

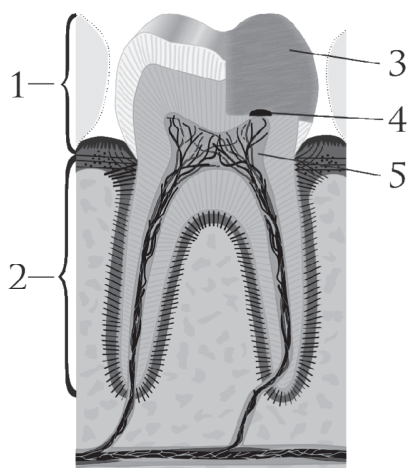
**PULP CAPPING WITH MINERAL TRIOXIDE AGGREGATE AT PULP EXPOSURE**

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This article is a fragment of the search topic.

**Introduction.** To prevent the pulp from deteriorating when a dental restoration gets near the pulp, the dentist will place a small amount of a sedative dressing, such as MTA. This material, protect the pulp from noxious agents (heat, cold and bacteria) and stimulate the cell-rich zone of the pulp to lay down a bridge of reparative dentin. Dentin formation usually starts within 30 days of the pulp capping (there can be a delay in onset of dentin formation if the odontoblasts of the pulp are injured during cavity removal) and is largely completed by 130 days (**Figure 1**).



**Figure 1.**  
Sedative material placed over exposed or nearly exposed pulp:  
1) crown 2) root 3) restoration  
4) pulp cap 5) pulp chamber

Carious pulp exposure presents a treatment dilemma for dentists. Treatment options include reliable, but expensive endodontics and affordable, but irrevocable extraction. Another alternative is a direct pulp cap the treatment of an exposed vital pulp with a dental material to facilitate the formation of reparative dentin and maintenance of a vital pulp [10] prior to placement of a direct restoration. However, there is conflicting data regarding pulp capping outcomes [1,22]. While the sequel of unsuccessful pulp capping are well established, that is often painful, irreversible pulpitis or clinically silent pulpal necrosis, the factors that lead to those outcomes are not as clear. It appears that material choices, such as zinc phosphate cement [2], zinc oxide eugenol cements [17], polycarbonate cements [12], glass-ionomer cements [7], resin adhesives [11] and cyanoacrylates [7]

do not lead to predictable success for the treatment of exposed pulps.

Outcomes with calcium hydroxide were superior but unpredictable for carious pulp exposure [1,17,3]. Retrospective analysis of pulp caps with calcium hydroxide showed a 44.5% failure rate after five years and a 79.7% failure rate after 10 years [4].

A new pulp capping material Mineral Trioxide Aggregate (MTA) was introduced. Current results suggest better postoperative outcomes when applied by an experienced clinician [5]. One factor contributing to more favourable results with both calcium hydroxide and MTA may be an antibacterial effect directed against microorganisms, and specifically their toxins. One of the vexing aspects of calcium hydroxide pulp capping therapy has been the fact that such treatments may eventually fail after early success. Several factors have been described for this phenomenon; the solubility of calcium hydroxide, even in products that feature a setting reaction [20].

Reparative dentin near the calcium hydroxide pulpal interface is likely produced by odontoblast like cells stemming from undifferentiated pulp cells [18].

These cells must replace destroyed mature odontoblasts in the presence of live bacteria and operative debris [13]. Even when the initial pulpal response is favourable, any reparative dentin formed in this situation is often associated with so called "tunnel defects" [8]. Microleakage of the coronal restoration then allows bacteria to migrate into pulp and initiate degenerative pathosis [15].

MTA has proven to be one of a very few exogenous materials that is not only well tolerated by connective tissues [19], but also contributes to a bacteria tight seal [21].

Both properties suggest that an application of MTA as a pulp capping material may be clinically successful under the conditions of minimal bacterial exposure. Indeed, several studies document that MTA is an effective material for direct pulp capping [16,6] and pulpotomy in deciduous teeth.

Excellent tissue healing has been observed over the useful life of the deciduous teeth and no adverse effects were noted on exfoliation or the eruption of succedaneous teeth.

Pulp capping in permanent teeth is less well understood and case reports dominate the literature. An exception is a recent study that reports on the outcome of 49 pulp caps performed by a single operator in a carefully controlled setting [12]. While such control is desir-

able, pulpal diagnoses and clinical application procedures vary widely across clinicians.

**Materials and Methods.** All treatments were performed under routine faculty supervision. Supervising faculty consisted of members of the Department of Restorative Dentistry of Dental School, Shiraz University of Medical Science (Iran). Students at the dental school are taught to remove caries methodically, establishing caries-free margins prior to excavating dentin close to the pulp. If a student suspects that further caries removal risks pulp exposure, faculty may recommend placing glass-ionomer cement as an indirect pulp cap. It is standard process at the academy for a student discovering a pulp exposure in the process of removing caries to ask for an endodontic consult.

Of the 84 teeth with pulp exposure in 30 patients that were included in the current study by clinical evaluation. Performing a pulpectomy is typically suggested upon frank exposure of the pulp, but a pulp cap using MTA is also routinely considered. Pulp capping with MTA at pulp exposure was used for 51 teeth in 11 patients. Patient ages ranged from 21 to 58 years. Treatment is then provided by students under the direct supervision of Restorative Department.

In the students participating in the current study were informed in detail about the study design; they were given an assessment form to document demographical and clinical data. In the students were asked to judge pulp exposure size as "minimal" (barely visible), "moderate" (up to 1mm) or "large" (> 1mm) and the amount of bleeding was classified as "none", "minimal" (barely visible), "moderate" (controlled with dry cotton pellet) or "significant" (difficult to control).

Follow up appointments were prescribed after 1,5, 2-3, 6, and 8 months. After 6 months the teeth were examined blind and independently by two assessors (K.M. and A.A.) and afterwards reviewed together.

**Treatment Guidelines.** The guidelines cautioned that direct pulp capping has not been proven to be a reliable procedure but suggested the use of MTA when the following conditions were present:

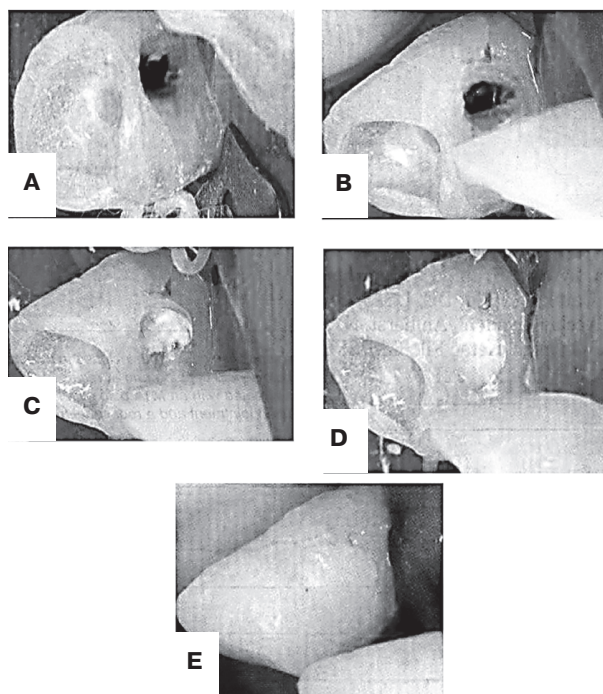
- no difficulty controlling bleeding from exposure.
- pin point should be up than 1mm exposure after caries has been removed.
- no treatment plan for a laboratory-fabricated prosthesis that is placed on the tooth.
- asymptomatic teeth without a history of pain.

In **figure 2**, illustrates the clinical procedures suggested in the guidelines that were employed in the current study. The teeth selected to receive MTA pulp caps first had bleeding controlled by placement of a cotton pellet moistened with 2.5% sodium hypochlorite. No further excavation of the exposure site was carried out at that time; that is, no attempt was made to fully remove carious dentin as soon as a bleeding pulp was observed. Care was taken to minimize the time to control bleeding and the time between exposure and application of the pulp capping material. MTA was mixed with an anaesthetic solution (2% lidocaine with 1:100,000 epinephrin). A thin layer of the mix was placed over the exposure. A resin-modified glass-ionomer lining material was mixed and immediately placed to completely cover the layer of MTA. After the liner was cured, prepa-

ration of the tooth for a direct restoration was completed and either Composite or glass-ionomer restorations were placed. Postoperative radiographs were not routinely taken.

**Patients.** 1.5 months later after each procedure was performed, attempts were made to have the patient return for a follow up appointment. Additional contemporary information about cases was gathered from clinic records identifying tooth that had since undergone endodontic treatment (n = 19) or extraction (n = 1). Records were examined to ascertain the reason for these subsequent procedures, whether the patient experienced symptoms consistent with irreversible pulpitis (n = 15) or restorative considerations required a more predictable foundation (n = 5). The reason for the subsequent treatment was established by examination of each patient's record and it was entered into the data for the study.

Subtracting those teeth (n = 20) left 31 teeth with "at-risk" pulp status, which were recalled for a follow up appointment after 2-3 months. Patients who responded were offered monetary compensation for their participation; those who consented to participation were interviewed as to their postoperative symptoms. Patients were asked about the type, severity and duration of any pain experienced after treatment. A periapical radiograph was taken with a 0.25 second exposure. Pulp sensitivity of the treated teeth was assessed with ethylene chloride on a cotton swab and with an electrical pulp tester. The teeth were considered vital if either cold testing or electrical testing showed a positive response. Recall radiographs were compared to preoperative films



**Figure 2.** Clinical procedures stipulated by the guidelines used in the current study. Pulp exposures (A) were cleaned with 2.5% NaOCl (B) after haemostasis was achieved, MTA was applied (C) which was then covered with a light-curing glass-ionomer (D). In the same appointment a definitive restoration was placed (E)

and interpreted for the absence or presence of apical pathology. At recall after 6 and 8 months, only 11 patients were clinically and radiographically assessed. All clinical tests, evaluations and radiographic assessments were done by a single clinician. Data was collected after approval of the study protocol by Dental School, Shiraz University of Medical Science.

**Results.** Pulp caps were done in 8 incisors, 5 canines, 15 premolars and 23 molars. Out of the 51 teeth with available postoperative data, 24 were restored with composite, 27 with glass-ionomer. **Table 1** includes preoperative variables determined from a questionnaire answered by the treating student clinicians after the pulp cap had been done. **Table 2** includes results from pulp testing on 31 teeth. These teeth were tested at a minimum of 2 months and as much as 3 months after placement of the pulp cap. Three of the tooth tested negative with both Endo Ice and an electric pulp tester. None of these teeth were symptomatic.

Twenty-eight teeth tested positive with an electric pulp tester, while 22 responded to cold testing (**Table 2**). Eight of the patients interviewed reported mild to moderate postoperative sensitivity from the pulp capped teeth immediately after the pulp cap had been performed. Sensitivity persisted for more than six weeks in five of those cases. Data collected through the Dental School's computerized patient management system had identified 20 teeth in the cohort of participating patients who had been treated with endodontic therapy or extraction following pulp capping. Chart entries indicated that 16 of these teeth were treated due to postoperative symptoms consistent with irreversible

pulpitis or pulpal necrosis (15 root canal treatments, one extraction). The other four teeth received intentional endodontic treatment preparatory to definitive prosthodontic treatment.

All of the 31 teeth had radiographically normal periapical tissues (**Figure 3**). At recall after 6 months, 11 patients were clinically and radiographically assessed. Totally, 6 months pulp survival was 67.7%, while the 8 months survival rate was 56.2%.

**Discussion.** The current study confirms that placing a direct pulp cap with MTA over a carious exposure in a mature permanent tooth may be a reasonable alternative to root canal therapy or extraction. However, it also showed that, when performed by practitioners inexperienced in handling the material and in non-standardized clinical situations, the pulp caps in the current study had a 32% failure rate after 6 months. Lower failure rates

Table 2.

**Clinical and Radiographic observations at recall interview of patients with MTA pulp caps**

	Teeth (recalled patients)
<b>Postoperative condition</b>	31
<b>Asymptomatic</b>	23 (74%)
<b>Cold sensitivity</b>	7 (23%)
<b>Heat sensitivity</b>	0
<b>Biting sensitivity</b>	1 (3%)
<b>Percussion sensitivity</b>	1 (3%)
<b>Spontaneous pain</b>	1 (3%)
<b>Intensity of pain</b>	
Mild	5 (16%)
Moderate	3 (10%)
Extreme	0
<b>Duration of pain</b>	
< 1 day	1 (3%)
1-6 days	2 (6%)
1-6 weeks	1 (3%)
> 6 weeks	5 (16%)
<b>Soft tissue</b>	
Local swelling	1 (3%)
Local tenderness	1 (3%)
Local inflammation	0
Within normal limits	30 (97%)
<b>Cold test</b>	
Positive-normal	22 (71%)
Positive-hypersensitive	3 (10%)
Positive-lingering	0
Negative	6 (19%)
<b>EPT</b>	
Response	27 (87%)
No response	4 (13%)
<b>Radiographic evaluation</b>	
No pathosis	31 (100%)
Radiolucency	0

Table 1.

**Preoperative variables determined from a Questionnaire answered by the treating student clinicians after the pulp cap had been done**

Preoperative variables	Number of primary teeth	Number of teeth for pulp cap
<b>Pre-operative condition</b>	84	51
<b>Asymptomatic</b>	60 (80%)	38 (76%)
<b>Cold sensitivity</b>	14 (19%)	9 (21%)
<b>Heat sensitivity</b>	3 (4%)	4 (8%)
<b>Biting sensitivity</b>	8 (10%)	4 (8%)
<b>Percussion sensitivity</b>	3 (4%)	3 (6%)
<b>Spontaneous pain</b>	3 (4%)	3 (6%)
<b>Size of exposure</b>		
Minimal(barely visible)	52 (70%)	34 (67%)
Moderate(up to 1mm)	21 (28%)	16 (31%)
Large(>1mm)	2 (2%)	1 (2%)
<b>Bleeding</b>		
None	22 (29%)	16 (31%)
Minimal	47 (63%)	31 (61%)
Moderate	6 (8%)	4 (8%)
Significant	0	0

Note: Numbers in parentheses are percentages relative to.

of 2% [5] and 7% [20] have been documented in two clinical studies on carious pulp exposures with similar follow up periods, a possible explanation for this apparent conflict is that the earlier studies showing more predictable results were performed under more controlled clinical conditions, including a single operator.

The current study included factors that are believed to give indications of the health and healing capacity of pulp tissues prior to treatment: age of the patient, symptoms associated with the tooth, preoperative restorative status and radiographic appearance. Each of these factors has been cited in the literature as having some relevance in the ability of a pulp to recover from a pulp exposure (carious or otherwise), but none has been shown to be reliably predictive.

Survival curves are usually concave, showing a steep initial failure rate and a flattening in the right-hand tail. The expected asymptote in survival rate of the pulp capping procedure was observed in the current study. There was, however, no clear evidence of an initial steep decline in survival (except perhaps for the six cases of "moderate" bleeding). This is customarily interpreted to mean that there is no interaction between the conditions that qualify patients for treatment and the treatment itself. There was no evidence that treatment with MTA had any direct adverse effects; moreover, there was no evidence that patients who are candidates for this therapy presented challenges for subsequent restorative procedures.

The authors of the current study expected that outcomes of carious pulp exposures capped with MTA would be affected by preoperative conditions (that is case selection). However, this is not reflected in the results of the current study. Some students elected to slightly deviate from the suggested guideline and elected to perform MTA pulp caps on patients who reported preoperative symptoms. However, the authors of the current study did not observe different outcomes from these pulp caps compared to patients without preoperative symptoms.

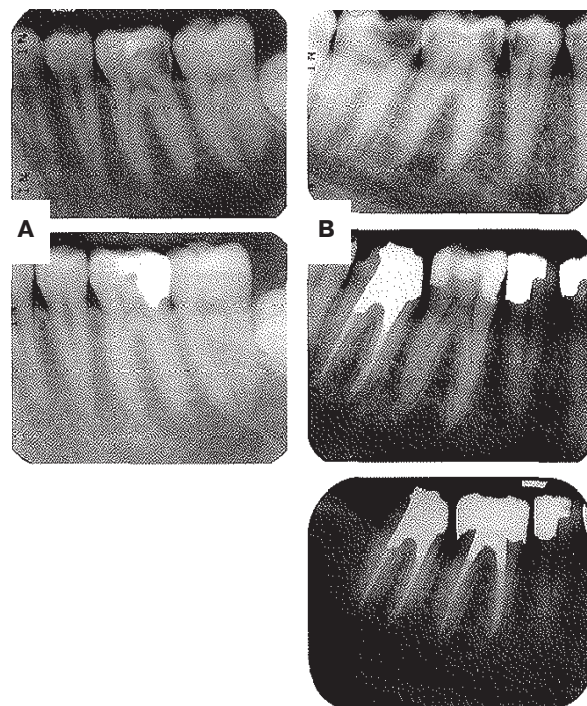
Moreover, the authors saw no significant difference in survival of teeth that students identified as having a "minimal" exposure compared to those having a "moderate" exposure. Of the two exposures characterized as having a "large" exposure, one failed and one was lost to recall.

The same holds true for the survival rates of tooth when intraoperative bleeding was described as "none" compared to "minimal" or "moderate". None of the teeth had bleeding described as "significant".

The age of the patient was also not a significant factor in success of the treatment. It is well documented that teeth lacking apical closure respond well to direct pulp treatment (pulp cap, partial pulpectomy or pulpotomy) [15,6,9].

All of the teeth in the current study had complete root formation; therefore, direct comparisons to teeth with immature apices cannot be made. However, the results of the current study suggest that changes in pulp physiology occurring after completed root formation do not affect the ability of the pulp to tolerate pulp capping.

The authors of the current study must acknowledge considerable, but unquantifiable variation in technique.



**Figure 3. Examples of radiographic appearance of teeth included in this study. A) case 1 (tooth 19) showed no apical pathosis before pulp capping and at recall. B) case 2 (tooth 30) tested positive to cold initially and was treated with MTA pulp cap.**

While seven students contributed more than one procedure to this study, most were working with mineral trioxide aggregate for the first time. MTA is a material that is unlike any other dental material students are trained to use. It is unique in its sand-like consistency and in its hours-long setting reaction.

Other unknowns in student technique include caries removal and the use of sodium hypochlorite. Students may not always be methodical or meticulous in their caries removal; infected dentin in contact with pulp tissue is likely to encourage inflammation and discourage reparative dentin formation. The use of sodium hypochlorite for haemostasis and disinfection is recommended in the school's guidelines for MTA pulp caps and is cited by several authors as being critical to the success of this procedure [23]. Others preferred a cotton pellet moistened with sterile saline for this step. The authors do not know if the students used sodium hypochlorite consistently in the cases they followed and cannot rule out the possibility that failure to perform this step contributed to the relatively high failure rate.

There are three plausible reasons for failure to detect statistically significant differences for patient age, extent of bleeding or size of exposure as factors predictive of survival rate of the procedure. Survival analysis tests are inherently underpowered. A sample size of 50 is small for purposes of this research. Second, no follow up data were available on patients other than at their last visit. In survival analysis, positive results are «censored» at their last known positive state and nothing further is concluded about survival. Several studies on the effectiveness of MTA as a direct pulp capping mate-

rial in permanent teeth followed the clinical guidelines proven to be most successful in calcium hydroxide pulp capping studies.

These included studies of experimentally created mechanical pulp exposures and immature permanent teeth. Several of these studies directly compared MTA to calcium hydroxide and all found MTA to be effective as a pulp capping material; several authors found comparable or better outcomes for MTA compared to Ca(OH)<sub>2</sub> pulp caps. The most common application for direct pulp caps has been the least studied and has generally been expected to be the least predictable that of carious pulp exposures on fully formed permanent teeth. The most through study of this clinical circumstance was recently presented by Bogen G. et al. [12]. In their study, a single operator, using a carefully standardized technique, placed direct pulp caps on 49 teeth using MTA. Followed for a period of one to seven years, 97% of the teeth that were treated tested positive for pulp vitality without persistent sensitivity. This was a very encouraging clinical result.

In the current study, outcomes were far less consistent and showed independence from the preoperative conditions, such as patient age, exposure size and extent of bleeding. Pulp cap with MTA was performed at 51 permanent teeth. 20 from these 51 teeth dropouted after 1,5 months for irreversible pulpitis (n = 15) or restorative considerations required a more predictable foundation (n = 5). At recall after 6 months, 11 patients with pulp caps were clinically and radiographically assessed. Totally, 6 months pulp survival was 67.7%, while the 8 months survival rate was 56.2%.

**Conclusions.** Within the limitations of the current study by student clinicians, it may be concluded that, for MTA placed on carious pulp exposures, several preoperative conditions patient age, exposure size and amount of bleeding are not predictive of clinical outcome. Considering the comparatively low success rate for the current patient cohort, a prospective clinical study with a larger sample size is needed to define predictive criteria for successful pulp capping with MTA.

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### НАКЛАДЕННЯ МІНЕРАЛ ТРИОКСИД АГРЕГАТУ ПРИ ВИПАДКОВОМУ РОЗКРИТТІ ПУЛЬПИ

**Масуд Кіані, Янко Наталія, Мохамед Сеєд Ахмед, Алі Аманібені**

**Резюме.** Ефект мінерал триоксид агрегату (МТА) при прямому покритті пульпи полягає в стимуляції утворення репаративного дентину протягом 1-4 місяців. Накладення МТА на розкриту точку пульпи діаметром до 1 мм при її розкритті під час препарування глибокого карієсу проводилося при можливості контролювати кровотечу з пульпової камери і відсутності болю в зубі в анамнезі. 23 з 31 зуба через 2-3 місяці після покриття не мали симптомів (74%), всі зуби не мали патологічних змін на рентгенограмі. Через 6 місяців ефективність покриття з МТА складала 67,7%, через 8 місяців – 56,2%.

**Ключові слова:** покриття пульпи; мінерал триоксид агрегат; постійні зуби.

УДК 616.314.9:615.327

### НАЛОЖЕНИЕ МИНЕРАЛ ТРИОКСИД АГРЕГАТА ПРИ СЛУЧАЙНОМ ВСКРЫТИИ ПУЛЬПЫ

**Масуд Киани, Янко Наталия, Мохамед Сеєд Ахмед, Али Аманибени**

**Резюме.** Эффект минерал триоксид агрегата (МТА) при прямом покрытии пульпы состоит в стимуляции образования репаративного дентина в течение 1-4 месяцев. Наложение МТА на вскрытую точку пульпы диаметром до 1 мм при её вскрытии во время препарирования глубокого кариеса проводилось при возможности контролировать кровотечение из пульповой камеры и отсутствии болей в зубе в анамнезе. 23 из 31 зуба через 2-3 месяца после покрытия не имели симптомов (74%), все зубы не имели патологических изменений на рентгенограмме. Через 6 месяцев эффективность покрытия с МТА составила 67.7%, через 8 месяцев – 56.2%.

**Ключевые слова:** покрытие пульпы; минерал триоксид агрегат; постоянные зубы.

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### PULP CAPPING WITH MINERAL TRIOXIDE AGGREGATE AT PULP EXPOSURE

**Masoud Kiani, Yanko Nataliia, Mohanad Seed Ahmed, Ali Amanibeni**

**Abstract.** To prevent the pulp from deteriorating when a dental restoration gets near the pulp, the dentist will place a small amount of a sedative dressing, such as MTA. This material, protect the pulp from noxious agents (heat, cold and bacteria) and stimulate the cell-rich zone of the pulp to lay down a bridge of reparative dentin. Dentin formation usually starts within 30 days of the pulp capping (there can be a delay in onset of dentin formation if the odontoblasts of the pulp are injured during cavity removal) and is largely completed by 130 days.

MTA pulp capping was performed at open reversible pulpitis-presence of ulceration among carious dentin-pulp exposure. Teeth had no difficulty controlling bleeding from exposure, pin point should be up than 1mm exposure after caries has been removed, no treatment plan for a laboratory-fabricated prosthesis that is placed on the tooth, asymptomatic teeth without a history of pain. The procedure for pulp capping consisted of several steps. First, the dental cavity was drilled, if pulp was disclosed, the area was cleaned and the pulp point was covered with MTA to protect it from becoming infected. Once the pulp is capped, the dentist will place a temporary or permanent dental filling in the tooth.

Of the 84 teeth with pulp exposure in 30 patients that were included in the current study by clinical evaluation. Performing a pulpectomy is typically suggested upon frank exposure of the pulp, but a pulp cap using MTA was used for 51 teeth in 11 patients. Patient ages ranged from 21 to 58 years.

The current study estimated pulp vitality after MTA pulp caps with clinical and radiographical criteria. Follow up appointments were prescribed after 1,5, 2-3, 6, and 8 months. 20 from these 51 teeth dropouted after 1,5 months for irreversible pulpitis (n = 15) or restorative considerations required a more predictable foundation (n = 5). At recall after 6 months, 11 patients with pulp caps were clinically and radiographically assessed. Totally, 6 months pulp survival was 67.7%, while the 8 months survival rate was 56.2%.

Within the limitations of the current study on procedures performed, it may be concluded that, for MTA pulp caps applied to carious exposures in adults, certain preoperative conditions patient age, exposure size and amount of bleeding are not predictive of clinical outcome. Considering the comparatively low success rate for the current cohort, more studies are needed to define predictive criteria for successful pulp capping with MTA. The success measured as pulp survival over a period of one year of pulp caps performed may be low. This study provides data regarding the impact of exposure sizes and other preoperative variables on outcomes of MTA pulp caps in adults.

**Keywords:** pulp capping; mineral trioxide aggregate, permanent teeth.

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