100 Years of Calcium Hydroxide in Dentistry: A Review of Literature

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Abstract

Ever since the introduction of calcium hydroxide in 1920, it has been widely used in dentistry. This is due to the therapeutic properties of calcium hydroxide imparted by its high pH and dissociation to form ions Ca^{+2} and OH^{-}. This makes it a remineralizing agent, a bactericidal or bacteriostatic agent based on the pH concentration and also an anti-inflammatory agent. It is being applied for various purposes in dentistry like intracanal medicament, pulp capping agent, root canal sealer, cavity liner, apexification, pulpotomy, canals with exudate, perforation management and root resorption. This review article aims to describe in detail the various properties of calcium hydroxide and applications marking 100 years of its use in dentistry.

Key words: *calcium hydroxide, intracanal medicament, remineralization.*

Introduction

Hermann in 1920 introduced calcium hydroxide in dentistry as "calxyl" to produce dentinal bridging of exposed pulp. This has led to the concept of remineralisation, shifting from doomed organ theory [(1)]. Calcium hydroxide has been around for a century and has shown to be effective in various clinical applications. It is an odourless white powder with a high pH and low solubility in water. It dissociates into calcium and hydroxyl ions which aids in remineralisation and anti bacterial properties, there by facilitating its use in dentistry [(2)]. The pH and vehicle used mainly influence the properties of Calcium hydroxide (table 1) [(3)]. Polyethylene glycol is one of the most commonly used vehicles due to its low solubility and antibacterial property [(4)]. The various applications of calcium hydroxide are due to its important properties such as mineralization, antibacterial property and dissolution of necrotic material (figure 1). The calcium hydroxide has various advantages like initial bactericidal and later bacteriostatic activity, high pH which stimulates fibroblasts, neutralizes low pH, promotes healing and repair, it is also in expensive and easy to use [(5)]. But it has few drawbacks like it does not exclusively stimulate dentinogenesis or reparative dentin formation; it may degrade during acid etching and does not adhere to dentin or resin restoration [(6)]. As the advantages outweigh the drawbacks the use of calcium hydroxide is being used in dentistry since 100 years for various clinical applications (figure 2) [(7,8,9)].

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Mechanism of Action:

Remineralization:

The calcium ions formed on dissociation is said to activate the calcium dependent adenosine triphosphate reaction in remineralization. But this calcium in calcium hydroxide is not present in the calcific barrier but the calcium derived from blood stream is incorporated into

it. The hydroxyl ions provide alkaline pH that prevents dissolution of mineral content in dentin by inactivating lactic acid and also activates alkaline phosphatases enzyme. Calcium hydroxide shows healing by causing necrosis and irritation of pulpal tissue and initiating the inflammatory pathway. It constitutes following characteristics [10,11] :

(i) Zone of obliteration: it is also called as zone of superficial debris. It can be visualized within an hour of contact due to the chemical injury caused by high pH of calcium hydroxide. This zone contains dentinal fragments, debris, blood clot and blood pigments formed due to the caustic effect.

(ii) Zone of coagulation necrosis: it is also called as Stanley's mummified zone or Schroder's layer. It is formed adjacent to the zone of obliteration due to the weaker chemical reaction. This zone consists of devitalized pulp tissue without any structural loss. This starts tissue reactions such as vascular changes and inflammatory cell migration. Later a zone of demarcation is formed differentiating the normal pulp tissue by deposition of protinate globules.

(iii) Dense zone: a modified cell rich zone is formed by proliferation of mesenchymal cells and fibroblasts. The undifferentiated mesenchymal cells in this layer differentiate into preodontoblasts and columnar shaped odontoblasts. Argyrophillic fibers or the Korff's fibers become organized perpendicular to the zone of demarcation. There is tubular formation in collagen matrix forming predentin.

(iv) Calcification of the bridge: Robinson in 1923 proposed the alkaline phosphate theory according to which the enzyme increases calcium phosphate ion concentration and initiates mineralization. Later matrix vesicle theory was introduced according to which extracellular matrix vesicle initiates calcification. But the seedling theory is one of the most accepted one, according to which mineralization mechanism occurs after initial seeding of collagenous tissue along with nucleation of hydroxyl appetite crystals [7].

Antibacterial action:

The highly oxidant free radicals released from calcium hydroxide is the main reason for its antimicrobial property [12]. The action of hydroxyl ions on bacterial cell cause lipid peroxidation of phospholipids, thereby damage the bacterial cytoplasmic membrane. Hydroxyl ions also cause damage to the DNA inhibiting its replication. Its high pH causes breakdown of protein ionic bonds leading to protein denaturation and inhibits cellular metabolism.

Anti-inflammatory action:

The high pH inhibits adhesion of macrophages and decreases the level of matrix metalloproteinase-8 (MMP-8). This inhibits the inflammatory reaction and exudation and also improves tissue circulation [12].

APPLICATIONS OF CALCIUM HYDROXIDE IN DENTISTRY:

Intracanal Medicament

Calcium hydroxide is one of the most commonly used intracanal medicament and is also considered the 'gold standard'. It plays a major role in the disinfection of the root canal when used as an inter appointment dressing. Though it is not a conventional antibacterial agent, it acts as a bactericidal agent at high ph and later as a bacteriostatic agent in root canal space [13]. It is effective against common endodontic pathogens especially E.faecalis [14]. It also helps in reduction of lipopolysaccharides and endotoxin released from bacteria [15]. But it has a longer duration of action. A minimum of 7 day dressing is required to obtain the effectiveness of the medicament [16]. Duration of calcium hydroxide medicament has been widely varied ranging from 10 days (Ostravik, 1990), 1 week (Sjogren, 1991), 2 weeks (Reit and Dahlen, 1988) and 4 weeks (Bystrom, 1985) [12]. The duration is dependent upon the objective of dressing. When used as a routine antibacterial dressing, then 7 days is sufficient.

Calcium hydroxide is also used in conjunction with other therapeutic agents for additive effects such as chlorhexidine and potassium iodide. Calcium hydroxide was initially mixed with sterilized dentine chips and alkaline blood salts by Flohr (1936). Later calcium hydroxide, methylcresilate and camphorated parachlorophenol mixture was prepared by Blanc-Benon (1967) as an intra canal medicament. Calcium hydroxide in 1% aqueous solution of parachlorophenol

was formulated by Martins et al. (1979) and Multical, a mixure of calcium hydroxide (34%), barium sulphate (15%) and chloro-timonol (51%) was made by Webber (1983). But, one of the most widely used is a combination of calcium hydroxide and Chlorhexidine. Calcium hydroxide combined with 0.5% CHX has been shown to eliminate C.albicans & E.faecalis effectively. But it was observed that the mixture of CHX and Ca(OH)2 may not provide a sufficient reservoir of free CHX molecules. The antimicrobial efficiency of this mixture was as effective as CHX alone on E.faecalis. CHX precipitates when mixed with calcium hydroxide and due to the deprotonation of the biguanide at pH > 8.0[9].

Pulp Capping Agent

Calcium hydroxide has been used as pulp capping agent for long time. Histologically calcium hydroxide causes coagulative necrosis followed by mineral deposition leading to complete dentinal bridging. Adjacent to the area of necrosis inflammatory mediators are released which help in mineral deposition and further healing. A Tubular Dentin Bridge which represents the mature type of dentinal bridge with well formed organic matrix and evident calcification is observed. Due to this property calcium hydroxide is used as direct and indirect pulp capping agent since long time in dentistry. But later it was observed that the barrier of osteodentine, which is produced, is often incomplete and results in the formation of the so-called tunnel defects. They occur due to vascular inclusions and such defects may allow bacterial re-infection hence is being replaced by bioceramic materials especially for direct pulp capping procedures.

Endodontic Sealer

Tight seal of root canal system is one of the main objectives of root canal therapy. But the property of calcium hydroxide to dissociate into ions causes dissolution of sealer leading to formation of voids during or after obturation [17]. Though it's solubility remains a matter of concern, the apical leakage cannot be attributed to its solubility, as there are studies reporting the potential for the formation of calcific repair tissues and even closure of apex by mineralized tissue in the vicinity of the materials [18]. And hence, it has been incorporated in many commercially available sealers like sealapex, apexit due to its antibacterial property and mineralization potential [9].

Cavity liner

Calcium hydroxide in fast setting formulations are used as cavity liner due to its therapeutic properties and additionally can resist condensation forces even in thinner sections [19] and also are compatible with light cure resin restorative materials [20]. The calcium hydroxide liner has an accelerated setting in presence of moisture. But the many drawbacks are heat generation during setting due to exothermic reaction and dissolution of material over time [7].

Apexification

Granath in 1959 first reported apical closure with calcium hydroxide. In non vital tooth closure of apex after calcium hydroxide dressing occurs as a cementum-like tissue across the root-end. This process is not true apex formation, but rather formation of only a calcific barrier which is similar to cementum. Because calcium hydroxide materials are soluble, there is a need to replace the dressing at 3-month intervals till the closure of apex occurs which is ussualy after 6-24 months [21]. The hard tissue barrier formed with the conventional calcium hydroxide apexification technique has been described as "swiss-cheese-like", because of the many soft tissue inclusions, representing a very permeable and weak barrier and more attention is needed when filling the root canal with gutta-percha and sealer. Hence calcium hydroxide use for apexification is no longer advocated.

Pulpotomy

Before the introduction of cvek's pulpotomy completer removal of coronal pulp is done and pulp chambered is filled with calcium hydroxide. Later for minimal pulpotomy procedures a hard setting formulation of calcium hydroxide are used [7]. Healing of the amputated pulp occurs due to release of inflammatory mediators. After the advent of materials such as MTA and Biodentine the use of calcium hydroxide for this purpose has steadily declined.

Canals with exudate

Obturation of root canal with continuous clear or reddish exudates is contraindicated. Hence, for such teeth use of calcium hydroxide dressing is recommended. It

is placed in canal after complete drying of canal with absorbent paper points. It is necessary to dress with a stiffer paste for a period of at least 14 days. If it is found that a substantial amount of the paste has been resorbed more frequent dressings with stiffer pastes may be required. Dressing and irrigation are continued until the exudate is stemmed. The high pH of calcium hydroxide neutralizes acidic pH of periapical lesion and favors bone formation [22].

Perforation Management

Root or furcation perforation is one of the common mishaps in root canal therapy. The mineralization property of calcium hydroxide favors the sealing of the perforation and improves the prognosis. It stimulates hard tissue formation and when extruded it enhances healing of damaged periodontal tissues [22]. Use of calcium hydroxide is contraindicated in crestal and furcation perforations as this may cause pocket formation and contamination. Though MTA is the ideal root repair material calcium hydroxide is still indicated to control infection, stop bleeding and as a temporary solution when inadequate time is available to perform a permanent repair.

Root Resorption

The high pH, mineralizing potential of calcium hydroxide aids in down regulating osteoclastic activity and stimulating hard tissue formation. It also facilitates periodontal tissue healing in the high pH environment. Hence in cases of resorption, pulp is extirpated and lacunae are filled with calcium hydroxide and left for 3 month interval and later removed and obturated. But use MTA is a more definite method of treating [9].

Periapical lesion

Intentional extrusion of calcium hydroxide beyond the root canal into the periradicular tissue is advocated by few authors in case of large periapical lesions as calcium hydroxide enhances the healing and osseous repair. As calcium hydroxide is mixed with barium sulphate in dental compositions the side effects of barium sulphate such as difficulty in resorption and initiation of inflammatory mediators which was observed in few studies [23]. Extrusion is not dangerous except if it reached the inferior alveolar canal where it can cause paresthesia, it doesnot compromise perapical healing [24]. But use of pure calcium hydroxide is preferred for this purpose [25].

REMOVAL FROM ROOT CANAL:

Removal of Calcium hydroxide is difficult especially in curved and narrow canals. Presence of residual paste at apical portion of root canal affects the apical patency during instrumentation and obturation. The retrievability of calcium hydroxide mainly depends on the vehicle used. An oil based mixture is more difficult to remove than powder form calcium hydroxide mixed with distilled water. Various methods have been advocated for removal of the medicament and one of the most commonly used method is by irrigating the canal with NaOCl & EDTA as advocated by Lambrianidis et al. (2006). Use of 10% citric acid was found to be better than EDTA by Nandini et al (2006). And, Ballal et al (2011) has advocated use of 7 % maleic acid. In addition to these irrigants, hand filing or rotary instrumentation, or ultrasonics are effective for removal [21].

SHORT COMINGS OF CALCIUM HYDROXIDE:

Varying alkaline potential of different formulation is a cause of concern as there is no standardization to evaluate the effectiveness. Low solubility and diffusability of calcium hydroxide makes it difficult to gain a rapid increase in pH necessary to kill bacteria within tubules and anatomical variations thereby showing no effect on dense biofilms of bacteria protected deeper inside tubules. The high alkalinity was found to negatively influence the mechanical properties of dentin. It is said to reduce the fracture resistance of radicular dentine and worsen the prognosis of tooth [23]. This can be explained by the Andresen's theory where, the proteolytic action could weaken the tooth up to 50% in one year [22].

Table 1: Types of vehicles used for calcium hydroxide and their applications

Vehicle	Ion release	Solubility	Applications	Examples
Aqueous	rapid	high	Direct and indirect pulp capping, pulpotomy	Distilled water Ringer's solution
Viscous	Slower, for extended periods	Medium	Apexification, Inter appointment Intra canal medicament	Glycerine Polyethylene glycol
Oily	Slower, for extended periods	Low	Perforation repair External root resorption	Olive oil Silicone oil

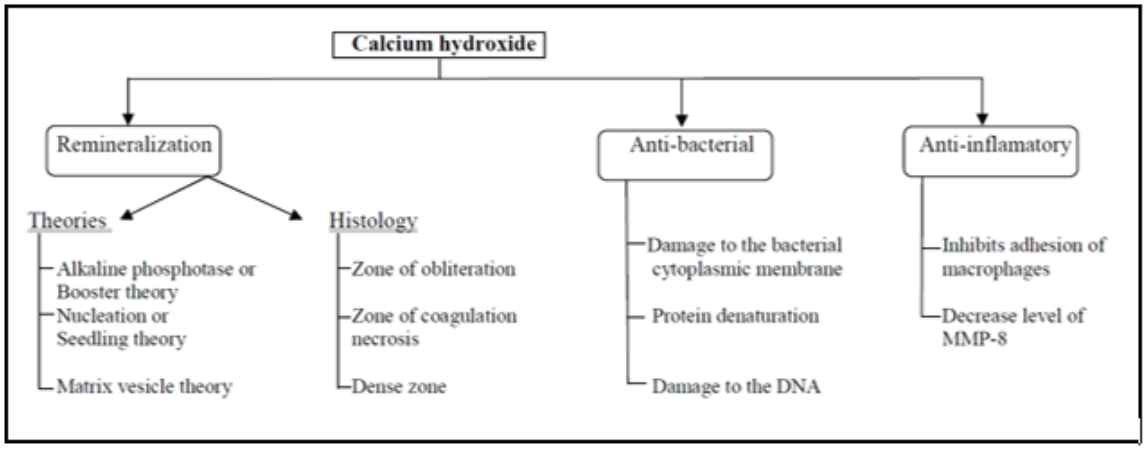

Figure 1: Mechanism of action of calcium hydroxide

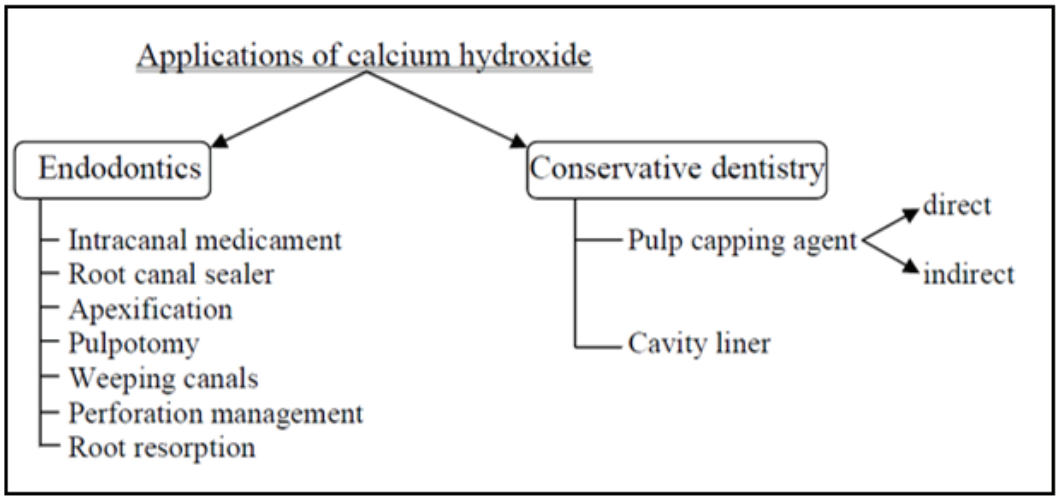

Figure 2: Applications of calcium hydroxide

Conclusion

Calcium hydroxide is considered as one of the gold standard materials in dentistry. Its varied applications and unique mechanism of action and low cytotoxicity has guaranteed its use for this long time and decades to come.

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Conflict of Interest: Nil

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