NEW PERSPECTIVE ARTICLE

From MTA to New Biomaterials Based on Calcium Silicate

De MTA a nuevos biomateriales basados en Silicato de Calcio

Received:17-VIII-2015 Accepted: 24-VIII-2015 Published Online First: 15-XI-2015

DOI: http://dx.doi.org/10.15517/ijds.v0i0.23483

ABSTRACT

One of the most revolutionary materials introduced in Endodontics was the Mineral Trioxide Aggregate (MTA). The investigations regarding MTA formulation allowed researchers to disclose the composition and also some clinical problems related to the clinical application of this material. The augmentation on MTA's studies resulted in the development a new generation of Endodontic materials, the calcium silicate-based cements. Thus, a brief description of new cements and the perspectives on calcium silicate-based materials development were presented in this communication.

KEYWORDS

Dental sciences; Endodontics; Dental cements; Dental research.

RESUMEN

Uno de los materiales más revolucionarios introducidos en Endodoncia fue el Agregado de Trióxido Mineral (MTA). Los estudios con respecto a la formulación del MTA permitieron a los investigadores conocer la composición de este material y también conocer algunos problemas clínicos relacionados con su aplicación clínica. El aumento de estudios acerca del MTA resultó en el desarrollo de una nueva generación de materiales endodónticos, los cementos a base de silicato de calcio. Por lo tanto, una breve descripción de los nuevos cementos y las perspectivas sobre el desarrollo de materiales a base de silicato de calcio están siendo presentadas en esta comunicación.

PALABRAS CLAVE

Ciencias dentales, Endodoncia, Cementos dentales, Investigación dental.

Mineral Trioxide Aggregate (MTA) is a biomaterial broadly used to seal communications between pulpal cavity and external root surface. The introduction of MTA in Dentistry represents one of the greatest advances in reparative dentistry. This material has several indications, such as pulp capping, retrograde obturation, apexification, internal or external root resorption and perforation repair.

MTA is basically composed by Portland cement (CP) in association to bismuth oxide, which participates in the composition as radiopacifier (1). Tricalcium and dicalcium silicates are the main compounds of Portland. Consequently, MTA can be classified as calcium silicate-based cement. This repair material is recognized by its bioactivity potential to induce mineralized

TANOMARU M., VIAPIANA R., GUERREIRO J., 2016: From MTA to New Biomaterials Based on Calcium Silicate.-ODOVTOS-Int. J. Dental Sc., 18-1: 18-22.

tissues formation when immersed in phosphate-containing solution.

The use of MTA in several clinical conditions reveals the incorporation of bioceramic materials as Endodontic repair materials. This is justified by the excellent reparative property exhibited by this material. CP has been suggested alternatively to MTA, since it represents the basic compound of MTA and exhibits similar composition and biologic properties. However, Portland may contain impurities, such as heavy metals and this fact justify the replacement of Portland by pure tricalcium silicate. Prelimiray studies were developed to investigate the performance of prototype cements formulated with pure tricalcium silicate and they showed that this cement is more bioactive than Portland cement (2). Moreover, the addition of bismuth oxide in the formulation of MTA had been responsible to induce mechanical deterioration (3) and to promote teeth discoloration (4). The association of zirconium oxide to pure tricalcium silicate resulted in a cement with radiopacity (above to 3 mmAl) and higher rate of hydration reaction than MTA (5). Based on these concepts, calcium silicate-based cements had been developed with the purpose of replacing MTA. These materials are commencially disposed as presented on Table 1.

Table 1. Commercial and experimental calcium-silicate based cements.

Reparative Cement	Composition	Manufacturer
Biodentine	Powder: Tricalcium silicate, Dicalcium silicate, calcium oxide, calcium carbonate, zirconium oxide, iron oxide Liquid: calcium chloride, water-soluble polymer, water	Septodont, Saint-Maur-des-fossés, Cedex, France
MTA Plus White	Powder: tricalcium silicate, dicalcium silicate, bismuth oxide, tricalcium aluminate, calcium sulphate and gypsum Liquid: Water-based gel with thickening agents and water soluble polymers	Avalon Biomed Inc., Bradenton, Florida, USA
MTA Plus gray	Powder: tricalcium silicate, dicalcium silicate, bismuth oxide, tricalcium aluminate, calcium sulfate, gypsum, calcium aluminoferrite Liquid: Water-based gel with thickening	Avalon Biomed Inc., Bradenton, Florida, USA
Neo MTA Plus	Powder: tricalcium silicate, dicalcium silicate, tantalum oxide, tricalcium aluminate, calcium sulphate and gypsum Liquid: Water-based gel with thickening agents and water soluble polymers	Avalon Biomed Inc., Bradenton, Florida, USA
iRoot BP, iRoot BP Plus e iRoot FS	Calcium silicates, zirconium oxide, tantalum pentoxide, calcium phosphate monobasic	Innovative BioCeramix Inc., Vancouver, BC, Canada

Biodentine (Septodont, Saint-Maur-des-fossés, Cedex, France) was one of the first calcium silicate cements containing pure tricalcium silicate introduced in the market. Biodentine had demonstrated similar performance to MTA with respect to the induction of hard tissue deposition and no inflammatory response.

Another calcium silicate-based material is the MTA Plus (Avalon Biomed Inc., Bradenton, FL, USA). This cement is available in a powder-liquid system, in white/gray colors and it has also been prescribed to vital teeth terapy, as retrograde filling material and reparative material in lateral perforations. Recently, another cement with similar composition to MTA Plus was developed, the Neo MTA Plus (Avalon Biomed Inc, Bradenton, FL). Neo MTA Plus was developed to be used in pulpomies without the risk of discoloration. The radiopacifier agent, which was bismuth oxide in MTA Plus, was replaced by tantalum oxide. Besides not provoking discoloration, the addition of tantalum oxide provided radiopacity and did not exert any effect on hydration (6).

The iRoot family exhibits different presentations and consistencies, which are adequate to the clinical application. iRoot BP is disposed on preloaded syringes, while the iRoot BP Plus is available in jars with thicker consistency and the iRoot FS was specially developed to set faster. This cements had demonstrate favorable biologic properties.

ROOT CANAL SEALERS BASED ON MTA, PORTLAND CEMENT OR CALCIUM SILICATE

MTA cannot be used as conventional sealer in orthograde root canal fillings due to the lack in flow ability. Thus, materials derived from the most reactive crystalline phase, which is the tricalcium silicate, have been developed to take the advantages of the biological properties exhibited by MTA on conventional endodontic therapy. MTA hydration can be affected by some vehicles that can act as a barrier preventing the diffusion of water and/or phosphate-containing solutions into the sealer's matrix to interact with tricalcium silicate particles. Thus, alternatives vehicles can also be considered promising in this field.

Up to date, a variety of root canal sealers based on MTA, CP or calcium silicate are disposed on the market or under investigation (Table 2).

Sealers composition and manufacturer are described in Table 2.

The Araraquara Dental School, UNESP – Univ Estadual Paulista (Araraquara, SP, Brazil) had dedicated 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. With the exception of radiopacity, all the versions of Portland cement-based experimental endodontic sealers presented physicochemical properties in accordance with specifications n. 57 ANSI/ADA and ISO 6876:2012. These sealers had setting time and flow ability adequate for clinical use, high compressive strength and low solubility (7) and they also exhibited some bioactivity degree although no evidence of cement hydration was observed on material's characterization (8).

A very recent development is the BioRoot RCS sealer by Septodont (Saint Maur Des Fosses, France). This sealer presents high purity degree and it is disposed as powder-liquid system. Despite the higher void volume degree verified into in obturations (9), Bioroot RCS had exhibited lower citotoxic effects on PDL cells in comparison to a zinc oxide-eugenol based sealer (10).

The discoloration potential of Neo MTA Plus had already been investigated and it did demonstrate no discoloration effect on in vitro studies (6). Further studies should be conducted to evaluate the physicochemical properties and

Table 2. Commercial and experimental calcium-silicate based root canal sealers.

Root Canal Sealer	Composition	Manufacturer
Endo CPM Sealer	Powder: tricalcium silicate, tricalcium oxide, tricalcium aluminate and other oxides Liquid: saline and calcium chloride	Egeu SRL, Buenos Aires, Argentina
MTA Fillapex	Binder A: methyl salicylate, butylene-glycol, colophony, bismuth trioxide, silica nanoparticles Binder B: MTA (tricalcium silicate, dicalcium silicate, tricalcium aluminate and calcium oxide), nanoparticulated silica, titanium dioxide, pentaerythritol rosinate and toluenesulfonamide	Angelus Soluções Odontológicas, Londrina, Paraná, Brazil
iRoot SP	Tricalcium silicate, dicalcium silicate, calcium phosphate monobasic, calcium hydroxide and zirconium oxide	Innovative, Bioceramix, Vancouver, Canada
BioRoot RCS	Tricalcium silicate and zirconium oxide. Resin-free	Septodont, Saint Maur Des Fosses, France
EndoSequence BC Sealer/ Total Fill	Calcium silicates, zirconium oxide, tantalum oxide and calcium-phosphate monobasic	Brasseler USA, Savannah, Georgia, USA
TechBiosealer	Powder: white portland cement, calcium chloride, montmorillonite, sodium fluoride, bismuth oxide Liquid: Dulbecco's phosphate buffered solution	Isasan, Rovello Porro, CO, Italy

the clinical performance of further studies should be conducted to evaluate the physicochemical properties and the clinical performance of orthograde root canal fillings.

The state of art in endodontic sealers development are the bioceramic cements. This class of endodontic sealers are represented by the EndoSequence BC Sealer (Brasseler, Savannah, GA), also known as TotalFill, and the iRoot SP (Variodent®, Vancouver, BC, Canadá). These materials present similar composition and unlike conventional base/catalyst sealers, they are supplied in premixed injectable forms and they use the moisture from dentinal tubules to initiate setting reaction.

In the view of the aforementioned aspects, it is possible to suggest that perspectives related to endodontic material are focused on the development of pure tricalcium silicate based materials in association to a radiopacifier agent, attempting to combine biocompatibility and bioactivity properties, which are the main features of calcium silicate-based materials, to flow and sealing ability, which are desired properties for a root canal sealer. Thus, as mentioned by Camilleri (11), further studies on MTA and calcium silicate based materials should first outline the specific indication of the material, if reparative or root canal filling purposes, to adjust the properties according to the clinical application.

REFERENCES

1. Camilleri J, Montesin FE, Brady K, Sweeney R, Curtis RV, Ford TR. The constitution of mineral trioxide aggregate. Dent Mater. 2005;21(4):297-303.
2. Formosa LM, Mallia B, Bull T, Camilleri J. The microstructure and surface morphology of radiopaque tricalcium silicate cement

exposed to different curing conditions. Dent Mater. 2012;28(5):584-95.
3. Coomaraswamy KS, Lumley PJ, Hofmann MP. Effect of bismuth oxide radioopacifier content on the material properties of an endodontic Portland cement-based (MTA-like) system. J Endod. 2007;33(3):295-8.
4. Marciano MA, Costa RM, Camilleri J, Mondelli RF, Guimaraes BM, Duarte MA. Assessment of color stability of white mineral trioxide aggregate angelus and bismuth oxide in contact with tooth structure. J Endod. 2014;40(8):1235-40.
5. Camilleri J, Sorrentino F, Damidot D. Investigation of the hydration and bioactivity of radiopacified tricalcium silicate cement, Biodentine and MTA Angelus. Dent Mater. 2013;29(5):580-93.
6. Camilleri J. Staining Potential of Neo MTA Plus, MTA Plus, and Biodentine Used for Pulpotomy Procedures. J Endod. 2015;41(7):1139-45.
7. Viapiana R, Flumignan DL, Guerreiro-Tanomaru JM, Camilleri J, Tanomaru-Filho M. Physicochemical and mechanical properties of zirconium oxide and niobium oxide modified Portland cement-based experimental endodontic sealers. Int Endod J. 2014;47(5):437-48.
8. Viapiana R, Guerreiro-Tanomaru JM, Hungaro-Duarte MA, Tanomaru-Filho M, Camilleri J. Chemical characterization and bioactivity of epoxy resin and Portland cement-based sealers with niobium and zirconium oxide radiopacifiers. Dent Mater. 2014;30(9):1005-20.
9. Viapiana R, Moinzadeh AT, Camilleri L, Wesselink PR, Tanomaru Filho M, Camilleri J. Porosity and sealing ability of root fillings with gutta-percha and BioRoot RCS or AH Plus sealers. Evaluation by three ex vivo methods. Int Endod J. 2015. In press
10. Camps J, Jeanneau C, El Ayachi I, Laurent P, About I. Bioactivity of a Calcium Silicate-based Endodontic Cement (BioRoot RCS): Interactions with Human Periodontal Ligament Cells In Vitro. J Endod. 2015;41(9):1469-73.
11. Camilleri J. Mineral trioxide aggregate: present and future developments. Endod Topics. 2015;32(1):31-46.

Mario Tanomaru-Filho[1]; Raqueli Viapiana[2]; Juliane Maria Guerreiro-Tanomaru[3]

1. Full Professor of Endodontics at Araraquara Dental School-UNESP, Brasil
2. Post-Doctoral student, Graduate Program in Endodontics, Araraquara Dental School–UNESP, Brasil
3. Associate Professor of Endodontics at Araraquara Dental School- UNESP, Brasil

Mario Tanomaru-Filho, Rua Humaitá, 1680, Caixa Postal 331, Centro, 14801-903 Araraquara, SP, Brasil. Telephone +55-16-3301-6390, Fax. +55-16-3301-6392. E-mail: tanomaru@uol.com.br