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Review Article

Calcium Hydroxide in Dentistry: A Review

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ABSTRACT

Calcium hydroxide has been used comprehensively in dentistry since its introduction by Hermann, for a number of procedures, such as direct & indirect pulp capping, apexogenesis, apexification, treatment of root resorption, iatrogenic root perforations, root fractures, replanted teeth, root canal sealer and inter-appointment intracanal dressing. Despite being available in varied forms & its wide range of antimicrobial activity, calcium hydroxide is less effective against some species. This paper is an attempt to reassess the properties and clinical applications of calcium hydroxide in dentistry.

INTRODUCTION

In 1920, Hermann introduced calcium hydroxide to dentistry as a pulp-capping material but today it is used widely in the field of endodontics.[1] Calcium hydroxide is a white odourless powder with the chemical formula $Ca(OH)_2$ & classified as a strong base in contact with aqueous fluids (its pH is about 12.5 - 12.8), and dissociate into calcium and hydroxyl ions.[2] Calcium hydroxide is used and supplied in various forms. It is used like a varnish when supplied as a liquid containing calcium hydroxide suspended in a solvent or supplied as a paste in which calcium hydroxide is suspended in methylcellulose. Another form of calcium hydroxide is marketed as a base and a catalyst. By using the catalyst, calcium hydroxide reacts faster & forms a hard, amorphous compound, within matter of a minute in the oral environment. Also, calcium hydroxide being supplied as a paste, contains a polymer resin that can be hardened when exposed to illumination from a handheld blue light source.[1]

The high pH of calcium hydroxide formulation alters the biologic properties of bacterial lipopolysaccharides in the cell walls of gram-negative species and inactivates membrane transport mechanisms, resulting in bacterial cell toxicity.[3] Currently, one of the concerns in endodontics is the treatment of teeth with necrotic pulps and periapical pathosis because post-treatment disease persists more often than in cases without periapical disease.[4]

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ADVANTAGES:[5]

1. Initially bactericidal effect then bacteriostatic.
2. Promotes healing and repair.
3. High pH stimulates fibroblasts.
4. Stops internal resorption.
5. Neutralizes low pH of acids.
6. Inexpensive and easy to use.

DISADVANTAGES:[5]

1. Does not exclusively stimulate dentinogenesis.
2. Does exclusively stimulate reparative dentin.
3. Associated with primary tooth resorption.
4. May dissolve after one year with cavosurface dissolution.
5. Degrades upon tooth flexure.
6. Marginal failure with amalgam condensation.
7. Does not adhere to dentin or resin restoration.

MECHANISM OF ACTION

Dissociation of calcium hydroxide is influenced by the vehicle used. It determines the ionic dissociation kinetics by causing calcium hydroxide to be solubilized and resorbed or absorbed at various rates in the periapical tissues and within the root canal.[6]

When used as an intra canal medicament in endodontic therapy, moisture in the canal activates the calcium hydroxide and the pH in the canal rises to level of 12 and above, within minutes. The average treatment time is 1-4 weeks.

$Ca(OH)_2 + H_2O \longrightarrow Ca^{2+} + OH^-$

The high concentration of hydroxyl ions from calcium hydroxide alters the pH gradient of the cytoplasmic membrane damaging its protein by acting on the organic components and transporting the nutrients or by a saponification reaction in which the phospholipids or unsaturated fatty acids of the cytoplasmic membrane are destructed during the peroxidation process.[7]

Three histologic zones seen under calcium hydroxide in 4-9 days:[8]

1. Coagulation necrosis.
2. Deep staining areas with varied osteodentin.
3. Relatively normal pulp tissue, slightly hyperemic, underlying an odontoblastic layer.

EFFECT OF LIQUID VEHICLE

$Ca(OH)_2$ should be combined with a liquid vehicle because the delivery of dry $Ca(OH)_2$ powder alone is difficult, and fluid is required for the release of hydroxyl ions. The lower the viscosity, the higher will be the ionic dissociation. The high molecular weight of common vehicles minimizes the dispersion of $Ca(OH)_2$ into the tissues and maintains the paste in the desired area for longer periods of time.[9]

ANTIBACTERIAL EFFECT

Calcium hydroxide will exert an antibacterial effect in the root canal system as long as a high pH is maintained. The antibacterial activity can be ascribed to the following mechanisms:[3]

1) Destruction of the bacterial cytoplasmic membrane.
2) Protein lysis, and
3) Bacterial DNA damage.

It has been reported that the 7 day application of calcium hydroxide is effective in bacterial elimination while the 10 minutes application was not effective.[7] Cook et. al.[10] evaluated the quality of root canal filling with or without calcium hydroxide application prior to the root canal filling or 2% chlorhexidine on the persistence of bacterial infection on the dentinal tubules, they found that the use of 2% chlorhexidine followed by root canal filling was more effective in

removing the bacterial infection especially E. faecalis than placement of calcium hydroxide or immediate canal filling.

ANTI-ENDOTOXIN ACTIVITY

Endotoxin (LPS) is released during multiplication or bacterial death causing a series of biological effects, which lead to an inflammatory reaction and periapical bone resorption.[11]

Nelson-Filho et. al.[12] carried out an in vivo study to evaluate radiographically the effect of endotoxin plus $Ca(OH)_2$ on the periapical tissues of dog's teeth. They observed that endotoxin caused the formation of periapical lesions after 30 days and that $Ca(OH)_2$ inactivated bacterial LPS. Tanomaru et. al.[13] evaluated the effect of biomechanical preparation using different irrigating solutions & a $Ca(OH)_2$ based root canal dressing in a dog experimental tooth model containing endotoxin. Biomechanical preparation with only irrigating solutions did not inactivate the endotoxin; however, the same treatment associated with the use of the $Ca(OH)_2$ dressing was effective in the inactivation of the toxic effects of this endotoxin.

MINERALIZATION PROPERTY

The high pH of 12.5 initially induces liquefaction necrosis in the superficial portion of the pulp (1.5-2mm). This may eliminate the inflamed pulp if present. Further, deeper portions of the pulp witness neutralization of the toxicity of calcium hydroxide so as to cause formation of a layer of tissue that undergoes coagulation necrosis at the junction of the necrotic and vital pulpal tissue. Beyond this portion, calcium hydroxide acts as a mild irritant, which stimulates hard tissue formation. The calcified material is termed osteodentine since it exhibits the characteristics of both bone and dentin.[14] The barrier of osteodentine, which is produced, is often incomplete and results in the formation of the so-called tunnel defects. Such defects may allow bacterial re-infection.[15]

ANTIFUNGAL EFFECT

The presence of Fungi represented by C. albicans was detected in primary root canal infection but is more common in failed endodontic treatments. Their occurrence varies between 1% and 17%.[7] Siqueira et. al.[16] investigated the antifungal ability of several medicaments against C. albicans, C. glabrata, C. guilliermondii, C. parapsilosis and S. cerevisiae. They reported that whereas the paste of $Ca(OH)_2$ in CPMC/glycerine had the most pronounced antifungal effects, $Ca(OH)_2$ in glycerine or CHX and CHX in detergent also had antifungal activity, but at a lower level than the paste of $Ca(OH)_2$ in CPMC/glycerine.

BUFFERING EFFECT OF DENTINE ON $CA(OH)_2$

The substantial effect of dentine on the antibacterial activity of $Ca(OH)_2$ can be attributed to the buffering action of dentine against alkali.[17] $Ca(OH)_2$ is used as a thick paste in vivo; however, its solubility is low and saturation is achieved in a relatively low concentration of hydroxyl ions. Both laboratory and in vivo studies have shown that buffering by dentine, particularly in the subsurface layers of the root canal walls, might be the main factor behind the reduced antibacterial effect of $Ca(OH)_2$. Besides dentine, remnants of necrotic pulp tissue as well as inflammatory exudate might affect the antibacterial potential of endodontic disinfectants.[18]

INTRACANAL MEDICAMENT

According to Weine,[19] a medicament is an antimicrobial agent that is placed inside the root canal between treatment appointments, in an attempt to destroy remaining micro-organisms and prevent reinfection. The application of calcium hydroxide paste at intervals of at least 7 days is able to eliminate and/or reduce the total number of bacteria surviving even after biomechanical preparation.[7] It has a wide range of antimicrobial activity against bacteria, but has limited effect against E. faecalis and C. albicans. It is also an effective anti-endotoxin agent.[1] Different techniques can be used for the placement of calcium hydroxide in the canals. Tan et. al.[20] compared the use of syringe and #25 finger spreader (group 1), syringe and #4 rotary lentulo spiral (group 2), specially designed paste carrier (group 3), they found that, the specially designed paste carrier was more effective than other tested techniques in the intracanal placement of calcium hydroxide.

ROOT CANAL SEALER

Some form of cement is required when filling the root canals to fill the minor spaces between the core material and the dentinal walls of the canal to prevent leakage. The outcome of endodontic treatment may be influenced by sealer selection. The dissociation of calcium hydroxide into Ca^{2+} & OH^- is necessary for its therapeutic effect. Therefore, dissolving an endodontic sealer based on calcium hydroxide resulted in the loss of its solid content and consequently obturation voids are formed.[1] The antibacterial activity of some calcium hydroxide based sealers such as RealSeal, Sealapex, Apexit, and Apexit Plus is related to the release of hydroxyl ions. These sealers may also help in the formation of root-end hard tissue. Despite their advantages, calcium hydroxide-based sealers exhibit some disadvantages such as limited antibacterial activity, poor cohesive strength, greater solubility, and marginal leakage.[21]

IN WEEPING CANAL

Weeping canal is a canal from which constant clear or reddish exudation appears. This exudate is associated with a large apical radiolucency. The tooth is difficult to treat as when opened, exudate stops but it again reappears in next appointment.[1] According to Weine, the best way to stop the exudate in such cases is to dry the canal with sterile paper points and to place $Ca(OH)_2$ paste in the canal. The possible mechanism of action of $Ca(OH)_2$ in these cases is related to its basic pH, which converts the acidic pH of periapical tissues to a more basic environment.[19]

PERFORATION MANAGEMENT

Calcium hydroxide was one of the most preferred materials that have been used to seal and manage perforations. It has many advantages in this treatment modality such as stimulation of hard tissue formation, rapid resorption when extruded into the periodontium and healing enhancement of damaged periodontal tissues. However, mineral trioxide aggregate (MTA) now is the material of choice for the permanent repair of perforations from both a conventional and surgical approach.[2]

Calcium hydroxide has to be replaced on a regular basis since:[22]

1) It is displaced by tissue fluids.
2) Exhibits poor marginal integrity, and
3) Lacks the required strength.

ROLE IN ROOT RESORPTION

Calcium hydroxide has alkaline pH, it actively influences the local environment around a resorptive area by reducing osteoclast activity and stimulating repair. The alkaline calcium hydroxide neutralizes the acidic environment which exists in the region of resorption, reversing the reaction and thus stimulating hard tissue formation. The diffusion of hydroxyl ions released by calcium hydroxide through the dentinal tubules that directly communicate with periodontal space would increase the pH of periodontal space from 6.0 to 7.4 - 9.6.[21] To treat an internal resorption, the canal and resorption lacuna are filled with calcium hydroxide paste. In this way, calcium hydroxide will induce the necrotization process of the remaining tissue in the lacuna, and then by irrigation with sodium hypochlorite the necrotic residuals are removed.[2]

According to Ravi et. al.[23] calcium hydroxide-induced resorption in deciduous teeth may be attributed to:

(1) Inflammatory cytokines, which contribute to transformation of pre-odontoclasts to odontoclasts.

(2) Pre-existing progenitor cells with a tendency to transform into odontoclasts, and loss of protective layer of pre-dentin over mineralized dentin.

EFFECT OF CALCIUM HYDROXIDE ON PULP VITALITY

Pulp repair and formation of hard tissue barrier can be induced when the pulp tissue directly capped with the different form of calcium hydroxide. Clinically, the formation of hard tissue barrier after pulp capping is precious as it provides natural protection from bacterial ingress and chemical products. Some proteins and growth factors are released from dentine because of the dissolved high alkaline pH of calcium hydroxide solution. These mechanisms may stimulate pulp repair and formation of hard tissue barrier. Additionally, a layer of coagulation necrosis is induced when the high pH of calcium hydroxide in direct contact with pulp tissue.[24]

PULP REVASCULARIZATION

Revascularization is defined as the restoration of the vascularity to a tissue or organ.[25] Calcium hydroxide is primarily used to decontaminate the root canal system prior to inducing bleeding. Triple antibiotic paste has also been shown to be an effective agent in terms of eliminating root canal infection but the minocycline component may induce tooth discoloration.[26] Cehreli et. al.[27] reported a case of successful revascularization with calcium hydroxide in immature necrotic molars after a follow-up of 10 months. Long-term use of calcium hydroxide may cause progressive calcification of the root canal space.[28]

EFFECT OF CALCIUM HYDROXIDE ON PERIAPICAL AREA

In case of large chronic periapical lesions, intentional pressing of calcium hydroxide beyond the root canal and into the peri-radicular tissue has been supported by some researchers. They claimed that calcium hydroxide enhances the healing and osseous repair by direct effect on inflamed tissues. However, this hypothesis was rejected by other researchers and not widely used as extrusion of calcium hydroxide beyond the apex can lead to damaging effects. The healing process might be delayed when using calcium hydroxide paste including barium sulfate, or in this condition the radiographic interpretation of osseous healing might be difficult.[29]

REMOVAL OF CALCIUM HYDROXIDE FROM THE CANALS

Thorough cleaning of root canal system can be achieved by delivering effective irrigation, solution activation as well as direct contact with all canal walls especially in the apical third.[30] Nandini et. al.[31] reported that the vehicle used to prepare $Ca(OH)_2$ paste was important for its removal. Oil-based $Ca(OH)_2$ paste was more difficult to remove than $Ca(OH)_2$ powder mixed with distilled water. Both 17% EDTA and 10% citric acid were found to remove $Ca(OH)_2$ powder mixed with distilled water, whereas 10% citric acid performed better than EDTA in removing an oil-based $Ca(OH)_2$ paste.

CONCLUSION

The applications of calcium hydroxide in the field of dentistry have been innumerable. Its high alkalinity has contributed to its antibacterial and hard tissue forming properties. However, the lack of effectiveness against certain bacteria, solubility in oral fluids, poor coronal seal and strength are some concerns that need to be addressed. Also further research needed in order to evaluate effectiveness in terms of improving and ascertaining the properties of calcium hydroxide.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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