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Literature Review Article

MTA *versus* Portland cement: review of literature

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Abstract

Introduction: Both Mineral Trioxide Aggregate (MTA) and Portland cement (PC) have been highlighted because of their favorable biological properties, with extensive applications in Endodontics, including the possibility of using into root canal filling. **Objective:** This article reviews literature related to MTA and PC comparing their physical, chemical and biological properties, as well as their indications. **Literature review:** Literature reports studies revealing the similarities between these materials' properties, including both biocompatibility and bone repair induction. Moreover, there is the need for the development of a root canal sealer based on these materials (MTA and PC). **Conclusion:** MTA and CP show promissory perspective both in Dentistry and Endodontics.

Introduction

The search for biocompatible dental materials presenting good physical, chemical and mechanical properties still continues nowadays. In Endodontics, this search has been intense [32]. Several studies have demonstrated that mineral trioxide aggregate (MTA) shows good physical, chemical, mechanical and biological properties [22, 33, 38, 39] and its behavior has been largely investigated in several clinical applications [7, 10]. However, its high cost does not allow its use in all levels of attention to health [22].

Portland cement (PC) has been analysed and compared to MTA due to the composition similarity [35] and it has been considered and alternative use

for Dentistry [7, 32, 38]. Both are composed of calcium phosphate, calcium and silicon oxide. MTA, however, contains bismuth oxide, which provides radiopacity [33]. MTA's main composition is 80% of PC added by 20% of bismuth oxide [1]. Because these materials exhibit compatibility among their compounds, the possibility of clinical use of PC has been considered as an alternative to MTA [32], once it shows compatible levels of some toxic metals.

The aim of this study was to analyze literature relating to researches conducted with MTA and PC, comparatively reporting their physical, chemical, and biological properties as well as to discuss about researches on the new indications for these materials.

Literature review

Mineral trioxide aggregate (MTA)

MTA appears in Dentistry in 1993, developed by Mahmoud Torabinejad at Loma Linda University, in USA, aiming to seal the communications between the tooth and its outer surface [25]. Consequently, MTA was introduced to be used in pathological or iatrogenic root perforations [21] as well as in root-end fillings [25, 46]. The hydrophilic nature of MTA particles allows its use in the presence of moisture [46], providing sealing [34] and marginal adaptation [49]. MTA has also been employed in pulp covering or pulpotomy, both in humans and animal-model experiments, demonstrating noticeable success, similarly to the results obtained with calcium hydroxide [18, 28].

In 2001, MTA-Angelus (Angelus, Londrina, PR, Brazil) was introduced into the Brazilian market. This material is composed of 80% of Portland cement and 20% of bismuth oxide. Calcium sulphate was removed from MTA composition to accelerate its setting time. This product color was also changed to a white color, receiving the name of white MTA (WMTA) [1].

In addition to be used in perforation cases [10], MTA is employed as root-end filling material [40], in cases of external apical root resorptions [21], pulpotomies and in the treatment of teeth with incomplete rhizogenesis. These indications are possible because MTA is a biocompatible material presenting an alkaline pH about 12.5, antimicrobial activity, marginal adaptation, low solubility, low bacterial leakage, resistance to displacement and low cytotoxicity [40].

On the other hand, MTA lacks in some properties: the cement resulting from the mixture of the powder with water is difficult to be handled [6, 45]; its granular consistency makes its insertion into cavities difficult [23]; its working time is short [27] and its setting time is large, favoring the material's solubility, disintegration or displacement [23]. Moreover, additional moisture is required [45] to activate the cement setting, and finally, it has a relatively high cost [28].

Portland cement (PC)

In 1824, Joseph Aspdin patented a product so-called Portland cement (PC) obtained from the calcination of the mixture of limestones coming from Portland in England and silicon-argillaceous materials [3]. The calcined product, after finely grinding, presented binder properties when mixed to water. The obtained mortar showed easy handling, binder capacity and stability. From that moment on, both cement's manufacturing and physic-chemical characteristics has constantly evolved [43].

The materials used in the cements composition are defined as follows: 1) Portland clinker – product composed in its greater part 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 on 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 react with calcium hydroxide, at environmental temperature, to form compounds with hydraulic properties; 5) carbonate materials – materials finally divided, constituted in their great part of calcium carbonate [43]. At the end of the last century, PC was referenced as a material of chemical composition and physical properties similar to MTA, resulting in similar tissue reactions when studied in animal models, however with a lower cost [13].

Considering that the tooth maintenance in satisfactory physiological conditions is the dentist's main goal, the use of a dental material presenting good physical, chemical and biological properties and accessible cost [13] justifies the importance and the increasingly interest towards the evolution of studies on PC.

MTA *versus* PC

Taking into consideration the similar chemical composition between MTA and PC, in a study on the evaluation of PC biocompatibility through odontoblast cell line (MG-63), extracellular matrix neoformation was observed in cell line cultures of both materials (MTA and PC). When these same materials were used for direct pulp covering in

molars of rats, a response similar to the *in vitro* study was found; in some cases, the authors observed the formation of reparative dentin [48]. Teeth of dogs undergoing pulpotomy and remnant pulp tissue covering with both MTA and PC exhibited tubular dentin formation in almost all samples. The authors concluded that when both cements were applied directly onto pulp, they allowed dentin formation [18].

One study on cavities executed in guinea pigs' mandibles evaluated PC and MTA biocompatibility. Despite of the presence of inflammatory process, bone tissue neoformation was observed in cavities containing both MTA and PC [36].

The similarity between MTA and PC suggests that some resources used for improving MTA's physical and chemical characteristics could be used in PC. The addition of accelerating agents reduces PC setting time. One of the most common agents used for this purpose is calcium chloride. Therefore, the addition of 5% of calcium chloride to MTA reduces the setting time from 50 min (MTA mixed with sterile water) to 25 min [23], allowing an improvement in the sealing capacity [4].

Studies comparing MTA to PC reported that the latter presents the same main constituents as MTA. Some of these components are calcium oxide and silica. MTA also contains bismuth oxide, which increases its radiopacity; however, this component is not present in PC [13, 45]. MTA and PC have almost identical radiographic, macro- and microscopic properties [48].

MTA and PC also are similar regarding to antimicrobial properties [44]. The antimicrobial action of these materials and of calcium hydroxide, Sealapex, and Dycal was evaluated against four bacterial species – *Staphylococcus aureus*, *Enterococcus faecalis*, *Pseudomonas aeruginosa*, *Bacillus subtilis* – and the fungus *Candida albicans*; and against a mixture of all of them. The chemical elements of MTA and of two PC (Itau Portland Cement and Liz Portland Cement) were also analyzed. The results showed that all materials exhibited some antimicrobial activity, and calcium hydroxide paste was better than all the other materials against the tested microorganisms [13].

To improve the antimicrobial properties, studies were conducted in which chlorhexidine was added to MTA, allowing an increase of the antimicrobial activity without apparently interfering in its biological properties [41].

The analysis of bacterial microleakage by *Enterococcus faecalis* in human central incisors, by using two different cements – white MTA (Angelus) and an experimental material with calcium aluminate – revealed that these materials employed as filling materials did not allow microbial growth. Additionally, when they were used as root-end filling materials, these materials were effective in root canal sealing, avoiding *Enterococcus faecalis* contamination during a 30-day period [20].

The ability of MTA and PC in preventing coronal leakage was analyzed by the repair of furcal perforation in human molars through a model of polymicrobial leakage. The teeth were extracted and stored at 37°C in culture medium containing saliva. After 50 day storage, the authors observed that eight (53%) out of fifteen MTA samples and nine (60%) out of fifteen PC samples were completely contaminated. The results were not statistically significant, and the authors concluded that both materials exhibited a similar sealing ability in furcal perforations [11].

By evaluating *in vitro* the cytomorphology of osteoblast cultures (MG-63) and the cytokine production in the presence of MTA, it was observed that, apparently, MTA offers a biologically active substrate to bone cell, allowing a good cell adhesion to the material and stimulating the production of interleukins: IL-1α, IL-1β, IL–6 [24].

Concerning to the biological properties, studies have demonstrated that MTA promotes a favorable tissue response, characterized by the presence of moderate inflammatory response at the initial periods, which tends to decrease after 30 or 60 days. Generally, it is reported that MTA is surrounded by a fibrous capsule and induced the formation of a mineralized tissue [34, 39]. Other studies proved that because MTA is a biocompatible material, it enables the repair in several situations, inducing the deposition of dentin, cementum and bone [18, 39, 47].

Despite MTA and PC biocompatibility, the latter shows low radiopacity. Therefore, as an option of radiopacifying agent, iodoform was added to Portland cement, and following, biocompatibility was compared to MTA (ProRoot); the results revealed that the addition of iodoform to PC did not result in statistically significant differences in the inflammatory response when compared to MTA [29].

Because low radiopacity is one of the most advantages of PC, one recent study evaluated the hypothesis that the experimental cement containing PC and bismuth oxide would show the same biocompatibility of MTA and PC in addition to MTA radiopacity. To determine the experimental cement's characteristics, it was compared to the other cements' chemical composition, radiopacity, cytotoxicity and tissue reaction, which did not present

statistically significant differences, suggesting that the experimental cement would replace MTA [19].

To improve PC radiopacity, some substances have been associated to this cement, such as bismuth oxide, zinc oxide, plumber oxide, bismuth subnitrate, bismuth carbonate, barium sulphate, iodoform, calcium tungsten and zircon oxide. All tested substances showed greater radiopacity than dentin and potential to be used as PC radiopacifying agents [12]. However, further studies are necessary to investigate whether these agents would interfere on PC biocompatibility.

Aiming to accelerate the setting, calcium chloride was added to ProRoot MTA, white MTA and PC to evaluate pH influence on calcium ion releasing. The results showed that calcium chloride added to MTA improved its physic-chemical properties. Additionally, calcium chloride addition to the materials facilitates the handling process because it demands a smaller water amount [5]. It was demonstrated than the addition of 3% NaOCl (sodium chloride) gel to MTA improved its setting time [23]. The addition of sodium chloride to MTA, ProRoot MTA, MTA-Angelus and white radiopaque PC also promotes a better sealing capacity of the three cement types [6]. Calcium chloride did not alter MTA biological properties because it enabled the formation of a hard tissue barrier when it was used after pulpotomy [4].

White MTA mixed to sodium hypophosphate (Na_2HPO_4), placed into subcutaneous of rats, showed more favorable results than white MTA, indicating that this addition makes the material more biocompatible than white MTA alone [26].

Discussion

Formation of calcification nodules in response to MTA and PC

Some studies evaluated the biocompatibility and hard tissue deposition onto subcutaneous, by using von Kossa and polarized light techniques, verifying areas of positive dystrophic calcification [15, 16, 17, 29], while others evaluated bone neoformation from defects created in rats' tibias and pigs' [47] and rats' [31] mandibles. The results strengthened the biological characteristics of MTA and PC cements.

The inflammatory response and the potential of bone formation after polyethylene tubes implantation filled with a new calcium hydroxide containing a sealer (MBPc) and ProRoot MTA was qualitatively and quantitatively evaluated in a new study model in rats' tooth sockets. Data analysis revealed that there were no statistically significant differences between both materials; additionally, the two materials were biocompatible [9].

MTA in osteoblast cultures stimulated these cells proliferation; in addition to that, these cells exhibited high expression for collagen type-I protein, osteocalcin and bone sialoprotein [42].

Biocompatibility to bone cells (MG-63) and the expression of bone markers were compared after treatment with a calcium and silicate-based (CS) cement and MTA. The results showed that in the presence of CS and MTA the cells exhibit the gene expression for collagen type I, bone sialoproteins, osteocalcin and osteopontin. Therefore, the materials were biocompatible and based on the markers' expression patterns of bone formation detection, MTA and CS cements could stimulate cellular activity, consequently presenting osteoconductor effects on these cells [8].

MTA and PC as root canal sealers

Due to several experimental studies reporting MTA and PC good properties when compared to the already existing materials, current researches in an attempt to obtain a root canal sealer have been formulating and testing several MTA- and PC-based sealers presenting biological, chemical, and physical properties capable of providing an ideal filling.

An endodontic sealer should exhibit the following properties to be considered as ideal: biocompatibility, marginal sealing, permission or induction of repair process and bone neoformation, antimicrobial activity, easy handling and insertion, to be insoluble to body fluids after setting, radiopacity and low cost [30].

Currently, the goal of several studies is to formulate a material based on MTA or Portland cement to be used not only in root-end filling materials, but also mainly as sealer material of root canals. Therefore, several components are frequently added to these already existing cements, and consequently several biological, chemical, and physical tests have been conducted to assess their properties [2, 14, 16, 17, 37].

Through modifications in MTA formulation, currently, it was developed and launched into the Argentine market the endodontic sealer EndoCPM[1] Sealer (EGEO S.R.L. Bajo licencia MTM Argentina S.A., Buenos Aires, Argentine).

[1] CPM stands for "modified Portland cement".

According to the manufacturer, EndoCPM Sealer exhibits special characteristics of leakage, plasticity, adherence, particles' size, pH, biological tolerance, biocompatibility, and osteogenic property. EndoCPM Sealer is indicated to be used as root canal sealer material; it could be also used in root or furcation perforations and as root-end filling material [39].

By evaluating tissue response to Endo CPM Sealer, Sealapex and MTA-Angelus in rats' subcutaneous, the results demonstrated that Endo CPM Sealer was biocompatible and stimulated mineralization [17].

The response of rats' conjunctive tissue after subcutaneous implant of polyethylene tubes and dentin containing MTA-Angelus and Light-cure MTA (experimental), whose formulation consists of hydrophilic resin (it is believed to be biocompatible) and active ingredients of Portland Cement, showed that the inflammatory reaction was similar in both materials. However, experimental MTA (Light-cure) did not stimulate the formation of a mineralized tissue [15].

Physical properties and chemical composition of a new endodontic cement –NEC (New Experimental Cement) – were compared to MTA. It was verified that the chemical composition of both materials is different; however, NEC exhibited acceptable physical properties for an endodontic sealer [2].

The cellular response was evaluated through utilization of a new PC, which is a mixture of PC with articaine solution, to form a paste. The results revealed that the new cement allowed bone cells' growth, presenting properties to be used as root-end filling materials and root canal sealer [14].

Another endodontic sealer is being developed in an attempt to obtain all necessary properties. It is presented as PC gel and it was called fast endodontic cement (REC). A recent study compared its tissue response to both MTA-Angelus and REC, through polyethylene implants in rats' subcutaneous. The results showed similar inflammatory response in both materials in addition to mineralized tissue. It can be concluded that REC was biocompatible and stimulated mineralization [16].

Another study evaluated the setting time and thermic expansion coefficient of REC and MTA-Angelus. The statistical analyses showed differences in setting time and thermic expansion coefficient of both materials. REC setting time was smaller than MTA and REC expansion coefficient was similar to dentin, decreasing contamination and microorganism proliferation [37].

Conclusion

These cements present similarity both in their compositions and physical, chemical and biological properties, as reported in several studies. Therefore, PC has been studied as an alternative to MTA.

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