

## Calcium Hydroxide in Endodontics

*Aayushi<sup>1</sup>, Arundeep<sup>2</sup>, Dax<sup>3</sup>, Ravjot<sup>4</sup>*

<sup>1</sup> Post Graduate Student, Manav Rachna Dental College, Faridabad  
<sup>2,3,4</sup> MDS, Manav Rachna Dental College, Faridabad

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### ABSTRACT

Calcium hydroxide has been included within several materials and antimicrobial formulations that are used in a number of treatment modalities in endodontics. These include, inter-appointment intracanal medicaments, pulp-capping agents and root canal sealers. Calcium hydroxide formulations are also used during treatment of root perforations, root fractures and root resorption and have a role in dental traumatology, for example, following tooth avulsion and luxation injuries. The purpose of this paper is to review the properties and clinical applications of calcium hydroxide in endodontics and dental traumatology including its antibacterial activity, antifungal activity, effect on bacterial biofilms, the synergism between calcium hydroxide and other agents, its effects on the properties of dentine, the diffusion of hydroxyl ions through dentine and its toxicity. Pure calcium hydroxide paste has a high pH (approximately 12.5–12.8) and is classified chemically as a strong base. Its main actions are achieved through the ionic dissociation of Ca<sup>2+</sup> and OH<sup>-</sup> ions and their effect on vital tissues, the induction of hard-tissue deposition and the antibacterial properties. The lethal effects of calcium hydroxide on bacterial cells are probably due to protein denaturation and damage to DNA and cytoplasmic membranes. It has a wide range of antimicrobial activity against common endodontic pathogens but is less effective against *Enterococcus faecalis* and *Candida albicans*. Calcium hydroxide is also an effective antiendotoxin agent. However, its effect on microbial biofilms is controversial.

### Introduction

Materials and therapeutic agents containing calcium hydroxide are used extensively in a variety of treatment modalities within endodontics and dental traumatology. The main purpose of this article is to review the properties and clinical applications of calcium hydroxide in endodontics and dental traumatology including its antibacterial activity, antifungal activity, effect on bacterial biofilms, the synergism between calcium hydroxide and other agents, its effects on the properties of dentine, the diffusion of hydroxyl ions through dentine, and its toxicity. Endodontic treatment is essentially directed

towards the prevention and control of pulpal and periradicular infections. Complete chemomechanical preparation may be considered an essential step in root canal disinfection. However total elimination of bacteria is difficult to accomplish. by remaining in the root canal between appointments, intracanal medicament may help to eliminate bacteria.

### *History*

- Introduced by herman in 1920.
- Antimicrobial activity suggested by bystrom etal 1985.
- Tissue dissolving activity by hasselgran etal 1988 and anerson etal 1992.

\* Corresponding author : Dr.Aayushi Manav Rachna Dental College, Sector-43, Delhi-Surajkund Road, Faridabad.

- Inhibition of tooth resorption by tronstad 1988.
- Induction of repair by hard tissue formation by foreman and barnes 1990.

### ***Properties of calcium hydroxide***

#### 1. Chemical composition

It is a white odourless powder with chemical formula  $\text{Ca(OH)}_2$  and molecular weight 74.08. Low solubility in water (around 1.2g/l at 12.5°C), which decreases with rise in temperature. Dissociation coefficient 0.17, this controls the slow release of both calcium and hydroxyl ions. Low solubility is useful clinically as an extended period is necessary before it becomes solubilise when in direct contact with fluids from vital tissues. Pure powder has a pH : 12.5- 12.8. Insoluble in alcohol. Chemically classified as strong base . Main actions come from the ionic dissociation of  $\text{Ca}^{2+}$  and  $\text{OH}^-$  ions and their effect on vital tissues , generating the induction of hard tissue deposition and being antibacterial

#### 2. Activity

According to rehman etal (1996),

$\text{Ca(OH)}_2 \longrightarrow \text{Ca}^{2+} + \text{OH}^-$  , on contact with aqueous fluids.

When calcium hydroxide is exposed to carbon dioxide ( $\text{CO}_2$ ) or carbonate ions ( $\text{CO}_3^{2-}$ ) in biological tissue, its dissociation leads to the formation of  $\text{CaCO}_3$  and an overall consumption of  $\text{Ca}^{2+}$  ions. However, it has been shown that after days of exposure to carbon dioxide, 6 preparations of  $\text{Ca(OH)}_2$  maintained a puportedly bactericidal pH within root canal.

Mode of action : Depending on its application, the mode of action of  $\text{Ca(OH)}_2$  may vary.

- Antimicrobial activity

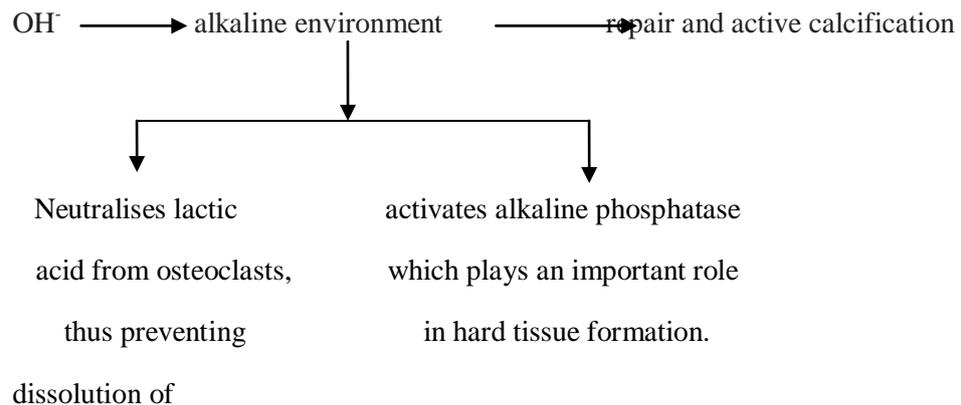
The antimicrobial activity of  $\text{Ca(OH)}_2$  is related to release of hydroxyl ions in an acqeous environment.  $\text{OH}^-$  are highly oxidant free radicals, show extreme

reactivity with several biomolecules , this reactivity is very high and indiscriminate , so this free radical rarely diffuses away from the sites of generation. The lethal effects of hydroxyl ions on bacterial cells are probably due to following mechanisms :

- Damage to bacterial cytoplasmic membrane
- Protein denaturation
- Damage to DNA

Estrela et al (1994) concluded that hydroxyl ions developed their mechanism of action in cytoplasmic membrane. Many cellular functions are affected by ph including enzymes that are essential for cellular metabolism. Estrela etal (1998) proved that bacterial enzymatic inactivation under extreme condition of pH for a long period of time was irreversible.

- Mineralisation activity : When used as a pulp-capping agent and in apexification cases, a calcified barrier may be induced by calcium hydroxide (eda 1961). Because of the high ph of pure calcium hydroxide, a superficial layer of necrosis occurs in the pulp to a depth of up to 2 mm (estrela & holland 2009). Beyond this layer, only a mild inflammatory response is seen and, provided the operating field is kept free from bacteria when the material was placed, hard tissue may be formed (estrela et al. 1995). However, commercial products containing  $\text{Ca(OH)}_2$  may not have such an alkaline pH.



mineral components of dentine.

$\text{OH}^-$  separates phosphoric esters, freeing phosphate ions which reacts with  $\text{Ca}^{2+}$  from blood stream precipitate calcium phosphate in organic matrix (molecular unit of hydroxyapatite) - seltzer and bender 1975

#### ***effect of liquid vehicle***

The vehicles mixed with  $\text{Ca}(\text{OH})_2$  powder play an important role in the overall dissociation process because they determine the velocity of ionic dissociation causing the paste to be solubilized and resorbed at various rates by the peri apical tissues and from within the root canal. The lower the viscosity, the higher will be the ionic dissociation. The high molecular weight of common vehicles minimizes the dispersion of  $\text{Ca}(\text{OH})_2$  into the tissues and maintains the paste in the desired area for longer periods of time (Athanasiadis et al. 2007). There are three main types of vehicles: Water-soluble substances such as water, saline, anaesthetic solutions, carboxymethylcellulose, methylcellulose and Ringers solution. Viscous vehicles such as glycerine, polyethyleneglycol (PEG) and propylene glycol. Oil-based vehicles such as olive oil,

silicone oil, camphor (the oil of camphorated parachlorophenol), some fatty acids (including oleic, linoleic, and isostearic acids), eugenol and

metacresylacetate (Fava & Saunders 1999).  $\text{Ca}(\text{OH})_2$  should be combined with a liquid vehicle because the delivery of dry  $\text{Ca}(\text{OH})_2$  powder alone is difficult, and fluid is required for the release of hydroxyl ions. Sterile water or saline are the most commonly used carriers. Although dental local anaesthetic solutions have an acidic pH (between 4 and 5), they provide an adequate vehicle because  $\text{Ca}(\text{OH})_2$  is a strong base, which is affected minimally by acid (Athanasiadis et al. 2007). A viscous vehicle may remain within root canals for several months, and hence the number of appointments required to change the dressing will be reduced (Fava & Saunders 1999). Behnen et al. (2001) reported that thick mixtures of  $\text{Ca}(\text{OH})_2$  and water (1 g ml<sup>-1</sup> H<sub>2</sub>O) resulted in a significant reduction in antibacterial activity against *E. Faecalis* in dentine tubules compared to a thin mix and the commercial product Pulpdent paste (Pulpdent Corporation, Watertown, MA, USA). Oily vehicles have restricted applications as they are difficult to remove and leave a

residue on the canal walls. The difficulty of removing them from the canal walls will affect the adherence of sealer or other materials used to fill the canal (Fava & Saunders 1999); they are not recommended.

Polyethylene glycol (PEG) is one of the most commonly used vehicles in root canal medicaments, and it possesses an ideal array of properties including low toxicity, high solubility in aqueous solutions and low immunogenicity and antigenicity (Athanassiadis et al. 2007).

#### ***Calcium hydroxide when used in medicaments during root canal treatment***

A medicament is an antimicrobial agent that is placed inside the root canal between treatment appointments in an attempt to destroy remaining microorganisms and prevent reinfection (Weine 2004). Thus, they may be utilized to kill bacteria, reduce inflammation (and thereby reduce pain), help eliminate apical exudate, control inflammatory root resorption and prevent contamination between appointments (Farhad & Mohammadi 2005). When intracanal medicaments were not used between appointments, bacterial numbers increased rapidly (Bystrom & Sundqvist 1981).

#### ***Anti-bacterial activity***

Calcium hydroxide will exert an antibacterial effect in the root canal system as long as a high pH is maintained (Siqueira & Lopes 1999). Bystrom et al. (1985) reported that root canals treated with  $\text{Ca}(\text{OH})_2$  had fewer bacteria than those dressed with camphorated phenol or camphorated monochlorophenol (CMCP) Safavi et al. (1990) demonstrated that *E. faecium* remained viable in dentinal tubules after relatively extended periods of  $\text{Ca}(\text{OH})_2$ /saline mixture treatment.

#### ***Anti-endotoxin activity***

Endotoxin, a part of the cell wall of all Gram-negative bacteria, is composed of polysaccharides, lipids and proteins and is referred to as lipopolysaccharide (LPS), emphasizing its chemical structure (Westphal 1975, Rietschel & Brade 1992). Endotoxin (LPS) is released during multiplication or bacterial death causing a series of biological effects (Barthel et al. 1997), which lead to an inflammatory reaction (Rietschel & Brade 1992) and periapical bone resorption (Stashenko 1990, Yamasaki et al. 1992). In teeth with chronic periapical lesions, there is a greater prevalence of Gram-negative anaerobic bacteria disseminated throughout the root canal system (dentinal tubules, apical resorptive defects and cementum lacunae), including apical bacterial biofilm (Leonardo et al. 1993, Katebzadeh et al. 1999, Nelson-Filho et al. 2002, Trope et al. 1999). Endotoxin, a component of the cell wall of Gram-negative bacteria, plays a fundamental role in the genesis and maintenance of periapical lesions because of the induction of inflammation and bone resorption.  $\text{Ca}(\text{OH})_2$  inactivates endotoxin, in vitro and in vivo, and appears currently the only clinically effective medicament for inactivation of endotoxin.

#### ***Anti-fungal activity***

Fungi constitute a small proportion of the oral microbiota and are largely restricted to *Candida albicans* (Siqueira & Sen 2004) fungi have occasionally been found in primary root canal infections, but they appear to occur more often in filled root canals of teeth in which treatment has failed. *C. albicans* is by far the fungal species most commonly isolated from infected root

canals. It seems that the combinations of  $\text{Ca(OH)}_2$  with camphorated paramonochlorophenol or CHX have the potential to be used as effective intracanal medicaments for cases in which fungal infection is suspected.

#### ***Activity against biofilms***

The term biofilm was introduced to designate the thinlayered (sessile) condensations of microbes that may occur on various surface structures in nature (Svensater & Bergenholtz 2004). Free-floating bacteria existing in an aqueous environment, the so-called planktonic form of microorganisms, are a prerequisite for biofilm formation (Bowden & Hamilton 1998) the few studies conducted on the antimicrobial potential of  $\text{Ca(OH)}_2$  on biofilms have demonstrated inconsistent results. Further studies are required to elucidate the anti-biofilm efficacy of  $\text{Ca(OH)}_2$ .

#### ***Clinical outcome studies on the use of $\text{Ca(OH)}_2$ medicaments***

Two factors must be taken into account before deciding upon a one-visit treatment of teeth with necrotic pulps: the incidence of postoperative pain and the long-term outcome of the treatment (Mohammadi et al. 2006). Studies have found no difference in the incidence of postoperative pain between one- and multiple-visit root canal treatment (O'Keefe 1976, Mulhern et al. 1982, direnzo et al. 2002, Mohammadi et al. 2006). On the other hand, several studies have concluded that one-visit treatment was as effective as multiple visit treatment or even more effective. There is still considerable controversy concerning the effect of the number of treatment visits on the biological outcome, whilst some studies support

two-visit treatment, other studies found that there was no significant difference between the two treatment modalities. It should be noted that some recent clinical trials and systematic reviews found similar healing results between one-visit and multiple-visit treatments.

#### ***Buffering effect of dentine on $\text{Ca(OH)}_2$***

Dentine, hydroxyapatite and remnants of necrotic pulp tissue as well as inflammatory exudate decrease the antibacterial potential of  $\text{Ca(OH)}_2$ . In other words,  $\text{Ca(OH)}_2$  is likely to be effective under laboratory conditions but relatively ineffective as a medicament in vivo.

#### ***Synergism between $\text{Ca(OH)}_2$ and sodium hypochlorite***

The pretreatment of root canals with  $\text{Ca(OH)}_2$  enhances the tissue-dissolving capability of sodium hypochlorite, and this may confer an advantage to multiple-visit root canal treatment where naocl would be used following a period of  $\text{Ca(OH)}_2$  medication.

#### ***$\text{Ca(OH)}_2$ and chlorhexidine***

Although the usefulness of mixing  $\text{Ca(OH)}_2$  with CHX remains unclear and controversial, it seems that by mixing  $\text{Ca(OH)}_2$  with CHX the antimicrobial activity of  $\text{Ca(OH)}_2$  is increased. In other words, the descending order of the antimicrobial activity of  $\text{Ca(OH)}_2$ , CHX and their combination is as follows: CHX,  $\text{Ca(OH)}_2/\text{CHX}$  and  $\text{Ca(OH)}_2$

#### ***Effect of $\text{Ca(OH)}_2$ on dentine***

Dentine exposed to  $\text{Ca(OH)}_2$  for an extended period (6 months to 1 year) results in reduced flexural strength and lower fracture resistance. Therefore, other treatment modalities such as the apical barrier technique using mineral trioxide

aggregate (MTA) should be used to manage teeth with non-vital pulps and open apices, following a short period of  $\text{Ca}(\text{OH})_2$  medication where indicated.

#### ***Diffusion of hydroxyl ions through dentine***

It seems that diffusion of hydroxyl ions through dentine depends on the period of medication, diameter of dentinal tubules (cervical versus apical) and smear layer removal (patency of dentinal tubules). Furthermore, diffusion of hydroxyl ions through to areas of root resorption where pH is acidic has a positive effect on the progression of inflammatory root resorption.

#### ***Removal of $\text{Ca}(\text{OH})_2$ from canals***

$\text{Ca}(\text{OH})_2$  placed as a medicament has to be removed before the canal is filled. Laboratory studies have revealed that remnants of  $\text{Ca}(\text{OH})_2$  can hinder the penetration of sealers into the dentinal tubules (Calt & Serper 1999), hinder the bonding of resin sealers to dentine, increase the apical leakage of root fillings (Kim & Kim 2002) and potentially interact with zinc oxide eugenol sealers and make them brittle and granular (Margelos et al. 1997). Therefore, complete removal of  $\text{Ca}(\text{OH})_2$  from the root canal before filling is recommended.

Oil-based  $\text{Ca}(\text{OH})_2$  paste was more difficult to remove than  $\text{Ca}(\text{OH})_2$  powder mixed with distilled water. Both 17% EDTA and 10% citric acid were found to remove  $\text{Ca}(\text{OH})_2$  powder mixed with distilled water, whereas 10% citric acid performed better than EDTA in removing an oil-based  $\text{Ca}(\text{OH})_2$  paste. Lambrianidis et al. (2006) compared the removal efficiency of  $\text{Ca}(\text{OH})_2/\text{CHX}$  gel,  $\text{Ca}(\text{OH})_2/\text{CHX}$  solution and

$\text{Ca}(\text{OH})_2/\text{saline}$  pastes using instrumentation with or without a patency file and irrigation with NaOCl and EDTA solutions. Remnants of medicaments were found in all canals regardless of the experimental material or use of patency filing. When examining the root canal as a whole,  $\text{Ca}(\text{OH})_2/\text{CHX}$  gel paste was associated with significantly larger amounts of residue, whereas the  $\text{Ca}(\text{OH})_2/\text{CHX}$  solution paste was associated with less residue than the other two groups with or without the use of patency filing. They also noted that the use of patency filing facilitated removal of more of the medicament in the apical third of straight canals (Lambrianidis et al. 2006). Another method to remove remnants of  $\text{Ca}(\text{OH})_2$  from the root canal involved the use of ultrasonic devices. It seems that complete removal of  $\text{Ca}(\text{OH})_2$  paste from the root canal walls is not achievable using routine techniques. However, the type of vehicle used, use of patency filing and combining EDTA and NaOCl with hand instrumentation improves the efficacy of  $\text{Ca}(\text{OH})_2$  paste removal. Furthermore, it seems that ultrasonic methods are more efficient in removing  $\text{Ca}(\text{OH})_2$  remnants than passive irrigation.

#### ***Toxicity of $\text{Ca}(\text{OH})_2$ in medicaments***

$\text{Ca}(\text{OH})_2$  paste is well tolerated by bone and dental pulp tissues. However, its effect on the periodontal tissue is controversial.

#### ***Calcium hydroxide when used in sealers during root canal treatment***

Sealers are responsible for the principal functions of a root filling, namely, sealing the root canal system, entombment of remaining bacteria and the filling of irregularities in the canal system (Ørstavik 2005). Sealapex (SybronEndo, Orange County, CA, USA)

and Apexit (Ivoclar Vivadent Inc., Schaan, Liechtenstein) are brand names of this type of material (Ørstavik 2005).

### ***Leakage***

The sealing ability of Ca(OH)<sub>2</sub>-based sealers compared to other sealers is ambiguous. This may be because of factors such as the method used to evaluate leakage and the often limited sample sizes included. However, it is clear that there is no superiority for Ca(OH)<sub>2</sub>-based sealers over other groups of sealers.

### ***Biocompatibility***

There are five approaches to assess the biocompatibility of endodontic materials such as sealers: cytotoxic evaluation, genotoxicity, subcutaneous implants, intraosseous implants, usage tests and human studies (Hauman & Love 2003). Some controversies regarding the biocompatibility of Ca(OH)<sub>2</sub>-based sealers could be attributed to the evaluation method. However, most studies concluded that the biocompatibility of Ca(OH)<sub>2</sub>-based sealers were within an acceptable range compared to other root canal sealers.

### ***Antibacterial activity***

The antibacterial activity of Ca(OH)<sub>2</sub>-based sealers is lower than other similar materials, especially zinc oxide–eugenol-based and resin-based sealers

### ***Solubility***

#### ***Solubility in tissue fluids***

Owing to the small number of studies, the solubility of Ca(OH)<sub>2</sub>-based sealers compared to other sealers in tissue fluids is not known.

#### ***Solubility in solvents***

The solubility rate of Ca(OH)<sub>2</sub>-based sealers compared to other sealers in solvents is still controversial.

### ***Toxicity of Ca(OH)<sub>2</sub> in sealers***

Although Ca(OH)<sub>2</sub> paste is well tolerated by periapical tissues, it has a detrimental effect on periodontal tissues when used as an intracanal medicament. The biocompatibility of Ca(OH)<sub>2</sub>-based sealers is controversial. Overall, because of their solubility, Ca(OH)<sub>2</sub>-based sealers do not fulfil all the criteria of an ideal sealer. The antibacterial effects of calcium hydroxide in sealers are variable. Cytotoxicity appears to be milder than for other groups of sealers.

## **CLINICAL APPLICATIONS OF CALCIUM HYDROXIDE WHEN USED AS PULP-CAPPING AGENTS IN VITAL PULP THERAPY**

The primary purpose of treating immature permanent teeth should be, where possible, to maintain pulp vitality in order for root development to continue (apexogenesis). Such vital pulp therapy includes indirect and direct pulp-capping, partial (superficial) pulpotomy and cervical pulpotomy. Because of its high pH, Ca(OH)<sub>2</sub> helps to maintain the immediate region in a state of alkalinity, which is necessary for bone and dentine formation. Under this region of Ca(OH)<sub>2</sub>-induced coagulation necrosis, which is saturated with calcium ions, cells from the underlying pulp tissue differentiate into odontoblast-like cells, which then begin to elaborate matrix (Farhad & Mohammadi 2005).

### ***Pulp capping/pulpotomy***

Considering its alkalinity, biocompatibility and antimicrobial activity, it seems that Ca(OH)<sub>2</sub>

is a suitable material for pulp capping and pulpotomy. However, its solubility in fluids is a problem that requires a good coronal seal.

### ***Apexification***

Apexification is defined as the process of creating an environment within the canal and periapical tissues after pulp death that allows a calcified barrier to form across the open apex of an immature root (Pitt Ford 2002). This calcified barrier consists of osteocementum or other bone-like tissue (Grossman 1988). Creation of a proper environment for formation of the calcified barrier involves cleaning and shaping of the canal to remove debris and bacteria, followed by placement of a suitable material to the apex (Pitt Ford 2002). Different materials have been used successfully, but the most favoured is a paste of  $\text{Ca(OH)}_2$  and water; the addition of other medicaments to  $\text{Ca(OH)}_2$  has no beneficial effect on apexification (Gutmann & Heaton 1981).  $\text{Ca(OH)}_2$  is the material of choice to create a calcified barrier at the root-end of teeth with necrotic pulps and immature 'open' apices. However, elimination of infection and necrotic pulp tissue, and the establishment of an effective coronal seal after placing the intracanal medicament appear to be more important than the type of intracanal medicament used. The more recent introduction of the MTA apical barrier technique may replace the use of  $\text{Ca(OH)}_2$  in this treatment modality.

### ***Other clinical applications of calcium hydroxide when used in endodontic therapy Canals with exudate***

A perplexing condition to treat is the tooth with constant clear or reddish exudate associated with a large apical radiolucency. Such a tooth is often asymptomatic, but it may be tender to percussion or

sensitive to digital pressure over the apex. If cultured, the drainage will not generally support bacterial growth (Weine 2004). When the pulp chamber is opened at the start of the appointment, a reddish discharge may appear, whereas at the succeeding appointment the exudate will be clear. If such a tooth is left opened under a rubber dam for 15–30 min, the exudate will stop; however, a similar condition will still be present at the next appointment even though canal preparation to an acceptable size has been achieved.

This is referred to as a 'weeping canal' (Weine 2004). According to Weine (2004), the best way to stop the exudate in such cases is to dry the canal with sterile paper points and to place  $\text{Ca(OH)}_2$  paste in the canal. The possible mechanism of action of  $\text{Ca(OH)}_2$  in these cases is related to its basic pH, which converts the acidic pH of periapical tissues to a more basic environment. Two other theories have also been proposed: (i) the calcifying potential of  $\text{Ca(OH)}_2$  may start to build up bone in the lesion and (ii) the caustic action of  $\text{Ca(OH)}_2$  cauterises residual chronically inflamed tissue (Weine 2004).

### ***Horizontal root fractures***

The use of  $\text{Ca(OH)}_2$  in teeth with horizontal root fractures was first recommended by Cvek (1974). He proposed that the canal at the level of the fracture line was comparable to the apical foramen of an immature tooth. Thus, he assumed that the repair would be similar to the apexification procedure employed for a tooth with an open apex (Cvek 1974). The benefits of root canal treatment with  $\text{Ca(OH)}_2$  occur probably because of its antibacterial effect and its ability to promote the formation of a hard-tissue barrier at the apical opening of the coronal fragment, thereby

facilitating filling with Guttapercha (Cvek et al. 2008). In the management of horizontal root fractures, the coronal segment is considered as an immature tooth with an open apex, and an apexification procedure is conducted. However, MTA can now be used for optimal closure of the apical end of the coronal root segment once canal infection has been eliminated.

### ***Perforations***

Root or furcation perforations can cause failure of root canal treatment, leading to tooth loss (Bramante & Berbert 1994). Several materials have been used to seal perforations, including  $\text{Ca}(\text{OH})_2$ .  $\text{Ca}(\text{OH})_2$  has many benefits in this treatment modality including, easy manipulation, rapid resorption when extruded into the periodontium, promotion of the reorganization of periodontal tissues and induction of mineralized material (Bramante & Berbert 1994). It has been suggested that in such cases, the  $\text{Ca}(\text{OH})_2$  should be renewed regularly (Heithersay 1975, Frank & Weine 1973).  $\text{Ca}(\text{OH})_2$  has been suggested as a traditional agent to manage perforations, and its use is still indicated to control infection, arrest bleeding and as a temporary solution when insufficient time is available to perform a permanent repair. However, MTA now appears to be the material of choice for the permanent repair of perforations from both a conventional and surgical approach.

### ***Root resorption***

Root resorption can affect the cementum and/or dentine of the root (Trope 2002). On the basis of the site of origin of the resorption, it may be referred to as internal, external or root-end resorption (Chivian 1991) by creating an alkaline environment,  $\text{Ca}(\text{OH})_2$

inhibits osteoclast activity and stimulates hard-tissue deposition. However, MTA can be used to repair teeth during the management of internal root resorption.

### **CONCLUSIONS**

Chemically, calcium hydroxide is classified as a strong base with a high pH (approximately 12.5–12.8). Its main properties come from the ionic dissociation of  $\text{Ca}^{2+}$  and  $\text{OH}^-$  ions and their effect on vital tissues, generating the induction of hard-tissue deposition and being antibacterial. The effectiveness of  $\text{Ca}(\text{OH})_2$  against bacterial biofilms is uncertain and needs to be further elucidated. It seems that the combinations of  $\text{Ca}(\text{OH})_2$  with camphorated paramonochlorophenol or CHX have the potential to be used as effective intracanal medicaments for cases in which fungal infection is suspected.  $\text{Ca}(\text{OH})_2$  inactivates endotoxin, in vitro and in vivo, and appears currently the only clinically effective medicament for inactivation of endotoxin. The inhibitory effect of dentine, hydroxyapatite and remnants of necrotic pulp tissue as well as inflammatory exudate on the antibacterial potential of  $\text{Ca}(\text{OH})_2$  has been demonstrated. Synergistic effect between  $\text{Ca}(\text{OH})_2$  and NaOCl as well as between  $\text{Ca}(\text{OH})_2$  and CHX has been demonstrated. Diffusion of hydroxyl ions through dentine depends on the diameter of dentinal tubules (cervical versus apical), smear layer removal (patency of dentinal tubules) and period of medication. Removing efficacy of  $\text{Ca}(\text{OH})_2$  paste from the root canal system seems to be improved by using patency file, combining EDTA and NaOCl with hand instrumentation and the type of vehicle used. In addition, ultrasonic methods are more efficient in removing  $\text{Ca}(\text{OH})_2$  remnants than passive irrigation.  $\text{Ca}(\text{OH})_2$  paste is well tolerated by bone and

dental pulp tissues. However, its effect on the periodontal tissue is controversial. The biocompatibility of  $\text{Ca(OH)}_2$ -based sealers is controversial and because of their solubility, they do not fulfil all the criteria of an ideal sealer. Furthermore, their antibacterial activity is variable, and their cytotoxicity appears to be milder than for other groups of sealers.  $\text{Ca(OH)}_2$  is a suitable material for pulp capping and pulpotomy. However, its solubility in fluids is a problem that requires a good coronal seal.  $\text{Ca(OH)}_2$  has been the material of choice to create a calcified barrier in non-vital open-apex teeth. However, MTA apical barrier technique may replace it.  $\text{Ca(OH)}_2$  has been successfully used to manage perforations, horizontal root fracture and root resorption.

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