Original Article

Efficacy and safety of mineral trioxide aggregate (MTA) pulpotomy for caries-exposed permanent teeth in children: a systematic review and meta-analysis

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Background: This study aimed to evaluate the effect of mineral trioxide aggregate (MTA) pulp capping for caries-exposed permanent teeth. However, the efficacy of MTA in the treatment of children's gums is still controversial, and different studies have shown different efficacy. Therefore, it is necessary to systematically review the efficacy and safety of MTA pulp incision in the treatment of pediatric caries using meta methods.

Methods: We used meta-analysis to compare differences in the efficacy of MTA and calcium hydroxide (CH) for treating caries in permanent teeth. The mean treatment success rate of MTA for reversible and irreversible pulpitis groups was calculated, and the effect of apical opening condition and surgical type on success rate were investigated.

Results: A total of 15 studies were included, and meta-analysis showed that there was a significant statistical difference between the MTA group and CH group in efficacy [odds ratio (OR) =1.87, 95% confidence interval (CI): 1.28, 2.73, P=0.001, I^2=63%, Z=3.25], success rate (OR =3.20, 95% CI: 1.93, 5.30, P<0.00001, I^2=0%, Z=4.52), influence of apical foramen condition on success rate (OR =1.77, 95% CI: 1.14, 2.73, P=0.01, I^2=15%, Z=2.56), and surgical procedure on success rate (OR =2.64, 95% CI: 1.65, 4.23, P<0.0001, I^2=45%, Z=4.05).

Discussion: Our results showed that MTA pulpotomy was superior to CH. Nonclosure of apical openings and complete coronal pulpotomy may be more beneficial than partial pulpotomy.

Keywords: Mineral trioxide aggregate pulpotomy (MTA pulpotomy); caries; permanent teeth; systematic review

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Introduction

Caries is the most common route to bacterial infection, the severity of which is associated with the progression of caries. Pulp defense and auto-repair functions are the biological basis for damaged pulp repair and active pulp preservation (1-3). Due to caries, trauma, and other reasons, the tooth root can suffer from pulpitis, dental pulp necrosis, or periapical inflammation, resulting in the cessation of root development (4-6). Gutmann proposed the concept of minimally invasive endodontics (MIE), suggesting that pulpotomy could be performed for moderate pulpitis and pulpectomy for severe pulpitis (7). In recent years, with the development of oral materials, treatment methods and efficacy have been continuously improving. In particular, the

rapid development of biological nanoceramic materials such as mineral trioxide aggregate (MTA) has attracted attention for use in dental root repair. The main components of MTA are tricalcium silicate and silicon oxide, providing it with X-ray resistance, antibacterial function, and good biocompatibility. MTA is not soluble in water and has excellent sealing performance.

Dental caries in children is a common disease of stomatology. The hard tissue of deciduous teeth is relatively weak, the dentinal tubule is thick and large, and bacteria and their metabolites easily infect pulp in affected teeth. Therefore, clinically deep caries in deciduous teeth often requires pulp treatment. Coronal pulpotomy is a treatment to remove pulp tissue from the crown and retain healthy pulp tissue at the root. This technique has been widely used in the preservation of living pulp in permanent teeth.

If enough attention is not paid in the early stage of tooth decay, the inflammation will slowly develop and form an apical abscess, which can seriously affect the normal work and life of patients. Therefore, early detection and timely professional treatment are important. Many clinical studies have reported on the treatment of caries-exposed permanent teeth with MTA pulpotomy. In one study, the success rate of MTA pulpotomy in the treatment of reversible and irreversible pulpitis was 92.7% at 3 years, which included 44 teeth with partially irreversible pulpitis (8). Another study (9) showed that the success rate for treating irreversible pulpitis in young permanent teeth at 1-year follow-up was 91% (20/22). More systematic clinical evidence is required for the use of MTA in permanent teeth. A recent systematic study (10) evaluated the effect of total coronal pulpectomy of apical caries-derived pulp. However, the included clinical studies were published before 2014 and there was substantial heterogeneity among the extracted data.

MTA pulp incision can effectively treat children's dental caries and relieve periodontal pain. However, MTA material is an exogenous material, which is easy to increase the risk of infection around the gingival area. There are different controversies in the treatment of children's dental caries by MTA pulp incision. Therefore, it is necessary to systematically review the clinical efficacy and safety of the meta-method, so as to provide valuable guidance for the treatment of children's dental caries. We present the following article in accordance with the PRISMA reporting checklist (available at https://tp.amegroups.com/article/view/10.21037/tp-22-68/rc).

Methods

Search strategy

We used databases, including PubMed, EMBASE, Cochrane, Web of Science, citation searching, and organisations (The International Children's Dental Center was established in Bibb, Meager Children's Dental Center, etc.), registers of clinical trials (http://www.medresman.org/) and other websites [International Association of Paediatric Dentistry (IAPD); American Society of Dentistry for Children (ASDC), etc.], retrieve relevant literature between January 2020 and December 2021. The retrieval start date was set to 1993 because the use of MTA as a material for pulp therapy. The retrieval formula we employed was: (exposure [TW] OR exposed [TW]) AND ("dental caries" [MH] OR carious [TW] OR decay [TW] OR pulp [TW])) OR (vital [TW] AND (Pulpotomy [TW] OR pulp [TW] OR therapy [TW]) OR coronal pulp [TW] OR pulpotomy [TW] OR (pulp [TW] AND debridement [TW])) AND ((permanent [TW]) OR "dentition, permanent" [MH] (TW = text word; MH = MeSH terms). *Figure 1* shows the literature screening process.

Inclusion criteria

The inclusion criteria were: (I) subjects were human permanent teeth with a diagnosis of reversible or irreversible pulpitis; (II) pulpotomy was used in the treatment, and the capping material contained MTA; (III) the outcome measures included the number of successfully preserved living pulp teeth, the total number of treated teeth, and diagnostic measures were based on the results of clinical and imaging examinations; (IV) follow-up period was at least 1 year, and the sample size was at least 10. Inclusion criteria for inclusion studies should be clarified using Participants, Intervention, Control, Outcome, Study design (PICOS) criteria (experimental group: MTA pulpotomy; control group: conventional pulpotomy).

Exclusion criteria

(I) Subjects with deciduous teeth; subjects with permanent teeth but no definite caries-derived pulp damage; (II) subjects with no pulp vitality; subjects with other oral and maxillofacial diseases such as apical periodontitis or periodontitis; (III) literature types which were meta-analysis, expert advice, *in vitro* experiments, or animal experiments; and literature with study data that could not be extracted.

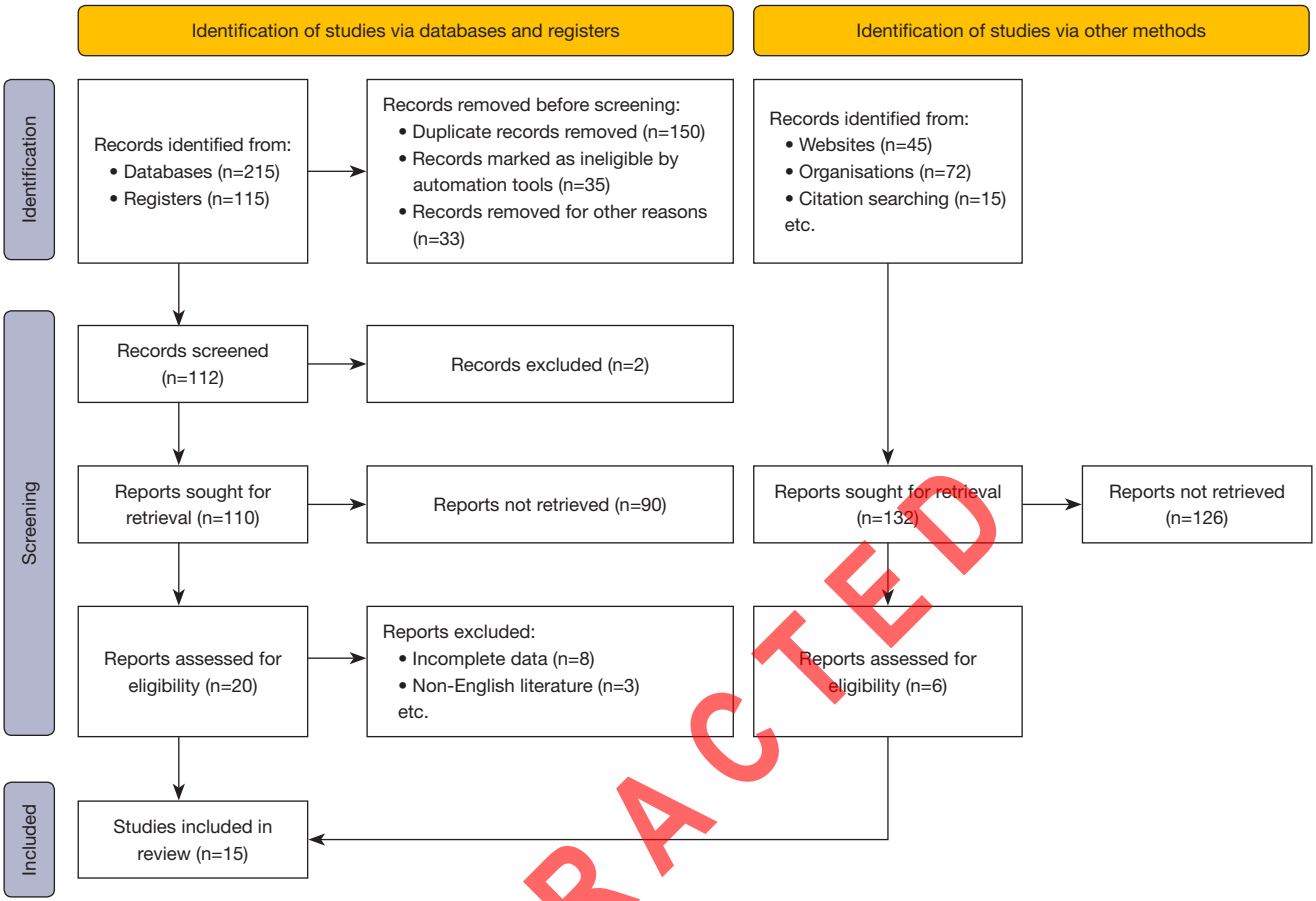

Figure 1 Flow chart of the literature screening.

Literature screening and classification

The literature screening process was carried out independently by 2 researchers according to the inclusion and exclusion criteria. If there was any disagreement, discussion was held to determine whether to include the literature. Comparative analysis was preformed of MTA and calcium hydroxide (CH) efficacy, efficacy at 1 and 2 years, pulp status, success rate at 1 and 2 years for each group, apical opening closure, and procedure type (complete or partial coronal pulpotomy). Subgroup analysis was performed in the 1- and 2-year refractory pulpitis groups.

Estimation of quality

The included studies were evaluated according to the quality score criteria developed, and the level of evidence classification based on the Cochrane scale (*Figure 2*).

Data extraction

RevMan 5.3 was used to extract data from the meta-analysis comparing MTA and CH, including 1-year success rate, 2-year success rate, total sample size, and various subgroups. The weighted average success rate was calculated using Stata 15.0 software. The criteria for treatment success were based on clinical examination and imaging examination. Clinical examination criteria included the absence during follow-up of spontaneous pain, night pain, hot or cold pain, occlusion pain, percussion pain, gingival or sinus canal swelling, fistula, discomfort, and loosening. The imaging examination criteria included no new lesions, no transmission image of apex or reduction of original apical transmission image, and no closure of apical openings.

Statistical analysis

According to the Cochrane ROB 2.0 principle, and

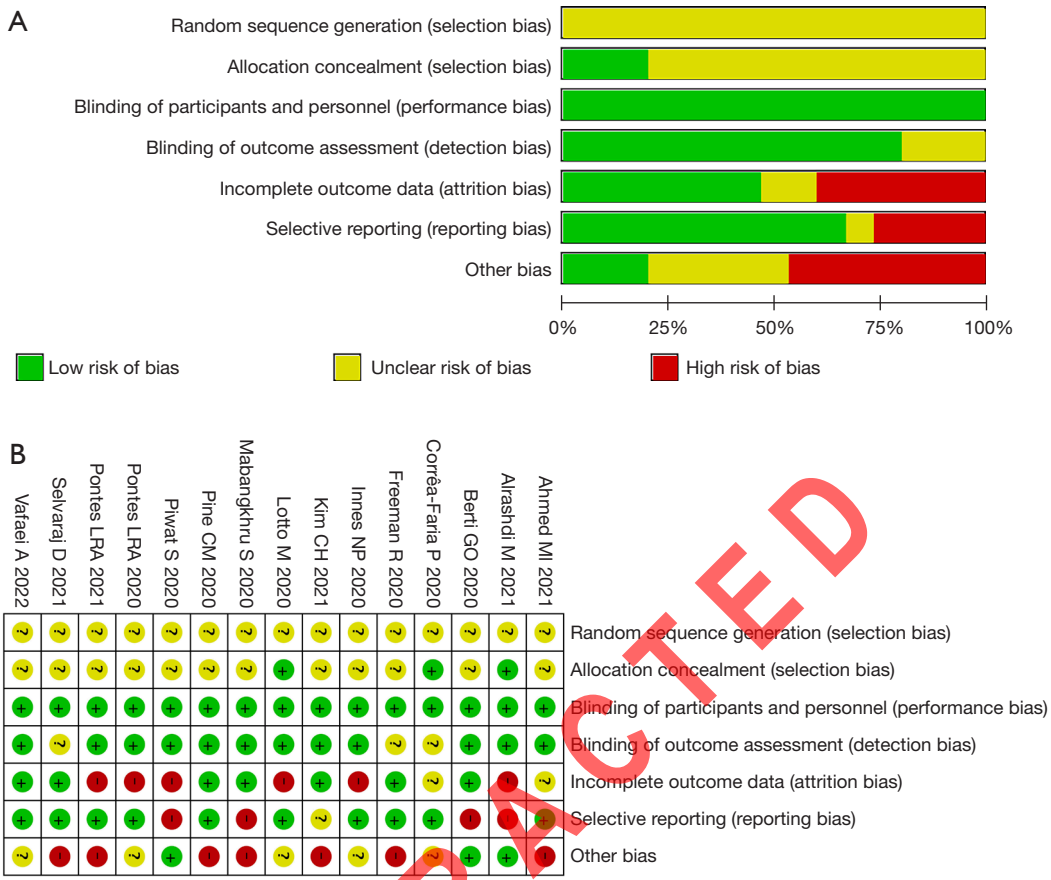

Figure 2 Literature quality evaluation chart. (A) Risk of bias graph; (B) risk of bias summary.

heterogeneity between studies was assessed using I^2 statistics, with 25%, 50%, and 75% representing low, medium, and high heterogeneity, respectively. If I^2<50% and P>0.1 between studies, a fixed effect model was used. If I^2>50% and P<0.1 from chi-square analysis showed study heterogeneity, meta-analysis was performed using a random effects model and the possible source of heterogeneity was assessed using subgroup analysis. Sensitivity analysis removed the included literature one by one to determine whether the pooled effect values were stable and reliable.

Results

The included studies

A total of 330 relevant records were retrieved, 110 remained after removing duplicate studies, and 20 were left after preliminary screening of titles and abstracts. Two researchers screened and evaluated the full text of 20 articles, and finally 15 articles were included (11-25). As shown in *Figure 3*, all the included studies were within the triangle area, and no obvious bias was observed (*Figure 3*). Among the 15 studies, 9 involved comparative analysis of the efficacy of MTA and CH, and 6 analyzed of efficacy of MTA (*Table 1*).

Comparative analysis of MTA and CH pulpotomy

Four literatures were included in this study, heterogeneity test was carried out, which showed that the heterogeneity of the selected studies was small and thus a fixed effect model could be used for meta-analysis. The results of meta-analysis showed that there was a significant statistical difference between the MTA group and CH group in the efficacy of pulpotomy [odds ratio (OR) =1.87, 95% confidence interval (CI): 1.28, 2.73, P=0.001, I^2=63%, Z=3.25] (*Figure 4*).

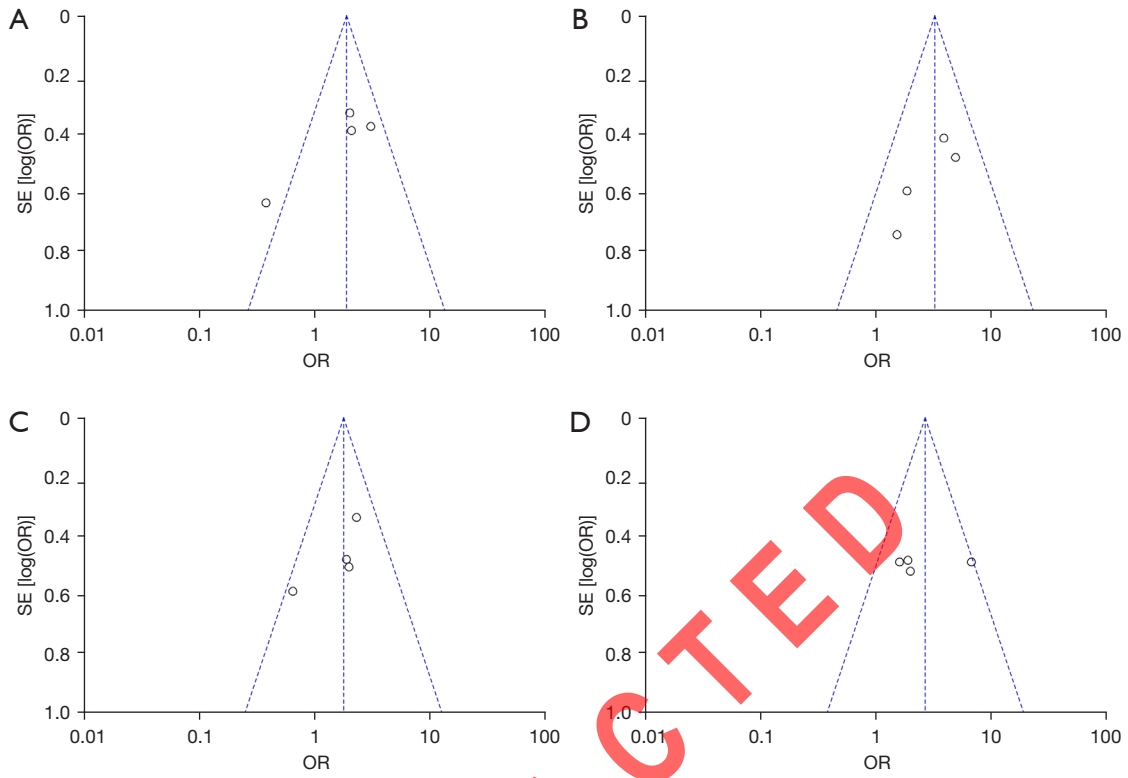

Figure 3 Funnel plot of literature publication bias. (A) Comparative analysis of MTA and CH pulpotomy of literature publication bias; (B) analysis of success rate of pulpotomy of literature publication bias; (C) influence of apical foramen condition of literature publication bias; (D) influence of different surgical procedures of literature publication bias. SE, standard error; OR, odds ratio; MTA, mineral trioxide aggregate; CH, calcium hydroxide.

Analysis of success rate of pulpotomy

Heterogeneity test was carried out for the 4 literatures included, showing that the heterogeneity of the selected studies was small and thus we used a fixed effect model for meta-analysis. The results of meta-analysis showed that there was a significant statistical difference between the MTA group and CH group in success rate of pulpotomy (OR =3.20, 95% CI: 1.93, 5.30, P<0.00001, I^2=0%, Z=4.52) (*Figure 5*).

Influence of apical foramen condition (apical foramen closed and apical foramen not closed) on success rate

In the 4 randomized controlled trial (RCT) references included, heterogeneity test was carried out and it was found that the heterogeneity of the selected studies was small and thus a fixed effect model was used for meta-analysis. The results of meta-analysis showed that there was a significant statistical difference between the MTA group and CH group in the influence of apical foramen condition on success rate (OR =1.77, 95% CI: 1.14, 2.73, P=0.01, I^2=15%, Z=2.56) (*Figure 6*).

Influence of different surgical procedures (complete and partial) on success rate

Four literatures were included in this study, heterogeneity test was carried out and it was found that the heterogeneity of the selected studies was small and thus a fixed effect model was used for meta-analysis. The results of meta-analysis showed that there was a significant statistical difference between the MTA group and CH group in the influence of surgical procedure on success rate (OR =2.64, 95% CI: 1.65, 4.23, P<0.0001, I^2=45%, Z=4.05) (*Figure 7*).

Discussion

CH, a classic material for pulpotomy, is strongly alkaline,

Table 1 Basic clinical features of the 15 studies included in our study

Study	Age (years)	Gender (male)	Follow-up time (months)	MTA group (N)	CH group (N)	NOS score
Vafaei A 2022	13.71±2.2	41.25%	3–12	95	74	8
Ahmed MI 2021	5.65±3.4	69.12%	12–24	85	62	7
Kim CH 2021	13.12±4.5	45.72%	6–12	117	107	–
Corrêa-Faria P 2020	7.15±4.5	44.12%	6–24	65	59	–
Pine CM 2020	12.85±8.4	51.89%	6–24	57	72	8
Mabangkhru S 2020	14.36±1.2	63.45%	4–12	53	64	7
Pontes LRA 2020	12.62±2.2	78.10%	6–12	79	74	9
Innes NP 2020	12.61±3.0	48.75%	6–18	78	62	9
Freeman R 2020	7.25±4.5	59.23%	6–24	40	55	7
Selvaraj D 2021	16.22±5.2	56.22%	4–24	63	69	–
Piwat S 2020	11.35±8.1	53.16%	3–12	107	95	7
Berti GO 2020	7.25±6.0	66.34%	4–14	95	76	7
Pontes LRA 2021	8.51±2.6	48.34%	6–24	62	77	9
Lotto M 2020	6.34±22.5	53.12%	6–24	82	75	8
Alrashdi M 2021	12.51±4.6	45.35%	4–12	44	32	9

CH, calcium hydroxide; MTA, mineral trioxide aggregate; NOS, Newcastle-Ottawa Scale.

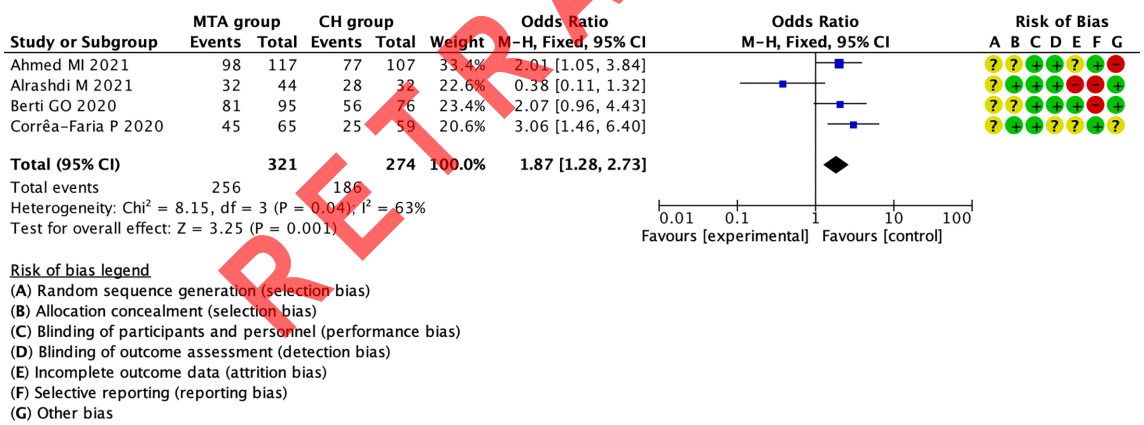

Figure 4 Meta-analysis of efficacy of the MTA and calcium hydroxide pulpotomy groups. CI, confidence interval; CH, calcium hydroxide; MTA, mineral trioxide aggregate; M-H, Mantel-Haenszel test.

suppresses bacteria, and induces the formation of dentin bridges (26). As a biological nanoceramic material, MTA has better biocompatibility, a mild inflammatory response, produces a dentine bridge similar to the normal dentine bridge, and also has unique closure properties that reduce the occurrence of microleakage (27). Animal studies have demonstrated significant superiority of biological nanoceramic materials such as MTA in controlling the pulp inflammatory response and promoting the formation of calcified bridges. Therefore, the advantages of MTA gradually emerge over an extended time (28). The success rate was 100% for refractory pulpitis 2 years after full coronal treatment, but the long-term efficacy of refractory surgery is uncertain due to the lack of sufficient research

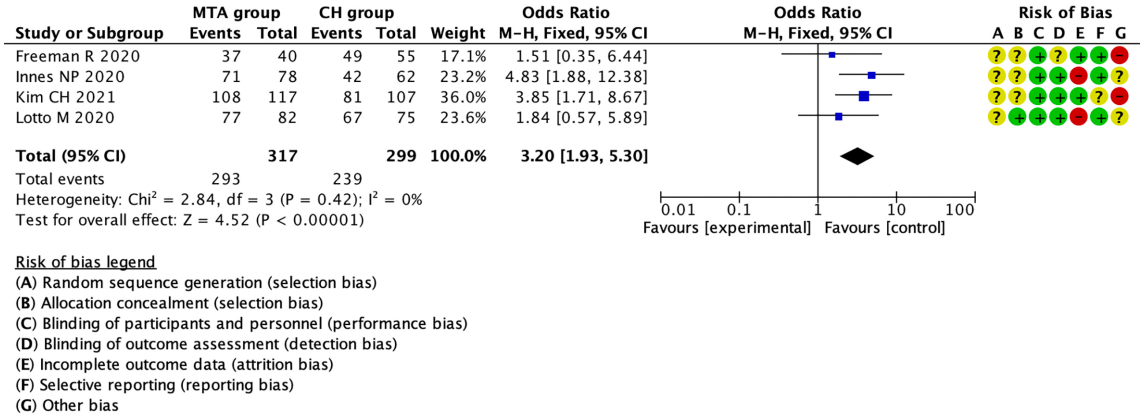

Figure 5 Meta-analysis of success rate of the MTA and CH pulpotomy groups. CI, confidence interval; CH, calcium hydroxide; MTA, mineral trioxide aggregate; M-H, Mantel-Haenszel test.

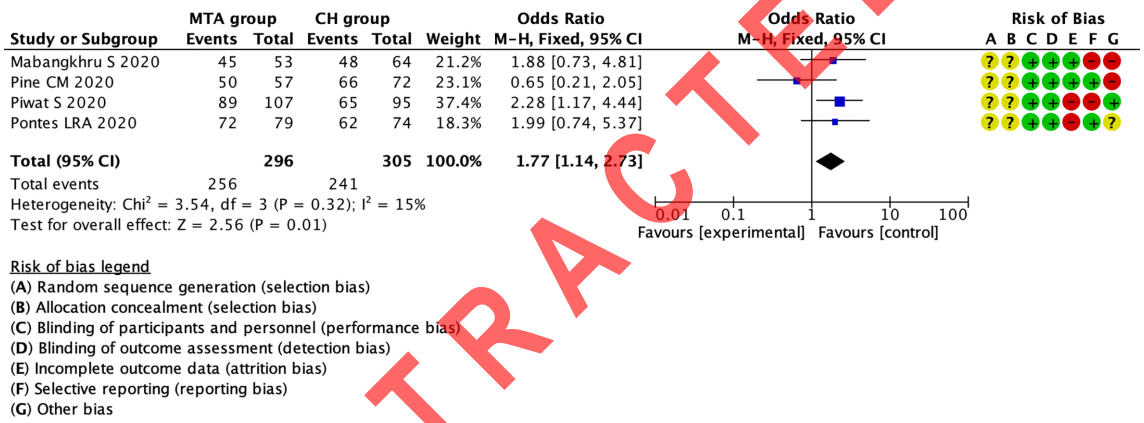

Figure 6 Meta-analysis of influence of apical foramen condition in the MTA and CH groups. CI, confidence interval; CH, calcium hydroxide; MTA, mineral trioxide aggregate; M-H, Mantel-Haenszel test.

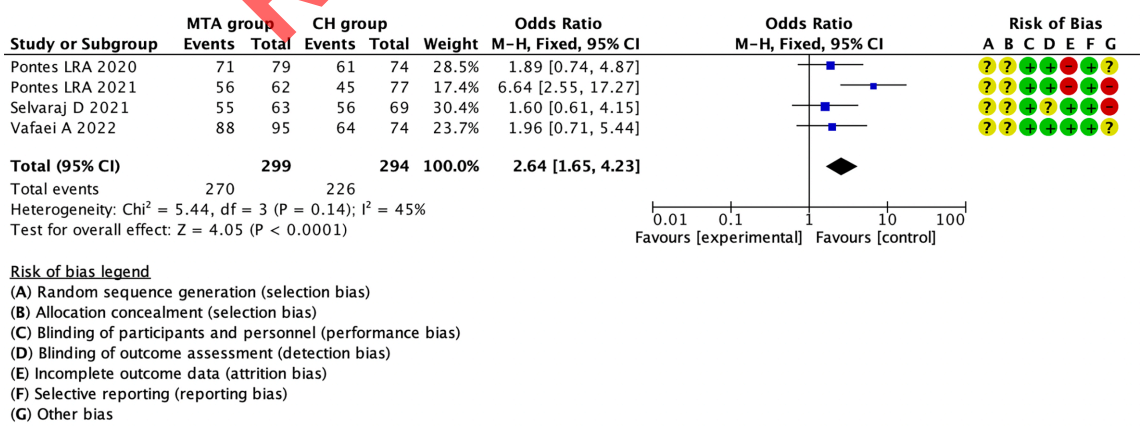

Figure 7 Meta-analysis of different surgical procedures on success rate in the MTA and CH groups. CI, confidence interval; CH, calcium hydroxide; MTA, mineral trioxide aggregate; M-H, Mantel-Haenszel test.

data, and thus cases with refractory pulpitis require follow-up for 2 years or longer. Moreover, based on medical history, clinical examination, and imaging, it is reasonable to believe that the inflammatory infection in the refractory pulpitis group was more severe; however, there was no accurate measure of pulp inflammation in each study subject, which is a defect of this article and also of each study included in our review (29).

In the analysis of MTA pulpotomy, apical hole closure had no significant effect on the success rate (30). For long-term efficacy, nonclosure of the apical opening was more conducive to postoperative prognosis, probably because young permanent teeth have stronger pulp self-repair ability than those with completed root development (31-33). Complete coronal resection was more beneficial for improving postoperative success rate than partial coronal resection. Complete clearance of inflammatory pulp tissue is crucial for prognosis, and total coronal resection is more likely to completely remove inflamed teeth than partial coronary resection, which is conducive to postoperative pulp tissue self-repair (34). However, studies with longer follow-up are still needed to further clarify the efficacy of MTA live pulp resection on caries-derived exposed permanent teeth.

Our study had some limitations. The included studies were all RCTs studies with a greater probability of selection bias, which may have affected the value of the meta-analysis conclusions. In addition, most studies did not directly report HR and its 95% CI, and the data extracted from the survival curve may have been biased from the real data, which may have biased the merger results.

For long-term efficacy, MTA pulpotomy is superior to CH (35). There was no significant effect on success rate, but a better prognostic trend for apical hole closure over time. Complete pulpotomy is more beneficial to improving success rates than partial pulpotomy. However, longer follow-up is still needed to further clarify the efficacy of MTA live pulp resection on cariogenic exposed permanent teeth.

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Footnote

Reporting Checklist: The authors have completed the PRISMA reporting checklist. Available at https://tp.amegroups.com/article/view/10.21037/tp-22-68/rc

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://tp.amegroups.com/article/view/10.21037/tp-22-68/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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