

Review Article

Clinical outcome of direct pulp capping with MTA or calcium hydroxide: a systematic review and meta-analysis

Chenxi Zhu, Bin Ju, Rong Ni

Research Center, Zhejiang Provincial Health Information Center, Hangzhou, Zhejiang, China

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Abstract: Direct pulp capping is one of the most common dental practices in endodontic therapy. This systematic review and meta-analysis aim to determine whether the effect of mineral trioxide aggregate (MTA) and calcium hydroxide for direct pulp capping is different, as measured by the clinical and radiographic analysis. The study list was obtained by searching PubMed, Springer Link, Scopus and Cochrane Database. Only those papers that met the inclusion criteria were analyzed. The results indicated that four studies met the inclusion criteria. Statistically significant difference was found between the success rates of MTA and calcium hydroxide treated teeth that needed direct pulp capping ($P=0.002$). Clinical assessments of the MTA versus calcium hydroxide for direct pulp capping suggested that MTA was superior to calcium hydroxide in direct pulp capping resulting in a lower failure rate (risk difference 0.1 [95% CI 0.04 to 0.16]). In conclusion, MTA has a higher clinical success rate for direct pulp capping comparing to calcium hydroxide, and might be a suitable replacement for calcium hydroxide

Keywords: MTA, calcium hydroxide, direct pulp capping

Introduction

Direct pulp capping is a procedure in which the exposed pulp is covered with a biocompatible material. The objectives of the treatment are formation of dentin bridges to wall off outside stimulation and preservation of healthy pulp tissue [1].

Calcium hydroxide has been widely used in clinical for direct pulp capping. The material has been the gold standard by which all the others were judged. However, considerable limitations of calcium hydroxide such as presence of tunnels in dentin bridge, pulp chamber obliteration, high solubility in oral fluids, poor sealing ability and degradation over time were reported [2, 3].

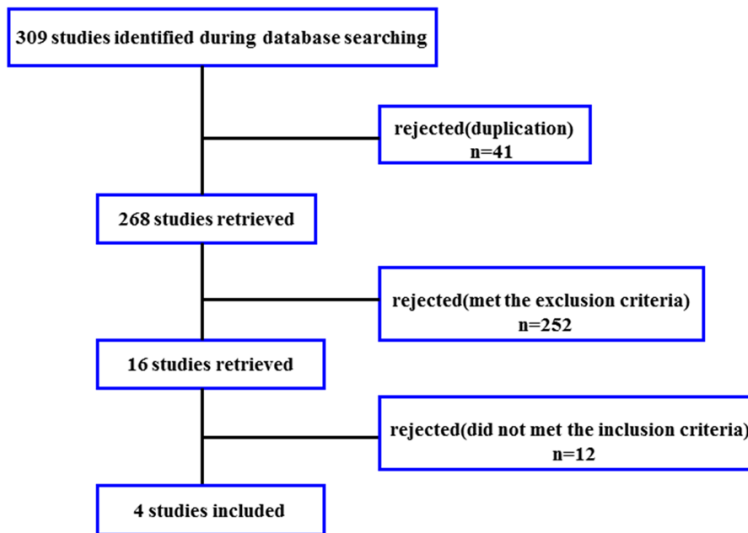
Mineral trioxide aggregate is a relatively novel pulping capping agent. Many histological studies showed that MTA formed thicker hard tissue barrier compared with calcium hydroxide in animals or human. However, these studies were relatively short term observations (less than 3 months) [4-6], and the long term hard tissue

formation capacity of both MTA and calcium hydroxide is unknown since both materials formed thicker and more complete dentin bridges with time increases. Moreover, the completeness and thickness of dentin barrier are not definitely positive correlated with clinical success. From a clinical point view, the most important outcome is long term pulp vitality and the absence of clinical symptoms.

Conflicting results has been report by previous studies when calcium hydroxide was compared with MTA as direct pulp capping agents. MTA was found to be as clinically successful as calcium hydroxide when used for direct pulp capping in both human primary teeth and third molars [7, 8]. Some studies showed MTA appears to be more effective than calcium hydroxide for maintaining pulp vitality after direct pulp capping both clinically and histologically [4, 9, 10]. However, the evidence of these studies is not very strong. In addition, some clinical trial demonstrated only borderline significance, which means the observed significance may not be clinically significant [10].

Table 1. PubMed search strategy and number of publications retrieved

No	Search History	Number of publications
1	Dental pulp capping	1235
2	Calcium hydroxide	4545
3	Mineral trioxide aggregate OR MTA cement OR aggregate ProRoot	1147
4	1 AND 2 AND 3	73

**Figure 1.** Flow diagram of included studies.

The systematic review and meta-analysis was undertaken to compare the effectiveness of MTA and calcium hydroxide regarding the clinical success. Thus, solving the choice problem the clinicians face (MTA or calcium hydroxide) in dental practice regarding direct pulp capping treatment for exposed pulp was the main objective of the present study.

Materials and methods

Literature research

The quantitative systematic review was performed by an exhaustive research for clinical studies that reported comparison of calcium hydroxide and mineral trioxide aggregate for direct pulp capping in human. The primary sources of the reviewed studies were PubMed, SpringerLink, Scopus and Cochrane Database. The search of literature published through September 2014 in PubMed database with English language restricted was listed in **Table 1**. A similar search strategy was undertaken on the other three databases as well as manual searches. Two authors independently evaluated and selected the studies that met the inclu-

sion criteria; disagreement among authors was resolved in consensus meetings.

Inclusion criteria and exclusion criteria used in the analysis

Inclusion criteria: ① Randomized controlled trial; ② Human teeth with exposed pulps with or without caries treated with a direct pulp capping procedure; ③ The study compared calcium hydroxide versus MTA; ④ The outcome was evaluated by clinical symptoms and radiographic evidence.

Exclusion criteria: ① Not randomized controlled trial; ② Only histological evaluation of calcium hydroxide versus MTA; ③ Non-human studies; ④ Indirect pulp capping/pulpectomy procedure.

Data extraction and quality assessment

Data from studies that fulfilled the inclusion criteria were processed for extraction and entering into a computerized database. The extracted data included the name of the first author, year of publication, number of cases, number of teeth, type of teeth and number of follow-ups. The quantitative 5-point Jadad score, which based on randomization, blinding, and reasons for withdrawal, was used to assess the methodological quality of included trials. The quality of each included investigation was evaluated by two of the authors. A consensus meeting was conducted to confirm agreement and to resolve disagreement between reviewers.

Meta-analysis

The meta-analysis was performed by software RevMan 5.2 provided by The Cochrane

Table 2. The characteristics of included studies

Study/country (year)	No of participants	No of teeth	Age range (year)	Type of teeth	Lost to follow up
Benoist et al. France (2012)	not mention	60	16-34	permanent	6
Hilton et al. USA (2013)	376	376	≥7	primary and permanent	18
Iwamoto et al. USA (2006)	not mention	48	18-60	permanent	1 lost without stating reasons
Tuna et al. Turkey (2008)	25	50	5-8	primary	8

Table 3. Methodological quality assessment of included studies

	Benoist et al.	Hilton et al.	Iwamoto et al.	Tuna et al.
Randomization	1	1	1	1
Blinding	1	0	1	1
Withdrawals and dropouts	1	1	0	1
Total score	3	2	2	3

Methodological quality assessment of included studies

Methodological quality was assessed with the use of a scale developed and validated by Jadad et al. Based on these criteria, study quality scores were 3 for the studies by Benoist et al., Hilton et al. and Tuna et al., and 2 for the study by Iwamoto (**Table 3**).

ne Collaboration (<http://ims.cochrane.org/revman>). For raw dichotomous data, relative risk (RR) and 95% confidence interval (CI) were calculated. The heterogeneity among studies was assessed using both the chi-squared test and the I-squared statistic. The fixed effect model was used to aggregate the data if homogeneity existed among studies ($P \geq 0.1$, $I^2 < 50\%$). The random effect model was used if the assumption of homogeneity was rejected ($P < 0.1$, $I^2 > 50\%$). Descriptive statistics were developed when heterogeneity was evident.

Results

Study selection and data summary

The majority of relevant studies were conducted using calcium hydroxide or MTA. Four studies comparing the two materials with a total of 501 teeth met inclusion criteria (**Figure 1**).

Designs of included studies

The included studies had control groups. The experimental group was the group that received direct pulp capping with MTA and the control the group that received direct pulp capping with calcium hydroxide.

Characteristics of included studies

Two studies were conducted in USA, one in France and one in Turkey. Most studies were conducted in a university teaching hospital environment. Characteristics of the participants in included studies are presented in **Table 2**.

Meta-analysis

The outcome measure was based on binary data success/failure, dentin bridge formation/absence of dentin bridge formation). The four studies were homogeneous according to χ^2 statistic and I^2 ($P=0.17$, $I^2=39\%$). A graphical informal test (Forest plot) also confirmed the homogeneity (**Figure 2**). Thus, fixed effect methods for combining study estimates were used, and overall estimate was produced. After synthesizing the results, we found that the rate of clinical success of the two interventions had significant difference (risk difference-0.1 [95% CI-0.04 to 0.16]; $P=0.002$). Based on these data, the difference in clinical success between the two treatment regimens was statistically significant.

Discussion

Dental pulp, an un-mineralized oral tissue, possesses a number of important functions including dentin induction and formation, nutrition, defense and sensation [1]. Thus ensuring dental pulp vitality is of great significant to maintain the normal functions of tooth. Both accidental mechanical pulp exposure and caries caused exposure may bring irreversible damage to dental pulp if not treated properly.

Direct pulp capping has been showed to be an effective way for maintaining pulpal vitality and health. The operation is considered successful if the tooth remains vital and a bridge is formed within 75-90 days [11]. Various materials have been used as pulp-capping agents, including bonding agents, cements, resin, calcium

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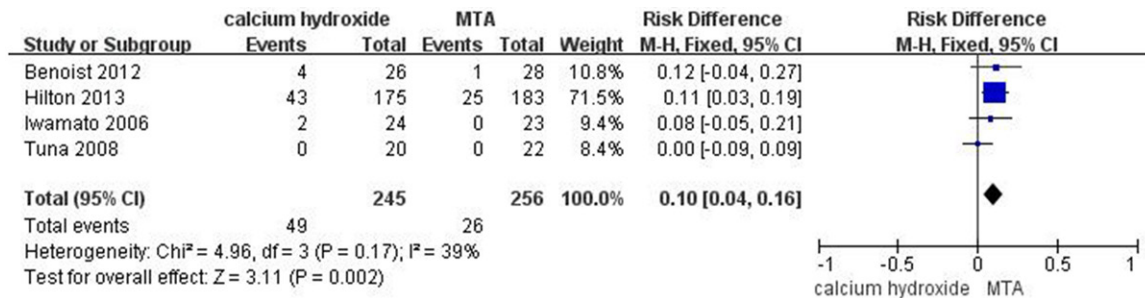


Figure 2. Illustration of the homogeneity confirmed by graphical informal test (Forest plot).

hydroxide, and many others [12]. Currently the most promising materials are calcium hydroxide and MTA, since both materials have the capacity to induce bridging of the pulp surface with reparative dentin.

MTA is a new and biocompatible biomaterial used for dental practice. It has been proved to be an excellent material for repairing of root perforations, apexification, root-end filling, repairing of root resorption and pulp capping. As to pulp capping, various in vivo studies have showed that MTA can form a thicker dentin bridge compared with traditional gold standard pulp capping material calcium hydroxide histologically [13, 14]. However, long time observation showed that no statistically significant difference was found in the dentine thickness between MTA and calcium hydroxide in human [7, 15]. In addition, there is no evidence to prove that the dentin thickness is related with clinical success of maintaining dental pulp vitality. Many clinical studies have showed that MTA is superior to calcium hydroxide as a direct pulp material. However, most of these studies are not randomized controlled trials (RCTs). Many confounding factors, such as type of pulp exposure, site of pulp exposure and tooth location etc, can influence the treatment outcome, thus the results are not very convincing. Moreover, some studies showed that calcium hydroxide performed as well as MTA [7, 8]. Furthermore, the cost of calcium hydroxide is much cheaper than MTA. The question whether MTA is better than calcium hydroxide clinically is still open to doubt.

Meta-analysis is an optional way to provide a reliable and suggestion for dental practice. We selected RCTs since the results of these studies are most convincing. Four RCTs were included in this meta-analysis [7, 8, 15, 16]. The prog-

nosis of direct pulp capping of MTA and calcium hydroxide was evaluated both clinically and radiographically. The meta-analysis showed there is statistically significant difference in success rate between two treatment regimens.

All four studies specified the concrete procedure of dental pulp capping. Clinical signs and radiography results are combined to determine the success or failure of the treatment. However, the clinical standard of the four studies are not complete the same. In addition, some studies did not specify the standard clearly. Benoist et al. and Iwamoto et al. also compared the dentin formation capacity of these two materials. Both studies showed no significant difference in histological findings between MTA and calcium hydroxide. The follow up time of four studies are various (Benoist et al. =6 months, Iwamoto et al. =136±24 days, Tuna et al. =24 months, Hilton et al. =24 months). Even though all studies stressed radiography results were important standard to evaluate the success or failure of dental pulp capping, only Tuna et al. mentioned the performance of radiography results. The other three studies did not mention the radiography results even about the failure cases. All studies reported that concrete number of cases that lost to follow up.

Due to the effectiveness of minimizing confounders and maximizing control over the trial environment, RCTs are regarded as the most reliable and accurate method for experimental design. In addition, RCTs are high in the hierarchy of quality of evidence and can establish the most convincing causal relationship in comparison with other clinical studies such as cohort, cross-sectional, or case control studies. All the included studies were described as random-

ized. Hilton et al. used the Sample function of R Version 2.15 method for randomization. However, all the other three studies failed to describe their way of randomization clearly. Ensuring the evaluator is blind to treatment variables when assessing outcomes is important. Iwamoto et al., Tuna et al. and Benoist et al. stated that evaluators are blind to treatment method. It seems difficult to blind the practitioners to the materials when they are performing the dental pulp capping operations, because the characteristics two materials are quite dissimilar. As to the sample size, only two of the papers reported rationale for the sample size. In addition, the reasons Benoist et al. given for the sample size may be not plausible. The importance of sample size calculation cannot be overemphasized. A small sample size will lead to a lower power of test and lack of adequate evidence, whereas a larger one will cause the difficulties of follow-up control and waste of unnecessary resources such as labor, money and time.

The meta-analysis showed statistically significant difference in success rate between the two treatment regimens. However, there were still some limitations that affect the final degree of reliability of literature review and meta-analysis which could not be neglected. The four studies were performed in teaching hospital schools, which make extrapolation for general practitioners difficult. In addition, bias of publication was not calculated, because of the number of included studies. The relatively small sample is also a limitation; a larger sample size would definitely be desirable with longer follow-up to firmly establish the effect of this treatment in the dental pulp.

In conclusion, based on available information at present, the results of this meta-analysis demonstrated that MTA performs superior to calcium hydroxide as a direct pulp-capping material. However, larger, blind, randomized controlled trials are needed to be conducted to provide more reliable clinical evidence.

Disclosure of conflict of interest

None.

Address correspondence to: Dr. Rong Ni, Research Center, Zhejiang Provincial Health Information Center, 216 Qingchun Road, Hangzhou 310006,

Zhejiang, P. R. China. Tel: +86-571-87709212; Fax: +86-571-87709202; E-mail: nihongdr@sina.com

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