

REVIEW PAPER

Portland cement: A Building of Evidence for Clinical Use

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Abstract

Mineral trioxide aggregate (MTA), has been successfully used in difficult endodontic situations such as immature pulp less teeth and vital pulp therapy. Portland cement (PC), which forms the bulk of MTA, has been reported to exhibit similar properties. The physical properties and biocompatibility of PC has been researched in vitro and on animals, with a few studies on humans as well. This article reviews the potential for clinical use of PC along with the existing drawbacks and concerns with the material.

Key Words: Portland Cement;MTA;Pulp Therapy

Received on: 10/09/2020

Accepted on: 06/12/2010

Introduction

Mineral trioxide aggregate (MTA) is a biocompatible, US Federal Drug Administration approved material, with a range of applications in endodontic therapy.(1) A comparative analysis of mineral trioxide aggregate and Portland cement using plasma emission spectrometry showed that except for no detectable quantity of bismuth in Portland cement, significant difference did not exist between the other 14 elements in both Portland cement and MTA.(2) According to its manufacturer's MSDS (material safety data sheet), Pro-Root™ MTA has in its composition 75% Portland cement, 20% bismuth oxide and 5% dehydrated calcium sulfate, while MTA-Angelus® is composed of 80% Portland cement and 20% bismuth oxide and no calcium sulfate (gypsum). Thus PC is currently being investigated for various properties which may promote its usage in clinical dentistry as an economically viable alternative to MTA.(3)

Portland cement is the most common type of cement in general use around the world, because it is a basic ingredient of concrete, mortar, stucco and most non-specialty grout. It is a fine powder produced by grinding Portland cement clinker (more than 90%), a limited amount of calcium sulfate which controls the set time, and up to 5% minor constituents (as allowed by various standards). Portland cement has been classified into 5 types with subtypes for the first three.(3) In most cases Portland cement in dentistry generally refers to type I variety of cement. Some of the physical properties of PC and their clinical implications have been reviewed in this paper.

Sealing ability: Preventing micro leakage is an important prerequisite in all endodontic applications. A study, using 1% methylene blue dye after 72 hours, reported no leakage beyond the retro fill area with PC. An

orthograde plug of PC was also evaluated with fluid filtration technique, which is a more sensitive and reproducible method.(4) The results suggest that Portland cement has the potential to be developed as a furcation repair material, even though leakage was noted. Compared to the commonly used retro fill materials such as amalgam, micro leakage and variable adaptation gaps on the interface between dentin and root-end filling material were found in all specimens including PC.(4)

One possible reason for the sealing ability of PC is its slight expansion upon setting. Mean expansion at 24 hours was noted to be 1.02% for Grey MTA, 0.29% for PC, and 0.08% for White MTA in water immersion.(5) The sealing ability of a material can be enhanced if it has antibacterial properties. One of the proposed antimicrobial mechanisms is the high alkalinity of the cement, comparable to that of calcium hydroxide. The pH of Portland cement rises from that of 7 to 12.3 after mixing and continues rising to a maximum pH of 12.9 after 3 hours. The potassium and sodium ions present come from the minor oxide constituents, which also provide an additional source of hydroxyl ions. The results of studies evaluating the antibacterial effect of PC have been equivocal. While several of the microorganisms such as *Micrococcus luteus* (ATCC9341), *Staphylococcus aureus* (ATCC6538), *Staphylococcus epidermidis* ATCC 12228, *Pseudomonas aeruginosa* ATCC 27853, showed inhibition, others such as *Escherichia coli* (ATCC10538) and *E. faecalis* showed resistance to all the sealers.(6) Other studies have found that despite the highly alkaline pH of both MTA and PC, they showed no antibacterial activity against *S. faecalis*, *S. aureus* and *B. subtilis* and no effect on any of the strict anaerobic bacteria.(7) The antibacterial

effect was not different in either fresh powders or powders from crushed set cements.(8)

Radio opacity of Portland cement:

While Portland cement in its natural state is slightly radiopaque; it fails to meet the ISO requirement for radiopacity. To overcome this disadvantage, radiopacifier additions have been carried out. Comparing different radiopacifiers, Portland cement/bismuth oxide and Portland cement/lead oxide presented the highest radiopacity values, whereas Portland cement/zinc oxide presented the lowest radiopacity values. However all presented higher radiopacity than that of dentin and may potentially be added to the Portland cement as radiopacifying agents.(9) The readings of white Portland cement with 15% bismuth oxide did not differ significantly from the reading observed for a thickness of 4 mm of aluminum which is considered ideal for a test specimen by ADA specification #57. Higher concentration of Bismuth oxide failed to improve radiopacity significantly.(9) The compressive strength of Portland cement is not altered with use of 20% bismuth oxide, and the material continues to be biocompatible. (10)

Setting time: Classically calcium chloride, calcium nitrite/nitrate, and calcium formate have been added as Portland cement accelerators. While it was found that all 3 accelerated the set of PC, statistically significant rise in temperature and pH were found with the use of different accelerators, thus meriting further evaluation including biocompatibility and sealing ability.(11) The setting time of Portland cement can also be reduced by excluding gypsum during the last stage of the manufacturing process without affecting its other properties. An admix of 1% methylcellulose and 2% calcium chloride resulted in a mix of Portland cement, when compared with unmodified MTA, (1) handled similarly to a reinforced zinc oxide-eugenol cement, (2) gave an approximately equal compressive strength, and (3) set one third faster (57 +/- 3 minutes).(11)

Solubility: Portland cement when placed in aqueous environments with prolonged setting times seems to be vulnerable to washout. The cement industry routinely deals with wet conditions (underwater concrete placement) that can potentially affect the properties of the material, not unlike conditions encountered during periapical surgery. The results of a study suggest that the sealing ability of MTA in an aqueous environment might be compromised during the first 72 hours because of the materials

excessive solubility may affect particle arrangement in dentinal cavity walls. Portland cement on the other hand behaved differently in that the solubility decreased within the first 24 hours to 1.46%.(12) To address these problems for dental application, an anti-washout mixture (methylcellulose) is added to the cement to facilitate more cohesive cement. The addition of this additive increases the viscosity of the water used in the mixture, therefore, producing a more thixotropic material to resist washout. The behavior of excessive initial solubility followed by a constant decrease over 72 hours is also a feature of routinely used root canal sealers AH 26 or Tubli Seal and does not per se contradict the use of these materials in clinical situations.(11)

As the process of cement manufacture requires 1500°C temperature and due to the high alkalinity of Portland cement, generally the commercially available samples are found to be sterile. While contaminated samples can be suitably sterilized with no microbial growth seen after dry heat sterilization, gases or by autoclaving, the physical properties after sterilization need further evaluation.(13)

Biocompatibility and tissue response In vitro studies: Freshly-mixed and partially-cured Portland cement (PC) pastes have been shown to exhibit good biological compatibility with a range of cells and tissue-types; particularly those associated with bone formation. Scanning electron microscopy revealed that human pulp cells attached to the Portland cement were flat and had numerous cytoplasmic extensions. These results suggest that Portland cement is biocompatible, allows the expression of mineralization-related genes on cultured human pulp cells, and has the potential to be used as a proper pulp-capping material. (14)

The cytotoxicity of MTA and Portland cement on human ECV304 endothelial cells was studied and no statistically significant difference between any of experimental materials was reported. ³² In this respect, using simulated body fluid (SBF) in vitro, PC has been found to promote the precipitation of a layer of 'bone-like' hydroxyapatite which underpins its ability to integrate with living tissue. The dissolution of portlandite and formation of calcite were also observed on contact with SBF.(15)

Animal Studies: The next logical step is studies on animals. A study evaluating bone healing following the implantation of PC in experimentally created intra bony defects in dogs found connective tissue proliferation and down

growth of epithelium to be significantly less than those of controls. This finding is in favor of new bone growth around the cavity and decreased secondary reaction of surface epithelium and sub mucosal connective tissue.(16) The tissue reaction to freshly prepared Portland cement when implanted in the mandible of the guinea pig, has been reported to be similar to MTA.(2)

The results of pulpotomy in primary teeth of pigs using formocresol, ferric sulfate, white mineral trioxide aggregate (WMTA), white Portland cement (WPC), and beta-tricalcium phosphate (beta-TCP) showed that in terms of primary pulp response, hard tissue formation, and normal pulp tissue preservation no significant difference was observed. A direct pulp capping study has reiterated the barrier forming capability of PC.

Concerns: A major concern regarding use of water based cements is the amount of leachable arsenic and lead present in the material. These impurities have been reported to be present in high concentrations in cement dust, a byproduct of cement manufacturing. Research has shown that, while arsenic is leached out from Portland cement, the levels are low and well within the ISO specifications of 2 mg/kg of acid soluble arsenic.(17) Leachable lead is yet to be studied and remains a concern in its clinical use.

Human studies using Portland cement: Two clinical cases in which Portland cement (PC) was applied as a medicament after pulpotomy of mandibular primary molars in children were studied. At the 3, 6 and 12-month follow-up appointments, clinical and radiographic examinations of the pulpotomized teeth and their periradicular area revealed that the treatments were successful in maintaining the teeth asymptomatic and preserving pulpal vitality.(18) A case report where a PC plug was used for apexification with absorbable collagen sponge barrier reported clinical success after 1 year of follow up along with no signs of periapical rarefaction.(19)

Conclusion

In recent times MTA has been approved for use in several difficult endodontic situations such as root end fillings, both orthograde and retrograde, furcation perforation repairs. Major bulk of MTA is formed by Portland cement, with the physical and mechanical properties being similar in most aspects. MTA has been rigorously evaluated and then approved by FDA for commercial use. Strong indicators exist suggesting that Portland cement is biocompatible, has good sealing ability and can

be made radiopaque without significantly altering its properties. This has even prompted some research onto human pulp tissue. However actively implanted medical devices require conformity to stringent guidelines, notably the FDA good manufacturing practices and the European Medical Device Regulations. The material in its current form also needs further modifications for better clinical performance, to expand its scope of application to include vital pulp therapy and as a restorative material.

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Source of Support: Nil, Conflict of Interest: None Declared