth exhibited a positive response to the pulp sensibility test without any evidence of irreversible pulpitis or pulp necrosis in either the clinical or

TABLE 1. Characteristics of the Failed Cases

Case	Age	Sex	Tooth no.	Cavity type*	Capping material	Survival time (wk)
A	42	M	1	Class I	ProRoot MTA	17
B	66	F	12	Class V	ProRoot MTA	4
C	43	F	30	Class V	ProRoot MTA	49
D	67	M	19	Class II	Endocem	10
E	58	M	5	Class V	Endocem	12
F	47	F	5	Class V	Endocem	32

F, female; M, male.

*Note that two thirds of the failed cases had class V cavities.

radiographic examinations. The following results were taken to indicate treatment failure: a negative response to the pulp sensibility test, spontaneous pain that was not resolved with analgesics, or well-defined apical radiolucency on the periapical radiograph.

Statistical Methods

Kaplan-Meier survival analyses and log-rank tests were conducted to compare the cumulative successes of ProRoot MTA and Endocem. To analyze the failed cases, the log-rank test was conducted according to the potential clinical variables (ie, patient age, sex, jaw, tooth type, preoperative symptom, and cavity type), and variables that were found to be statistically significant were then submitted to Cox proportional hazard regression analysis with capping material. All data were analyzed in IBM SPSS statistics 19 (IBM Corp, Somers, NY) at a significance level of 0.05.

Results

In this study, 46 subjects (median age = 42; age range, 19–79 years) were initially included. Among these subjects, 41 were followed up and analyzed at a 1-year postoperative evaluation (overall recall rate = 89.13%). In the ProRoot MTA group, all subjects were recalled (23/23 cases), and the success rate of DPC was 86.96% (20/23 cases). In the Endocem group, 18 of 23 cases were recalled, and the success rate of DPC was 83.33% (15/18 cases). The overall success rate was 85.37% (35/41 cases), which indicated a 7.65% point reduction compared with the 93.02% (40/43 cases) success rate observed at the preceding 3-month outcome. The failed cases and their characteristics are described in Table 1. The proportional hazards assumption was validated with time versus log-minus-log curves within each variable (Fig. 1*A* and *B*) before the Cox proportional hazard regression analysis.

Capping Material

The cumulative DPC success was calculated by Kaplan-Meier survival analysis according to the types of capping material, and the relevant survival curves were plotted (Fig. 2*A*). Both materials (ProRoot MTA and Endocem) exhibited success rates over 80%, and there was no significant difference between the treatment outcomes of the 2 materials when analyzed by the log-rank test (Table 2 and Fig. 2*A*) or Cox proportional hazard regression analysis (Table 3) ($P > .05$).

Failed Case Analysis and Other Clinical Variables

Two thirds of the failed cases (4/6 cases) had class V cavities that were caused by root caries. In this condition, log-rank tests were

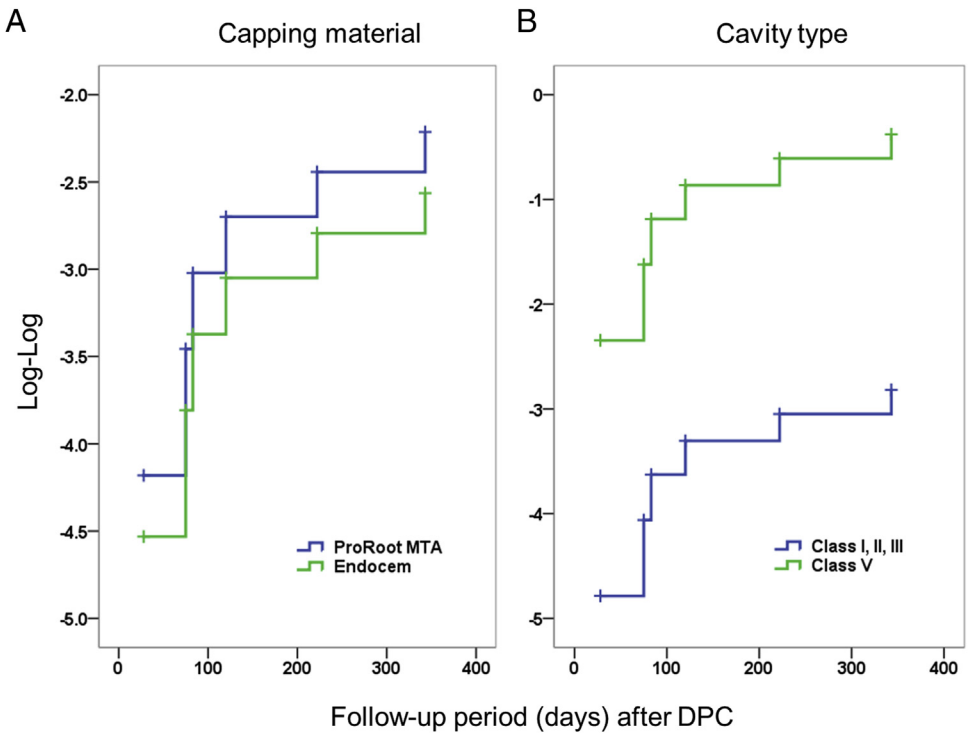

Figure 1. Time versus log-minus-log curves arranged according to (*A*) capping material and (*B*) cavity type.

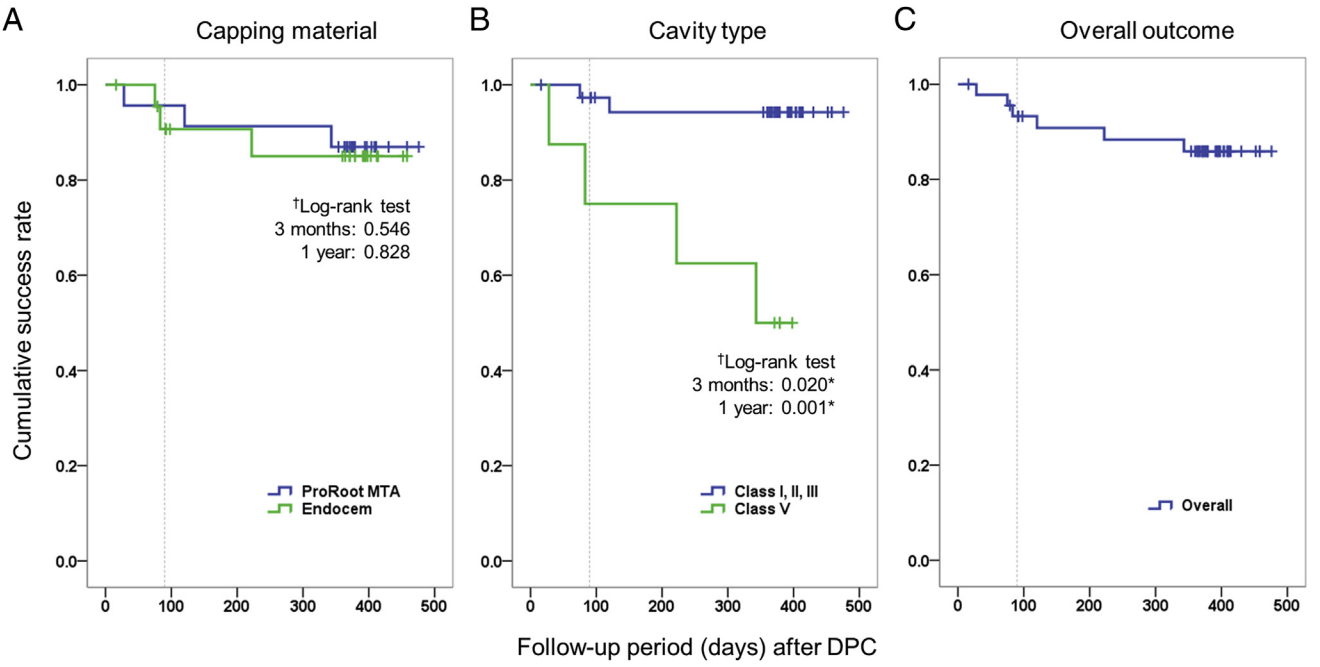

Figure 2. Kaplan-Meier survival curves arranged according to (*A*) capping material and (*B*) cavity type and survival curve of the (*C*) overall outcome. The *dotted lines* represent 3 months after the DPC. *Statistical significance was identified at $\alpha = 0.05$. †Cumulative success was compared by log-rank tests within capping material and cavity type at the follow-up periods of 3 months and 1 year.

additionally conducted to identify other potential prognostic factors; consequently, cavity type was verified as a significant variable at both the 3-month and 1-year follow-ups ($P < .05$) (Fig. 2*B*). Cox proportional hazard regression analysis also confirmed that cavity type was statistically significant at the 1-year follow-up ($P = .006$) (Table 3).

TABLE 2. Univariate Analysis of Potential Clinical Variables by Log-rank Test

	Censored (*n*, %)	Failed (*n*, %)	*P* value
†Age (y)			.071
≤42	23/24 (95.8)	1/24 (4.2)	
>42	17/22 (77.3)	5/22 (22.7)	
Sex			.874
Male	21/24 (87.5)	3/24 (12.5)	
Female	19/22 (86.4)	3/22 (13.6)	
Jaw			.805
Maxilla	25/29 (86.2)	4/29 (13.8)	
Mandible	15/17 (88.2)	2/17 (11.8)	
Tooth type			.939
Incisor and premolar	21/24 (87.5)	3/24 (12.5)	
Molar	19/22 (86.4)	3/22 (13.6)	
Preoperative symptom			.561
Asymptomatic (VAS = 0)	10/12 (83.3)	2/12 (16.7)	
Symptomatic (VAS ≥1)	30/34 (88.2)	4/34 (11.8)	
Cavity type			.001*
Class I, II, III	36/38 (94.7)	2/38 (5.3)	
Class V	4/8 (50)	4/8 (50)	
Capping material			.828
ProRoot MTA	20/23 (87)	3/23 (13)	
Endocem	20/23 (87)	3/23 (13)	

VAS, visual analog scale.

*Statistical significance was identified at $\alpha = 0.05$.

†When the age groups were divided based on the criterion of 40 years (age >40 or age ≤40), age was significant in the log-rank test ($P = .015$). However, in this classification, subsequent multivariate analysis with a Cox proportional hazard regression model, which consisted of the capping material, cavity type, and age, was not possible because the younger age group (age ≤40) did not include any failed cases ($n = 0$). Therefore, the age groups were reclassified on the basis of 42 years (age >42 or age ≤42), which was the median age of this study population.

Discussion

In this study, the clinical performances of ProRoot MTA and Endocem as pulp capping materials were evaluated for up to 1 year in a prospective, randomized controlled trial. The cumulative successes of both materials were not statistically different (Fig. 2*A* and Tables 2 and 3), which indicated the clinical potential of Endocem as a pulp capping material.

Because the clinical outcome of DPC with MTA has been verified, MTA is becoming a material of choice for DPC procedures (1, 5, 8–10, 25, 26). However, there are still several drawbacks of MTA that restrict the broader application of its use in DPC; the long setting time is one of these drawbacks. The setting time of ProRoot MTA has been reported to exceed 4 hours (15), which restricts the immediate sealing of the cavity with a bonded restoration in a single visit (14). Although MTA exhibits excellent resistance to bacterial leakage, it does not cover all dentinal tubules in the cavity when applied during the DPC procedure, which permits the possibility of bacterial penetration into the pulp. It should be noted that temporary filling materials exhibit satisfactory sealing only when sufficient cavity depth (over 3 mm) is retained (27), and in clinical situations, restorative cavities do not always provide sufficient cavity depth for the temporary filling materials. In this respect, Mente et al (8, 26) reported that the "time span before the placement of a permanent restoration after DPC" is a prognostic factor that influences the outcome of DPC (ie, when the time span increases to longer than 2 days, the success rate of DPC significantly decreases compared with a short time span before the placement of a permanent restoration [<2 days]). Therefore, Endocem seems to be a favorable alternative to conventional MTA as a capping material because it exhibits rapid setting (setting time less than 5 minutes)

TABLE 3. Multivariate Cox Proportional Hazard Regression Analysis of Selected Clinical Variables

Prognostic factor	OR	95% CI lower limit	95% CI upper limit	*P* value
Capping material				.677
ProRoot MTA	1	Reference		
Endocem	0.70	0.14	3.67	
Cavity type				.006*
Class I, II, III	1	Reference		
Class V	11.47	2.00	65.88	

CI, confidence interval; OR, odds ratio.

*Statistical significance was identified at $\alpha = 0.05$.

(15), which enables the immediate sealing of the cavity with bonded restoration and a single-visit completion of treatment.

Analysis of the failed cases suggests notable implications about the prognostic factors of DPC. Interestingly, two thirds of the failed cases (4/6 cases) were restored with class V cavities caused by root caries (Table 1), and a relatively high failure rate (50%) was identified within the class V cavity group compared with the groups with other types of cavities (Table 2). When analyzed by the log-rank test and Cox proportional hazard regression model, "cavity type" was highly significant ($P < .01$) (Tables 2 and 3). In clinical situations, proper sealing of the pulp exposure site might be limited in class V cavities because they typically do not provide sufficient cavity volume for both the capping materials and the subsequent bonded restorations (28, 29). Additionally, the cervical region adjacent to the alveolar bone crest is the place at which the tensile stress is concentrated under occlusal loading (30), which might cause subclinical bonding failure around any class V restoration. Therefore, the sealing quality of class V restorations might be reduced more rapidly compared with those of class I or II restorations, which would deteriorate the long-term prognosis of DPC (8). Actually, in this study, the cumulative success of the class V restoration group deteriorated more rapidly than the other groups as the follow-up time increased (Fig. 2*B*).

In this study, the majority of the failures occurred within the first 3 months (6.98% point cumulative failure) (19), but the failures occurred continuously in the period after 3 months up to 1 year (7.65% point cumulative failure) (Fig. 2*C*), which is consistent with the findings of previous clinical trials (1, 5, 8). Mente et al (8) reported that, although the outcomes of MTA pulp capping are more stable over time than those of calcium hydroxide pulp capping, MTA pulp capping still exhibits a time-dependent decline in cumulative success as the follow-up period increases. Another point to consider is that the short-term outcome of DPC might be strongly affected by prior pulpal conditions, disturbing the identification of other significant variables (5). Indeed, clinical trials that have confirmed significant differences between the performances of MTA and CH over long-term periods have often failed to reveal such a difference in short-term periods and exhibited similar survival curves for both materials for up to 3 or 6 months (1, 5, 8). Therefore, these results indicate that follow-up periods of at least 1 year are needed to assess the prognosis of MTA pulp capping.

The strength of this study is that all of the subjects went through thorough randomization that resulted in a uniform distribution of subjects between the 2 material groups in terms of the potential clinical variables, such as patient age, sex, tooth type, type of exposure, and site of exposure (19). Additionally, the entire research process, including patient enrollment and allocation, recall, and data analysis, was in accordance with the CONSORT 2010 statement, which has been reported to be associated with an improved quality of reporting of randomized controlled trials (31, 32). However, because of the strict eligible criteria, this study was conducted with a relatively small sample size, which might have reduced the statistical power of this clinical trial. In this regard, further clinical trials and meta-analyses of such trials are required to enrich our understanding of the prognosis of DPC.

In conclusion, this study identified no significant differences in the 1-year cumulative successes of Endocem and ProRoot MTA as direct pulp capping materials, and this study also suggests that the cumulative success of DPC might be reduced in teeth restored with class V cavities compared with teeth restored with other types of cavities. Compared with the preceding 3-month outcomes, it appears that a follow-up period of at least 1 year is required to assess the prognosis of MTA pulp capping.

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

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