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Review Article

Role of Mineral Trioxide Aggregate (MTA) and Calcium Hydroxide in Conservative Dentistry as Pulp Capping Material: A Review

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Abstract: The main purpose of this article is to review the properties and clinical applications of calcium hydroxide and Mineral Trioxide Aggregate in conservative dentistry including its antibacterial effect activity for protection of the dental pulp. Therefore, in latest years, the use of calcium hydroxide or mineral trioxide aggregate in indirect and direct pulp capping was one of the most popular lining materials for protection of the pulp in dentistry. Both materials showed a high success rate for reparative dentin when used as pulp capping. In general, the priority the procedure of placement material for pulp protection as pulp capping, indirect or direct must be clinically no pain, no radiographic exchange in pre-apical area and vital tissue of the pulp.

Keywords: Calcium Hydroxide, Mineral Trioxide Aggregate, Pulp Capping

1. Introduction

Calcium hydroxide has been used extensively in dentistry since by Hermann in 1920, and since that time calcium hydroxide has been a very popular cavity liner as a pulp capping agent dates back 60-70 years and it is used to elicit a regenerative response of the dentine-complex component tissues [1, 2]. Calcium hydroxide has been used in dentistry for almost a century also today, it is still the most commonly used endodontic medicament throughout the world [3]. Mineral trioxide aggregate was developed and introduced to dentistry by Mahmoud Torabinejad in 1999, and it was mainly used as a cement in root canal therapy, it's composed of tricalcium silicate, dicalcium silicate and tricalcium aluminate, and some manufactures add bismuth oxide to enhance radio-opacity of the material [4]

Pulp protection from restorative material toxicity after cavity preparation, use of cavity liner if deep, as a cavity liner, with a thickening agent with mineral trioxide aggregate, according to several studies, has proven to have good biocompatibility in direct contact with the pulp. Also MTA prevents micro-leakage, and promotes regeneration of the tissue and provides better seal than calcium hydroxide [4, 5]. Traditionally, standard material for pulp capping of normal vital pulp tissue is calcium hydroxide has been the most common indirect and direct pulp capping agent, as cavity liner, is placed to a thickness of typically less than 0.5 mm. Additionally, calcium hydroxide when used in pulp capping can reduce bacterial count in the cavity which also promotes reparative dentin formation [4].

Preservation of pulp vitality continues to be a major challenge for restorative dentistry in view of the numbers of new and replacement restorations performed each year.

For a successful vital pulp therapy has a high success rate,

the following conditions should be met:

(1) The pulp is not inflamed
(2) Hemorrhage is properly controlled
(3) A non-toxic capping material is applied
(4) The capping material and restoration seal out bacteria [6].

(a) Composition of Calcium Hydroxide & Composition of MTA:

Pure calcium hydroxide paste has a high pH (approximately 12.5–12.8) and is classified chemically as a strong base, however the effects of calcium hydroxide on bacterial cells are probably due to protein denaturation and damage to DNA and cytoplasmic membranes [7]

MTA powder contains particles that require moisture in order to set. Several liquids have been suggested to be mixed with MTA [8], the main cardinal components of an MTA are silica, calcium and bisthmus oxide. MTA is marketed in two forms, grey MTA and white MTA. Grey MTA basically consists of dicalcium and tricalcium silicate and bismuth oxide, whereas white MTA is primarily composed of tricalcium silicate and bismuth oxide. Calcium hydroxide and calcium silicate hydrates are formed when MTA is mixed with water which transforms into crystalized and porous solid gel [9].

(b) Applications of Calcium Hydroxide:

Calcium hydroxide dissociates into calcium and hydroxyl ions, these calcium ions reduce capillary permeability thus in turn reducing the serum flow and reducing the levels of inhibitory pyrophosphates that cause the mineralization [10].

The hydroxyl ions neutralize acid produced by osteoclasts maintaining optimum pH for pyrophosphatase activity, leading to increase level of calcium dependent pyrophosphatase which reduced the levels of inhibitory pyrophosphate and causing mineralization [11].

It is generally believed that calcium hydroxide is ideal for direct pulp capping since it accelerates the formation of reparative dentin. There are 2 reasons for this: first, since the material is basic (pH of 11 to 12), it serves as an irritant, stimulating the formation of reparative dentin; and second, the therapeutic effect of calcium hydroxide may be due to its ability to extract growth factors from the dentin matrix [4].

Direct pulp capping is the treatment of the exposed vital pulp by sealing the pulpal wound with a dental material to induce a reparative dentinogenic [5] response, and is one of the most important endodontic modalities for maintaining dental pulp vitality [12, 13].

The material must act as a barrier, protecting the pulp while inducing the formation of new dentine bridge between the pulp and restorative material [14].

The indirect pulp cap when caries is thought to extend close to, or into the pulp, excavation of the pulpal caries can be stopped at stained but firm dentine [15]. The underlying pulp becomes inflamed to a varying and unknown degree, depending on the extent of the dental caries [16].

Calcium hydroxide lining is applied over the pulpal dentine prior to placement of the definitive restoration, this is classically referred to as the indirect pulp cap. The difficulty with this technique is knowing how rapid the carious process has been, how much tertiary dentine has been formed and knowing exactly when to stop excavating to avoid pulp exposure [17].

Calcium hydroxide is an ideal lining material for the very deep cavity preparation and also continues to represent an option for both the indirect and direct pulp cap [18, 19].

Calcium hydroxide is a multipurpose agent and there are several indications for its clinical application. Some of its indications include direct and indirect pulp capping, apexogenesis, apexification and treatment of root resorption, iatrogenic root perforations, root fractures, replanted teeth and interappointment intracanal dressing [20].

It is the material of choice for all pulp conservative treatment because of its biological and therapeutic potential [21].

The dry powder of calcium hydroxide, a suspension or cement form, has been recommended for the treatment of exposed pulp due to its beneficial properties, such as induction of mineralization and inhibition of bacterial growth [22].

Indirect pulp treatment is a procedure performed in a tooth with a diagnosis of reversible pulpitis and deep caries that might otherwise need endodontic therapy if the decay was completely removed [23].

(c) Applications of MTA:

MTA has been proposed as the material of choice for pulp capping [24], It is believed that MTA effect differs on different tissues. In [25] study there were normal and irregular odontoblasts, that might be attributed to the action of trioxides and oxides on pulpal cells. MTA also induced bone-like cells that are responsible for the formation of hard tissue [26]. Pulp capping procedure is indicated in teeth with immature root to preserve pulpal vitality [5]. MTA has been extensively studied as a pulp capping material in comparison to calcium hydroxide which has been shown to be superior to calcium hydroxide if not similar [2728]

MTA also has been used in pulpotomy techniques where part or all of the pulp chamber is removed while maintaining the radicular pulp, in an attempt to preserve its vitality, so the root can continue maturation [2930].

It was [31] reported that MTA use in pediatric dentistry is prohibited, due to the high cost of an MTA, as the material also can't be kept after the envelop has been opened.

2. Indication for Indirect Pulp Treatment

The indication for indirect pulp treatment is limited to teeth that have no signs of irreversible pulp pathologies based on a thorough clinical and radiographic examination and a direct evaluation of the cavity preparation [32].

Even today, the subject of vital pulp therapy remains controversial; especially regarding which type of pulp dressing provides the most predictable healing. Calcium hydroxide has been the standard, but newer alternatives are being studied [6].

(a) Calcium hydroxide widely used for pulp capping procedures: [33]

(1) Is nowadays widely used as an intra-canal medicament in endodontic therapy
(2) Clinically, calcium hydroxide appears to control infection
(3) To reduce the incidence of symptoms between appointments
(4) This antibacterial effect is believed to be dependent on its strongly alkaline pH (12.4) (5), Pure calcium hydroxide paste has a high pH (approximately 12.5-12.8)

(b) Factors of successful pulp capping:

Direct pulp capping is the most conservative restorative procedure for protecting the pulp from further insult, permitting healing and repair, a calcium hydroxide is the most commonly used materials for direct pulp capping [34].

Direct pulp capping is a treatment for exposed vital pulp due to several causes: caries, trauma or mechanical reasons, the latter typically due to a misadventure during tooth preparation. which uses a dental material to facilitate both the formation of reparative dentin from odontoblasts, and the maintenance of vital pulp [35,36].

Selection of pulp capping materials is important to ensure dental pulp cell vitality. Historically, Hermann discovered that calcium hydroxide is effective in repairing a pulp exposure site and the calcium hydroxide possesses antibacterial properties and promotes pulp tissue repair, therefore direct pulp capping is one of the most common dental practices in restorative dentistry [37-39].

Direct pulp capping is a vital pulp therapy technique which aims at maintaining pulpal tissues viability by protecting the pulpal system from bacterial ingress and hence enhancing its reparative capacity. Bridging off the communication site with new dentine is a prerequisite for the long term success of direct pulp capping treatment [40, 41].

Successful direct pulp capping prevents the need for more complex or invasive treatment options such as root canal therapy or extraction [42]

There are several factors that can increase the success rate of direct pulp capping, such as the following:[43]

1. Asymptomatic tooth with no history of spontaneous or lingering pain.
2. Less than 0.5mm pulp exposure.
3. Controlled pulpal bleeding after exposure.
4. Proper isolation of the tooth during the procedure.
5. Minimal blood contamination of adjacent dentin

3. Properties of Calcium Hydroxide and Mineral Trioxide Aggregate: [7] [9]

(a) STRUCTURE:

1. Arrangement amorphous matrix, crystalline fillers.
2. Bonding covalent; ionic.
3. Defects pores, cracks.
4. Setting reaction acid base reaction.

(b) MECHANICAL & BIOLOGICAL PROPERTIES:

Elastic modulus and compressive strength of MTA is higher than that of calcium hydroxide which made it a more suitable option when the final restoration is placed with condensation forces. The high bond strength of mineral trioxide aggregate is important due to the fact that the material can suffer displacement under occlusal forces which might result in sealing failure, MTA is biocompatible with the pulp and its biocompatibility is enhanced over time when the material is completely set.

Calcium hydroxide is not acutely toxic via the oral, dermal, or inhalation route. It's used as dressing for treatment of the vital pulp, the ability to encourage hard tissue healing around infected dentin and have an antibacterial effect.

(c) Chemical properties:

The calcium hydroxide is relatively soluble in water, its solubility drastically decreases, but hardened MTA contains calcium hydroxide in a silicate matrix which contribute to its high pH, this composition may differ according to the solution that was used to mix the MTA powder [8]. Also some antibacterial properties and activities, depending on its powder to liquid ratio and related to the release of highly reactive hydroxyl ions in a fluids environment, which mainly affects cytoplasmic membranes proteins and DNA.

(d) Physical properties:

Thermal and electrical conductivity insulator.

1. SETTING TIME: average setting time is 2.8 hours.
2. SOLUBILITY: when MTA was immersed in physiologic solutions for 7 days it decreases in weight, but it increases in weight 30 days after immersion. Its decrease in weight was attributed to the release of calcium hydroxide and the increase in weight to the formation of apatite crystals over the material surface.
3. PARTICLE SIZE: the particle size ranges from 1-10 μm.
4. RADIO-OPACITY: The mean radio-opacity is 7.17 mm of an equivalent thickness of aluminum.

(e) Antibacterial properties:

The literature shows that MTA has an antibacterial and antifungal properties. Powder liquid ratio has a direct effect on antibacterial properties of MTA, decreasing the ratio will decrease its antibacterial properties.

4. Advantages of Calcium Hydroxide and MTA: [20]

- Calcium hydroxide is initially bactericidal then bacteriostatic while MTA antibacterial properties has been extensively researched with inconsistent results, a few studies has shown that MTA has an antibacterial effect [44].
- Both materials promote healing and repair.
- Both materials have high pH and stimulates fibroblasts.
- Both materials neutralize pH when acidic.
- Stop internal resorption.
- Calcium hydroxide is more inexpensive and easy to use when compared to MTA which is difficult to manipulate and too expensive than calcium hydroxide.

5. Disadvantages of Calcium Hydroxide and MTA: [45]

- They do not exclusively stimulate dentinogenesis.
- They do exclusively stimulate reparative dentin.
- Calcium hydroxide is associated with primary tooth resorption.
- Calcium hydroxide may dissolve after one year with cavo-surface dissolution.
- Calcium hydroxide may degrade during acid etching.
- Calcium hydroxide degrades upon tooth flexure.
- Calcium hydroxide shows marginal failure with amalgam condensation.
- Calcium hydroxide does not adhere to dentin or resin restoration
- Also the disadvantages of calcium hydroxide are that it has no inherent adhesive properties and provides a poor seal, and the self-cure formulations are soluble and subject to dissolution over time [4].
- MTA has a long setting time.
- MTA manipulation is difficult.

6. Calcium Hydroxide as a Pulp Capping Agent: [1, 2]

Calcium hydroxide is generally accepted as the material of choice for pulp capping. Histologically there is a complete dentinal bridging with healthy radicular pulp under calcium hydroxide dressings. When calcium hydroxide is applied directly to pulp tissue there is necrosis of adjacent pulp tissue and an inflammation of contiguous tissue. Dentinal bridge formation occurs at the junction of necrotic tissue and vital inflamed tissue. Beneath the region of necrosis, cells of underlying pulp tissue differentiate into odontoblasts and elaborate dentin matrix.

7. Outcome of Pulp Capping Using Either Calcium Hydroxide or MTA

In a new multi-center, parallel-group randomized controlled trial that compare the effectiveness of MTA and CH as a direct pulp capping material in adult molars with carious pulpal exposure. [46] tooth survival was set as a primary outcome which was defined as asymptomatic tooth that responds normally to vitality testing and periapical radiographs don't show any bone rarefaction, the survival rate in MTA group was 53% while in the Calcium hydroxide group was 52%.

[47] in their study reported that calcium hydroxide was found not to have any beneficial effect on the healing of the exposed inflamed pulp. The results with zinc oxide and eugenol were more favorable.

In an observational study of the direct pulp capping with mineral trioxide aggregate, [48] observed 49 of 53 teeth in 37 patient between one and nine years with a mean age being 16.6 years and a recall rate of 92.5%. they found that the survival rate was 97.96% that has been based on cold testing, sings & symptoms and radiographs at recall appointment.

[39] in their systematic review and meta-analysis stated that MTA performs better than calcium hydroxide in direct pulp capping therapy, with 100% success rate for the MTA after six months follow up in comparison to 79.4% success rate for the calcium hydroxide group with the same follow up duration.

8. Conclusion

In conclusion, can be suggested as the materials of best choice for pulp capping and no significant difference was found between them in terms of calcified bridge formation and thickness with a well-structured dentin is formed when using MTA, as well as pulpal inflammatory response. MTA is a bioactive material that influences its surrounding environment required to promote wound healing, provides immediate bond and sealing properties, and stimulates hydroxyl-apatite and secondary dentin formation within affected tissues.

The handling characteristics of calcium hydroxide and its lower price render the material the first choice to be clinically used in comparison to the high cost of MTA and the difficulties of it is mixing and handling characteristics.

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 Ca^{2+} and OH^- ions and their effect on vital tissues, generating the induction of hard tissue deposition and being antibacterial. Calcium hydroxide is a suitable material for pulp capping. Calcium hydroxide is a necessary material which has a number of applications especially in conservative dentistry. Because of the extreme importance of these materials has become without competition serves as a bread every day for practitioner dentist.

References

[1] Fuks, Anna B. "Vital Pulp Therapy with New Materials for Primary Teeth: New Directions and Treatment Perspectives." *Journal of endodontics* 34.7 (2008): S18-S24.

[2] Kakehashi, S, HR Stanley, and RJ Fitzgerald. "The Effects of Surgical Exposures of Dental Pulps in Germ-Free and Conventional Laboratory Rats." *Oral Surgery, Oral Medicine, Oral Pathology* 20.3 (1965): 340-49.

[3] Siqueira, JF, and HP Lopes. "Mechanisms of Antimicrobial Activity of Calcium Hydroxide: A Critical Review." International endodontic journal 32.5 (1999) 361- 69.

[4] Hilton, Thomas J. "Keys to Clinical Success with Pulp Capping: A Review of the Literature." *Operative dentistry* 34.5 (2009): 615-25.

[5] Torabinejad, Mahmoud, and Noah Chivian. "Clinical Applications of Mineral Trioxide Aggregate." *Journal of endodontics* 25.3 (1999): 197-205.

[6] Swift, Edward J, Martin Trope, and Andre V Ritter. "Vital Pulp Therapy for the Mature Tooth–Can It Work?" *Endodontic Topics* 5.1 (2003): 49-56.

[7] Mohammadi, Z, and Paul Michael Howell Dummer. "Properties and Applications of Calcium Hydroxide in Endodontics and Dental Traumatology." *International endodontic journal* 44.8 (2011): 697-730.

[8] Camilleri, Josette, et al. "The Constitution of Mineral Trioxide Aggregate." *Dental Materials* 21.4 (2005): 297-303.

[9] Parirokh, Masoud, and Mahmoud Torabinejad. "Mineral Trioxide Aggregate: A Comprehensive Literature Review—Part I: Chemical, Physical, and Antibacterial Properties." *Journal of endodontics* 36.1 (2010): 16-27.

[10] Sonarkar, Snehal, and Rucheet Purba. "Bioactive Materials in Conservative Dentistry." *International Journal of Contemporary Dental and Medical Reviews* 2015 (2015).

[11] B. Suresh Chandra, V. Gopi Krishna. "Vital Pulp Therapy, Pulpotomy and Apexification." *Grossman's Endodontic Practice. 12th ed. New Delhi: Wolters Kluwer; 2* 010P 315.

[12] Goldberg, Michel, and Anthony J Smith. "Cells and Extracellular Matrices of Dentin and Pulp: A Biological Basis for Repair and Tissue Engineering." *Critical Reviews in Oral Biology & Medicine* 15.1 (2004): 13-27.

[13] Modena, Karin Cristina da Silva ,et al. "Cytotoxicity and Biocompatibility of Direct and Indirect Pulp Capping Materials." *Journal of Applied Oral Science* 17.6 (2009): 544-54.

[14] Desai, Shalin, and Nicholas Chandler. "Calcium Hydroxide–Based Root Canal Sealers: A Review." *Journal of endodontics* 35.4 (2009): 475-80.

[15] Kidd E A M, Smith B G N. *Pickard's Manual of Operative Dentistry*. 7th ed: Oxford University Press, 1996. Print.

[16] Lin, Louis, and Kaare Langeland. "Light and Electron Microscopic Study of Teeth with Carious Pulp Exposures." *Oral Surgery, Oral Medicine, Oral Pathology* 51.3 (1981): 292-316.

[17] Ricketts, D_. "Restorative Dentistry: Management of the Deep Carious Lesion and the Vital Pulp Dentine Complex." *British dental journal* 191.11 (2001): 606-10.

[18] Estrela, Carlos, and Roberto Holland. "Calcium Hydroxide: Study Based on Scientific Evidences." *Journal of Applied Oral Science* 11.4 (2003): 269-82.

[19] Weiner, R. "Liners, Bases, and Cements: Material Selection and Clinical Applications." *Dentistry today* 24.6 (2005): 64, 66.

[20] Farhad, Alireza, and Zahed Mohammadi. "Calcium Hydroxide: A Review." *International dental journal* 55.5 (2005): 293-301.

[21] Demarco, Flávio Fernando, et al. "Pulp Response and Cytotoxicity Evaluation of 2 Dentin Bonding Agents." *Quintessence International* 32.3 (2001).

[22] Cavalcanti, BN, SM Rode, and MM Marques. "Cytotoxicity of Substances Leached or Dissolved from Pulp Capping Materials." *International endodontic journal* 38.8 (2005): 505-09.

[23] JH, Camp, and Fuks AB. "Pediatric Endodontics: Endodontic Treatment for the Primary and Young Permanent Dentition." *Pathways of the Pulp, 10th ed. St Louis, MO: Mosby Elsevier* (2011): 808-57.

[24] Nair, PNR, et al. "Histological, Ultrastructural and Quantitative Investigations on the Response of Healthy Human Pulps to Experimental Capping with Mineral Trioxide Aggregate: A Randomized Controlled Trial." *International endodontic journal* 41.2 (2008): 128-50.

[25] Caicedo, R, et al. "Clinical, Radiographic and Histological Analysis of the Effects of Mineral Trioxide Aggregate Used in Direct Pulp Capping and Pulpotomies of Primary Teeth." *Australian dental journal* 51.4 (2006): 297-305.

[26] Torabinejad, Mahmoud, et al. "Histologic Assessment of Mineral Trioxide Aggregate as a Root-End Filling in Monkeys." *Journal of Endodontics* 23.4 (1997): 225-28.

[27] Cho, Sin-Yeon, et al. "Prognostic Factors for Clinical Outcomes According to Time after Direct Pulp Capping." *Journal of endodontics* 39.3 (2013): 327-31.

[28] Aeinehchi, M, et al. "Mineral Trioxide Aggregate (Mta) and Calcium Hydroxide as Pulp-Capping Agents in Human Teeth: A Preliminary Report." *International endodontic journal* 36.3 (2003): 225-31.

[29] Barrieshi-Nusair, Kefah Mahmood, and Muawia Abdulla Qudeimat. "A Prospective Clinical Study of Mineral Trioxide Aggregate for Partial Pulpotomy in Cariously Exposed Permanent Teeth." *Journal of Endodontics* 32.8 (2006): 731-35.

[30] Bortoluzzi, Eduardo Antunes, et al. "Mineral Trioxide Aggregate with or without Calcium Chloride in Pulpotomy." *Journal of Endodontics* 34.2 (2008): 172-75.

[31] Fuks, AB. "Current Concepts in Vital Primary Pulp Therapy." *European Journal of Paediatric Dentistry* 3 (2002): 115-20.

[32] Tziafas, D, AJ Smith, and H Lesot. "Designing New Treatment Strategies in Vital Pulp Therapy." *Journal of dentistry* 28.2 (2000): 77-92.

[33] Teixeira, Fabrício B, Linda G Levin, and Martin Trope. "Investigation of Ph at Different Dentinal Sites after Placement of Calcium Hydroxide Dressing by Two Methods." *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology* 99.4 (2005): 511-16.

[34] Jamjoom, Hana M. "Clinical Evaluation of Directly Pupl Capped Permanent Teeth with Glass Ionomer Materials." *Cairo Dental Journal* 2.24 (2008): P 177-85.

[35] Pashley, David Henry. "Dynamics of the Pulpo-Dentin Complex." *Critical Reviews in Oral Biology & Medicine* 7.2 (1996): 104-33.

[36] Bergenholtz, Gunnar. "Advances since the Paper by Zander and Glass (1949) on the Pursuit of Healing Methods for Pulpal Exposures: Historical Perspectives." *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology* 100.2 (2005): S102-S08.

[37] Hermann, BW. "Dentin Obliteration Der Wurzelkanale Nach Behandlung Mit Calcium." *Zahnärztl Rundschau* 39 (1930): 888-98.

[38] Matsuo, Takashi, et al. "A Clinical Study of Direct Pulp Capping Applied to Carious-Exposed Pulps." *Journal of endodontics* 22.10 (1996): 551-.56

[39] Zhu, Chenxi, Bin Ju, and Rong Ni. "Clinical Outcome of Direct Pulp Capping with Mta or Calcium Hydroxide: A Systematic Review and Meta-Analysis." *International journal of clinical and experimental medicine* 8.10 (2015): 17055.

[40] Schröder, U. "Effects of Calcium Hydroxide-Containing Pulp-Capping Agents on Pulp Cell Migration, Proliferation, and Differentiation." *Journal of dental research* 64.4 (1985): 541-48.

[41] Stanley, Harold R. "Pulp Capping: Conserving the Dental Pulp—Can It Be Done? Is It Worth It?" *Oral Surgery, Oral Medicine, Oral Pathology* 68.5 (1989): 628-39.

[42] Li, Zhaofei, et al. "Direct Pulp Capping with Calcium Hydroxide or Mineral Trioxide Aggregate: A Meta-Analysis." *Journal of endodontics* 41.9 (2015): 1412-17.

[43] Roberson, Theodore M., et al. *Sturdevant's Art and Science of Operative Dentistry*. 5th ed. St. Louis, Mo.: Mosby Elsevier, 2006. Print.

[44] Estrela, Carlos, et al. "Antimicrobial and Chemical Study of Mta, Portland Cement, Calcium Hydroxide Paste, Sealapex and Dycal." *Braz Dent J* 11.1 (2000): .9-3.

[45] Foreman, PC, and IE Barnes. "A Review of Calcium Hydroxide." *International Endodontic Journal* 23.6 (1990): 283-97.

[46] Kundzina, R, et al. "Capping Carious Exposures in Adults: A Randomized Controlled Trial Investigating Mineral Trioxide Aggregate Versus Calcium Hydroxide." *International Endodontic Journal* doi: 10.1111/iej.12719 (2016).

[47] Tronstad, Leif, and Ivar A Mjör. "Capping of the Inflamed Pulp." *Oral Surgery, Oral Medicine, Oral Pathology* 34.3 (1972): 477-85.

[48] Bogen, George, Jay S Kim, and Leif K Bakland. "Direct Pulp Capping with Mineral Trioxide Aggregate: An Observational Study." *The Journal of the American Dental Association* 139.3 (2008): 305-15.