ORIGINAL RESEARCH

Evaluation of Indirect Pulp Capping Using MTA, Light-cured Calcium Silicate, and Propolis in Primary Teeth: A Clinical and Radiographic Study Using VistaScan

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Abstract

Aims: Clinical and radiographic evaluation of mineral trioxide aggregate (MTA), TheraCal LC, and propolis when used as an indirect pulp capping agent in primary teeth over a period of 6 months.

Materials and methods: A total of 42 primary molar teeth from children aged 4–10 years were chosen for the study. The teeth were divided equally into three groups (group I: MTA, group II: light cured calcium silicate, and group III: propolis). The teeth were followed up clinically and radiographically at 3 and 6 months. The teeth that showed successful treatment outcomes clinically and radiographically were evaluated for the amount of dentin bridge formed at the end of 3 and 6 months, which was measured using CorelDRAW software. The data obtained was analyzed statistically using Statistical Package for the Social Sciences (SPSS) version 21.

Results: The mean change in dentin thickness from baseline to 3 months in group II was found to be the highest, followed by groups I and III. The mean change in dentin thickness from 3 months to 6 months was highest in group I, followed by groups III and II. The mean change in dentin thickness from baseline to 6 months in group II was found to be significantly higher than that of group I, followed by group III.

Conclusion: Clinically and radiographically, all three materials showed favorable outcomes when used as an indirect pulp capping material with significant reparative dentin formation. The highest amount of dentin deposition was recorded with light-cured calcium silicate, followed by MTA and propolis, respectively.

Keywords: Indirect pulp capping, Light-cured calcium silicate, Mineral trioxide aggregate, Primary teeth, Propolis.

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Introduction

Indirect pulp treatment (IPT) is a procedure wherein teeth with caries approaching the pulp but which are free of symptoms of degeneration of pulp are treated. Pulp exposure is avoided by leaving the caries surrounding the pulp and placing a biocompatible material over it.[1] The ideology behind this is that a dentin-like matrix (tertiary dentin) can be formed by the dental pulp in the dentin-pulp complex as a part of its repair.[2]

Indirect pulp capping (IPC) is a time-tested protocol, and calcium hydroxide [$Ca(OH)_2$] is considered a gold standard for this procedure. It allows reparative dentin formation by cellular differentiation, secretion of extracellular matrix, and, ultimately, mineralization. Failures in this treatment approach due to the unwanted effects of $Ca(OH)_2$, like internal resorption, subsequent degeneration, tunnel defects, and inadequate seal, lead to the decline of this procedure.[3]

To overcome the undesirable effects of $Ca(OH)_2$, the latest materials, which included bioactive properties like mineral trioxide aggregate (MTA), light-cured calcium silicate (TheraCal LC, BISCO), and biodentin, were introduced. MTA relies on a hydration reaction for setting as it is a hydraulic silicate cement and is composed of tricalcium silicate, tetracalcium aluminoferrite, dicalcium silicate, tricalcium aluminate, and gypsum. Many *in vivo* studies have confirmed its good reparative dentin-forming ability. The unfavorable characteristics of MTA, like prolonged setting time, handling difficulties, high solubility, and cost, indicated the search for a new indirect pulp capping material.

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A new generation of resin-modified calcium silicate materials, namely TheraCal LC, has reported the formation of apatite crystals and reparative dentin. It comprises approximately 45% wt mineral material (type III Portland cement), 10% wt radiopaque component, 5% wt hydrophilic thickening agent (fumed silica), and approximately 45% hydrophobic resin. Induction of reparative dentin formation has been established by TheraCal LC.[4]

Propolis has been used recently as a traditional medicine owing to its good pharmaceutical properties, chemical constituents, and low toxicity. It is a resin-like substance collected from the buds of various trees by honeybees, which is used for the sealing of the crevices and cracks of the bee hive. "Propolis" is a

Greek word that translates to pro, "in front of" or "at the entrance to," and polis, "community" or "city," and means a substance in defense of the hive.[5] The constituents of propolis are 55% resin, 30% essential oils, 5% pollen, and 10% other constituents such as amino acids, minerals, ethanol (alcohol), vitamins A, B-complex, E, and bioflavonoid, which is a highly active biochemical substance.[6] Components present in propolis, such as arginine, vitamin C, pro-vitamin A, and B-complex, and minerals like copper, iron, and zinc in trace amounts, as well as bioflavonoids, help in dentin bridge formation. All of the above properties of propolis help in the healing of wounds, and by breaking the cell wall and cytoplasm and preventing cell division of bacteria, it makes a good antimicrobial agent, too.[7]

Zinc oxide base filler and propolis flavonoids were compared by Sabir et al.[8] as direct pulp capping agents in rats. They concluded that dental pulp inflammation was delayed, and reparative dentin formation was stimulated by propolis flavonoids.[8]

In direct pulp capping, to form reparative dentin, and to reduce dentin permeability, propolis have been routinely used in restorative dentistry. Ahangari et al.[9] have already proved that propolis is more efficient in direct pulp capping compared to $Ca(OH)_2$ products. It stops microbial infection, inflammatory reactions, and pulpal necrosis. Stem cell stimulation promotes high-quality tubular dentin formation. The presence of flavonoids stimulates the effect of propolis on the pulp.[9]

Calcium hydroxide [$Ca(OH)_2$] has been routinely used for IPC by clinicians, and now MTA is a gold standard for IPC. Many authors have conducted studies that have evaluated MTA and TheraCal as indirect pulp-capping agents. However, on a thorough literature search of scientific papers, we found that studies have yet to be conducted evaluating propolis as an indirect pulp-capping agent in primary teeth.

Materials and Methods

The ethical clearance was obtained from the Institutional Ethical Committee. A total of 42 primary molar teeth from patients between 4 and 10 years were chosen for the study. The teeth were allocated into three groups equally and randomly comprising 14 teeth in each group (group I: MTA, group II: light-cured calcium silicate, and group III: propolis) based on the following criteria.

Inclusion Criteria

- History of dull, intermittent, but bearable pain associated with eating.
- On clinical examination, involvement of the occlusal or proximal surfaces with a large carious lesion with the gingiva appearing normal.
- Radiographically, more than two-thirds of dentin thickness is being involved by caries nearing the pulp, lamina dura, and periodontal ligament (PDL) space appearing normal, more than two-thirds of root present, no periapical changes, and no pathologic external or internal resorption.

Exclusion Criteria

- Acute pulpal inflammation and necrosis indicated by a history of sharp penetrating pulpalgia and prolonged spontaneous pain at night.
- Clinically, mobile tooth, discolored tooth, negative electric pulp testing results, a tooth with sinus opening or abscess.

Before the procedure, a preoperative diagnostic radiograph of the tooth with a grid was taken. Topical anesthesia was applied first, following which local anesthesia was administered, after which isolation was achieved with a rubber dam. A two-step carious lesion removal procedure was undertaken: (1) a high-speed round diamond bur was used to remove carious enamel and dentin; and (2) a sharp spoon excavator was used to curette the dentin manually only to remove the infected dentin. Care was taken not to expose the pulp. Then, a pulp capping medicament was selected and placed in the cavity after manipulating it by following the instructions given by the manufacturer.

In group I, MTA (Angelus® Indústria de Produtos Odontológicos, Brazil) powder and sterile water were mixed for 30 seconds (following the instructions of the manufacturer) until a sandy consistency was obtained, carried with an MTA carrier and light pressure was applied by a cotton pellet which was moist and then temporized. After 24 hours, a base with glass ionomer cement (GIC) followed by composite restoration was done.

In group II, using a dispensing syringe, light-cured calcium silicate (TheraCal LC®, BISCO Inc, Illinois, United States of America) was applied to the dentin surface directly and was light-cured for 20 seconds, followed by a GIC base and composite restoration.

In group III, 100% propolis powder (Holistic Herbal Solutions, Ohio, United States of America) and 70% ethyl alcohol were manipulated on a paper pad with a plastic spatula to attain a thick consistency. The mixture was carried with a metal carrier and applied over the treatment site. GIC base and composite restoration was done subsequently.

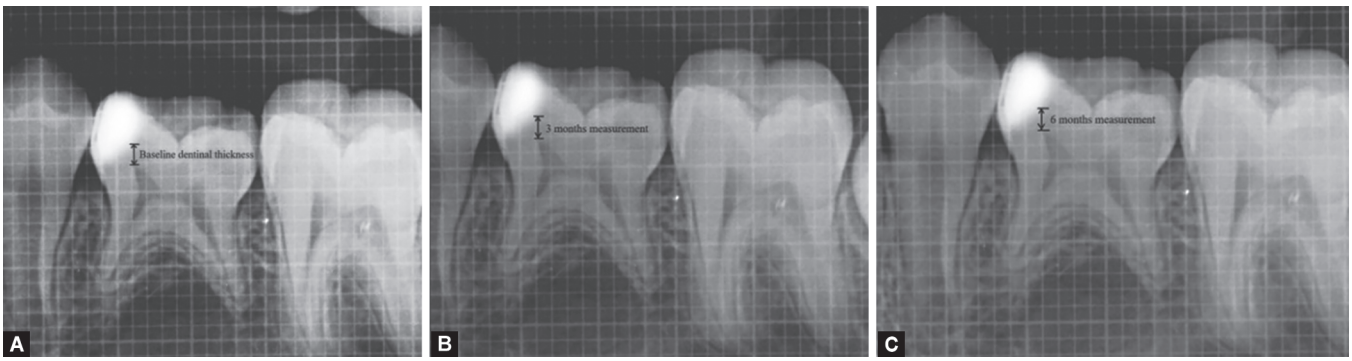
Immediately, with the help of VistaScan, a baseline radiograph was taken with the grid. Subsequently, the tooth was examined clinically and radiographically at the 3rd and 6th month.

Clinically, treatment was considered successful when there was an absence of the following: pain, sensitivity to pressure, abnormal tooth mobility, and abscess. The treatment was radiographically considered successful when reactionary dentin was present over the lesion with the absence of the following: furcation radiolucency, pulp exposure, broken lamina dura, widening of PDL space, and external and internal resorption of the root. The teeth that showed successful treatment clinically and radiographically were evaluated for dentin bridge thickness at 3 and 6 months (Fig. 1). The distance vertically from the base of the restoration and the uppermost point of the pulp horn was recorded, which was employed in a study done by Chauhan et al.[10] Statistical Package for the Social Sciences (SPSS) version 21 was used to evaluate the records obtained.

Results

A total of 42 primary molar teeth were equally allocated into three groups of 14 each (group I: MTA, group II: light-cured calcium silicate, group III: propolis). One patient, each from group I (MTA) and group III (propolis), and two patients from group II (TheraCal LC) did not appear for follow-up and were excluded from the study. One patient from group I showed signs of clinical and radiographic failure at the 6-month follow-up and was excluded from the study (Flowchart 1).

The mean change in dentin thickness from baseline to 3 months among group II (0.09883 ± 0.000835) participants was found to be significantly higher than that among group I (0.09538 ± 0.001121) participants, which was further significantly higher than that among group III (0.09415 ± 0.001144) participants (Table 1).



Figs 1A to C: Measurement of dentin thickness at different intervals

Flowchart 1: Sample collection and distribution

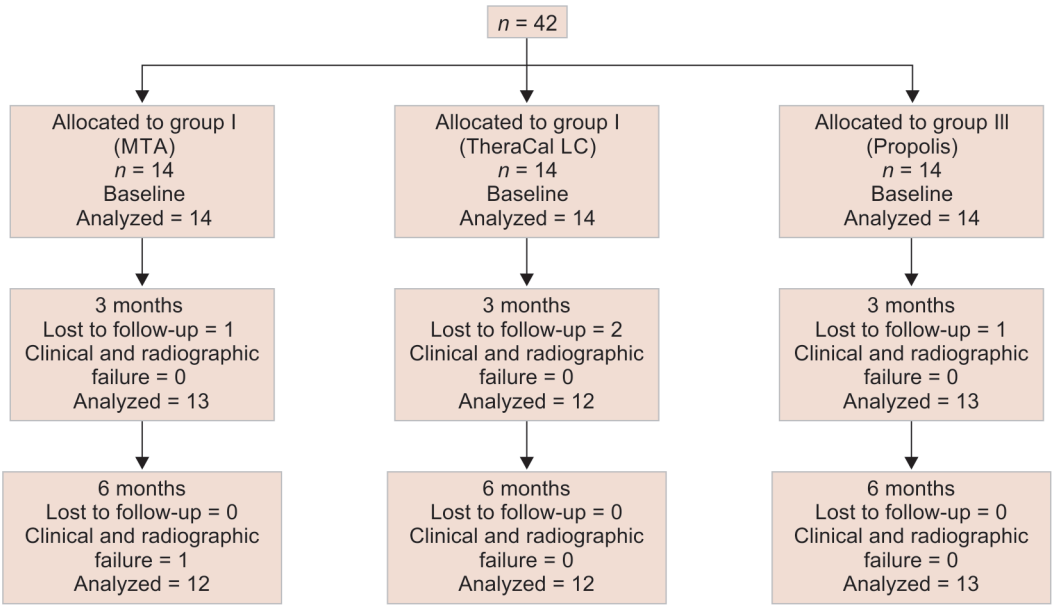


Table 1: Change in dentin thickness from baseline to 3 months

Change in dentin thickness from baseline to 3 months						
				95% confidence interval for mean		
	N	*Mean*	*Standard deviation*	*Lower bound*	*Upper bound*	*p-value of intragroup comparison*
Group I	13	0.09538	0.001121	0.09471	0.09606	<0.001
Group II	12	0.09883	0.000835	0.09830	0.09936	<0.001
Group III	13	0.09415	0.001144	0.09346	0.09484	<0.001
p-value	<0.001, significant (S)					
p-value of *post hoc* pairwise comparison using Tukey's test	Groups I–II: <0.001, S Groups I–III: 0.014, S Groups II–III: <0.001, S					

The mean change in dentin thickness from 3 to 6 months among group I (0.05583 ± 0.000937) participants was found to be significantly higher than that among group III (0.05508 ± 0.000862) participants, which was further significantly higher than that among group II (0.05333 ± 0.001073) participants (Table 2).

The mean change in dentin thickness from baseline to 6 months among group II (0.15217 ± 0.001337) participants was found to be significantly higher than that among group I (0.15108 ± 0.001165) participants, which was further significantly higher than that among group III (0.14923 ± 0.001641) participants (Table 3).

Discussion

Due to higher consumption of sugary substances, poor oral hygiene, inadequate fluoride exposure, and insufficient dental service utilization, the incidence of dental caries is increasing in children.[11]

Table 2: Change in dentin thickness from 3 to 6 months

Change in dentin thickness from 3 to 6 months						
				95% confidence interval for mean		
	N	*Mean*	*Standard deviation*	*Lower bound*	*Upper bound*	*p-value of intragroup comparison*
Gr I	12	0.05583	0.000937	0.05524	0.05643	<0.001
Gr II	12	0.05333	0.001073	0.05265	0.05402	<0.001
Gr III	13	0.05508	0.000862	0.05456	0.05560	<0.001
p-value	0.001. S					
p-value of *post hoc* pairwise comparison using Tukey's test	Groups I–II: <0.001, S Groups I–III: 0.135, NS Groups II–III: <0.001, S					

Table 3: Change in dentin thickness from baseline to 6 months

Change in dentin thickness from baseline to 6 months						
				95% confidence interval for mean		
	N	*Mean*	*Standard deviation*	*Lower bound*	*Upper bound*	*p-value of intragroup comparison*
Gr I	12	0.15108	0.001165	0.15034	0.15182	<0.001
Gr II	12	0.15217	0.001337	0.15132	0.15302	<0.001
Gr III	13	0.14923	0.001641	0.14824	0.15022	<0.001
p-value	<0.001, S					
p-value of *post hoc* pairwise comparison using Tukey's test	Groups I–II: 0.156, S Groups I–III: 0.006, S Groups II–III: <0.001, S					

Clinically, there are two ways of managing deep dentinal caries—the first is by preserving the vitality of the tooth by direct or indirect pulp capping, and the second is through root canal therapy. A favorable prognosis for pulp healing can be achieved by a conservative approach such as pulp capping.[12] Maintaining the vitality of the pulp while arresting the carious lesion, promoting the sclerosis of dentin (reducing permeability), stimulating tertiary dentin formation, and carious dentin remineralization are its ultimate objectives.[13]

Intergroup comparison of change in dentin thickness from baseline to 3 months revealed that the mean change in dentin thickness among group II (TheraCal LC) participants was significantly higher than that among group I (MTA) participants, which was further significantly higher than that among group III (propolis) participants. The intragroup comparison showed that among all the groups, the dentin thickness increased significantly from baseline to 3rd month.

This inference was similar to Menon et al.,[4] Gandolfi et al.,[14] and Makkar et al.[15] who stated that in the first 28 days, there is an increase in calcium iron release, which decreases later. A favorable environment is created for the viability of pulpal cells and metabolic activity with reparative dentin formation as there is a decrease in the pH of TheraCal LC from 10–11 to 8–8.5 in 7–14 days. Whereas a prolonged direct contact between MTA and pulp is required for the differentiation of odontoblast and formation of reparative dentin.[16] Furthermore, in the MTA group, irregularity in the formation of dentinal bridges can be attributed to a prolonged setting time contributing to leakage, surface disintegration, marginal adaptation loss, and material continuity loss.[17]

Intergroup comparison of the change in dentin thickness from 3 months to 6 months revealed that the mean change in dentin thickness among group I (MTA) and group III (propolis) participants was found to be significantly higher than that among group II (TheraCal LC) participants. The intragroup comparison showed that among all the groups, the dentin thickness increased significantly from 3rd to 6th month.

This finding was similar to Esmeraldo et al.[18] and Sabir et al.[19]; after 28 days, collagen bridges and dentin formation were induced by an alcoholic extract of propolis. The process of dental pulp healing and formation of collagen and subsequent regeneration is due to the properties of propolis, such as antibacterial, anti-inflammatory, antioxidant, and immunomodulatory properties.[19]

Furthermore, after direct contact with propolis, dentin bridge formation was reported by Ahangari et al.[9] after 15 days and 1 month, by Parolia et al.[20] after 15 and 45 days, and by Saleh et al.[16] 2 months. This favorable result might be due to the growth factors (TGF)—β1 interacting with the extracellular matrix, which occurs due to the presence of flavonoid in propolis, which forms odontoblastic differentiation to induce dentin bridge formation. Propolis was able to induce transforming growth factor-β1 and the synthesis of collagen.[16]

Intergroup comparison of change in dentin thickness from baseline to 6 months revealed that the mean change in dentin thickness among group II (TheraCal LC) participants was found to be significantly higher than that among group I (MTA) and group III (propolis) participants. The intragroup comparison showed that among all the groups, the dentin thickness increased significantly from baseline to 6th month.

The results of the current study correspond with George et al.,[3] who compared the formation of reparative dentin among MTA and $Ca(OH)_2$ and found that in the MTA group, the dentin thickness was 0.089 ± 0.031 mm in the first 3 months and 0.055 ± 0.022 mm

at the second 3 months. In a total of 6 months, tertiary dentin deposition was 0.143 mm in the MTA group. For matrix formation and odontoblastic cell division, a favorable environment is created by high alkalinity with a pH between 11 and 12, which can be maintained by MTA.[3]

The results of the current study are also in agreement with Menon et al.,[4] who found that in the MTA group, the mean increase in the thickness of dentin in the first 3 months was 0.095 ± 0.014 mm, and from 3 to 6 months it was 0.056 ± 0.009 mm. In 6 months, the dentin thickness increased by 0.151 ± 0.022 mm. In the TheraCal group, the mean increment in dentin thickness in the first 3 months was 0.101 mm ± 0.008 mm, and from 3 to 6 months, it was 0.053 ± 0.004 mm. In 6 months, the thickness of dentin increased by 0.154 ± 0.012 mm. The better performance of TheraCal could be its high alkalinity, which creates an encouraging environment for the viability of pulp cells and metabolic activity with reparative dentin formation.[4]

In a study done by Cannon et al.,[21] statistically higher hard tissue bridges were formed by pure Portland and TheraCal LC groups compared to the other two groups (GIC and VLC Dycal). TheraCal LC has good adherence to moist substrate, and application, clinically, is straightforward. For the treatment of compromised pulp, the added advantage of precise placement and command set of TheraCal is an important addition.[21]

In the current study, TheraCal LC showed the highest amount of reparative dentin formation when used as an indirect pulp capping agent. This was also earlier observed by Gandolfi et al.,[14] who identified that Ca^{2+} ions play an important part in the numerous biological events on the cells required for the formation of mineralized hard tissues. Mediated by calcium channels, bone-associated proteins are stimulated by Ca^{2+} ions, and ATP can be activated by large quantities of Ca^{2+} ions, which has a major role in the mineralization process. He also inferred that throughout the trial, Ca^{2+} and OH^- ions are released more by TheraCal LC than ProRoot MTA or Calcimol LC for at least 60 days.[11]

Beegum et al.[22] also concluded that throughout the trial, more calcium was released by TheraCal LC than ProRoot MTA and calcimol LC for at least 60 days. The greater amounts of Ca^{2+} ions released from TheraCal LC can be correlated to the presence of a calcium silicate component in a hydrophilic monomer, which makes it a very durable and stable material. High calcium release and low solubility have been shown by TheraCal LC due to its faster hydration reaction.[19]

The thickness of dentin formed in the present study in group III (propolis) was 0.09415 ± 0.001144 mm at the end of the first 3 months and 0.05508 ± 0.000862 mm at the end of the next 3 months. A total of 0.14923 ± 0.001641 mm of dentin was formed at the end of 6 months.

Meto et al.[23] stated that dentin bridges were formed in the propolis-treated teeth without any inflammatory response after three months of application. The presence of flavonoids and caffeic acid in propolis contributes to its anti-inflammatory properties, which are known to decrease inflammation.[23]

A histologic study on dog teeth by Saleh et al.[16] revealed that after a 2-month observation period, a reparative dentin bridge was induced by experimental Propolis direct pulp capping material. As direct pulp capping materials, both experimental propolis paste and MTA are considered quite successful.[16]

In another histologic study, Dwiandhono et al.[24] found that on the 14th day, a significant difference ($p < 0.05$) between the $Ca(OH)_2$ group and the propolis extract group was found. The odontoblast-like cells in the propolis extract group were thicker than the positive control group and $Ca(OH)_2$ group, which were statistically significant. A significant difference was seen on the 28th day ($p < 0.05$) between the positive control group, $Ca(OH)_2$ group, and propolis extract group. The odontoblast-like cells in the propolis extract group were thicker than the positive control group and $Ca(OH)_2$ group, which were statistically significant.[20]

The quantity and quality of dentin bridges formed by biodentin and propolis were compared by Mohanty et al.[25] with MTA by using them for direct pulp-capping and concluded after follow-up that in all the assessed teeth dentin bridges were successfully aided by all three materials. The quality and amount of dentin bridge formation of group I—MTA and group II—biodentine were superior to group III—propolis. Propolis can be used favorably for direct pulp capping as it improves wound healing due to its antimicrobial, anti-inflammatory, and tissue regeneration properties.[25]

A high clinical and radiographic success rate for the procedure has been demonstrated by the clinical and radiographic study presented here. This study suggests that irrespective of the base material applied, new tissue was formed at the dentin-pulp junction and that the technique of IPT was successful. The high percentage of success rate reported here could be directly correlated with a thorough pulp status diagnosis, associated with a careful restorative technique involving complete removal of caries from the lateral walls of the cavity and proper bonding procedures.

Conclusion

On the basis of the results, observations, and statistical analysis of this clinical and radiographic study, the following inferences were drawn:

- Clinically and radiographically, all three materials showed favorable outcomes when used for indirect pulp capping with significant reparative dentin formation.
- Radiographically, the highest amount of dentin deposition was recorded with light-cured calcium silicate, followed by MTA and propolis, respectively.
- Due to its natural properties, easy clinical application, comparable tertiary dentin formation, and good sealing ability, propolis may be suggested as a substitute for MTA and light-cured calcium silicate for indirect pulp capping in primary teeth.

The inferences cited above are centered on a clinical trial. However, additional research is warranted with a greater sample size and a longer follow-up. To support these findings, additional histological investigations are needed.

Clinical Significance

This study suggests that in primary teeth, propolis can be used for indirect pulp capping. The good results shown by propolis in our study shall allow its recommendation as an indirect pulp-capping medicament for primary teeth.

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