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CAN PORTLAND CEMENT BE A CHEAPER SUBSTITUTE OF BIOACTIVE ENDODONTIC CEMENT USE IN DENTISTRY? : A COMPREHENSIVE REVIEW OF LITERATURE

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ABSTRACT

Mineral Trioxide Aggregate (MTA), being conceptualized from Portland Cement (PC), has been highlighted because of its favourable biological properties with extensive applications in Endodontics. Recently a number of new Bioactive Endodontic Cements (BECs) have also been introduced to the market and it has been claimed that these materials have almost similar properties like MTA but without its drawbacks. The current article thus reviews the experiments done comparing the properties of these materials and the potential of PC for clinical use in future as a cheaper alternative to them.

KEYWORDS: Portland Cement, Mineral Trioxide Aggregate, Bioactive Endodontic Cement, Calcium Enriched Mixture, vital pulp therapy, apical plug, perforation repair, root end filling, discolouration.

INTRODUCTION

In the field of dental science, there is always a search for biocompatible dental materials presenting good physical, chemical and mechanical properties and that search still continues, aiming to find cost-effective options also. In the year 1824, Joseph Aspdin patented a product named Portland Cement (PC), which was obtained when the mixture of limestones coming from Portland in England and silicon-argillaceous materials were calcined. The calcined product following finely grinding, presented binder properties when mixed to water and the obtained mortar showed easy handling, binder capacity and stability. Observing that, the manufacturing and physic-chemical characteristics of both cements are gradually developed.[1]

On the other hand, MTA appears in Dentistry in the year 1993, introduced by Mahmoud Torabinejad at Loma Linda University, in USA, aiming to secure the communications between the tooth and its outer surface.[2]

Since then hundreds of publications came in favour of MTA to be used in dentine and cementum injuries and the MTA was evolved as an essential material in dentistry for all types of dental hard tissue repair like pulp capping, pulpotomy, perforations, and apical seal in wide open apex etc.

Couple of years later Dr. Torabinejad, the inventor of MTA, presented an article where it has been mentioned that MTA has similarity with Portland cement (PC) in its composition and physical and chemical properties.[3]

Later, to overcome the shortcomings of MTA, a range of bioactive endodontic cements (BECs) have been developed, with manufacturers claiming they have similar properties to MTA but without its drawbacks. As a result of that large number of publications have arisen to understand thoroughly the characteristics of these new materials and thus their potential for use in place of or alongside MTA.

The term ‘bioactive endodontic cement’ are those new materials having a variety of chemical compositions; however, they all have one common capability, that is bioactivity. This implies calcium ions release, electroconductivity, calcium hydroxide production, interfacial layer formation between the cement and dentinal wall and apatite crystals formation over the

surface of the material in an artificial tissue fluid environment such as phosphate buffer saline.[4-6]

In this article, we will thus review the comparative studies published involving these materials in different parameters.

CHEMICAL COMPOSITION

The composition of Portland Cement are defined as follows: 1) Portland clinker – product composed mainly of calcium silicates with hydraulic properties; 2) plaster – calcium sulfate; 3) blast furnace slag – product resulting from the treatment of iron ore at high temperatures, obtained as granulated form by abrupt cooling; 4) pozzolanic materials – silicon or silicon-aluminum materials with little or none binder property, but when divided and in the presence of water they can react with calcium hydroxide, at environmental temperature, to create compounds with hydraulic properties; 5) carbonate materials – materials finally divided, constituted in their majority of calcium carbonate.[1]

The basic major content of MTA and PC are tri-calcium silicate, di-calcium silicate, tri-calcium aluminate, and tri-calcium oxide. Beside this silica, alumina, ferric oxide, magnesium oxide are also present. The basic difference between these two materials is that the PC does not contain Bismuth Oxide[7,8] but contains potassium.[9]

For convenience, the chemical composition of BECs are listed below[10],

CHEMICAL COMPOSITION OF BIOACTIVE ENDODONTIC CEMENTS

MATERIALS	MANUFACTURER	COMPOSITION
ProRoot MTA (Grey)	Dentsply Tulsa Dental Specialities, Johnson City, TN, USA	Tricalcium silicate, dicalcium silicate, bismuth oxide, tricalcium aluminate, calcium sulphate dehydrate(gypsum) and calcium aluminoferrite Liquid: distilled water
Tooth-coloured ProRoot MTA(White)	Dentsply Tulsa Dental Specialities, Johnson City, TN, USA	Tricalcium silicate, dicalcium silicate, bismuth oxide, tricalcium aluminate, calcium sulphate dehydrate(gypsum) Liquid: distilled water
Angelus MTA	Angelus, Londrina, PR, Brazil	Tricalcium silicate, dicalcium silicate, bismuth oxide, tricalcium aluminate, calcium oxide, aluminium oxide, silicon dioxide Liquid:distilled water
Bioaggregate	Innovative BioCeramix, Vancouver, BC, Canada	Tricalcium silicate, dicalcium silicate, calcium phosphate monobasic, amorphous silicon oxide and tantalum pentoxides Liquid : deionized water
Biodentine	Septodont, Saint-Maur-des-Fosses Cedex,France	Tricalcium silicate, dicalcium silicate, calcium carbonate, zirconium oxide, calcium oxide, iron oxide Liquid : calcium chloride, a hydrosoluble polymer and water
Calcium-enriched mixture (CEM) cement	BioniqueDent, Tehran, Iran	Calcium oxide, silicon dioxide, Al_2O_3, MgO, SO_3, P_2O_5, Na_2O, Cl and H&C Liquid : water-based solution
EndoBinder	Binderware, Sao Carlos, SP, Brazil	Al_2O_3 and CaO
Endocem MTA	Maruchi,Wonju,Korea	CaO, Al_2O_3, SiO_2, MgO, Fe_2O_3,SO_3, TiO_2, H_2O/CO_2, bismuth oxide
Endocem Zr	Maruchi,Wonju,Korea	Calcium oxide, silicon dioxide, aluminium oxide, magnesium oxide, ferrous oxide, zirconium oxide
Endosequence, RRM, RRP	Brasseler, Savannah, GA, USA	Zirconium oxide, calcium silicates, tantalum oxide, calcium phosphate monobasic and filling and thickening agents
MicroMega MTA	MicroMega, Besancon, France	Tricalcium silicate, dicalcium silicate, tricalcium aluminate, bismuth oxide, calcium sulphate dehydrate and magnesium oxide
MTA Bio	Angelus; Londrina or Angelus Solucoes Odontologicas, PR, Brazil	Portland Cement and Bismuth oxide

MTA Plus(White)	Avalon Biomed Inc., Bradenton, FL	Tricalcium silicate, $2CaO.SiO_2$, Bi_2O_3, $3CaO.Al_2O_3$ and $CaSO_4$
MTA Plus(Grey)	Avalon Biomed Inc., Bradenton, FL	Tricalcium silicate, dicalcium silicate, bismuth oxide, tricalcium aluminium oxide,calcium sulphate and $Ca_2(Al,Fe)_2O_5$
NeoMTA Plus	Avalon Biomed Inc, Bradenton, FL	Tricalcium silicate, dicalcium silicate, tantalite, calcium sulphate and silica
OrthoMTA	BioMTA, Seoul, Korea	Tricalcium silicate, dicalcium silicate, tricalcium aluminate, tetracalcium aluminoferrite, free calcium oxide and bismuth oxide
Quick-Set	Avalon Biomed Inc, Bradenton, FL, patent pending	Monocalcium aluminate powder that contains bismuth oxide (as a radiopacifier) and hydroxyapatite
RetroMTA	BioMTA,Seoul,Republic of Korea	Calcium carbonate, silicon oxide, aluminium oxide and hydraulic calcium zirconia complex; Liquid:water
iRoot as iRoot SP, iRoot FS, iRoot BP and iRoot BP Plus	Innovative BioCeramix Inc., Vancouver, Canada	iRoot SP: zirconium oxide, calcium silicates, calcium phosphate, calcium hydroxide, filler and thickening agents iRoot FS: calcium silicates, zirconium oxide, tantalum oxide and calcium phosphate monobasic iRoot BP: zirconium oxide, calcium silicates, tantalum oxide, calcium phosphate monobasic, filler and thickening agents
Tech Biosealer	Isasan,Como,Italy	Mixture of white CEM, calcium sulphate, calcium chloride, bismuth oxide, montmorillonite
Auroseal MTA	Giovanni Ogna and Figli,Muggio, Milano, Italy	Portland cement, bismuth oxide, setting time controllers, plastifying agents and radiopaque substances Liquid : distilled water
Portland cement	Around the world	The main composition of MTA and PC are very similar in that both consist of tricalcium and dicalcium silicate
BioRoot RCS	Septodont, Saint-Maur-des-Fosses Cedex, France	Tricalcium silicate,zirconium oxide(opacifier) and excipients in powder form and calcium chloride and excipients as an aqueous liquid
Endo-CPM	EGEO SRL, Buenos Aires, Argentina	MTA, calcium chloride, calcium carbonate, sodium citrate, propylene glycol alginate and propylene glycol
EndoSeal MTA	Maruchi, Wonju, Korea	Calcium silicates, calcium aluminates, calcium aluminoferrite, calcium sulphates,radiopacifier and a thickening agent
MTA Fillapex	Angelus Industria de Produtos Odontologicos S/A, Londrina, Brazil	A MTA root canal sealer with nanoparticles of silica
TheraCal LC	Bisco Inc., Schaumburg, IL, USA	CaO, Sr glass, fumed silica, barium sulphate, barium zirconate, Portland cement type III and resin containing Bis-GMA and PEGDMA

SETTING REACTION

It has been well documented that setting reaction of all BECs including PC and MTA basically consists of two phases such as,

INITIAL REACTION

Tricalcium aluminate + Water ⟶ Ettringite (in presence of Calcium sulfate)

FINAL REACTION

Tricalcium silicate + Dicalcium silicate + Water ⟶ Calcium silicate hydrate + Calcium hydroxide

Thus by changing the proportion of each of the constituent compounds in the cement and other factors such as grain size, different types of cements are made available.

BECs vs PC

A number of animal studies and clinical trials were carried out regarding comparison among MTA, PC and different BECs in terms of vital pulp therapy, apical plug formation, perforation repair, root end filling, antimicrobial property and biocompatibility.

Regarding ***vital pulp therapy***,

In separate investigations, Biodentine, CEM cement, MicroMega MTA, Endocem and iRoot BP Plus were associated with similar pulp responses when compared to ProRoot MTA, tooth-coloured ProRoot MTA and white MTA Angelus in providing optimal pulp tissue healing following direct pulp capping in animals.

These materials as well as Portland cement and TheraCal LC have also expressed similar to significantly better outcomes compared to calcium hydroxide in terms of pulp inflammation and dentine tissue formation.[11-19]

Despite there being no significant difference in the outcome when using Portland cement and MTA Angelus following pulpotomy in primary molars[20], emphasization should be given on the fact that using Portland cement is not recommended, as the material may contain heavy metal elements that could be harmful, particularly in children.[4]

On the other hand, Several BECs such as tooth-coloured ProRoot MTA, ProRoot MTA, Portland cement, Biodentine and CEM cement were found to be associated with canal obliteration following pulpotomy in primary molars.[5,21-24]

However, successful treatment following the use of ProRoot MTA and tooth-coloured ProRoot MTA, white Portland cement and CEM cement as pulpotomy materials in either intact or cariously involved human permanent teeth have been documented in several investigations.[25-29]

Regarding ***apical plug formation***,

Numerous case reports have described the successful use of ProRoot MTA, tooth-coloured ProRoot MTA, MTA Angelus, white MTA Angelus, calcium-enriched mixture (CEM) cement, Biodentine and Portland cement as apical plugs in teeth with necrotic pulps, open apices, periapical radiolucencies and root resorption.

Among them in one study four anterior teeth with open apex were treated with single step apexification plug using WPC. 3 to 24 months follow-up showed successful apical repair.[30] In another clinical trial, the author and his associates used White PC with 20% BO as an apical plug in three non-vital upper central incisors having radiographic apical pathosis. Three to six months follow-up showed total healing of radiographic apical pathosis and the teeth became asymptomatic.[31]

Regarding ***perforation repair***,

New bone formation was seen which was characterized by osteoid formation, osteoblastic rimming, and new bone trabeculae was seen to be formed around a surgically created bony cavity in mandible of a dog filled with accelerated PC (APC), indicating maximum chance of use of APC as bone substitute.[32]

Successful and similar type of perforation repair was observed in deliberately perforated dog's teeth using WPC, PC Type II, Type V, and MTA (as control). On histological analysis no significant differences in the amount and histology of newly formed bone in all materials was found.[33]

Several case reports have shown the successful use of MTA Angelus, ProRoot MTA, tooth-coloured ProRoot MTA, Root MTA, Portland cement, Biodentine and CEM cement as perforation repair materials in furcation and lateral perforations and also in defects that may be induced by cemental tears or resorption of which the study[34] which used Portland Cement as perforation repair material showed after 9-year follow up, the tooth in masticatory function with radiographic and clinical aspects compatible with normality.

As ***root end filling material***,

Several case reports and case series have illustrated favourable outcomes following the use of ProRoot MTA, tooth-coloured ProRoot MTA and other BECs, including Portland cement, MTA Angelus, Biodentine, Tech Biosealer RootEnd and CEM cement as root-end filling materials during either periapical surgery or intentional replantation and transplantation.[35]

As ***endodontic sealer***,

The Araraquara Dental School, UNESP, Brazil had conducted some studies to develop a Portland cement-based root canal sealer. Initially, this prototype sealer was denominated MTA Sealer and it was composed by white Portland cement, a radiopacifying agent (zirconium oxide), additives (calcium chloride) and a resinous vehicle. In the subsequent studies, the formulation of this sealer was modified to investigate zirconium oxide and niobium oxide alternatively to bismuth oxide as radiopacifiers. These sealers had setting time and flow ability sufficient for clinical use, high compressive strength and low solubility[36] and they also showed some bioactivity degree although no evidence of cement hydration was observed on material's characterization.[37]

DISCUSSION

PC is mainly composed of 65% lime, 20% silica, 10% aluminium and ferric oxide, and 5% other compounds. Two major components are tricalcium silicate ($3CaOSiO_2$) and dicalcium silicate ($2CaO\text{-}SiO_2$). PC sets through a hydration reaction in two stages, exactly similar to that of MTA.[38] Gray PC is of 5 types from Type I to Type V. Though Type I PC is pure PC, but all the types contain some amount of heavy metals. White

PC is manufactured from purest raw materials (kaolinite with very low iron content) and contains no C_4AF (ferric-calcium aluminate phase) and very Low MgO. The heavy metal content of WPC is almost similar to that of MTA.[39]

A fundamental concept in reaction kinetics is that any reduction of particle size of a powder reactant will result in a higher surface area per unit mass and, therefore, is generally expected to increase the rate of reaction. This increased rate of reaction with a reduced particle size has been noted with PC when used in industrial applications.[40] Therefore, an MTA cement with a lower (average) particle size is anticipated to have an accelerated reaction with setting time reduced. Particle sizes within a given sample of PC typically vary over 3 orders of magnitude[41], and the Particle Size Distribution is typically described using 3 reference points: the 10th percentile (D10), 10% of the estimated particle diameters fall under this size; the median (D50), 50% of the particles fall under this size; and the 90th percentile (D90), 90% of the particles fall under this size.

The particle size distribution of the tricalcium silicate powders affects handling and setting properties. Smaller particles may penetrate tubules and also hydrate faster than larger particles because of their higher surface-to-volume ratio. If the tricalcium silicate material dissolves during setting and precipitates to penetrate the tubules, sealing is enhanced. Dentinal tubules range in size from 2-5 μm.[42] Komabayashi et al. in their study showed that the finer fractions of PC have a smaller diameter than a dentinal tubule. Therefore, the geometry of small particles makes PC easier to enter into open dentin tubules. This may be an important mechanism for providing a hydraulic seal.[43]

Particle size is not important for root-end filling or perforation repair but is crucial for endodontic sealer use, where low film thickness is required for use with gutta percha. Despite its smaller particle size compared to some other MTA-type materials (including NeoMTA), EndoSequence BC Sealer did not show superior tubule penetration. With nearly equivalent tubule penetration in both the middle and apical thirds of canals, both EndoSequence BC Sealer and NeoMTA were found to be suitable for endodontic obturation.[44]

Describing the characterization of hydration product Camilleri commented that the hydration mechanism of MTA is different to that of PC and MTA produces a high proportion of Ca ions than PC, as a by-product of hydration and MTA releases, over several weeks, more calcium ions than white PC while white PC releases nearly no bismuth ions.[45] Analysis of the presence of 10 heavy metals showed that GPC have much higher heavy metal than WPC, GMTA, and WMTA. The WPC also contains little more heavy meals than WMTA.[46]

The white MTA Angelus and MTA bio has the shortest setting times, higher pH, and more calcium ion release in comparison to light cured MTA and PC with 20% BO.[47] MTA was found to be much less soluble than two types of PC in water immersion for a different period of time. The same study shows that the microhardness of MTA is significantly higher than PC type I and Type II.[48] A review that included 156 citations from January 1990 to August 2006, concluded that replacement of MTA by PC is discouraged,[49] though they have undertaken only two articles which support the possibility of substitution of MTA by PC.[8,50]

In another detailed review, it was concluded that PC can be a possible replacement for MTA, but the type of PC, which is more comparable to MTA has to be determined first through further researches.[51] MTA is an excellent material for several endodontic uses, especially dental hard tissue repair. PC also has shown similar characteristics to MTA and certain other BECs with respect to its composition, biocompatibility, hydration product, sealing ability and microleakage through animal and clinical studies.

DRAWBACKS

Radiopacity: In comparison with other BECs, the most common problem with PC to be used for clinical purpose is its low radiopacity. To improve PC radiopacity, some substances, such as bismuth oxide, zinc oxide, plumber oxide, bismuth subnitrate, bismuth carbonate, barium sulphate, iodoform, calcium tungsten and zircon oxide have been added to the cement. All tested substances expressed greater radiopacity than dentin and potential to be used as PC radiopacifying agents.[52]

However, further studies are needed to examine whether these agents would interfere on PC biocompatibility.

Arsenic release: Concerning about the presence of arsenic, few researches have shown that set MTA and PC both release arsenic in an aqueous medium. However, the amount of release is much lower than set limit by Environmental Protection Agency (EPA)/FDA, which is 0.01 ppm for arsenic in drinking water.

De-Deus et al. tested four most common commercially available MTA and two brands of white PC from Brazil for presence of arsenic and came to the conclusion that Gray MTA Angelus, Gray Pro Root MTA, and one brand of PC does not contain arsenic and all other material tested have very negligible amount of arsenic present in them.[53]

Discolouration: The discolouration potential of Portland cement based cements has been attributed to the porosity of the materials, particularly when exposed to blood. In addition to tooth-coloured ProRoot MTA, Portland cement without bismuth oxide also discoloured following blood contamination.[54]

Another cause of discolouration is the combination of the oxygen-free environment with light found in clinical settings. The absence of oxygen and the presence of light on the colour stability of tooth-coloured ProRoot MTA, white MTA Angelus, Portland cement with and without bismuth oxide and Biodentine revealed that Portland cement without bismuth oxide and Biodentine did not undergo discolouration when the samples were kept in an oxygen-free environment in the presence of light.

However, Portland cement with bismuth oxide, tooth-coloured ProRoot MTA and white MTA Angelus discoloured in the same conditions.[55]

Retreatability: One of the shortcomings of BECs is the difficulty of removing the material during retreatment, as it has no known solvent.[5] Removing MTA from the root canal space completely when used as either a root filling or apical plug is difficult, if not impossible.

Few studies have discussed the retreatability of BECs. Bioactive endodontic sealers such as MTA Fillapex, EndoSequence BC sealer, and MTA Plus, iRoot SP can be removed. However, other forms of BECs have not been evaluated for their ability to be removed from root canals because no solvents are known to actively dissolve them.

CONCLUSION

The disadvantage of PC is its lower radio-opacity but the main advantage is the cost effectivity. A cheaper alternative of BECs will certainly benefit millions of people, especially most of the patients in developing countries, who cannot bear the cost of BEC. At present several researches establish that PC is similar to commercially available MTA in its basic composition, physical, chemical characteristics as well as in biocompatibility. Though several articles recommended for substituting MTA materials by PC for clinical use, but no reason has been found to substitute MTA or BEC at present.

Rather the existing researches show that PC, specifically WPC has a great potential to be used as an alternative material to MTA and other BECs. Those literatures provide a firm base for further well-designed clinical trials. However, proper selection of material and lot more clinical trials are needed to establish PC as a cheaper alternative to BECs to appropriate medical/dental regulatory authorities as a permitted material for clinical use.

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