Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 16, Issue, 07, pp.29102-29105, July, 2024
DOI: https://doi.org/10.24941/ijcr.47446.07.2024

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

CALCIUM HYDROXIDE AND ITS APPLICATIONS: A CONCISE REVIEW

[1]Dr. Shakuntala Bethur Siddaiah and [2*]Dr. Pragna S Vijaya

[1]MDS, Professor and Head, Department of Pediatric and Preventive Dentistry, Rajarajeswari Dental College and Hospital, Bangalore; [2]Post Graduate Student, Department of Pediatric and Preventive Dentistry, Rajarajeswari Dental College and Hospital, Bangalore; [3]Department of Pediatric and Preventive Dentistry, Rajarajeswari Dental College and Hospital, Bangalore

ARTICLE INFO

Article History:
Received 19th April, 2024
Received in revised form
15th May, 2024
Accepted 20th June, 2024
Published online 29th July, 2024

Key words:
Calcium hydroxide, Dental Pulp, Biofilm, Apexification, Endodontics, Root Resorption.

***Corresponding author:**
Shakuntala Bethur Siddaiah

ABSTRACT

Since its creation in 1920, calcium hydroxide has been widely utilized in dentistry. As calcium hydroxide is a versatile agent, there are a greater number of applications for it. With a pH of 12.5–12.8, calcium hydroxide is categorized as a strong base chemically. The principle mode of action is the ionic dissociation of Calcium and hydroxyl ions, which has an impact on vital tissues and induces hard tissue. Calcium hydroxide has broad antimicrobial activity against common endodontic infections. Lethal impacts of calcium hydroxide on bacteria are most likely caused by denaturing proteins, damaging DNA, and disrupting cytoplasmic membranes. Several materials and antimicrobial compositions used in various endodontic treatment techniques contain calcium hydroxide. These include pulp-capping agents, root canal sealers, and intracanal medications provided in between appointments. Calcium hydroxide formulations play a function in dental traumatology, such as after tooth avulsion and luxation injuries, and are also employed in the treatment of root perforations, fractures, and resorption. The purpose of this study is to review the clinical applications of calcium hydroxide in endodontics and dental traumatology.

Citation: Dr. Shakuntala Bethur Siddaiah and Dr. Pragna S Vijaya. 2024. "Calcium hydroxide and its applications: A concise review". *International Journal of Current Research*, 16, (07), 29102-29105.

INTRODUCTION

The primary goal of Endodontics is to preserve the natural tooth. The main goals of endodontic therapy are to prevent and manage periradicular and pulpal infections. Numerous medications have been introduced to help achieve this. One such agent is calcium hydroxide, which is regarded as a miracle due to its numerous applications. [(1)] Calcium hydroxide was originally introduced to dentistry by Hermann in Germany in 1920 as a pulp-capping agent. Nygren (1838) is recognised as the first to describe its use in treating "fistula dentalis," whilst Codman (1851) was the first to attempt to preserve the damaged dental pulp. [(2)] The deposition of a hard tissue bridge, which often shields the dental pulp, is encouraged by calcium hydroxide. [(3)] Researchers have demonstrated through scientific data that calcium hydroxide can induce a mineralized bridge to form over pulpal tissue. Maintaining a high hydroxyl ion concentration has the ability to alter the enzymatic activity of bacteria and facilitate their inactivation. The site of action of hydroxyl ions includes the enzymes in the cytoplasmic membrane.

As the cytoplasmic membranes in the microbial world are comparable regardless of the morphological, tinctorial, and respiratory traits of microorganisms, this drug acts similarly on both aerobic and anaerobic bacteria, as well as Gram-positive and Gram-negative bacteria. When used as a temporary dressing in between appointments, calcium hydroxide dressings improve the periapical healing process more than the treatment in single appointment. [(4)] The current success of this medication as an endodontic is attributed to its capacity to induce mineralization, which is linked to its antibacterial efficiency. [(3)] Since its introduction, it has been used to perform treatments including direct and indirect pulp capping, apexogenesis, apexification, treatment of root resorption, iatrogenic root perforations, root fractures, replanted teeth, interappointment intracanal medicament. [(2)] The main purpose of the paper is to review the various purposes of calcium hydroxide. Calcium hydroxide is an odourless, white powder with a molecular weight of 74.08. Its water solubility is modest (approximately 1.2g/L at 25 °C), which decreases as the temperature rises. It has a pH between 12.5 and 12.8. It is chemically categorised as a strong base.

It is insoluble in alcohol. Chemical formula of calcium hydroxide is $Ca(OH)_2$. It behaves thixotropically in water, implying that when agitated, it will become extremely fluid. [2,5] The compressive strength greater than 24 hours is equal to 138 Pa, while its elastic modulus is 588 Pa. Calcium hydroxide is arranged with crystalline fillers and an amorphous matrix. It forms both ionic and covalent bonds. Composition of calcium hydroxide being a multiphase. [3] The dissociation coefficient of Ca(OH)2 (0.17) has been shown to be antibacterial and to permit for the gradual, regulated release of calcium and hydroxyl ions, which in turn induces the deposition of hard tissues. [6,7] This low solubility is a beneficial clinical feature due to the fact that it takes an extended time to dissolve when it comes into direct contact with fluids from vital tissues. [7]

A study by Estrela (1996) investigated chemically the liberation of calcium and hydroxyl ions from Ca (OH)2 pastes with vehicles of varying acid–base and hydrosolubility characteristics in the connective tissues of dogs. Given that calcium hydroxide has a molecular weight of 74.08, the percentage of hydroxyl ions is 45.89%, while the calcium ions correspond to 54.11% which indicates that the liberation of hydroxyl ions was determined by comparing the liberated calcium ions to the molecular weight of calcium hydroxide. [8] The length of fine calcium hydroxide particles varies between 0.5 to 2 micrometres. A high local pH produced by the penetrating particles into dentin may be a direct source of dissociated calcium hydroxide, which would have a more potent and effective antibacterial action. [9]

APPLICATIONS OF CALCIUM HYDROXIDE

Intracanal medicament: An efficient antimicrobial treatment protocol should be implemented to minimise the impact of bacterial endotoxins and enable the defence system of the host to take over. This will create an environment that is conducive to healing. It is recommended to apply an interappointment antimicrobial dressing in infected root canals since irrigation and instrumentation alone are not always sufficient to completely remove the bacteria. One of the most often utilised intracanal medications is calcium hydroxide. Because of its high pH (about 12.5), it affects the biological characteristics of the bacterial lipopolysaccharides found in the cell walls of Gram-negative species, deactivating the membrane transport mechanisms. However, the buffering effect of dentin neutralises the action of calcium hydroxide at deeper levels of dentinal tubules, resulting in the survival of bacteria. Several studies have reported the failure of $Ca(OH)_2$to eliminate *Enterococci* effectively as they tolerate high pH values, varying from 9 to 11. [10] In a study by Lima *et al*., 106 single-rooted human teeth were inoculated with *Enterococcus faecalis* (ATCC 29212) and cultured in a microaerophilic environment for 21 days in order to assess the antimicrobial efficacy of calcium hydroxide-based intracanal medications against this pathogen. Microbial samples were taken seven days later and immediately after the intracanal dressing was removed. Following dressing removal, all medications were linked to a decrease in *E. faecalis* (post-medication harvest). However, all specimens were related with a rise in CFU /mL levels after 7 days. The investigation found that any medication based on calcium hydroxide could considerably lower the amount of *E. faecalis* in the root canal system. In light of the used technique, the correlations between Calen/CMCP (14 days) and Calen/CHX (7 or 14 days) were more effective in eliminating *E. faecalis*. [11] As long as a high pH is maintained, calcium hydroxide will have an antimicrobial impact in the root canal system. Lin *et al*. observed that treatment with electrophoresis was substantially more successful than pure $Ca(OH)_2$ up to depths of 200–500μm. Within days of treating specimens with electrophoretically activated $Ca(OH)_2$, no living bacteria were found in dentinal tubules down to 500 μm from the root canal area. [12] It has been found that endodontic therapy with intracanal dressing has a high success rate of over 94%. Research has indicated that the hydroxyl ions only diffused a little distance within the canal and that they diffused more rapidly cervically than apically. Therefore, for effective antibacterial action in clinical conditions including weeping canals, pulpal necrosis, and periapical lesions, the medication must be delivered till the apical third. For a significant pH rise and antibacterial conditions, it is desirable to place considerable amounts of calcium hydroxide slurry. [13] The pH of the dentin outside the root canal and inside the root canal is influenced by the calcium hydroxide placement technique. Stated in distinct ways, the antibacterial activity is determined by the diffusion of hydroxyl ions throughout the root canal system, necessitating efficient delivery. According to studies, lentulo spirals resulted in fillings that were uniform. According to a study by Teixeira *et al*. (2005), utilising paper points alone did not result in higher pH values than placing calcium hydroxide paste with a lentulo spiral and then compaction with the blunt end of the paper point. [14]

Root canal sealer: The primary goal of root canal obturation is to create a tight seal within the root canal system, which will facilitate the healing process of periapical and apical regions following endodontic therapy. [15] Sealer is essential to the root canal obturation process as it essentially fills in the spaces left by the prepared dentine walls and the gutta-percha, which the gutta-percha is unable to occupy. For calcium hydroxide to have a therapeutic effect, it must dissociate into Calcium and Hydroxyl ions. Consequently, the dissolution of a calcium hydroxide-based endodontic sealer resulted in the loss of its solid content, which in turn caused the formation of obturation voids. [6] The antibacterial activity of several calcium hydroxide based sealers such as RealSeal, Sealapex, Apexit, and Apexit Plus is connected to the release of hydroxyl ions. The development of hard tissue at the root end may also benefit from these sealants. [16] Calcium hydroxide-based sealers offer multiple benefits, yet they additionally come with some drawbacks, including weak cohesive strength, higher solubility, marginal leakage, and low antibacterial action. [17] To prove that calcium hydroxide in root canal sealers has tissue-healing capabilities, further research is required.

Indirect pulp treatment and direct pulp capping: Indirect pulp treatment is a technique for avoiding pulp exposure in the treatment of teeth with deep carious lesions in which there exists no clinical evidence of pulpal degeneration or periapical disease. The major goal is to halt the carious process by encouraging dentinal sclerosis, remineralization of carious dentine and preserving pulp vitality.

It is well acknowledged that calcium hydroxide is the best material to use for pulp capping as it is an ideal pulp protectant. [12] Histologically there is complete dentinal bridging with healthy radicular pulp under calcium hydroxide dressings. Direct application of calcium hydroxide to pulp tissue results in necrosis of adjacent pulp tissue and an inflammation of contiguous tissue. The intersection between vital inflamed tissue and necrotic tissue is where dentinal bridge formation takes place. Cells from the pulp tissue beneath the necrotic area develop into odontoblasts and generate the dentin matrix. It is well known that commercially available calcium hydroxide compounds in a modified form are less alkaline and, hence, less caustic on pulp. [(18)] According to Stanley and Pameijer, Dycal has several benefits, including increased strength, relatively instantaneous attainment of the maximal physical characteristics, minimal solubility in acid, and low solubility in water. [(19)] Schroder discovered that the highest pH of 12.5 for calcium hydroxide results in liquefaction necrosis in the superficial layers of pulp, and that the toxicity of the pulp appears to be rapidly neutralised when it affects the deeper layers of pulp. The mild irritation will initiate an inflammatory response and in the absence of bacteria will heal with a hard tissue barrier. [(20)] In contrast, Stanley and Lundy reported that pure calcium hydroxide is the only formulation that initiates healing with a hard-tissue barrier, and that hard-setting calcium hydroxide formulations do not result in necrosis of the superficial layers of pulp. [(21)]

In weeping canals: Weeping canal is a canal from which constant clear or reddish exudation appears. There is a significant apical radiolucency linked to this exudate. The tooth is challenging to treat since, when it is opened, the exudate ceases, but it reappears in the next appointment. There is a range of signs and symptoms, including soreness, percussion, palpation. Obturation of canals containing exudates is contraindicated. When periapical tissues are weeping, their pH is acidic and calcium hydroxide converts acidic to a basic pH. [(3,14)] Additionally, two more mechanisms have been suggested: 1) build up bone in the lesion due to the calcifying potential of calcium hydroxide and 2) the residual chronically inflamed tissue is cauterized by the caustic action of calcium hydroxide. [(7)]

Apexification: Apexification is defined as 'a method to induce a calcified barrier in a root with an open apex or the continued apical development of an incomplete root in teeth with necrotic pulp. [(22)] Unfortunately, trauma-related damage to young permanent teeth are not uncommon and are estimated to impact 30% of youngsters before root formation is complete. [(23)] Due to the vital significance of Hertwig's epithelial root sheath in ongoing root development after pulpal injury, every effort should be made to maintain its viability. It is believed to offer a source of undifferentiated cells that may eventually give rise to more hard tissue development. Additionally, it might prevent periodontal ligament cells from growing into the root canal, which could lead to intracanal bone formation and arrest of root development. [(24)] Custom-fit gutta-percha cones were used in the past; however, this is not advised because proper guttapercha condensation is impossible as the apical portion of the root is often wider than the coronal portion. The root would become considerably weaker and fracture risk would rise if the coronal segment were to sufficiently enlarge to make its diameter larger than the apical region. The wide foramen results in a huge volume of filling material and a weakened seal. An extremely unfavourable crown root ratio is the outcome of apicoectomy, which further shortens the root length. The very low success rate of these procedures led to an abundance of interest in the phenomenon of apical barrier establishment or continued apical development, which was originally described in the 1960s.Although many materials have been suggested to induce the establishment of the apical barrier, calcium hydroxide has received the most support. In 1964, Kaiser introduced the concept to employ calcium hydroxide, proposing that when combined with camphorated parachlorophenol (CMCP), it would cause a calcified barrier to form across the apex. Frank made this process more widely known by emphasising the need to use medication and instruments to reduce contamination inside the root canal and to temporarily decrease the canal space using a resorbable paste seal. [(25,26)] The establishment of the apical barrier is more successful in the absence of microorganisms and the antibacterial activity of calcium hydroxide has been demonstrated. The release of hydroxyl ions, which are extremely reactive and highly oxidant, is linked to the antibacterial activity. These ions damage bacterial DNA, denaturize proteins, and destroy the cytoplasmic membrane of the bacteria. [(27)] Controversy exists as to whether or how often the calcium hydroxide dressing should be changed. While Chosack *et al*. discovered that there was no benefit to repeating calcium hydroxide root filling every month or every three months after the initial treatment, Chawla contends that it is sufficient to apply the paste just once and wait for radiographic evidence of barrier construction. [(28,29)] Sheehy and Roberts observed an average duration of 5 to 20 months for the establishment of the apical barrier in an analysis of ten studies.[30] Finucane and Kinirons examined 44 immature, non-vital teeth undergoing calcium hydroxide apexification and discovered that the average duration required for barrier creation was 34.2 weeks, with a range of 13–67 weeks also observed. [(31)]

Root resorption: Root resorption is the resorption affecting the cementum and/or dentine of the root of a tooth. It is classified into internal, external or root-ended resorption based on the site of origin. [(32)] Since calcium hydroxide has alkaline pH, it decreases osteoclast activity and promotes healing in the surrounding environment of a resorptive region. In order to reverse the reaction and promote the creation of hard tissue, the alkaline calcium hydroxide neutralises the acidic environment that prevails in the resorption zone. The pH of periodontal space would rise from 6.0 to 7.4–9.6 due to the diffusion of hydroxyl ions generated by calcium hydroxide through the dentinal tubules that directly interface with periodontal space. [(33)] Calcium hydroxide paste is used to fill the canal and resorption lacuna in order to treat an internal resorption. In this approach calcium hydroxide will promote the necrotization process of the remaining tissue in the lacuna, and subsequently by irrigation with sodium hypochlorite the necrotic residuals are eliminated. [(7)] The recommended treatment for lateral resorption is pulp extraction, root canal debridement, and calcium hydroxide application. Calcium hydroxide fillings should be applied to the resorptive defect every three months until hard tissue creation can be observed as verified by radiographs and direct examinations through the access cavity. [(34)] Once a physical barrier has been established, the defect can be compacted using gutta-percha. Andreasen employed intracanal calcium hydroxide dressing and was able to halt inflammatory root resorption in nine out of ten cases. [(35)]

CONCLUSION

Calcium hydroxide has been used for different purpose in endodontics and available in different forms. Despite its wide range of antimicrobial activity, calcium hydroxide is less effective against some species. Its cytotoxicity appears to be milder than other groups of sealers. The biocompatibility of calcium hydroxide based sealers is controversial and because of their solubility, they do not fulfill all the criteria of an ideal sealer. It is difficult to remove calcium hydroxide completely from the root canals. Further studies are recommended to evaluate the effectiveness of calcium hydroxide and its applications in the field of endodontics

REFERENCES

1. Siqueira Jr JF, Lopes H. Mechanisms of antimicrobial activity of calcium hydroxide: a critical review. International endodontic journal. 1999 Sep;32(5):361-9.
2. Fava LR, Saunders WP. Calcium hydroxide pastes: classification and clinical indications. International endodontic journal. 1999 Jul;32(4):257-82.
3. Agrawal V. Calcium hydroxide: A miracle munition. Indian J Dent Res Rev. 2011;1:16-8.
4. Estrela C, Holland R. Calcium hydroxide: study based on scientific evidences. Journal of Applied Oral Science. 2003;11:269-82.
5. Mohammadi Z, Shalavi S, Yazdizadeh M. Antimicrobial activity of calcium hydroxide in endodontics: a review. Chonnam medical journal. 2012 Dec 1;48(3):133-40.
6. Farhad A, Mohammadi Z. Calcium hydroxide: a review. International dental journal. 2005 Oct 1;55(5):293-301.
7. Mohammadi Z, Dummer PM. Properties and applications of calcium hydroxide in endodontics and dental traumatology. International endodontic journal. 2011 Aug;44(8):697-730.
8. Estrela C, Pesce HF (1996) Chemical analysis of the liberation of calcium and hydroxyl ions of calcium hydroxide pastes in the presence of connective tissue of the dog. Part I. Brazilian Dental Journal 7, 41–6
9. Komabayashi T, D'souza RN, Dechow PC, Safavi KE, Spångberg LS. Particle size and shape of calcium hydroxide. Journal of endodontics. 2009 Feb 1;35(2):284-7.
10. Hemamalini R, Kavitha M, Vishalini A, Arunprasad M. Calcium hydroxide as an intracanal medicament-a review. IOSR J Dent Med Sci. 2020;19:9-13.
11. Lima RK, Guerreiro-Tanomaru JM, Faria-Júnior NB, Tanomaru-Filho M. Effectiveness of calcium hydroxide-based intracanal medicaments against Enterococcus faecalis. International endodontic journal. 2012 Apr;45(4):311-6.
12. Strom, T A *et al*. "Endodontic release system for apexification with calcium hydroxide microspheres." Journal of dental research vol. 91(11), 2012, 1055-9.
13. Calişkan MK. Prognosis of large cyst-like periapical lesions following nonsurgical root canal treatment: A clinical review. Int Endod J 2004;37:408-16.
14. Mustafa M, Saujanya KP, Jain D, Sajjanshetty S, Arun A, Uppin L, Kadri M. Role of calcium hydroxide in endodontics: a review. Glob J Med Public Health. 2012 Jan;1(1):66-70.
15. Waltimo TMT, Siren EK, Torkko HLK, Olsen I, Haapasalo MPP. Fungi in therapy-resistant apical periodontitis. Int Endod J 1997; 30: 96–101
16. Hugh Devlin, The use of Calcium Hydroxide in Direct Pulp Capping, Operative dentistry: a practical guide to recent innovations, 2006, 40-41.
17. Warfving J, *et al*. Effect of Calcium hydroxide treated dentine on pulpal responses. Int Endod J 1987 20: 183-190.
18. Buck RA, Cai J, Eleazer PD, Staat RH, Hurst HE. Detoxification of endotoxin by endodontic irrigants and calcium hydroxide. Journal of endodontics. 2001 May 1;27(5):325-7.
19. Stanley HR, Pameijer CH. Pulp capping with a new visible light-curing calcium hydroxide composition (Prisma VLC Dycal). Oper Dent 1985 10: 159-163.
20. Schroder U. Reaction of human dental pulp to experimental pulpotomy and capping with calcium hydroxide. Odont Rev 1973 24: 97-105
21. Stanley HR, Lundy T. Dycal therapy for pulp exposure. Oral Surg 1972 34: 818-825
22. American Association of Endodontists. Glossary of endodontic terms, 7th edn. Chicago: American Association of Endodontists; 2003.
23. Andreasen JO, Andreasen FM. Textbook and color atlas of traumatic injuries to the teeth, 3rd edn. Copenhagen: Munksgaard; 1994.
24. Andreasen JO, Borum MK, Andreasen FM. Replantation of 400 avulsed permanent incisors. Endod Dent Traumatol 1992;8:45–55.
25. Kaiser HJ. Management of wide open apex canals with calcium hydroxide. Presented at the 21st Annual Meeting of the American Association of Endodontists, Washington DC April 17 1964.
26. Frank AL. Therapy for the divergent pulpless tooth by continued apical formation. J Am Dent Assoc 1966;72:87–93.
27. Barthel CR, Levin LG, Reisner HM, Trope M. TNFalpha release in monocytes after exposure to calcium hydroxide treated E. coli LPS. Int Endod J 1997;30:155–9
28. Chosack A, Sela J, Cleaton-Jones P. A histological and quantitative histomorphometric study of apexification of nonvital permanent incisors of vervet monkeys after repeated root filling with a calcium hydroxide paste. Endod Dent Traumatol 1997;13:211–7.
29. Chawla HS. Apical closure in a non-vital permanent tooth using one calcium hydroxide dressing. J Dent Child 1986;53:44–7. 72.
30. Sheehy EC, Roberts GJ. Use of calcium hydroxide for apical barrier formation and healing in non-vital immature permanent teeth: a review. Br Dent J 1997;183:241–6.
31. Finucane D, Kinirons MJ. Non-vital immature permanent incisors: factors that may influence treatment outcome. Endod Dent Traumatol 1999;15:273–7.
32. Chivian N. Root resorption. In Cohen S, Burns RC (eds) Pathways of the pulp. 5th ed. Pp 504-547. St. Louis: Mosby, 1991
33. Revathi, N. and Sharath Chandra, S.M. (2014) Merits and Demerits of Calcium Hydroxide as a Therapeutic Agent: A Review. International Journal of Dental Sciences and Research, 2, 1-4.
34. Mohammadi Z, Shalavi S, Yazdizadeh M. Antimicrobial activity of calcium hydroxide in endodontics: a review. Chonnam medical journal. 2012 Dec 1;48(3):133-40.
35. Andreasen JO. Treatment of fractured and avulsed teeth. J Dent Child 1971 38. 29-32.

****