Differences of the Success of Apexification with Calcium Hydroxide and Mineral Trioxide Aggregate: Scoping Review

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Abstract

Apexification is a treatment for non-vital immature permanent teeth with an open apex, that aim to induce an apical barrier. The most prequently materials for apexification are calcium hydroxide [Ca(OH)2] and Mineral Trioxide Aggregate (MTA). They are several factors influence the treatment success of apexification using both materials. Thus, this study aimed to find the success differences of Ca(OH)2 and MTA in apexification.

A scoping review was use in this study according to PRISMA Extension for Scoping Reviews, and conducted through databases searching on PubMed, The Cochrane Library, EBSCOhost, ScienceDirect, and SAGE Journals.

A total of eight articles was selected following inclusion and exclusion criteria. Two articles that only studied Ca(OH)2 stated that Ca(OH)2 formed an apical barrier. Four articles studied apexification using MTA claimed that MTA formed apical barrier. Two articles compared Ca(OH)2 and MTA, proclaimed that there was no significant difference in the success of apexification.

There was no significant success difference of apexification by Ca(OH)2 and MTA, both clinically and radiographically. However, MTA more rapidly formed the apical barrier.

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Keywords: Apexification, calcium hydroxide, MTA, apical barrier.

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Introduction

Necrotic pulp may occur in immature permanent teeth which the root canal has not yet formed perfectly.[1] Necrotic pulp may be caused by deep and disperse carries, abnormalities on the pulp or periapical, and dental trauma. Necrotic pulp may result in delayed development of immature teeth, which causes the teeth have several characterictics such as open apex, wide root canal, and fragile walls.[2,3]

The apex formation usually complete in 3 years after teeth eruption.[4] First permanent incisive teeth erupted at 7 – 8-years-old, and the root formation completes at 10 years old. Second permanent incisive teeth erupted at 8 – 9-years-old, and the root formation completes at 11 years old. However, a study by Tarpomanov Y *et al*. stated that upper incisive teeth formation completed at 12-years-old.[5,6]

Several studies claimed that immature teeth with open apex may generate some problems, for instance: bacteria and toxin can enter into periapical tissue through root canal, difficulties in debridement and obturation due to the bigger apical diameter, and thin wall that is susceptible to fracture.[7,8] To avoid those complications, apex closure is necessary. The treatment that commonly use for non-vital teeth with open apex is apexification. Apexification is treatment for non-vital immature permanent teeth with an open apex, with or without periapical lesion to induce calcific barrier (or the form an artificial barrier).[9] Because an apical barrier is necessary at the time of obturation to prevent extrusion of cement and gutta percha to the periapical, apexification must be conducted prior to obturation.[3,10] The most prequently materials for apexification are calcium hydroxide [$Ca(OH)_2$] and Mineral Trioxide Aggregate (MTA).

$Ca(OH)_2$ is utilized for pulp capping, intracanal dressing, root canal sealer, apexogenesis, apexification, and root resorption in endodontic treatment.[11,12] $Ca(OH)_2$ is the first and most common material used for apexification

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due to its ability for inducing hard tissue at the apex, no periapical side effects, antibacterial properties, promote healing or tissue repair, and affordable.[13,14,15] However, $Ca(OH)_2$ has several limitation, which are longer treatment duration that cause unpredictable apex closure, poor patient's compliance, high rate of reinfection, and susceptible to root fracture.[14,16,17]

Mineral Trioxide Aggregate (MTA) is an appropriate alternative material for apexification beside $Ca(OH)_2$. MTA is a powder containing fine hydrophilic particles. When these particles are mixed with water, they may form colloid gel with pH 12.5 that will harden into cement after 3 – 4 hours.[18] MTA may be used as an apical plug that fill apical end without the need to wait on apical calcific barrier formation. Consequently, root canal filling may be done faster.[13] Several MTA superiority including biocompatibility, antimicrobial capability, ability prevent leakage, no cytotoxicity, high adaptation margin, stimulates hard tissue formation, and faster treatment compared to calcium hydroide.[3,14] Nevertheless, MTA also has several limitation such as longer setting time (3 – 4 hours), may cause dental discoloration, and higher cost for MTA material.[19,20]

Based on a study by Paulindraraj S *et al*. time needed to form apical barrier in $Ca(OH)_2$ varied between 6 – 24 months.[21] Meanwhile, according to Lin JC *et al.*, apical barrier formation using MTA was around 3 – 4.5 months.[14] Previous studies had described the success of apexification using both $Ca(OH)_2$ and MTA[22,23] However, a study performed by Bonte *et al.*, which compares MTA and $Ca(OH)_2$ in apexification, claimed that there was a root fracture on treatment using $Ca(OH)_2$. Yet, no root fracture has been found in treatment using MTA.[24] Long term evaluation on the result of apexification using MTA in Bogen G *et al.* study revealed swelling and pus after 17 years from initial treatment.[25] They are several factors influence the treatment success of apexification using both materials. Thus, this scoping review aimed to find the success differences of $Ca(OH)_2$ and MTA in apexification.

Materials and methods

This study was done using scoping review method. Specific research question was categorized based mnemonic PCC (Population – Concept – Context). Population: Patients with non-vital immature permanent teeth with open apex. Concept: The success of apexification using $Ca(OH)_2$ and MTA. Content; In vivo research. Articles' search and selection was analyzed based on PRISMA Extension for Scoping Reviews (PRIMA-ScR) guidelines. PRISMA-ScR was done to provide guidelines on scoping review reporting.[26] Articles search strategy was done on 5 electronic literature databases, which are: PubMed, The Cochrane Library, EBSCOhost, ScienceDirect, and SAGE Journals. Articles search was done using keywords combined by Boolean operators as follows (Immature teeth OR Permanent teeth) AND (Calcium Hydroxide OR $Ca(OH)_2$ OR MTA OR Mineral Trioxide Aggregate) AND (Apexification). PRISMA guidelines as article selection is depicted on Figure 1. After eliminating the articles duplicates and considering full-text availability, author read all articles completely and analyzed them based on inclusion and exclusion criteria summarized in Table 1. Result and findings of the selected studies were analyzed qualitatively.

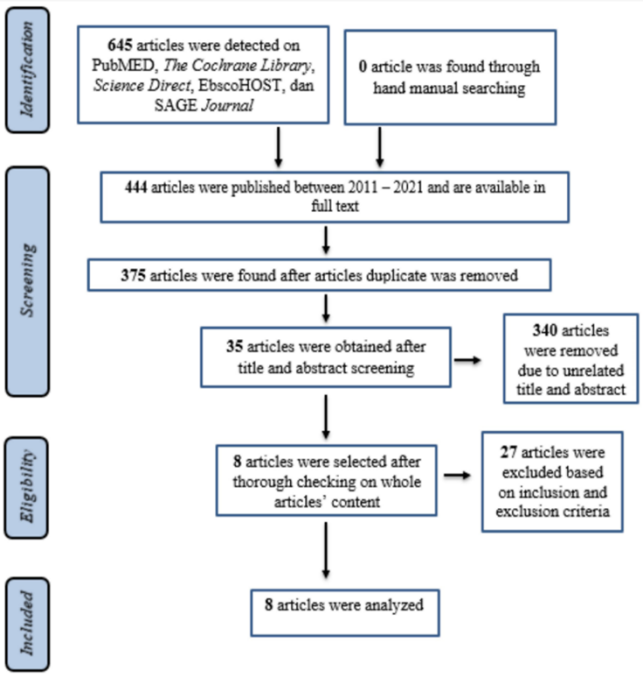

Figure 1. PRISMA-ScR flow diagram.

Results

After articles search and selection process was done, 8 articles were included in the study. There were 2 articles discussing

apexification using $Ca(OH)_2$ (Table 2), 4 articles discussing apexification using MTA (Table 3), And 2 articles discussing comparison between apexification using $Ca(OH)_2$ and MTA (Table 4).

Discussion

Article written by Ghosh S *et al.* divided $Ca(OH)_2$ into 3 groups. Time needed for barrier formation on 1st group was 9.12 months, on 2nd group was 7.7 months, and on 3rd group was 6.09 months. On this article failure was observed on 7 out of 51 teeth with no cause mentioned.[27] According to Torbinejad *et al.* failure on apexification generally caused by bacteria contamination, usually due to the loss of coronal restoration or during inadequate debridement on canal area.[9] Other possibility of failure on apexification using $Ca(OH)_2$ is root fracture, due to alkali pH of $Ca(OH)_2$ that will produce antibacterial properties. This antibacterial function will lessen as long as hydroxyl ion diffused. Therefore, reapplication of $Ca(OH)_2$ is necessary. Continuous use of $Ca(OH)_2$ will cause alteration of pH that affects acidity of organic matrix in dentin tissue. Due to that, dentin is weakened. This will cause dental fragility to root fracture.[17]

Article from Gupta V *et al.* on apexification using $Ca(OH)_2$ reported a success result in this case, although patient never came for follow-up. Clinically, there was no pain and symptoms in apexification using $Ca(OH)_2$. This result is similar with study from Alpianti LT, which described the clinical success factors, including no spontaneous pain, no pain on percussion and palpation.[2] Radiographically successful apexification indicates an apical barrier formation, in accordance with study conducted by Krianawati *et al.,* stated that radiography success factor was marked by radiopaque presentation on the apex, normal appearance on tissue surrounding the teeth, and no radiolucent on apical area.[1] Radiopaque image on the apex showed apical closure.[1] Time needed for apical barrier formation on article written by Gupta V *et al.* was around 9 months.[28] Ghosh S *et al.* and Gupta V *et al.* described time needed for apical barrier formation was similar with study from Paulindraraj S *et al.*, which were 6 – 24 months.[21]

There were four articles reported the success of apexification using MTA. Clinically, apexification using MTA has no symptoms and pain, similar to study conducted by Alpianti LT.[2] Radiographically, radiolucent lesion disappears and apical barrier was formed. This result is in accordance with study by Krianawati *et al.*[1] Time needed for barrier formation on articles written by Lee LW *et al.* which are 6 to 7 weeks, analogous to Lin JC *et al*., stated the time needed for apical barrier formation ranged between 3 to 4.5 months.[14] Article from Floratos SG *et al.* reveal time needed for apical barrier formation on 1st case was 16 months. Meanwhile, on the 2nd case time needed was 12 months, not corresponding with study by Lin JC *et al*. The reason was described in article written by Floratos SG *et al.* stated that no direct contact between MTA and root canal wall or MTA application was not hermetic. Due to that, there was a delay in apical barrier formation time and time needed was longer. Articles from Purra A R *et al.* and Gunes B *et al*. did not state time needed for apical barrier formation on apexification using MTA. However, they showed success both clinically and radiographically.

Damle SG *et al.* on 2016 and 2012 compared apexification on MTA and $Ca(OH)_2$ described no significant difference in clinical and radiographical success. On the study from 2016 describing time needed for barrier formation was faster on apexification treatment using MTA, although the difference was not significant.[7,29] On apexification with $Ca(OH)_2$ there were 2 teeth failed due to resorptive process, and also 1 tooth failed using MTA due to over-extrusion on periapical area.[7] Article from Damle SG *et al.* on 2012 stated there was failure on 1 tooth using $Ca(OH)_2$ due to internal resorption, meanwhile no failure was noted on MTA.[29]

Demiriz L *et al.* compared the MTA apexification result between extruded and not extruded MTA. The result showed no significant difference, however longer healing time on follow up was recorded on extruded MTA. MTA extrusion only caused a delay and did not completely stop periapical lesion healing.[30] The result differs with the result from Damle SG *et al.* (2016) that only follow up until 12 months. A longer follow up time was needed to be able to see optimal apexification result.

The difference between success of apexification with $Ca(OH)_2$ and MTA was not significant because both $Ca(OH)_2$ and MTA was alkali. Alkali condition of $Ca(OH)_2$ and MTA may cause the release of several wound healing

signal (growth factors), delaying bacteria growth, and stimulate hard tissue, therefore both materials were good for inducing apical barrier formation.[15] The Apical barrier formation was faster in MTA compared to $Ca(OH)_2$, even though the difference is not significant.

Limitation on this review was lack of randomized controlled trial studies (RCT). Subsequent RCT studies was needed with further follow up time, in order to describe further results of apexification using MTA and $Ca(OH)_2$.

Conclusions

Based on the analysis of all articles, there was no significant success difference of apexification by $Ca(OH)_2$ and MTA, both clinically and radiographically. However, MTA more rapidly formed the apical barrier.

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Declaration of Interest

The authors report no conflict of interest.

Inclusion criteria	Exclusion criteria
1) Articles published between 2011 - 2021	1) Articles discussing on apexogenesis and revascularization
2) Articles are available in full text	2) Articles on in vitro research
3) Articles in Indonesian and English	3) Research articles in the form of review
4) Non-vital immature permanent teeth with open apex	
5) Upper jaw incisive teeth	
6) Patients aged between 8 – 18 years-old	

Table 1. Inclusion and exclusion criteria.

	No	1	2
Source	**Title**	Comparative evaluation of different forms of calcium hydroxide in apexification	Non Physiologic Root Closure with Calcium Hydroxide: A Case Report
	Authors (Year)	Ghosh S *et al.*[27] (2014)	Gupta V *et al.*[28] (2016)
	Aim	Determining efficacy of calcium hydroxide in different formulation in order to induce apexification	Report apexification treatment with calcium hydroxide
Methods	**Study Design**	Non-randomized controlled trial	Case report
	Sample	Total: 51 teeth 1. Group I $Ca(OH)_2$ powder + distilled water 2. Group II $Ca(OH)_2$ non-setting without iodoform 3. Group III $Ca(OH)_2$ non-setting with iodoform	1 tooth
	Intervention	RCT→ application different forms of $Ca(OH)_2$ according to group → periodic recall → apical bridge present → obturation (follow-up 3, 6, 9 and 12 months)	RCT → 1 week (symptom lessen)→ application of $Ca(OH)_2$ → 8 months (apical bridge)→ obturation
Results	**Clinical presentation**	Clinical symptoms before operation And apexification success: 1. Symptomatic (14 teeth): • Success 9 teeth • Failure 5 teeth 2. Asymptomatic (37 teeth): • Success 35 teeth • Failure 2 teeth.	1. No symptoms on 3 months follow up 2. Patient did not show up for control and came after 5 months: uncomfortable on percussion and $Ca(OH)_2$ was reapplied
	Radiography	1. Group I: • Success 12 teeth • Failure 5 teeth • Time: 9,12 months. 2. Group II: • Success 15 teeth • Failure 2 teeth • Time: 7,7 months. 3. Group III: • Success on all teeth which are 17 teeth • Time: 6,09 months.	1. Follow up 3 months: barrier was not formed 2. Patient did not come for control and presented with horizontal bridge 5 months afterward. $Ca(OH)_2$ was reapplied 3. Apical bridge was formed on 3 months follow up. 4. No periapical tissue abnormality was found on 6 months review
Conclusion		No significant difference on apical barrier formation time. Success rate on group I was 70.6%, 88.2% on group II, and 100% on group III. Mean rate of success was 86.27%.	Apexification using $Ca(OH)_2$ in this case is a success

Table 2. Data extraction on apexification using $Ca(OH)_2$. *RCT: Root Canal Treatment.

No		1	2	3	4
Source	Title	Outcomes of necrotic immature open-apex central incisors treated by MTA apexification using poly(ε-caprolactone) fiber mesh as an apical barrier	Apical Barrier Formation After Incomplete Orthograde MTA Apical Plug Placement in Teeth with Open Apex - Report of Two Cases	Mineral trioxide aggregate apexification: A novel approach	Mineral trioxide aggregate apical plug method for the treatment of nonvital immature permanent maxillary incisors: Three case reports
	Authors (Year)	Lee LW *et al.*[31] (2019)	Floratos SG *et al.*[32] (2013)	Purra AR *et al.*[33] (2016)	Gunes B *et al.*[34] (2012)
	Aim	Evaluates the results of non-vital immature permanent incisive teeth with open apex after treatment with apexification PCL-FM/MTA	Demonstrates the forming of apical barrier on non-vital immature permanent teeth with open apex which apical plug MTA placement was not completed	Reports on apexification with MTA using resorbable suture thread polyglactin-based as apical matrix	Reports on apexification treatment with MTA
Methods	Study Design	Case series	Case report	Case report	Case report
	Sample	8 teeth	2 teeth	2 teeth	3 teeth
	Intervention	RCT → PCL-FM as thick as 7×7 mm and 0,5 mm to root canal→ application of MTA→ 6 hours/the next day→ obturation→ composite (follow-up once a week for as long as the first 7 weeks, followed by twice a week from 8 weeks – 3 months)	RCT → application of MTA→ radiography (incomplete MTA placement)→ 3 days → obturation → composite	RCT → resorbable thread material polyglactin-based Vicryl (apical matrix)→ application of MTA → 1 day→ obturation→ composite	RCT → application of MTA → 2 days→ obturation→ composite
Results	Clinical presentation	3 months follow up: Pain disappears and no discoloration	1. First case: no pain on 6 months follow-up 2. Second case: no pain on 12 months follow-up.	3 months follow-up: 1. First case: normal mobility, pricing depth, and normal function without any symptoms 2. Second case: no symptoms, no pain on percussion	1. First case: 6 and 18 months follow up clinical function is adequate, no clinical symptoms and sinus tract. 2. Second case: on 6 and 18 months follow up there was no sinus buccal tract. 3. Third case: on 1 year follow up sinus tract disappear and there were no clinical symptoms

	Radiography	Barrier formation: 6-7 weeks Increase on root length: 1-3 mm (7 weeks) and 2-4 mm (3 months) An increase in apical wall thickness: 1-2 mm (7 weeks) and 1,5-3 mm (3 months) After 3 months: lesion disappear	1. First case: 6 months follow up lesion disappears 16 months follow up apical close 2. Second case: On 12 months follow up lesion disappears and apical close	On 3 months follow up: 1. First case: apical matrix resorption and lesion disappears **2.** Second case: apical matrix resorption and lesion disappears.	1. First case: • Follow up 6 months: periapical lesion decreases • Follow up 18 months: lesion disappears 2. Second case: • Follow up 6 months: periapical lesion lessens • Follow up 18 months: further decrease on periapical lesion 3. Third case: • Follow up 1 year: lesion disappears
Conclusion			Apexification with MTA material in this case is a success.	Apexification with MTA using polyglactin-based resorbable suture thread in this case is a success	Apexification with MTA material in this case is a success

Table 3. Data extraction on apexification using MTA. *RCT: Root Canal Treatment.

No		1	2
Source	**Title**	Clinical and radiographic assessment of mineral trioxide aggregate and calcium hydroxide as apexification agents in traumatized immature permanent anterior teeth: A comparative study	Apexification of Anterior Teeth: A Comparative Evaluation of Mineral Trioxide Aggregate and Calcium Hydroxide Paste
	Authors (Year)	Damle SG *et al*.[7] (2016)	Damle SG *et al*.[29] (2012)
	Aim	Determining the clinical and radiography efficacy of MTA and $Ca(OH)_2$ on stimulating the formation of root tip from non-vital immature permanent teeth with an open apex. It also aims to evaluate time needed for periapical radiolucency resolution.	Determining the clinical and radiography efficacy of MTA and $Ca(OH)_2$ on stimulating the formation of root tip from non-vital immature permanent teeth with an open apex. It also aims to evaluate time needed for apical barrier formation
Methods	**Study Design**	Randomized controlled trial	Randomized controlled trial
	Sample	Total: 22 teeth (divided into 2 groups) 1. Group 1 MTA 2. Group 2 Ca(OH)	Total: 30 teeth, divided into 2 groups: 1. Group 1 MTA 2. Group 2 $Ca(OH)_2$

	Intervention	1. Group1: RCT→application of MTA→ 24 hours→ obturation→ GIC. 2. Group 2: PSA→application of $Ca(OH)_2$→ periodic recall → apical barrier formation→ obturation→ GIC. (follow-up 3, 6 dan 9 months)	3. Group1: RCT→application of MTA→ 24 hours→ obturation→ composite / jacket crown 4. Group 2: PSA→application of $Ca(OH)_2$→ periodic recall → apical barrier formation→ obturation→ composite / jacket crown (follow-up 1, 3, 6, 9 and 12 months)
Results	**Clinical presentation**	Follow up 9 months: 1. Group I (MTA): • 10 teeth success • 1 tooth failed • Success percentage 90.09% 2. Group II ($Ca(OH)_2$): • 9 teeth success • 2 teeth failed • Success percentage 81,81%	Follow up 12 months: 1. Group I (MTA): • 15 teeth • Success percentage 100% 2. Group II ($Ca(OH)_2$): • 14 teeth asymptomatic • Success percentage 93,33%.
	Radiography	1. Group I (MTA): • Barrier formation: 4,90 months • 10 teeth success • 1 tooth failed • Success percentage 90.09% 2. Group II ($Ca(OH)_2$): • Barrier formation: 5,33 months • 9 teeth success • 2 teeth failed • Success percentage 81,81%	Follow up 12 months: 1. Group I (MTA): • Barrier formation: 4,5+1,56 months • All teeth: calcific barrier formed without periapical pathology. 2. Group II ($Ca(OH)_2$): • Barrier formation: 7,93+2,53 months • 1 tooth failed: internal resorption • Success percentage 93,33%.
Conclusion			There was a significant difference in barrier formation time. There was no significant difference between clinical and radiography success.

Table 4. Data extraction on comparison between apexification using MTA and $Ca(OH)_2$.
*RCT: Root Canal Treatment.

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