Original Article

Clinical Assessment of Mineral Trioxide Aggregate in the Treatment of Deep Carious Lesions

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Abstract

Objective: This clinical study aimed to assess the effectiveness of mineral trioxide aggregate (MTA) and calcium hydroxide ($Ca[OH]_2$) in the treatment of deep carious lesions using the direct complete caries excavation technique. **Subjects and Methods:** Hundred permanent molars/premolars were capped either with $Ca(OH)_2$ (n = 49) or MTA (n = 51) and restored with composite resin in 73 patients. Periapical radiographs were taken prior to the treatment, at 6 months and 12 months. Two calibrated examiners clinically and radiographically assessed the periapical pathology and pulpal symptoms. Inter-group comparisons of the observed values were analyzed using Fisher's exact test. Significance was predetermined at $\alpha = 0.05$. **Results:** Recall rates were 100% at 6 and 12 months. Four teeth capped with $Ca(OH)_2$ (two each at the end of 6 and 12 months) and one tooth capped with MTA (at the end of 12 months) received endodontic emergency treatment because of symptoms of irreversible pulpitis that were clinically and/or radiographically established. There was no significant difference between the protection of the tooth vitality and pulp capping agents at 6 and 12 months (P = 0.238, P = 0.606, respectively). **Conclusion:** Both materials were clinically applicable at the end of 12 months.

Keywords: *Calcium hydroxide, complete caries excavation, deep carious lesions, mineral trioxide aggregate, pulp capping*

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Introduction

Infected deep carious lesions can be clinically managed either by an attempt to preserve the tooth tissue or by performing root canal therapy. Preserving the dental pulp vitality is important during the treatment of deep carious lesions. A conservative approach can still produce a favorable prognosis for pulpal healing. Some alternative approaches for the treatment of deep carious lesions include stepwise excavation, indirect pulp capping, and partial caries removal. Whereas complete excavation aims at removing all infected and affected carious dentin, stepwise excavation allows carious dentin to remain during the initial excavation step, seals the whole cavity with a temporary restoration, and then re-enters the cavity to complete excavation.[1] Dilemmas regarding stepwise caries excavation still continue because of the risk of pulp exposure during the removal of temporary filling, requirement to re-enter, and high costs of treatment as two or more appointments are required.[1-3] Furthermore, according to the outcome of a previous histological study, infected dentin should be completely removed to arrest the carious process.[4]

The direct complete excavation technique is preferred by the majority of professionals for the treatment of deep carious lesions.[3,5] This is a procedure in which the pulp is covered with a protective base where the remaining dentin thickness is ≤0.5 mm.

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Different materials could be used in the treatment of deep carious lesions for maintaining pulp vitality. This includes calcium hydroxide ($Ca[OH]_2$) that is regarded as the gold standard;[6] however, several disadvantages have been reported, including high solubility in oral fluids[7] and the formation of tunnel defects in dentin bridges, leading to failure over time.[8,9] New materials have been tested as alternatives to $Ca(OH)_2$, including mineral trioxide aggregate (MTA). After the approval of MTA by the US Food and Drug Administration, the use of this material has expanded and offers promising results in many areas, particularly indirect pulp capping, although it was first introduced as a root canal filling material in 1993.[10] This material is essentially composed of Portland cement and bismuth oxide at 4:1 proportions[11] and is capable of releasing calcium ions into the environment.[12] MTA has been well studied in experiments and offers good sealing ability[13] and bio-compatibility,[14] which is resistant to bacterial penetration and is insoluble, in contrast to $Ca(OH)_2$ that resorbs over time.[15] Witherspoon[16] reported that MTA was an optimum material to use in vital pulp therapy. These advantages have directed investigators to evaluate the possibility of its use as an alternative to $Ca(OH)_2$ in pulp capping.

Comparative studies on the treatment of deep carious lesions have been previously performed;[17] however, only a few studies have compared the efficacy of MTA and $Ca(OH)_2$ in the treatment of deep carious lesions.[18] This clinical study aimed to assess the effectiveness of MTA versus $Ca(OH)_2$ (control group) as indirect pulp capping materials using the complete caries excavation technique in patients with deep carious lesions. The null hypothesis tested was that no significant difference would be observed in pulps capped with MTA or $Ca(OH)_2$ during 6 and 12 months.

Subjects and Methods

In this single-blinded, randomized controlled clinical trial, MTA was evaluated as the test material and $Ca(OH)_2$ as the control. This study was not operator blinded because of the different application procedures of the materials.

This clinical study was approved by the Committee of the Ethics of Interventional Human Experimentation, University of Hacettepe, Turkey. Informed written consents were obtained from all participants after they were clearly informed regarding the reporting of their pain background and how the reporting could affect the treatment planning they received. This research has been conducted in full accordance with the World Medical Association Declaration of Helsinki.

The study population comprised patients who were admitted to the outpatient clinic at the Department of Restorative Dentistry, Hacettepe University, Ankara, Turkey, and who were suffering from deep carious lesions. A single operator, trained to standardize the procedures, performed all restorative treatments. The methods of clinical assessment included the electronic pulp test (Parkell, Farmingdale, NY, USA); thermal test via an air–water syringe, palpation, and percussion; and the presence of signs of inflammation. Periapical radiographs were taken prior to the treatment, at baseline (1 week), 6 months, and 12 months and were assessed to exclude any signs of irreversible pulpitis. All the teeth were clinically and radiographically examined to ensure the absence of widening of the periodontal ligament or periapical lesions.

The inclusion criteria were deep carious lesions involving 75% or more of the dentin without pulp exposure, restorable permanent posterior teeth without a history of spontaneous and severe pain, abscesses, and a sinus tract or the presence of other clinical signs of irreversible pulpitis. A maximum of two teeth per patient were included in this study. A simple randomization was used, and the first tooth selected was assigned to MTA, whereas the second was alternatively assigned to $Ca(OH)_2$.

The isolation was performed using a saliva ejector and cotton rolls. Cavities were prepared by means of sterile diamond burs at high speed under water cooling. After gaining suitable access through the cavitated enamel, superficial, soft, and infected dentin was excavated using sharp hand tools, particularly wide spoon excavators. The remaining caries were removed using a single-use steel bur applied at a low speed to avoid pulp exposure. Patients were asked whether they experienced severe sensitivity or pain during the preparation period, and if required, a local anesthetic was administered. When pulp exposure developed, these teeth were excluded from the study.

The teeth were then divided into two experimental groups. For group I, the pulp capping material used was $Ca(OH)_2$ (Dycal, Dentsply/Caulk, Dentsply International, Inc., Milford, Del), whereas, in group II, MTA was used. If two teeth were restored in one patient, one of the teeth was capped with MTA, whereas the other was capped with $Ca(OH)_2$.

All materials were applied according to the instructions of the manufacturer. MTA powder was mixed with its

respective solution, and $Ca(OH)_2$ paste was mixed at a ratio of 1:1. Materials were placed on the deepest part of the cavity, and no pressure was applied to avoid pulp exposure. Only light pressure was applied on MTA material with a wet cotton pellet for adaptation of the material onto the dentin. When necessary, the excess material was carefully removed using hand instruments.

Following the application of the pulp capping materials, light-cured glass ionomer cement base (Riva Light Cure, Southern Dental Industries [SDI]) was applied and light-cured for 20 s (light emitting diode [LED], Radii Plus, SDI, Australia). The teeth were then etched with 37% phosphoric acid for 30 s, and one bottle adhesive system Prime and Bond NT (Dentsply Detrey, Konstanz, Germany) was used. Microfilled hybrid composite resin material (Gradia Direct Posterior, GC) was then incrementally inserted into the cavities and light-cured for 20 s with the same LED device. Restoration was completed and polished using diamond composite finishing burs, discs, and rubber cons. Phosphor plates were taken with a dental X-ray unit (Sorodex, 70 kVp, 7 mA, Tuusula, Finland) using a paralleling technique with Rinn film holders permitting standardization.

Patients were informed of recall appointments at baseline (1 week), 6 months, and 12 months.

During the observation periods, two calibrated and experienced dentists assessed all subjective symptoms, such as pain or tooth sensitivity to various stimuli. They recorded the case as clinically successful when pulp vitality was observed with a normal response to thermal, electrical, and tactile tests without signs of spontaneous pain. When radiolucency and periodontal ligament space widening were not present, the treatment was considered to be radiographically successful.

Data were statistically analyzed using Chi-square, frequencies, and Fisher's exact tests. Significance was predetermined at $\alpha = 0.05$.

Results

A sample of 100 permanent molar/premolar teeth were capped either with $Ca(OH)_2$ (n = 49) or MTA (n = 51) randomly and restored with composite resin in 73 patients, comprising 47 women (64.4%) and 26 men (35.6%), with ages ranging between 18 and 30 years. The mean age was 21 years (X ± SS = 20.93 ± 3.48). The recall rate was 100% at 6 and 12 months. Molars accounted for 62% of the total treated teeth. The distributions of teeth included in the current study are shown in Table 1.

Table 1: Distribution of tooth type by location

Dental arch	Tooth type	*n* (%)
$Ca(OH)_2$ (*n*=49)		
Upper (*n*=29)	Premolar	16 (16.0)
	Molar	13 (13.0)
Lower (*n*=20)	Premolar	7 (7.0)
	Molar	13 (13.0)
MTA (*n*=51)		
Upper (*n*=23)	Premolar	10 (10.0)
	Molar	13 (13.0)
Lower (*n*=28)	Premolar	5 (5.0)
	Molar	23 (23.0)
Total		100 (100)

MTA=Mineral trioxide aggregate; $Ca(OH)_2$=Calcium hydroxide

Table 2: Clinical assessment of tooth vitality distribution

Time interval	Pulp vitality *n* (%)	*P*
$Ca(OH)_2$ (*n*=49)		
6 months	47 (95.9)	0.238
12 months	45 (95.7)	
MTA (*n*=51)		
6 months	51 (100)	0.606
12 months	50 (98.0)	

MTA=Mineral trioxide aggregate; $Ca(OH)_2$=Calcium hydroxide

Four teeth capped with $Ca(OH)_2$ (two each at the end of 6 and 12 months) and one tooth capped with MTA (at the end of 12 months) received endodontic emergency treatment because of symptoms of irreversible pulpitis that were clinically and/or radiographically established [Table 2].

The success rate of pulp vitality was 89.8% for $Ca(OH)_2$ and 98% for MTA at the end of 12 months. The Fisher's exact test revealed no significant statistical differences between pulp vitality and the type of capping material used ($P > 0.05$) [Table 2]. A correlation between the presence of symptom(s) at pretreatment and the maintenance of pulp vitality was not found to be significant ($P = 0.279$).

At the end of 12 months, the frequency of observed symptoms reduced in the MTA Group but increased in the $Ca(OH)_2$ group. However, there was no significant relationship between the pulp capping material and frequency of symptoms observed at 6 and 12 months ($P = 0.588$ and $P = 0.087$, respectively). The most observed symptom was sensitivity to cold air, and the symptoms are summarized in Table 3.

Table 3: Clinical assessment of the distribution of symptoms for $Ca(OH)_2$ and MTA at pretreatment, baseline, 6 months and 12 months

Sensitivity	MTA				$Ca(OH)_2$			
	Pretreatment	Baseline	6 months	12 months	Pretreatment	Baseline	6 months	12 months
Cold	24	7	5	3	17	6	2	7
Hot	16	1	-	-	6	2	-	1
Bite	7	-	-	-	4	2	1	1
Percussion	16	1	2	1	10	2	2	1

MTA=Mineral trioxide aggregate; $Ca(OH)_2$=Calcium hydroxide

In the current study, restoration failure did not occur in both the groups because of the loss of materials.

Discussion

In this clinical study, MTA efficiency was clinically and radiographically compared with $Ca(OH)_2$ when using the direct complete excavation technique for the treatment of teeth diagnosed with deep dentin carious lesions with reversible pulpitis.

While dilemmas regarding diagnosis between reversible and irreversible pulpitis still continue, the severity of pain does not absolutely reflect pulp histopathology. Studies have reported that the more severe the pain, the worse the histopathosis;[19] however, this is not always the case.[20] Nonetheless, symptom intensity is subjective, and patients can exaggerate severity. In this study, results revealed no significant correlation between the symptom intensity and treatment outcome. It is usual to observe symptoms after treatment because of the remaining thin dentin layer. Accorinte Mde *et al*.[21] investigated the histomorphological response of human dental pulp capped with MTA and $Ca(OH)_2$ cement and reported that 2 months after the treatment, both materials provided similar results, although pulp healing using $Ca(OH)_2$ was slower than that of MTA. In this study, while symptoms were increased in the $Ca(OH)_2$ group, they were reduced in the MTA group after 12 months. Although histopathological findings are regarded as the gold standard,[22] a standard histological reference to compare these two materials was not possible because of the design of this study. In addition, early histological changes in the periapical hard tissues may not be visible in periapical radiographs.

According to the literature, different treatment options for the treatment of deep carious lesions exist. In many studies, direct complete caries excavation was the preferred treatment method[3,23-25] In Turkey, direct complete caries excavation is the most popular technique. It was reported that complete caries excavation is the most preferred technique among the private practicing dentists in the capital city, Ankara.[26] However, the literature provides conflicting results. At the end of 12 months follow-up for the treatment of deep carious lesion, Leksell *et al*.[27] reported more successful results using stepwise excavation than using complete caries excavation, whereas Orhan *et al*.[25] and Franzon *et al*.[28] reported more successful results for complete caries excavation. The latter two studies used the same technique termed as direct complete caries excavation, and our results revealed a positive correlation with theirs. In this study, the success rate was 95% at the end of 12 months.

Many studies have compared the treatment outcome of pulp capping with MTA and $Ca(OH)_2$. Comparative studies have been mostly performed on exposed pulp tissue in the human or animal tooth. Results of these studies underlined the success of MTA in both the animal[29] and human teeth.[14,15] Treatment with MTA was found to be more successful with faster pulp healing[21] and less inflammation, hyperemia, and necrosis and with a thicker dentinal bridge and more frequent odontoblastic layer formation than other palp-capping materials.[10] Mente *et al*.[30] reported increased risk of failure for teeth that were directly pulp capped with $Ca(OH)_2$ as compared with MTA. In a study conducted by Leye Benoist *et al*.,[18] which compared $Ca(OH)_2$ and MTA on indirect pulp capping, no statistically significant difference in the dentin thickness and success rate at the end of 6 months was reported; however, MTA was more successful than $Ca(OH)_2$. The success rate reported in this study is supported by the results of the aforementioned study.

In this study, no significant difference between pulp vitality and MTA/$Ca(OH)_2$ was found; however, MTA was more successful than $Ca(OH)_2$ at the 12 months follow-up. The high success rate achieved in this study may be attributed to the 8 weeks continuous high pH level (12.5) of MTA. The hard dentin tissue barrier forms earlier when using MTA than when using $Ca(OH)_2$. It is reported that following MTA application, cellular dentin appeared within 3 weeks, and the formation of a tight seal prevents bacterial penetration into the pulp.[31] These features of MTA are useful for the treatment of deep dentin caries.

$Ca(OH)_2$ is ready to use as paste is easier whenn compared to MTA. This advantage has maintained the

popularity of $Ca(OH)_2$. Although many advantages of using MTA exist, there are difficulties in mixing or handling MTA because of the sandy consistency, transport, and adaptation of the cavity, discoloration of tooth, and prolonged setting time; thus, MTA may not be preferred by some dental practitioners. Using current technology, capsulated MTA can be produced, and the material can be mechanically mixed. These recent advantages may increase MTA popularity in the future.

In this study, MTA was applied using hand instruments and immediately lined with light-curing glass ionomer cement to overcome prolonged setting time. The final attempt was conducted to permanently restore the teeth. It should be emphasized that a well-diagnosed condition of the pulp and sealed restorations are basic necessities for success of pulp vitality of teeth treated with the direct complete caries excavation technique. The high success rate achieved regardless of the materials used in the current study confirmed that carious dentin removal and subsequently permanent restoration placement provides a good marginal seal in all teeth.

Conclusion

Both materials were clinically applicable at the end of 12 months. The consideration of prevalence of symptoms is important for patient comfort, and in this respect, it appeared that MTA was associated with fewer symptoms than $Ca(OH)_2$. This should be kept in mind during treatment. Further clinical research is required to confirm the results of the current study.

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Conflicts of interest

There are no conflicts of interest.

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