Sports Science, Human Performance, and Health Journal
ISSN 3064-7533
Volume 11 Issue 4
October - December 2023
Impact Factor: 6.71
Enquiry: contact@continentalpub.online
Published by Continental Publication | http:// https://continentalpub.online/index.php/sshphj

COMPARING MTA AND BIODENTINE FOR MOLAR PULPOTOMY: A COMPREHENSIVE META-ANALYSIS

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Abstract: *Pulp tissue, a complex connective tissue housing nerves, blood vessels, and various cells, plays a vital role in formative, nutritive, sensory, and defensive functions within the tooth. In contemporary dental practice, the preservation of pulp vitality in deep carious lesions involving primary molars is a paramount consideration for long-term tooth health. Various treatment modalities exist for deep carious exposure of pulp, spanning from conservative approaches like vital pulp therapy (VPT), encompassing direct pulp capping, partial pulpotomy, and complete pulpotomy, to more invasive treatments like pulpotomy and root canal therapy.*

In the context of primary teeth, pulpotomy stands as a prevalent and valuable procedure for managing exposed pulp in children with carious primary molars. The American Academy of Pediatric Dentistry defines pulpotomy as the surgical removal of infected or affected pulp tissue, followed by the application of medication to the remaining vital pulp tissue. This intervention aims to preserve the functionality and vitality of the root pulp, either partially or entirely.

Keywords: *Pulp tissue preservation, Pulpotomy, Vital pulp therapy, Primary molars, Pediatric dentistry*

1. Introduction

Pulp tissue is a loose connective tissue containing nerves, blood vessels, connective tissue, cells, etc. It has formative, nutritive, sensory and defensive functions. In recent years, clinicians prefer to preserve the pulp when dealing with deep carious exposed milk molars, as maintaining the vitality of the pulp is a key factor in long-term tooth survival. There are several treatment options for deep carious exposed pulp, ranging from conservative minimally invasive pulp therapy (VPT), including direct pulp capping (DPC), partial and complete pulpotomy, to more invasive pulpotomy and root canal treatment.[1] . For milk teeth, pulpotomy is one of the most common treatments for exposed pulp in children with milk molar caries. The American Academy of Pediatric Dentistry defines pulpotomy as the removal of infected or affected pulp tissue, with the remaining living pulp tissue covered with medication, thereby preserving the vitality and function of the root pulp (partially or completely)[2] .

MTA has been approved by the FDA since 1998 and has become a successful drug used for vital pulp therapy, apical and restorative root perforation. made from calcium hydrogen silicate or tricalcium silicate and bismuth oxide, MTA has several desirable properties such as biocompatibility, bioactivity, hydrophilicity, radiopacity, sealing ability and low solubility, but MTA is costly, takes a long time to harden, is difficult to handle, and may cause discoloration[3, 4] . To compensate for these disadvantages, a new calcium silicate based material called Biodentine was launched in 2009, consisting of a powder

and a liquid, with the powder consisting of tricalcium silicate, zirconium oxide and calcium carbonate, and the liquid containing mainly water, calcium chloride and a water-soluble polymer.[5] Biodentine has mechanical properties similar to those of dentin and can therefore be used as a substitute for dentin. Biodentine has been shown to promote the formation of restorative dentin when placed on healthy pulp tissue. It has the advantages of biocompatibility, short setting time, long shelf life, high compressive strength and better handling properties [6-8]. There is ample evidence that Biodentine has a positive effect on pulp cells, stimulates tertiary dentin formation and restorative dentin formation, and allows for the formation of higher thickness dentin bridges.[9-12] Few studies have investigated the superiority of the performance of MTA and Biodentine as drugs commonly used in pulpotomy, so this Meta-analysis systematically compares the clinical and imaging success rates of both in pulpotomy.

2. Materials and methods

2.1 Inclusion and exclusion criteria

The inclusion criteria for this meta-analysis were developed in strict accordance with the PICOS principles: ①Population: human milk molars requiring pulpotomy for deep caries exposure; ② Intervention: MTA as pulp capping agent in the experimental group; ③Comparison: Biodentine as pulp capping agent in the control group ④ Outcome: clinical success rate (no history of pain, palpation/percussion pressure, intraoral/extraoral swelling, intraoral/extraoral sinus or any pathological loosening of the tooth, no abnormality in pulp electrical vitality test), imaging success rate (no pathological internal or external root resorption, radiographic permeability of the tooth bifurcation area, periapical permeability, no pathological shadows in the periapical area) ; ⑤ Study type (Study design): randomized controlled trial (RCT).

Exclusion criteria: (i) in vitro experiments, animal studies; (ii) experimental studies performed in human permanent teeth; (iii) no comparison of two pulp-capping agents, MTA and Biodentine; (iv) Metaanalyses, reviews, case reports and letters, repeatedly published literature; (v) literature without clinical and imaging evaluation; (vi) literature from which data could not be effectively extracted.

2.2 Search strategy

Computer search of PubMed, The Cochrane Library, Embase, Scopus, CNKI, and WanFang databases for randomized controlled trials (RCTs) of the efficacy of MTA and Biodentin in pulpotomy of mastoid molars in English only, with a search deadline of September 2022. Chinese search terms include: MTA, Biodentine, pulpotomy, deep caries pulp exposure. English search terms include: Pulpotomy, mineral trioxide aggregate, MTA, tricalcium silicate, biodentine, etc. The search formula was based on PubMed as Table 1.

Table 1: Database search formula

Database	Search Type
PubMed	#1 (("Pulpotomy"[Mesh]) OR (Pulpotomies)) #2 (((((((mineral trioxide aggregate) OR (MTA cement)) OR (MT aggregate)) OR (aggregate ProRoot)) OR (ProRoot (aggregate))) OR (OrthoMTA)) OR (RetroMTA)) OR (MTAFillapex) #3 ((((tricalcium silicate) OR (Ca_3SiO_5)) OR (tricalcium silicon pentaoxide)) OR (biodentine))) #1 AND #2 AND #3

2.3 Literature screening and data extraction

Literature screening and information extraction were performed independently by two evaluators according to the established inclusion and exclusion criteria, and any disagreement was decided through discussion or by a third researcher. The literature screening was done by first reading the title and abstract, and after excluding obviously irrelevant literature, the full text was further read to determine the final inclusion of information according to the nadir criteria. The extracts included: (i) general information: title, author, year of publication, and country; (ii) study characteristics: number

of teeth, age, and followup time; and (iii) outcome indicators: clinical success rate and imaging success rate.

2.4 Risk of bias assessment of included studies

Risk of bias was assessed for the nine included studies by two evaluators according to the Cochrane systematic reviews manual 5.1.0.

2.5 Statistical analysis

Statistical methods were used to conduct meta-analysis of the nine papers included in the study using RevMan 5.3 software provided by the Cochrane Collaboration Network. The data included in this study were dichotomous variables, and the odds ratio (*OR*) and 95% confidence intervals (*CI*) were used as effect indicators for the dichotomous variables. The heterogeneity between the results of the included studies was analyzed by chi-square test (test level $\alpha=0.05$), and the size of the heterogeneity was determined by combining the P-value and I^2. If $P > 0.10$ and $I^2 < 50\%$, a fixed-effects model was used for meta-analysis, and if the heterogeneity between groups was large, the source of heterogeneity was further analyzed, and after excluding the effect of obvious clinical heterogeneity, a random-effects model was used for meta-analysis. Obvious clinical heterogeneity was addressed using methods such as subgroup analysis or sensitivity analysis.

3. Results

3.1 Literature screening results

Nine papers were finally included[13-21] , with a total of 450 teeth.

3.2 Basic characteristics of the included studies

Nine included studies[13-21] compared the efficacy of MTA and Biodentine based on inclusion and exclusion criteria, of which nine studies documented clinical success and imaging success at 6 months, five studies documented clinical success and imaging success at 12 months, and two documented clinical success and imaging success at 24 months. Specific characteristics are shown in Tables 2 and 3.

Table 2: Basic characteristics of included studies

Inclusion in the study	Country	Design Type	Age (years)	Number of samples included in MTA (Pieces)	Number of samples included in Biodentine (pills)	Followup time (months)
Ahuja 2020	India	RCT	4-7	20	20	3, 6, 9
Bani 2017	Turkey	RCT	4-9	32	32	6, 12, 18, 24
Carti 2017	Turkey	RCT	5-9	25	25	1, 3, 6, 12
Çelik 2019	Turkey	RCT	5-9	24	20	3, 6, 12, 18, 24
Cuadros-Fernández 2016	Spain	RCT	4-9	43	41	6, 12
Juneja 2017	India	RCT	5-9	17	17	3, 6, 12, 18
Kusum 2015	India	RCT	3-10	25	25	3, 6, 9
Rajasekharan 2017	Belgium	RCT	3-8	29	25	6, 12, 18
Ramanandvignesh 2020	India	RCT	4-9	18	18	3, 6, 9

Table 3: Data from included studies

Inclusion in the study	MTA/ Biodentine 6 Months Success Rate		MTA/ Biodentine 12 Months Success Rate		MTA/ Biodentine 24 Months Success Rate	
	Clinical Success Rate	Imaging Success Rate	Clinical Success Rate	Imaging Success Rate	Clinical Success Rate	Imaging Success Rate
Ahuja 2020	19/20	18/20	-/-	-/-	-/-	-/-
Bani 2017	32/32	32/32	31/31	31/31	30/30	27/29
Carti 2017	25/25	21/17	24/24	20/15	-/-	-/-

Çelik 2019	24/19	24/19	23/17	23/17	22/17	22/17
Cuadros-Fernández 2016	41/40	43/41	38/39	38/37	-/-	-/-
Juneja 2017	15/15	15/14	15/15	15/14	-/-	-/-
Kusum 2015	25/25	23/22	-/-	-/-	-/-	-/-
Rajasekharan 2017	29/24	29/24	26/23	24/23	-/-	-/-
Ramanandvignesh 2020	14/17	14/16	-/-	-/-	-/-	-/-

3.3 Risk of bias evaluation of included studies

Included studies were assessed for risk of bias according to the Cochrane Handbook of Systematic Reviews 5.1.0 for the nine included studies (see Figure 1 and Table 4).

Table 4: Risk of bias assessment for included studies

Inclusion in the study	Random method	Assign hidden	Implementer and participant double blind	Blinding in Ending Evaluation	Resulting data is incomplete	Selective reporting	Other biases
Ahuja 2020	Not sure	Not sure	Not sure	Not sure	Low Risk	Low Risk	Not sure
Bani 2017	Coin Toss	Low Risk	Not sure	Low Risk	Low Risk	Low Risk	Not sure
Carti 2017	Lottery	Low Risk	Not sure	Low Risk	Low Risk	Low Risk	Not sure
Çelik 2019	Random Numbers	Not sure	Not sure	Low Risk	High Risk	Low Risk	Not sure
CuadrosFernández 2016	Random Numbers	Not sure	Not sure	Not sure	High Risk	Low Risk	Not sure
Juneja 2017	Not sure	Low Risk	Not sure	Low Risk	Low Risk	Low Risk	Not sure
Kusum 2015	Envelopes	Low Risk	Not sure	Low Risk	Low Risk	Low Risk	Low Risk
Rajasekharan 2017	Random Numbers	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Not sure
Ramanandvig nesh 2020	Not sure	Not sure	Low Risk	Not sure	Not sure	Low Risk	Not sure

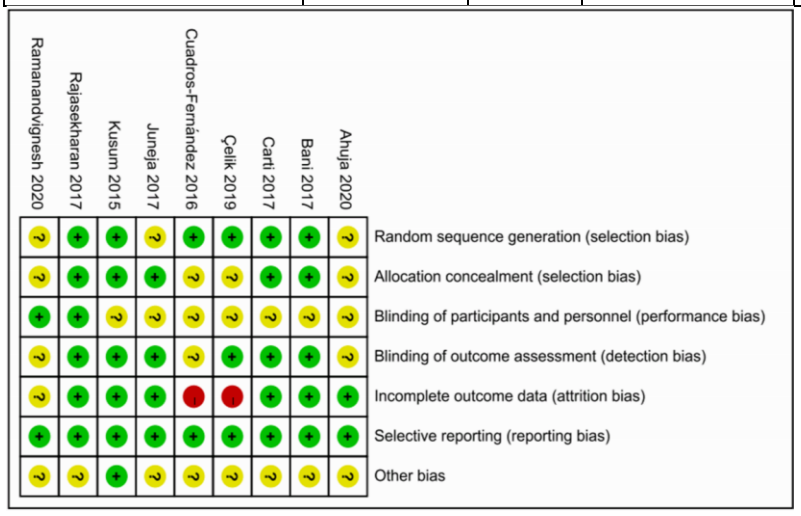

Figure 1: Inclusion of study bias risk assessment

3.4 Meta-analysis results

3.4.1 Clinical success rate

A total of 9 studies with 450 teeth were included to compare the clinical success rate of cariogenic pulpotomy of papillae with MTA and Biodentine as pulp capping agents, respectively, at 6 months; 7 studies with 314 teeth were included at 12 months postoperatively; and 2 studies with 103 teeth were included at 24 months postoperatively. The results showed no heterogeneity betweenthe data of the studies (P=0.46,I^2 =0%; P=0.71,I^2 =0%; P=0.38,I^2 =0%), and a fixed-effects model was used for metaanalysis. The results of the combined analysis showed no statistically significant differences between the clinical success rates of the MTA group and the Biodentine group at 6, 12, and 24 months [OR=0.66,*95%CI(o*.21,2.03),P=0.47], [OR=1.55, *95%CI*(0.46,5.21),P=0.48], [OR=2.16. *95%CI*(0.38,17.95), P=0.33]. (See Figure 2)

3.4.2 Imaging success rate

3.4.2.1 Success rate

The results showed no statistical heterogeneity in the data across studies at 6, 12 months (P=0.55, I^2 =0%; P=0.82,I^2 =0%), solidly using afixed effects model for meta-analysis, while the results at 24 months showed ahigh degree of heterogeneity in the data between studies (P=0.15,I^2 =53%), soli-dly using a random effects model for meta-analysis. The results of the combined analysis showed no statistically significant differences between the imagingsuccess rates of the MTA group and the Biodentine group at 6, 12, and 24 months [OR=1.39, 95% *CI(o*.64,3.00), P=0.40], [OR=2.10, 95% *CI*(0.90,4.90), P=0.08], [OR=1.26. *95%CI*(0.10,15.79),P=0.86]. (See Figure 3)

3.4.2.2 Sensitivity analysis

When analyzing the imaging success rate at 24 months postoperatively, we found heterogeneity among the included data, and a sensitivity analysis was solidly performed. The analysis model was first changed and the results were found to be unchanged from the previous ones, and then the included studies were excluded for analysis one by one, and the results are shown in Table 5: the combined effect values did not change significantly, and the overall analysis results remained statistically insignificant as in the previous analysis.

Table 5: Sensitivity analysis

Serial number	Exclude literature	*OR*	95% *CI*
1-2	Fixed effects model	1.05	[0.27,4.03]
1-2	Random effects model	1.26	[0.10,15.79]
1	Bani 2017	6.43	[0.29,142.7]
2	Çelik 2019	0.47	[0.09,2.75]

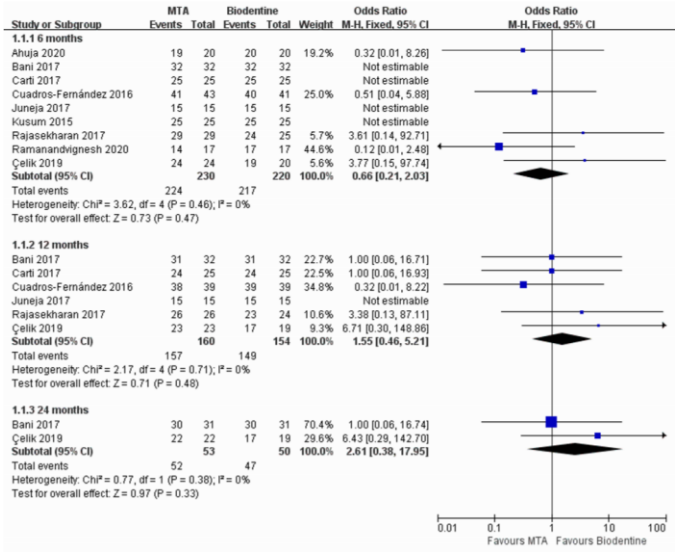

Figure 2: Comparison of clinical success rate between MTA group and Biodentine group

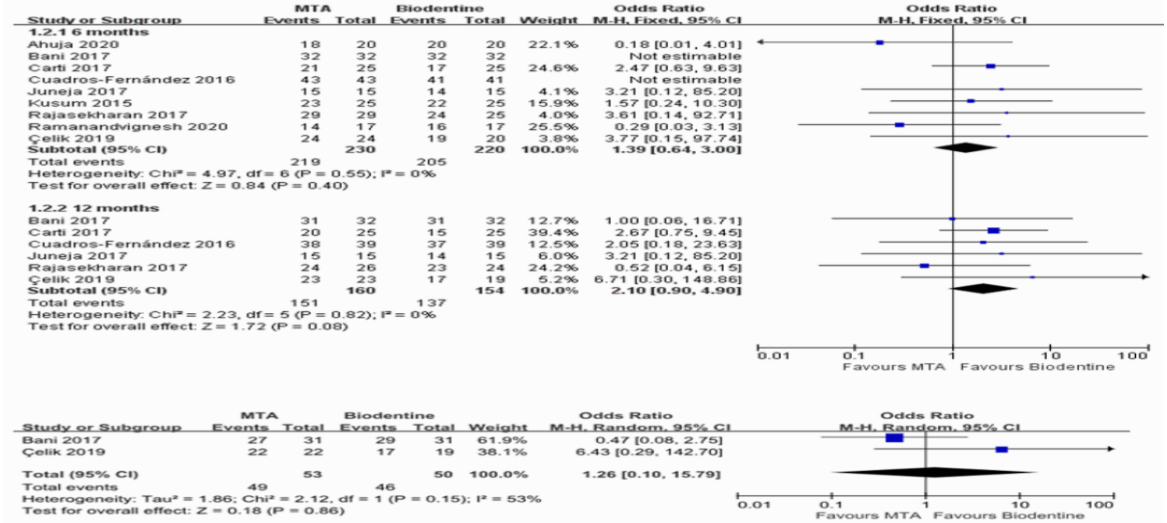

Figure 3: Comparison of imaging success rate between MTA group and Biodentine group

4. Discussion

The most common cause of pulpal damage in milk teeth is deep caries exposure, and the most important goal of milk teeth treatment is to keep the milk tooth series intact and healthy until the eruption of permanent teeth. Therefore, pulpotomy is the procedure of choice when there is no inflammation in the root pulp and only the coronal pulp is inflamed due to bacterial invasion caused by dental caries.[22] Pulpotomy treatment is classified according to three objectives: inactivation, preservation and regeneration of remaining pulp tissue. The advantage of pulpotomy is that the infected or affected pulp tissue is removed and the remaining living pulp tissue is subsequently covered with medication, thus preserving the vitality and function of the root pulp. The key to current pulpotomy is the choice of pulpcapping medication. Historically, formocresol (FC) was considered the "gold standard" pulpotomy drug, but has many drawbacks such as cytotoxicity, necrosis, mutagenicity, carcinogenic potential, and immune response.[23] It has many disadvantages such as cytotoxicity, necrosis, mutagenicity, carcinogenic potential and immune response. Calcium hydroxide is also a commonly used drug for pulp capping, but it is not usually recommended for use in milk teeth because its alkaline nature leads to necrosis, inflammation and dystrophic calcification of the pulp tissue, resulting in internal resorption. Therefore, calcium silicon-based bioactive capping materials such as MTA and the bioactive dentin replacement material Biodentin have been shown to have good biocompatibility, sealing ability, and

antibacterial properties [24] . However, compared to MTA, Biodentine has the advantages of easy handling, high viscosity, short setting time, superior mechanical properties, and also does not cause tooth discoloration, which indicate the potential of Biodentine for pulpotomy medication in milk teeth. The human oral cavity is home to a wide range of bacteria and saliva is contaminated during pulpotomy, so the use of a rubber barrier or not may have an effect on the outcome, and seven studies included in this Meta-analysis used a rubber barrier [13-19]. Secondly, the use of pulp capping agents with fillers and good restorations on them better ensures closure, five studies included in this meta-analysis [13-14, 18, 20] used glass ions as fillers on pulp capping agents, another four studies [16, 17, 19, 21] used zinc oxide eugenol, eight studies [13-18, 20-21] used stainless steel restorations, and one study[19] used glass ionomer restorations. However, stainless steel restorations may cause gingivitis, and in the study by Cuadros-Fernándezde et al [17], all clinical failure cases suffered from gingivitis, and although there is no clear evidence of an association between stainless steel crowns and gingivitis, the level of oral hygiene in patients with stainless steel crowns had a significant effect on the gingival index [25]. In addition, the presence of pulp canal occlusion (PCO) on imaging was considered successful in only four of the RCTs included in this study [16, 18-20]. In some studies, it was considered to be the result of adult dentin cell activity, which may indicate that the pulp would maintain a certain degree of viability and function.

The literature included in this meta-analysis is unclear in terms of allocation concealment, blinding, and the existence of other biases that inevitably result in selection or measurement bias. Firstly, there is subjectivity in physicians' judgments of clinical success and imaging success. Secondly, a limitation of the studies included in this meta-analysis is also the follow-up period of the studies, not all present the same follow-up time, which may affect the reliability of the results when these are ignored. Ahuja et al.[13] , Ramanandvignesh et al.[20] , Kusum et al.[19] assessed clinical and imaging success at 3, 6, and 9 months, Bani et al.[14] assessed clinical and imaging success at 6, 12, 18, 24 months, Carti et al.[15] evaluated clinical and imaging success rates at 1, 3, 6, and 12 months, Çelik et al.[16] evaluated clinical and imaging success rates at 3, 6, 12, 18, and 24 months, Cuadros-Fernández et al.[17] evaluated clinical and imaging success rates at 6 and 12 months, Juneja et al.[18] evaluated clinical and imaging success rates at 3, 6, 12, and 18 months, Juneja et al, 12, and 18 months, and Rajasekharan et al.[20] assessed clinical and imaging success rates at 6, 12, and 18 months. The results of this meta-analysis, while not showing any statistically significant differences between the two groups, the study by Çelik et al.[16] found lower success rates in the Biodentine group over time, suggesting that differences between success rates may vary due to longer follow-up periods.

In summary, the nine included RCTs showed no statistically significant differences in clinical success and imaging success between MTA compared to Biodentine in pulpotomy of mastoid molars, and therefore no one material was superior to the other. Limited by the number and quality of included studies, there is still a need for a high quality, large sample size, and long follow-up RCT to validate the above conclusions.

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