Clinical Application of Calcium Hydroxide in Dental Pathology and Endodontics

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Abstract

Calcium hydroxide has a hard tissue inducing effect. It is a powder, that can be mixed with a physiological saline to a paste. The paste is highly alkaline with a pH 12.5 and its application to the pulp results in necrosis of the part of coronal pulp tissue shows no or only a milled inflammatory reaction. Analyzing the pH and the concentration of calcium ions in the periapical area, it is obvious that at least 2 weeks are necessary for calcium hydroxide bactericide activity.

Calcium hydroxide retains its anti-bacterial properties for about two months when placed under a restoration, after which it degrades to calcium oxide and other less effective calcium salts. All calcium hydroxide preparations have a limited shelf life as they eventually turn into calcium oxide.
Calcium hydroxide can be used as linings, for indirect and direct pulp cupping, root dressing, root canal sealant, apical closure.

The vehicles play a supportive role, giving pastes chemical characteristics such as dissociation and diffusion as well as favoring the correct filling of the root canal which are decisive factors for antimicrobial potential and tissue healing.
The mechanism of action of calcium hydroxide on tissues, inducing the deposition of mineralized tissue, is an extremely important aspect for the indication of calcium hydroxide, because it demonstrates biological compatibility of calcium hydroxide.

Key words: calcium hydroxide, antibacterial, mineralizing, pH, vehicles, clinical application

Introduction

History of previous application shows a number of medicaments that have been used as pulp capping agents; gold, silver, different types of cements, antiseptic pastes, chemotherapeutics, ivory powder, dentin clips and calcium hydroxide (1).
The first important progress with this type of therapy was gained in 1920 with a paste of zinc oxide and eugenol. This approach showed some promise, but it was not until late 1930, when calcium hydroxide was introduced as a wound dressing and pulp cupping as a clinical treatment method started to be taken seriously. With calcium hydroxide it became possible for the first time on a routine bases to obtain a healthy pulp free of inflammation, covered by hard tissue barrier a dentin bridge at the exposure site. Calcium hydroxide is a white powder, that can be mixed with a physiological saline to a paste. The paste is highly alkaline with a pH 12.5 and its application to the pulp results in necrosis of part of the coronal pulp tissue shows no or only a milled inflammatory reaction.

Action

Calcium hydroxide is alkaline (pH 10), and thus kills bacteria. All the beneficial effects of calcium hydroxide are believed to be secondary to its bactericidal properties. I.e., in the absence of infection, natural healing can take place. This healing includes creation of tertiary dentine to protect the pulp in vital teeth, and to close the apices of immature non-vital teeth.
Calcium hydroxide retains its anti-bacterial properties for about two months when placed under a restoration, after which it degrades to calcium oxide and other less effective calcium salts.
All calcium hydroxide preparations have a limited shelf life as they eventually turn into calcium oxide.
The control of microorganisms by calcium hydroxide is determined by the liberation of hydroxyl ions, which requires an ideal length of time for effective microbial destruction (2,3). The liberation of hydroxyl ions to attain the high pH that may completely eliminate the microorganisms can be delayed (4,5). However, the time necessary for calcium hydroxide to express its control on microorganisms resistant to antimicrobial substances has not been determined yet.

Linings

Calcium hydroxide is used as a lining. It should be placed very thinly over the deepest part of the cavity only.

It has very poor compressive strength, and is thus unsuitable for use directly under amalgam, as it is crushed and displaced by packing the amalgam. For similar reasons, any restoration subject to occlusal loading will fail if built over an extensive calcium hydroxide lining. It does not bond to dentine, and has a limited anti-bacterial life. If used in conjunction with an acid etch technique, it will reduce the area available for bonding smear.

Pulp capping and indications

The exposed pulp of a tooth to be treated with pulp capping should be healthy and free of inflammation. The pulp capping should therefore if at all possible be performed within two days after the exposure occurred. If the treatment is then carried out correctly, the prognosis is excellent approximately 90%. Its application to the pulp results in necrosis of part of the coronal pulp tissue shows no or only a miled inflammatory reaction. In the transition zone between the necrotic and vital tissue relatively structureless "demarcation zone" is observed after a few days. This zone is rich in collagen and gradually becomes mineralized barrier. This first formed hard tissue contains no dentinal tubules, but after approximately ten days odontoblasts which have differentiated from cells in the pulp are seen lining up along pulpal aspect of the hard tissue and formation of tubular dentin, onto the atubular tissues begins. The dentin formation goes on until the bridge has reached a certain thickness and then stops usually after about sixty days. The pulp is now again completely surrounded by a hard tissue and in the successful cases will be healthy and free of inflammation.

If pulp capping is performed in teeth with carious exposures the number of failures will increase dramatically and success rate in the area of 30-40% can be expected.

It is especially useful in the treatment of incompletely formed incisors in children where the preservation of the teeth to continue, resulting in fully formed, strong teeth that can function for a lifetime.

Indirect Pulp Capping

When caries is so deep that further removal will expose the pulp, it is allowable to leave the final layer of hard, and place a layer of calcium hydroxide over it. This will completely sterilise the dentine, and allow formation of new tertiary dentine under it.

However, the vitality of the tooth should be careful monitored, and a cast restoration should not be placed on the tooth until its vitality is assured (some months later).

Direct Pulp Capping

When a frank exposure of the pulp has occurred, a layer of calcium hydroxide can be placed to achieve completely cover of the exposure. This direct pulp cap is then protected as above.

The tooth must be vital. No history of spontaneous pain. Pain from hot and cold stimulus testing must disappear as soon as the stimulus is removed (i.e. no pulpitis). There must be no periradicular pathology on the periapical film. The tooth must be capable of being restored afterwards to prevent subsequent bacterial ingress. Indirect pulp caps are preferable to direct ones.

Root Dressing

If endodontic treatment is not completed in a single visit, the root canal must be dressed with calcium hydroxide. Its high pH kills bacteria within the root canal, and thus provides the best conditions for healing of the periodontal tissues in between endodontic visits.

Root canal sealant

Calcium hydroxide is available as a root sealer paste, for sealing gutta percha cones into a root canal. However, over time it is soluble and the apical seal soon disappears.

Apical closure

When a root canal with an open apex is dressed for a long period with calcium hydroxide, the apex will eventually close due to deposition of tertiary dentine. This will allow a conventional root filling to then be placed. The dressing must be changed each two months as its anti-bacterial effect diminishes. Up to a year should be allowed for apical closure.

Chemical properties of calcium hydroxide

Calcium hydroxide is a strong base obtained from the calcination of calcium carbonate until its transformation into calcium oxide. Calcium hydroxide is then obtained through the hydration of calcium oxide and the chemical reaction between calcium hydroxide and carbon dioxide forms calcium carbonate. It is a white powder with a high pH (12.5) and is only slightly soluble in water (solubility of 1.2 g/l, at a temperature of 25°C).

Hydrosoluble vehicles (distilled water and saline solution) have presented the best chemical characteristics in terms of speed of ionic dissociation and diffusion, which helps the already known antimicrobial and tissue healing induction powers of calcium hydroxide. Thus, in order to choose an intracanal dressing, it is necessary to know the microbiota of the infected root canal, the response of host and the mechanism of action of the target medication. However, to be effective, it is necessary that medication has adequate time to express its antimicrobial effectiveness and neutralize metabolic products, enzymes, toxins, etc.

The absence of differences in the time required for antimicrobial effect indicates that these vehicles play a supportive role in the process, giving pastes chemical characteristics such as dissociation and diffusion as well as favoring the correct filling of the root canal which are decisive factors for antimicrobial potential and tissue healing. Other vehicles and substances have also been added to calcium hydroxide, such as chlorhexidine, detergent, corticosteroid-antibiotic, iodoform; however, the results have not been encouraging (6).

Ionic dissociation and diffusion are essential for activity in the interior of dentinal tubules. The change of dentinal pH caused by hydroxyl ions is slow and depends on several factors that can alter the rate of ionic dissociation and diffusion, such as level of hydrosolubility of the vehicle employed, difference in viscosity, acid-base characteristic, dentinal permeability, and level of existing calcification. The pH on the outer surface of dentin after placement of calcium hydroxide paste ranged from 7 to 8, depending on the root third and remained at 12.6 in the interior of the root canal from 1 to 60 days (7).

However, the pH in mineralized structures is difficult to measure. It is necessary to develop an applicable methodology in order to reproduce, as precisely as possible, the transportation of hydroxyl ions through dentinal tubules and then obtain an exact pH.
High pH values can supply a large amount of hydroxyl ions and influence the viability of microorganisms. The pH of vehicles and calcium hydroxide pastes have presented interesting results, such as the low pH (5.0) of camphorated paramonochlorophenol (CMCP), the intermediate pH (7.8) resulting from the association of calcium hydroxide and CMCP and the high pH (12.6) of calcium hydroxide pastes associated with distilled water, sodium lauryl diethylene ether sulfate, Tween 80, and polyethylene glycol. The molar conductivity of calcium hydroxide pastes did not present significant differences associated with distilled water, sodium lauryl diethylene ether sulfate, or Tween 80 (5057.74, 4976.87 and 4936.45 microSiemens, respectively) (8,9).

The chemical analysis of essential aspects of the substance being studied is important in order to use it correctly, i.e., influence of vehicle on the rate of ionic dissociation; time necessary for dentinal diffusion to reach the appropriate pH level for microbial control and level of reabsorption; action of carbon dioxide from tissue and atmosphere that favors the transformation of calcium hydroxide into calcium carbonate and interferes in the antimicrobial and mineralizing effects, making dressing changes necessary; antimicrobial effect of vehicle and calcium hydroxide paste.

Biological properties of calcium hydroxide

An important property of calcium hydroxide is the ability to activate alkaline phosphatase. The pH necessary for the activation of this enzyme varies from 8.6 to 10.3 according to the type and concentration of substratum, temperature and source of enzymes (10).

It is reported (11) that the action of calcium hydroxide would explain how its high pH inhibits enzyme activities that are essential to bacterial life, i.e., metabolism, growth and cellular division. The effect of pH on the transport of nutrients and organic components through the cytoplasmic membrane determines its toxic action on bacteria. This also activates the hydrolytic enzyme alkaline phosphatase, which is closely related to the process of tissue mineralization.
The mechanism of action of calcium hydroxide on tissues, inducing the deposition of mineralized tissue, is an extremely important aspect for the indication of calcium hydroxide, because it demonstrates biological compatibility of calcium hydroxide.

The influence of pH on growth, metabolism and bacterial cell division is important to explain the mechanism of antimicrobial action of calcium hydroxide. Estrela et al. (1994) studied the biological effect of pH on the enzymatic activity of anaerobic bacteria. The authors believe that the hydroxyl ions from calcium hydroxide develop their mechanism of action in the cytoplasmic membrane, because enzymatic sites are located in the cytoplasmic membrane. This membrane is responsible for essential functions such as metabolism, cellular division and growth and it takes part in the final stages of cellular wall formation, biosynthesis of lipids, transport of electrons and oxidative phosphorylation. Extracellular enzymes act on nutrients, carbohydrates, proteins, and lipids that, through hydrolysis, favor digestion. Intracellular enzymes located in the cell favor respiratory activity of the cellular wall structure. The pH gradient of the cytoplasmic membrane is altered by the high concentration of hydroxyl ions of calcium hydroxide acting on the proteins of the membrane (proteic denaturation). The effect of the high pH of calcium hydroxide alters the integrity of the cytoplasmic membrane by means of chemical injury to organic components and transport of nutrients, or by means of the destruction of phospholipids or unsaturated fatty acids of the cytoplasmic membrane, observed in the peroxidation process, which is a saponification reaction.

The irreversible enzymatic inactivation was demonstrated by Estrela (12) who determined in vitro the direct antimicrobial effect of calcium hydroxide on different microorganisms (Micrococcus luteus, Staphylococcus aureus, Pseudomonas aeruginosa, Fusobacterium nucleatum, Escherichia coli and Streptococcus sp.)

Conclusion

Calcium hydroxide has a hard tissue inducing effect. This effect is presently being utilized in many areas of modern endodontic therapy, in pulp cupping, and pulpotomies, in apexigenesis, and apexification treatment of teeth with incompletely formed roots and in the treatment of perforation and resorption effects in the root.
It has antimicrobial effectiveness against microorganisms in root canal infections. Its antimicrobial mechanism of action involves the speed of dissociation into calcium and hydroxyl ions in a high pH (12.6) environment that inhibits enzymatic activities - metabolism, growth and cellular division -essential to microbial life (13).
Calcium hydroxide has shown clinical efficiency in reducing exudate due to its hygroscopic properties (14) and in stimulating apical and periapical repair, with no discomfort (15). However, these clinical conditions have not been substantially supported by histological studies based on the length of time of use necessary for root canal dressings (16).
Analyzing the pH and the concentration of calcium ions in the periapical area, Takahashi (17), concluded that at least 2 weeks are necessary for calcium hydroxide bactericide activity.

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