Original Article

Chemomechanical Caries Removal With Calcium Hydroxide: An SEM Study

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Abstract

Chemomechanical caries removal, though one of the most viable alternatives to conventional methods of caries removal, is still not much practiced due to the high treatment cost and extensive training required for its use, especially in developing countries. The present paper aims to highlight at a chemomechanical agent that is readily available and inexpensive, analyze its effectiveness as a chemomechanical agent and further discuss the alterations that can be made to use it as a chemomechanical agent commercially for the pediatric population.

Keywords: Calcium hydroxide, dentinal morphology, SEM, resin tags

INTRODUCTION

Fear of pain and anxiety are known barriers to the receptivity of dental treatment and is detriment to dental health, especially among children. Children with caries experiences (dmft/DMFT>0) have been reported to be more anxious than children without such experiences. In a study by Klingberg et al, children with behaviour management problems had fewer filled tooth surfaces than children without behaviour management problems.[2] There is also a high correlation of adult dental fear and avoidance stemming from childhood experiences.[3] Painful dental operations cause fear, whereas fear and anxiety increases the amount of perceived pain.[4]

Studies on dental anxiety have revealed that injection and drill were reported to be the most highly stressful factors in producing pain during dental treatment.[5] Despite a drill's proven efficacy in removing carious tissue, the conventional drilling technique presents negative experiences to the patient, such as tooth vibration, noise, heat and pressure on the pulp, dentine sensitivity, the possibility of overextending the cavity and healthy tissue removal. These factors trigger reaction of pain and discomfort, and this method usually requires local anesthesia.[1, 6]

Hence, a painless technique is one of the keys to avoid dentally fearful and uncooperative patients, and a skill every pediatric dentist should strive to master.[5]

With this aim, the chemomechanical concept of caries removal was introduced by Habib et al in 1975 who used 5% sodium hypochlorite (NaOCl) to remove carious tissues. However, its sole use was known to be unstable, toxic and aggressive to adjacent healthy tissues.[7] Subsequently, various chemomechanical agents like GK101 and Caridex (National Patent Medical Products Inc, NJ), Carisolv and Papacarie have been introduced.

The ongoing search for a new, easily available and cost effective chemomechanical caries removal agent led to a study by Dammaschke T et al in 2005. They hypothesized that an alkaline substance used in dentistry for many years Calcium Hydroxide [$Ca(OH)_2$]—might be effective in chemo-mechanical caries removal as well. Though their research could not yield any significant results, it proved $Ca(OH)_2$ to be an effective chemomechanical caries removal agent. [8]

To further establish the usefulness of $Ca(OH)_2$ as a possible CMCR agent, the present study observed the morphology and nature of prepared carious dentin surfaces after treatment with $Ca(OH)_2$ and that how it influences bonding of the adhesive restorative materials that are used to restore the tooth under scanning electron microscope (SEM).

MATERIALS & METHOD:

Twenty extracted human permanent molars, with large and visible carious cavities involving the occlusal surface and extending into dentine, were used in this institutionally approved study. All the teeth were cleaned with prophylactic instruments and stored in distilled water until use.

In all the samples, carious tissue removal was performed using freshly mixed calcium hydroxide and saline. The paste was allowed to remain in the cavity for 30-40 seconds and the softened carious tissue was removed with a blunt excavator. The procedure was repeated till no further softened carious tissue could be obtained which was confirmed by using an exploratory probe. The cavity was then wiped with a moistened cotton pellet and rinsed. After caries removal, the samples were divided into two groups:

GROUP 1- consisted of 10 samples prepared for morphological evaluation of residual dentin after caries removal. The crowns were separated from the roots and split in the center of the cavity with a diamond disc under running water to obtain the treated dentinal surfaces and embedded into acrylic resin with dentinal surface facing upwards.

GROUP 2 - consisted of 10 samples prepared for evaluating the bonding characteristics of residual dentin by analyzing the tags formed between the dentin and resin. After carious tissue removal, the cavities of teeth in Group 2 were etched with 34% phosphoric acid for 15 seconds, followed by rinsing, drying, application of an adhesive (Prime & Bond NT) following manufacturer's instructions and filling with composite resin (Ceram X, Nanoceramic, Dentsply) using increments that were light cured for 40 seconds each.

The crowns were separated from the roots and sectioned vertically through the resin fillings and dentin with help of diamond disc under running water into two halves (mesial and distal) to expose the resin- dentin interface. They were then embedded in self-cure acrylic resin and the resin-dentin interface was polished with 600, 1000, 2000 grit polishing paper and Sof- lex finishing and polishing systems followed by immersion in 4% NaOCl for 20 minutes and 20% hydrochloric acid for 30 seconds.

All the samples were rinsed with distilled water and then sequentially dehydrated in ascending grades of 60% ,70%, 80%, 90% alcohol for 20 min each and in 100% alcohol for 1 hr.

Sample preparation for SEM viewing (Fig. 24, 25 & 26)
The samples to be observed for surface morphology and dentin-resin interface were dried, mounted on aluminium stubs, placed in vaccum chamber, sputter coated with gold layer and observed under a scanning electron microscope. Series of microphotographs were taken field by field at a magnification of 2000x and 5000x for viewing the surface morphology and at 1000x for viewing the dentin resin interface.

Resin tags were evaluated quantitatively by measuring their length on the photographs with a ruler according to the scale given on the photograph. Five different measurements were done on each photograph and the mean was taken as the representative value. Qualitative evaluation of tags was done using a four- step (0-3) scale method according to Ferrari et al: [9]
Score 0 – no resin tag formation
Score 1- few and short resin tags
Score 2- when long resin tags were visible
Score 3- dense resin tags with numerous lateral branches.
The evaluation was then subjected to statistical analysis.

RESULTS:

The surface morphology of the residual dentin obtained after treatment with $Ca(OH)_2$ revealed a variable pattern of dentinal morphology. The dentine surfaces of few teeth showed a uniform, well-formed smear layer (Fig 1) while those of other teeth showed an amorphous layer with accumulation of debris (Fig 2). In certain areas, exposed dentinal tubules were evident (Fig 1) while in other areas they were almost completely occluded or narrowed in diameter due to their plugging by smear layer and accumulated debris (Fig 2).

Further analysis of the specimens in longitudinal sections revealed that the resin/dentin interfaces exhibited widely ranging results. At few locations on the resin-dentin inter-diffusion zone, the tags were short or even absent (Fig 3) while on the others the tags were longer and dense (Fig 4) with the mean length ranging from 4 - 38.86 µm. At a few locations, the tags were greatly entangled (Fig 4). Morphologically, they were broad at base and narrowed slightly towards the tubules. No microtags were evident.

Table 1 shows the outcome of quantitative and qualitative assessment of the photomicrographs in Group II samples

Table 1: Quantitative and Qualitative Assessment of Tags in Group II Samples

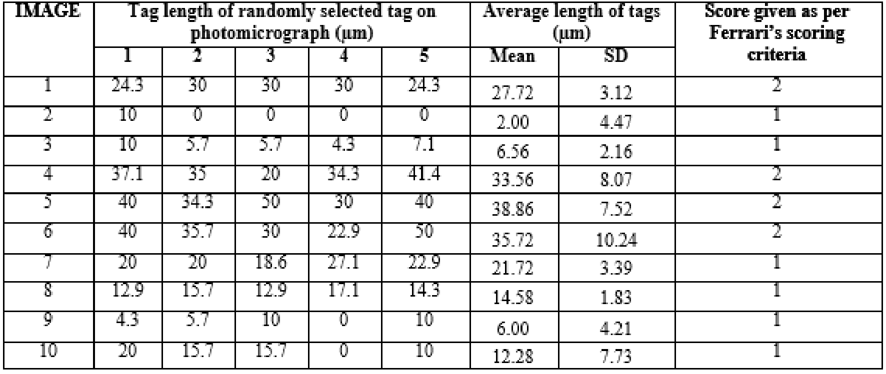


IMAGE	Tag length of randomly selected tag on photomicrograph (µm)					Average length of tags (µm)		Score given as per Ferrari's scoring criteria
	1	2	3	4	5	Mean	SD	
1	24.3	30	30	30	24.3	27.72	3.12	2
2	10	0	0	0	0	2.00	4.47	1
3	10	5.7	5.7	4.3	7.1	6.56	2.16	1
4	37.1	35	20	34.3	41.4	33.56	8.07	2
5	40	34.3	50	30	40	38.86	7.52	2
6	40	35.7	30	22.9	50	35.72	10.24	2
7	20	20	18.6	27.1	22.9	21.72	3.39	1
8	12.9	15.7	12.9	17.1	14.3	14.58	1.83	1
9	4.3	5.7	10	0	10	6.00	4.21	1
10	20	15.7	15.7	0	10	12.28	7.73	1

The tag length in Group II ranged from 0 to 50 µm while the mean value of tag length ranged from 2.00 to 38.86 µm. Results of objective scoring showed that 60% (6 samples) had score 1 while 40% (4 samples) of the samples had score 2 which proves the utility of Ca $(OH)_2$ as a chemomechanical agent.

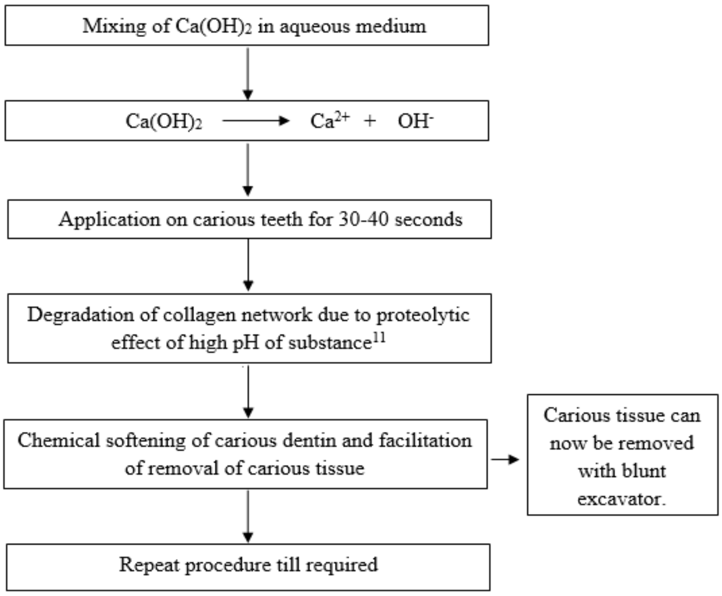
DISCUSSION:

Calcium hydroxide, traditionally called slaked lime, is an inorganic compound with the chemical formula $Ca(OH)_2$. It is a colourless crystal or white powder and is obtained when calcium oxide (called lime or quicklime) is mixed, or "slaked" with water. It is of low toxicity and finds many applications in the world of dentistry.

Since its introduction in 1920 by Hermann, calcium hydroxide has been widely used in endodontics. It is a strong alkaline substance, which has a pH of approximately 12.5. In an aqueous solution, calcium hydroxide dissociates into calcium and hydroxyl ions. Various biological properties have been attributed to this substance, such as antimicrobial activity (Bystrom et al. 1985), tissue-dissolving ability (Hasselgren et al. 1988, Andersen et al. 1992), inhibition of tooth resorption (Tronstad 1988), and induction of repair by hard tissue formation (Foreman & Barnes 1990). Because of such effects, calcium hydroxide has been recommended for use in several clinical situations (Heithersay 1975, Fava 1991).[10]

The antimicrobial action of calcium hydroxide is directly proportional to the ability of hydroxyl ions to be released from the calcium hydroxide compound and then diffuse through the dentin. Dentinal strength is determined by the link between hydroxyapatite and collagenous fibrils and disruption of this link occurs because of the strong alkalinity of calcium hydroxide. The disruption could take place due to neutralization, dissolution or denaturation of the acid proteins and proteoglycans which serve as bonding agents between the collagen network and hydroxyapatite crystals in dentin.[11]

The mechanism of action of calcium hydroxide can be explained in the following chart:-



In 1980, Bergenholtz and Reit suggested that the topical application of calcium hydroxide reduced dentin permeability. The mechanisms responsible for reducing dentin permeability in their experiments included:

a) Physical blockage of the openings of the tubules by $Ca(OH)_2$
b) Production of intratubular mineralizations or precipitates
c) Production of irritation dentin

Besides, in the work of Bergenholtz and Reit, there was presumably a smear layer present over all cut dentin surfaces which can have a profound effect on dentin permeability.[12]

In 2005, Pinheiro IVA, Vieira LB and Lima KC tested the effectiveness of the cavity cleansing solution (calcium hydroxide 20%) in the elimination or reduction of microorganisms associated with dentine caries and could find a considerable reduction in the count of *S. anginosus*, *S.mitis* and *S. sobrinus*, as well as for *S. aureus* and *S. epidermidis*, although it was not significant. Thus they concluded that the calcium hydroxide solution seems to be efficient in the reduction of the microbiota associated with dentine caries and, therefore, is recommended for use in the clinical practice to support the cavity preparation aiming at recurrent caries reduction.[13]

Chemo-mechanical caries removal with calcium hydroxide has shown 50-60% caries free specimens in the study by Dammaschke T et al. The high pH of an alkaline solution also causes swelling of organic tissue which can further facilitate penetration of compounds into the demineralised dentin whose ions react with altered collagen of carious dentin. However, the proteolytic effects of calcium hydroxide seemed to be too weak to dissolve collagen completely.[8]
In 1995, Wakabayashi *et al* explained the limitation of calcium hydroxide to dissolve soft tissue as follows: the solubility of $Ca(OH)_2$ powder to water is very low (0.16g/100g of water at 20˚C), and the number of dissociated hydroxyl ions is little, although the mixture of $Ca(OH)_2$ to water exhibits a pH of 12 or higher. As soon as the $Ca(OH)_2$ dissolves the soft tissues, the hydroxyl ions are consumed during the reaction.[8]

In the present study, however, mixed results have been obtained. At few places, the dentinal tubules are open and tags are reasonably formed while at others, there is amorphous layer with few short or absolutely no tags.

The smear layer produced in dentin affected by caries possesses acid-resistant crystals that may hinder the diffusion of primer into the intact underlying dentin. This layer acts as a barrier, decreasing the dentin's permeability and is also considered to be an impediment to the establishment of intimate contact between tooth and resin. On the other hand, the presence of such deposits in the dentinal tubules may reduce dentin's permeability, constituting a protective barrier for the pulp since it reduces the intrusion of bacteria and bacterial products. Thus, the treatment of dentinal surface and the resulting characteristics of dentinal substrate will be important for adhesion and will affect the performance of composite resin restorations. Adhesion of resins to dentin is considered to be mainly based upon micromechanical retention based on the formation of resin tags inside dentinal tubules, branching or microtags, and the formation of hybrid layer or resin-dentin interdiffusion zone. Obtaining a hybrid layer involves applying an acid etch to dentin to remove the smear layer and smear plugs, opening up the dentinal tubules and increasing dentinal permeability as well as exposing the collagen network of intertubular dentin due to mineral removal.[14]

The sample selection of the present study includes teeth with wide, open carious lesions involving occlusal surface and is in accordance with earlier studies[15, 16, 17, 18] done for evaluating dentinal morphology after caries removal with chemomechanical and conventional methods. No study has been undertaken till date to evaluate the effects of $Ca(OH)_2$ for caries removal on residual dentin. However, its effectiveness in caries removal cannot be denied. One of the disadvantages of chemo-mechanical caries removal, that is, the presence of bacteria in the remaining dentin can be easily overcome by the high antimicrobial activity of $Ca(OH)_2$. Apparently, there were no bacteria found in dentin surface treated with $Ca(OH)_2$ in our study.

In general, three types of vehicles are used for making $Ca(OH)_2$ paste: aqueous, viscous or oily (Fava 1991, Holland 1994, Lopes et al. 1996). The first group is represented by water-soluble substances, including water, saline, dental anaesthetics, and Ringer's solution, aqueous suspension of methylcellulose or carboxymethylcellulose and anionic detergent solution. When calcium hydroxide is mixed with one of these substances, Ca_2^+ and OH^- ions are rapidly released. This type of vehicle promotes a high degree of solubility when the paste remains in direct contact with the tissue and tissue fluids, causing it to be rapidly solubilized and resorbed by macrophages. In 1998, Lopes *et al* suggested that few viscous vehicles are also water-soluble substances that release Ca_2^+ and OH^- ions more slowly for extended periods. They promote a lower solubility of the paste when compared with aqueous vehicles, probably because of their high molecular weights.

According to Silva LB (1988) the high molecular weight of these vehicles minimizes the dispersion of calcium hydroxide into the tissue and maintains the paste in the desired area for longer intervals; this factor prolongs the action of the paste. It is through this mechanism that these pastes remain in direct contact with vital tissues for extended time intervals.[19]

Dammaschke T *et al* have used calcium hydroxide mixed in an aqueous medium of distilled water (Calxyl rot) for caries removal and found its proteolytic effects to be too weak to dissolve collagen completely.[8] Calcium hydroxide used in the present study was also mixed in an aqueous medium of normal saline and may not have been able to remove carious tissue completely. It is probable that mixing calcium hydroxide with a viscous water soluble substance or non-water soluble substance can help increase the duration of action of the paste as well as enhance its time of contact with vital tissues.
Besides, the presence of open tubules in chemo-mechanical caries removal with other chemo-mechanical agents is attributed to the initial high pH of the gel and mechanical preparation technique. The study by Tonami K *et al* (2003) has revealed that treatment with chloramines, a component of Papacarie®, resulted in the opening of dentinal tubules in the

outer layer of carious dentin. Thus, it is suggested that several factors like the incomplete caries removal, inability to enter the deeper dentinal layers along with the absence of additives like chloramine are responsible for the obtained surface morphology of residual dentin treated with $Ca(OH)_2$.[20]

Pashley *et al* observed that the treatment of acid etched dentin surfaces with $Ca(OH)_2$ produced a statistically significant ($p < 0.001$), 75% reduction in hydraulic conductance (Lp) of dentin which is indicative of dentine permeability while re-etching the $Ca(OH)_2$ treated surface restored Lp to levels slightly higher than the initial Lp.[12]

The results of this study showed variance with regard to tag formation after use of $Ca(OH)_2$. At some places there were either no or very short tags while at others the tags were relatively longer. The relatively poor quality of tags can be attributed to the above discussed physical properties of calcium hydroxide and its effect on dentinal characteristics. It is probable that etching the dentinal surface with a more aggressive solution, increasing the etching time or even adding a suitable additive to calcium hydroxide like chloramines could have yielded better results.

The excellent antimicrobial activity and easy availability of calcium hydroxide can make it an extremely useful chemo-mechanical agent. Further studies on preparing a calcium hydroxide with suitable additives may definitely help increase its proteolytic effect and prove it as a suitable chemo-mechanical agent.

Conflict of Interest: - None

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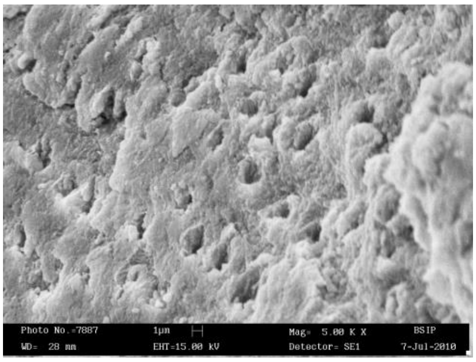

Fig 1

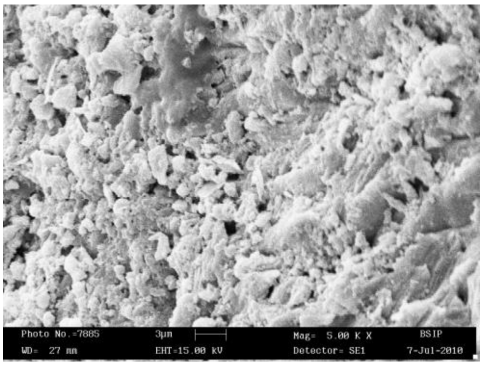

Fig 2

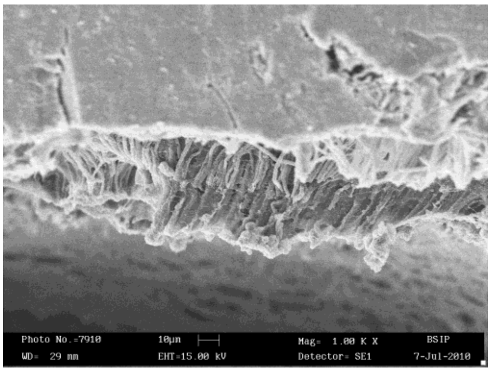

Fig 3

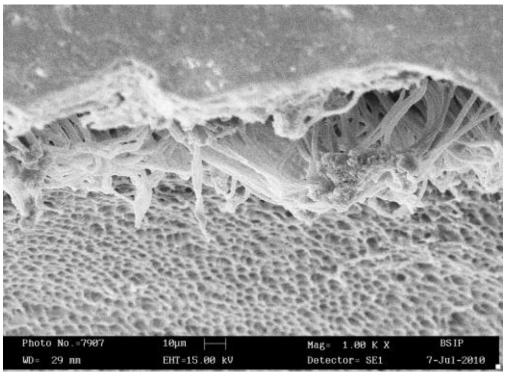

Fig 4

Figures With Legends

Figure 1 – Well formed smear layer formed on residual dentin with partially occluded dentinal tubules visible under SEM (5000 X)
Figure 2 – Amorphous layer formed on residual dentin with completely occluded dentinal tubules visible under SEM (5000 X)
Figure 3 – Resin-dentin interface showing short resin tags or no resin tags at all at few locations under SEM (1000X)
Figure 4 – Resin-dentin interface showing well-formed resin tags along the entire zone visible under SEM (1000X)