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Portland Cement – An Effective And Cheap Alternative To Mta

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ABSTRACT:

The cementitious material generally known by its trade name of "Mineral Trioxide Aggregate" (MTA) is a derivative of Portland cement (PC) mainly comprised of calcium and silicate elements. Mineral trioxide aggregate (MTA), has been successfully used in various endodontic therapies such as root end fillings, furcation perforation repairs and in vital pulp therapies. But MTA is an expensive material compared to ordinary Portland cement. Because of their chemical similarity, the possibility of using PC as a less expensive alternative to MTA in dental practice should be considered. The aim of this article was to analyze the literature related to physical, chemical, and biological properties of Portland cement as well as researches conducted with PC.

Keywords: Portland cement, MTA, less expensive

INTRODUCTION:

In 1993 Mohmoud Torabinejad invented MTA by combining a grey Portland cement with bismuth oxide and successfully used for various endodontic applications. However, the elevated cost of this product restricted its use in all levels of health attention[1]. So ever since the launch of MTA researchers were attempting to find economical alternatives which will act similarly on the pulp and periodontal tissues. Ordinary Portland cement [OPC] is an inexpensive material. Because of its chemical similarity to MTA some investigations suggested PC as a substitute material for MTA. In 1999 Wucherpfennig proved through X-ray diffraction analysis that both MTA and PC have similar characteristics. Following this both the materials has been experimentally compared through several in vivo and in vitro studies and recently through human trials to see whether PC can be used as an inexpensive alternative of MTA in clinical use[2]. The physical, chemical, and biological properties of Portland cement had been analysed in this paper.

CHEMICAL PROPERTIES:

The constituents of the Portland cement are minerals, among which the most important are tricalcium silicate (3CaO.SiO2), dicalcium silicate (2CaO.SiO2), tricalcium aluminate (3CaO.Al2O3), tetracalcium aluminoferrite ($4CaO.Al2O_3.Fe2O_3$) and dehydrated calcium sulfate ($CaO.SO_3.2H2O$)[1]. Beside this silica, alumina, ferric oxide, magnesium oxide is also present[2]. The original MTA patent enrolled in 1995 declared that 'MTA is Type 1 Portland cement with a fineness (Blaine number) within the range of 4,500– 4,600 cm^2/g. A radiopacifier (bismuth oxide) is added to the cement for dental radiological diagnostic purpose. Chemical composition of MTA and PC has been analyzed through various methods like X-ray diffraction analyses, scanning electron microscopy (SEM), energy-dispersive spectroscopy (EDS) , X-ray diffraction (XRD) analysis, X-ray fluorescence spectrometry etc., and found that both the materials are similar in their composition[3]. Estrela et al[4] implemented a study in 2000 to analyze the chemical elements of MTA and Portland cements and reported

that Portland cement contained the same principal chemical elements as MTA, except for bismuth oxide. Oliveira et al[1] also found a similar composition when comparing Portland cement (Votoran®) to two commercial brands of MTA (Pro-Root™ and MTA Angelus®), except that Portland cement did not contain bismuth oxide. Funteas et al.[5] evaluated 15 elements of MTA and Portland cement composition. The outcomes indicated similarities between the materials, except for the fact that there was no appreciable quantity of bismuth in Portland cement. It was concluded that there was no remarkable difference between the other 14 elements in both Portland cement and MTA. The primary differences between both types of MTA and PC are a lack of potassium and the presence of bismuth oxide[6].MTA products may contain approximately half the gypsum content of Portland cement, as well as smaller amounts of aluminium species, which provides a longer working time than Portland cement[7].As far as setting reaction is concerned calcium hydroxide is produced as a by-product of hydration reaction in both MTA and PC. The pH of MTA immediately after manipulation with sterile water is 10.2, increasing to 12.5 after 3 h and then remain constant. Similarly, the pH of PC rises from that of 7-12.3 after mixing with water and rising to a maximum pH of 12.9 after 3 h[2]. The mild variations of pH between MTA and PC doesn't have much clinical importance.

PHYSICAL PROPERTIES:

The compressive strength, setting time, dimensional changes, and radio-opacity of PC have been investigated in many studies.

COMPRESSIVE STRENGTH:

Compressive strength of MTA within 24 hours of mixing was about 40.0 MPa and increases to 67.3 MPa after 21 days[8]. The compressive strength of MTA was slightly higher than Portland cement at 28 days[9].

SETTING TIME:

The mean setting time of MTA is 165 $\pm$ 5 minutes[6]. Islam et al performed a study compared the setting time of MTA shows slightly higher setting time than PC, but the different is statistically insignificant[9]. But the long setting time of MTA prevents its usage in all treatment modalities, so the usage of accelerators has been suggested . Several chemicals are known to act as accelerators like calcium formate, calcium nitrate and calcium chloride — but calcium chloride is most widely used. But calcium nitrate has replaced calcium chloride as a setting accelerator in Europeon countries[10]. Hoshyari et al[11] performed a study to evaluate the biocompatibility of Portland cement (PC) blended with titanium oxide and calcium chloride and concluded that PCs mixed with titanium oxide and calcium chloride have excellent biocompatibility and may be appropriate substitute for MTA. One study evaluated the effect of accelerators on the pH and antimicrobial activity of white Portland cement and concluded that 15% calcium chloride as an accelerant revealed highest antimicrobial activity of white Portland cement and white MTA due to its high pH values[12].

RADIOPACITY:

Portland Cement does not meet the ISO standard of radiopacity because of its insufficient radiopacity (<3 mm equivalent AI)[13] whereas Proroot MTA and MTA Angelus has about 7.5 mm AI[14] and 5.7 mm AI[15] respectively. In most of the current studies, PC is modified with the addition of radiopacifiers like bismuth oxide, zirconium oxide etc to get the radiopacity. A study compared the tissue reaction of 80 wt% of White Portland cement (WPC) mixed with 20 wt% of three radiopacifying agents: Bismuth oxide/Iodoform/Zirconium oxide with MTA in rat subcutaneous connective tissue and concluded that tissue reaction of the tested materials were similar to MTA[16]. Another study evaluated the radiopacity, compressive strength, setting time, and porosity of white Portland cement (PC) with the addition of bismuth oxide (Bi2O3), zirconium dioxide (ZrO2), and ytterbium trifluoride (YbF3) after immersion at 37 °C for 7 days in distilled water or phosphate buffer saline and the results showed that PC with the addition of 10 wt% Bi_2O_3 and 20 wt% ZrO_2 or YbF_3 demonstrated greater radiopacity value than the recommended 3mmAl cut-off. ZrO_2 and YbF3 increased the compressive strength of PC, but Bi2O3 decreased it[17]. Similarly, Duarte et al[18] evaluated the pH, calcium ion release, setting time, and solubility of white mineral trioxide aggregate (WMTA) and white Portland cement (WPC) combined with bismuth oxide (BO), calcium tungstate (CT), and zirconium oxide (ZO) and concluded that all materials released calcium ions and ZO/ CT can be considered as potential radiopacifying agents to be used in combination with PC. According to Coomaraswamy et al[19], addition of BO to PC increases porosity by leaving

more unreacted water within the set material . BO does not participate in the hydration reaction of MTA[20] and it negatively affect the mechanical strength of the product. The compressive strength and setting time of MTA and Portland cement (PC) associated with bismuth oxide (BO), zirconium oxide (ZO), calcium tungstate (CT), and strontium carbonate (SC) was evaluated by Filho et al[21] and reported that all the materials tested had similar compression strength values, except for PC + BO, which presented the lowest mean compression strength value. WPC enriched with Zinc oxide and Zirconium oxide increased ALP activity and calcium ion release of human dental pulp stem cells over a period of 21 days in vitro[22]. Niobium oxide, a metal which is commonly combined with titanium for endosseous implants displays excellent biocompatibility. More recently, niobium oxide (NbO) has been evaluated as a radiopacifying agent for dental cements[23]. Niobium is capable of stimulating proliferation and differentiation of osteoblastic cells -like Saos-2 and MG-63 cells[24]. The results of the study performed by Mestieri et al concluded that the combination of PC+NbO is a potential alternative for MTA based on radiopacity, cell viability, and bioactivity assays[23]. Another study evaluated the cytotoxicity and bioactivity of Portland cement combined with Niobium oxide in different cell lines and stated that bioactivity was better detected in human osteoblast-like cell line, Saos-2, using ALP activity assay[25]. The findings of another study proved that calcium silicate-based material associated with zirconium oxide or niobium oxide induced fibroblast proliferation and accelerated the regression of the inflammatory reaction when compared to MTA Angelus, indicating that ZrO2 and Nb2O5 may be useful alternative radiopacifiers to bismuth oxide[26].

SEALING ABILITY:

Lack of adequate apical seal is the major cause for surgical endodontic failure. A tight hermetic seal is required to prevent the ingress of bacteria and other contaminants. Shahi et al experimented the sealing ability of white mineral trioxide aggregate (MTA), gray MTA, white Portland cement (PC) and gray PC by dye leakage method and the tested materials showed the same microleakage in vitro[27]. In the experimental study of De deus et al[28] , pulp chambers of 36 human mandibular molar teeth (15 sealed with MTA and 15 sealed with PC and 5 kept in control group) were accessed using a polymicrobial leakage model concluding that the leakage patterns of MTA and Portland cement in furcation repairs were similar over a period of 50 day. Both MTA and PC contain calcium oxide that forms calcium hydroxide when mixed with water. Holland et al[29] reported that calcium hydroxide reacts with carbon dioxide from the pulp tissue and forms calcite crystals which is an initial step in the hard tissue barrier formation. Many studies have been done to evaluate the micro-leakage and sealing ability of MTA and Portland cement by using different parameters and concluded that both the materials have similar leakage pattern.

BIOCOMPATIBILITY:

An ideal retrograde filling material and pulp capping agent needs to have good biocompatibility and promote reparative dentinogenesis. Several studies are available which showed that PC and MTA are equally biocompatible. Yoshino et al[30] analyzed the in vitro cytotoxicity of white mineral trioxide aggregate (MTA), MTA Fillapex and Portland cement (PC) on human cultured periodontal ligament fibroblasts and concluded that MTA Fillapex demonstrated the most noteworthy cytotoxic effect on periodontal ligament fibroblasts followed by white MTA and PC. PC presented significantly less toxicity in comparison with both MTA and MTA Fillapex. Khalil et al[31] evaluated cytotoxicity in vitro and its biocompatibility in vivo of Modified Portland cement [MPC] in comparison with MTA. Portland cement powder is mixed with a radiopaque element [Barium chloride] and a setting time accelerator [Calcium carbonate] and it is sterilized (under 180°C for 2 hours). Under general anaesthesia, three holes (2.5 mm) were made in both the left and right femurs of six White New Zealand rabbits. MPC is kept in the first hole, MTA in the second and the third one is left vacant. The in vivo test demonstrated comparable biocompatibility between MTA® and MPC. Bone healing and negligible inflammatory response were seen adjacent to MTA® and MPC implants at all experimental periods (3, 6 and 12 weeks), suggesting that both materials are well tolerated. Similarly, Hoshyari et al[32] evaluated the biocompatibility of Portland cement (PC) mixed with titanium oxide and calcium chloride and the results showed favourable biocompatibility of modified PC mixed with calcium chloride and titanium oxide. Modified PC exhibited favourable tissue response characterized by absence of severe inflammatory reactions and the presence of a fibrous capsule. The formation of fibrous capsules indicates that these materials are tolerated by tissues[33] and the addition of calcium chloride increased the biocompatibility by accelerating the setting time.

A study by Fayazi et el[34] experimented the effect of ProRoot MTA, Portland cement, and amalgam on the expression of fibronectin, collagen I, and TGFβ by human periodontal ligament fibroblasts. Based on the result of the study it was reported that collagen expression in MTA specimens was higher than the other groups in 24 hours. After 48 h, the Portland cement group showed the significant collagen expression and after 1 week there was no significant difference between these 2 groups[MTA and PC] in terms of collagen expression. Mohammed[35] et al evaluated the biocompatibility and the bone healing efficacy following the WPC graft material in experimentally created intrabony defects in rabbit's mandible and the results revealed that after one week in experimental side newly formed bone trabeculae were observed and the graft material was surrounded by moderate inflamed high cellular CT with collagen fibres and bone spicules. Mangala et al[36] tested the Indian Portland cement for biocompatibility in Swiss albino mice and concluded that it was biocompatible. Min et al examined the cellular effects of Portland cement on cultured human pulp cells and the results revealed that Portland cement permits the expression of mineralization related genes [osteonectin and dentin sialo phosphoprotein mRNAs][37] and it is biocompatible.

DISCUSSION:

MTA revolutionized the field of dentistry as a successful root end filling material and vital pulp repair agent. But It is an expensive material which restricts its use in all levels. So ever since the launch of MTA researchers were attempting to find economical alternatives which will act similar to MTA. It has always been an well known fact that MTA is a derivative of Portland cement or both MTA and Portland cement are derived from a common source. Comparatively PC is less expensive and widely available. In the last few years, many studies have compared the physical, chemical and biological properties of MTA and PC. According to Wucherpfennig et al[38] MTA and PC have similar chemical composition as well as biological behaviour. Comparative chemical study of MTA and PC done by Oliveira et al[1] concluded that both cements presented similar chemical formulations except for bismuth oxide which confers radiopacity to MTA. Estrela et al[4] reported that the antimicrobial effect of MTA and PC was similar. Ribeiro et al[39] evaluated in vitro on mouse lymphoma cells the genotoxic and cytotoxic effects of MTA and PCs and concluded that none of them were cytotoxic. Similarly, several studies evaluated the biocompatibility of MTA and PC and the results suggested that both are equally biocompatible. The primary differences between both types of MTA and PC are absence of potassium and the presence of bismuth oxide[40]. Another contrasting feature between these two materials is the particle size. MTA has smaller and regular particles compared to ordinary Portland cement. Komabayashi et al[41] reported that small MTA particles (size, 1.5 μm) made it possible to enter into open dentin tubules (2–5μm) in regards to size and shape. This might be an important mechanism to provide a hermetic seal. Though Portland cement behaves identical to MTA in living tissues, the reasons offered for discouraging PC use are heavy metal content and lack of sterilization. MTA is sold sterile and Portland cement is not sold as a sterile powder. so there is a fear of transmitting microbes to the patient through non sterile PC. But sterilization of PC is easily achievable by a clinician[42]. H. Simon et al stated that Portland cement is manufactured at 1500o C and hence it is manufactured sterile. Secondly, they have stated that the high alkalinity of Portland cement prevents bacterial growth. Thirdly they have stated that contamination may occur during packing and shipping. Lastly, they have recommended that dry heat of 170o C for 1 hour be used to sterilize Portland cement[43]. Another major concern regarding the use of PC in dentistry is the presence of heavy metals like lead, arsenic. Studies have measured the arsenic content in Portland cements and MTA products and found amounts that exceed the ISO 9917-1:2007 limits[44]. It specifies a maximum value of 2 mg/kg and 100 mg/kg for acid-soluble arsenic and lead, respectively, for restorative dental material[44]. Although hydraulic cements may have higher amounts of contaminants than those established by ISO 9917-1:2007 , leaching in solution is low as arsenic oxide is dissolved in the silicate and is relatively insoluble[45]. A study by Duarte et al[46] concluded that concentration of arsenic is low in Portland cements and MTAs and closely similar, thus demonstrating no contraindication for the use of these materials in clinical practice.

CONCLUSION:

As reported in several studies, MTA and Portland cement shows similarity in their compositions and physical, chemical and biological properties which concludes that Portland cement has a great potential to be used as an alternative material to MTA. But more clinical trials are required to establish PC as an alternative to MTA .

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