



PROPERTIES OF BIOCERAMIC MATERIALS USED IN ENDODONTICS

Dental Science

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ABSTRACT

The introduction of bioceramic materials in dentistry has resulted in tremendous changes, especially in endodontics. The peculiar properties of these materials have led to their widespread usage in endodontics.

Aim: To discuss and compare the peculiar properties of bio ceramic materials available for endodontic treatment.

Method: Terms bioceramics, bioceramic materials, bioceramics in dentistry, bioactivity, bioactive materials, were searched in pubmed Index, ESBCO and sciencehub, Research gate and 25 articles were selected on the basis of the predetermined inclusion and exclusion criteria.

Conclusion: Properties, such as biocompatibility and bioactivity, give the bioceramics an edge over the other materials for dental applications, especially endodontic use.

KEYWORDS

Bioceramic materials, bioceramics in dentistry, bioactivity, bioactive materials.

Introduction

The introduction of bioceramic materials in dentistry has resulted in tremendous changes, especially in endodontics. The peculiar properties of these materials such as absolute biocompatibility, osseointegration, conductivity, ability to achieve excellent hermetic seal, formation of chemical bond with the tooth structure, insolubility in tissue fluids, good radiopacity and easy handling characteristics have led to their widespread usage in endodontics.

They function as cements, root repair materials, root canal sealers and filling materials, which have the advantages of enhanced biocompatibility, potential increased root strength following obturation, antibacterial properties and sealing ability.

More than the other properties of these bioceramic materials, the bioactive property: the ability to elicit a specific biological response at the interface of the material, resulting in the formation of a bond between the tissue and the material, make these, one of the most promising materials in endodontics.

The uses of bioceramic materials are burgeoning but tend to be rather limited from its potential due to lack of awareness of their properties and advantages. Hence this article briefly discusses the peculiar properties of bio ceramic materials available for use in endodontic treatment.

Bioceramics in Endodontics:

Bioceramic materials have been used in various endodontic clinical applications and procedures. Some of these are:

1. Pulp capping.
2. Furcation repair material.
3. Endodontic sealer.
4. Root end filling material.
5. Root repair material.
6. Periapical surgery.

MTA- The forerunner of Bioceramic Materials:

MTA belongs to a group of materials called "calcium silicate based cement" or "hydraulic calcium silicate based cement". They produce an apatite-rich surface layer subsequent to contact with body fluids.

ProRoot MTA, considered as prototype of bioceramics in endodontics, was developed and first introduced in Loma Linda University, USA in 1993, and was patent registered in 1995. Later in 2002, the white ProRoot MTA was developed.

It was in the year 2001 that MTA Angelus was introduced, first as gray and later white, with a setting time of 14 minutes. A new group of cost-effective materials called MTA Plus was introduced into the market for all conceivable applications of bioactive ceramic materials. Later Neo MTA plus, a finer powder-gel system was developed without bismuth oxide in order to prevent tooth staining. Recently MTA Fillapex has been introduced as calcium silicate-based bioceramic sealer. It has been developed in an attempt to combine the physico-chemical properties of a resin-based root canal sealer with the biological properties of MTA.

MTA was developed as root end filling material. But it is used for pulp capping, pulpotomy, apexogenesis, apical barrier formation in teeth with open apex, repair of root perforations and root canal filling.

Even though MTA possesses many advantageous properties including the bioactivity and biocompatibility, properties such as discoloration potential, presence of toxic elements, difficult handling characteristics, long setting time, high material cost, absence of a known solvent, difficulty in removal after setting have led to the development of newer and better materials such as bioceramics.

RECENT BIOCERAMIC MATERIALS: The terms bioceramics, bioactivity and bioactive materials in dentistry and endodontics were searched on Pubmed index, EBSCO, Sciencehub and research gate. Amongst the various articles found, 25 were short listed on the basis of their content reflecting review of the bioceramic materials used in endodontics and studies on bioactivity of the materials, used in endodontic treatments.

Over the past decade, new developments, especially bioceramic nanotechnology, has resulted in introduction of various new bioceramic materials.

BioAggregate

This novel laboratory – synthesized, water based cement was the first nano particle based cement introduced commercially. It consists of pure, fine powder composed of contamination-free bioceramic nanoparticles, produced under controlled conditions.

The major components of bioaggregate are calcium silicate oxide and calcium silicate with significant amount of tantalum oxide and composed of a powder component consisting of tricalcium silicate, dicalcium silicate, tantalum pentoxide, calcium phosphate monobasic and amorphous silicon oxide and a liquid component of deionized water.

With its properties of excellent sealing ability, antimicrobial action, biocompatibility, less microleakage and the ability to induce mineralization, periodontal regeneration, it is a preferred material for root end filling, pulp capping, root perforation, root resorption. Its nano-sized particles that adhere to the dentinal wall and the hydrophilic nature make it an excellent sealing material.¹

Biodentine:

Biodentine, a quick-setting calcium silicate based dental cement, was introduced by Septodont in 2011. It is dispersed as a capsule containing both powder and liquid. The powder consists of Tricalciumsilicate (main core material, that regulates the setting reaction) Dicalcium silicate (second core material) Calcium carbonate (filler), Zirconium oxide (radiopacifier) radiopacity and Iron oxide, (shading agent). The liquid consists of Calcium chloride (accelerator) that reduces the amount of water required by the mix, decreases viscosity and improves handling of the cement and water.

Compared to the other dentine substitutes, Biodentine has reduced setting time, better handling characteristics and mechanical properties. The bioactivity of biodentine induces regeneration of dentin enhanced microleakage resistance. Presence of mineral tags in the dentinal tubules makes it an excellent sealing material. Further, it has high push out bond strength, excellent surface hardness and high compressive strength. It exhibits colour stability and non-toxic with no adverse effects on cell differentiation and function.²

Biodentine has been used widely as a dentine substitute under a composite restoration, direct pulp capping material and as root end filling material. It is used for pulpotomy as well as apexification procedures and for repair of perforations.

Endosequence BC Sealer

Is a pure bioceramic root canal sealer, marketed as a premixed ready-to-use, injectable white hydraulic cement paste. It is composed of tricalcium silicate, dicalcium silicate, colloidal silica, calcium phosphate monobasic, calcium hydroxide and thickening agent. Zirconium oxide is used as the radiopacifier.

Its main advantages lie in being aluminum-free, non-soluble, antibacterial and easy to handle. It requires lesser setting time and does not shrink during setting. Some of the studies have proved that it kills all bacteria within two minutes of contact and results in a gap-free interface between gutta-percha (GP), sealer, and dentin.³

Some studies have revealed that its setting time depends on the amount of fluid present within the canal. Although obturation with BCS, and a single GP master cone may result in blockage of the apical foramen and a loss of patency in some cases.

Calcium enriched mixture (CEM):

CEM/Noval Endodontic Cement (NEC) was introduced to dentistry in 2006 by Asgray as an endodontic filling material.

It is primarily composed of alkaline earth metal oxides and hydroxides e.g. calcium oxide and calcium hydroxide, calcium phosphate and calcium silicate. More precisely, calcium oxide and silica in Portland cement and calcium oxide, silica, and bismuth oxide in MTA are the major ingredients.

This cement releases both calcium and phosphorus ions, leading to hydroxyapatite production and the process of stem cell differentiation and induces hard tissue formation.

It can be used as pulp capping agent, for furcation perforation repair and for vital pulp therapy of primary molars as well as mature/immature permanent teeth with reversible/irreversible pulpitis.

Generex A:

Generex A is a calcium silicate based material that has some similarities to MTA but instead of water, it is mixed with unique gels.

It contains calcium silicate, special gels, and hydroxyapatite. Due to its properties of superior resistance to washing, compressive strength and radiopacity, it is used mainly for retrograde fillings and perforation repair.

Ceramicrete:

It is a versatile phosphate ceramic, modified for use in dentistry and medical application.

This self-setting phosphate ceramic sets, by an acid-base reaction, to form a potassium magnesium phosphate hexahydrate ceramic matrix phase. Its mechanical properties are improved by adding calcium silicate whiskers to produce a phosphosilicate ceramic material. Hydroxyapatite is formed on the surface, when set ceramicrete material is immersed in a phosphate containing fluid. A dental or bone material was introduced which had hydroxyapatite powder and cerium oxide radioopaque fillers. The material is nonporous and generates calcium and phosphate ions during the setting reactions, it is used as a root-end-filling material. Due to possessing radio opacity similar to root dentin, ceramicrete is a better apical sealing material.⁴

Doxadent:

It is a calcium aluminate product available in powder liquid form that can be used as a permanent restorative material. The main components in Doxadent are alumina, calcium oxide, water, zirconium dioxide and other alkali oxides. As the powder and liquid are mixed, water dissolves the calcium aluminate powder that leads to the formation of calcium, aluminum and hydroxyl ions, helping in the formation of katoite and gibbsite.⁵

Bioactive Glass (BAG):

This silicate-based versatile material is used in dentistry for several procedures, with excellent results.

The main characteristics of bioactive glasses are related to its reactivity in water and aqueous liquids. The reaction of bioactive glass with tissue fluids, results in the formation of a hydroxycarbonate apatite (hydroxyapatite) layer on the glass. Contact with body fluids leads to a rapid leach of Na⁺ and congruent dissolution of Ca²⁺, PO₄³⁻ and Si⁴⁺ on glass surface. A polycondensated silica-rich (Si-gel), formed on the glass bulk, serves as a template for the formation of a calcium phosphate (Ca/P) layer at its outer surface. Consequently, the Ca/P crystallizes into hydroxyapatite, the composition of which corresponds to that of bone. Because of this phenomenon and their good biocompatibility bio active glass were introduced in dentistry.

It is considered as the most biocompatible material. Being, bioactive, osteoconductive, osteoinductive, antibacterial, antimicrobial, it induces hard tissue formation and mineralization. It is the material of choice for treatment of oral bone defects, root canal disinfection, pulp capping and periapical bone healing.

The bulk formulation, high modulus, related to its formation and low fracture toughness, low load bearing are the major disadvantages of bioactive glass. But this limitation of bulk micron scale formulation, has been overcome by the recent advancement of bioactive glasses in the form of amorphous nanopowders of size 20- to 60-nm size.⁶

DISCUSSION:

Endodontic bioceramics are not sensitive to moisture and blood contamination and therefore are relatively non technique sensitive. They are dimensionally stable and expand slightly on setting, making them one of the best sealing materials in dentistry.⁷ As endodontic sealing materials they produce gap-free interface between gutta-percha (GP), sealer, and dentin. They are highly biocompatible and antibacterial because of their high alkaline pH, thus recommended as endodontic sealer.⁸

Koch et al proved that Endosequence when used as an endodontic sealer has the superior advantage over the other sealing materials, due to enhanced biocompatibility. It increases strength of the root following obturation. It has high pH (12.8) during the setting process and provides anti-bacterial effect. Its sealing ability is related to its hydrophilicity and is easy of use. Endosequence sealers have excellent seal that results in negligible leakage. They are difficult to remove in retreatment conditions because of this excellent seal. Enrique et al pointed out the limited retreatability of Endosequence bioceramic and found that BC Sealer group had significantly more residual filling material than the AH Plus group.⁹ Further, EndoSequence BC Sealer is difficult to remove from the root canal using conventional retreatment techniques, including heat, chloroform, rotary instruments, and hand files. As regards the biocompatibility, Lovato and Sedgley validated that ERRM displayed similar in vitro biocompatibility to MTA.¹⁰

Contrary to other studies Hirschberg et al compared the sealing ability of ProRoot mineral trioxide aggregate (MTA) to the sealing ability of EndoSequenceBioceramic Root Repair Material (ES-BCRR) and found that ES-BCRR group leaks significantly more than the MTA group.¹¹

Sayed and Saeed found Bioaggregate to display excellent hermetic seal that can be attributed to its nano-sized particles which adhere to the dentinal wall, and its hydrophilic nature.¹² Leal et al found that, when used as a root end filling material, Bioaggregate shows excellent sealing ability.¹³ Along with better seal Bioaggregate is more biocompatible than MTA as well. Yousuf et al found Bioaggregate to be more biocompatible than Proroot MTA. The latter produces higher inflammation and foreign body reaction than Bioaggregate.¹⁴

Leal et al have advocated Ceramcrete as a root end filling material. They found Ceramcrete to produce lower glucose penetration than the other root end filling materials.¹³ Ribeiro et al found that, Generex A, designed for retrograde fillings and perforation repair, has superior resistance to washing, compressive strength and good radiopacity.¹⁵

Compared to MTA, Torabinejad et al and Septodont scientific society found Biodentine with relatively short setting time (around 12 min) [30], to enable the use of this cement for restorative procedures, which is relatively not possible with MTAs that achieve an initial set in 3–4 h.¹⁶

According to Bonneck, Biodentine is the material of choice for the repair of root perforations and apexification owing to its appreciable properties like ease of handling, faster setting kinetics, biocompatibility, early mineralisation. Compared to MTA, Biodentine handles easily and needs much less time for setting. Unlike other Portland cement-based products, Biodentine is sufficiently stable so that it can be used both for pulp protection and temporary fillings.¹⁷

Bioceramic materials, when unset have antibacterial properties and when set, are biocompatible and even bioactive. As they come in contact with tissue fluids, calcium hydroxide is released, which interact with phosphates, in the tissue fluids, to form hydroxyapatite.

Han et al found that when immersed in PBS for up to 90 days, BC sealer, compared to Biodentine and white MTA, had less Ca ion release and had no Ca and Si incorporation as in human root canal dentine.¹⁸

For pulp capping, the optimal material should be biocompatible, stimulate differentiation of pulp cells to odontoblasts/odontoblast like cells, seal the perforation site completely, be antimicrobial, have sufficient mechanical strength including hardness, compressive strength and flexural modulus. With respect to pulp capping, Zhang et al found BioAggregate to possess a greater potential to induce odontoblastic differentiation and mineralization than that of MTA.¹⁹ Camilleri et al found MTA to be a bioactive material that can be used for direct pulp capping.²⁰ Mente et al. reported 80.5% success rate of direct pulp capping with MTA and 59 % when using calcium hydroxide.²¹

Pradeep et al found Bioglass to possess bioactivity which can be used for the treatment of the dentinal hypersensitivity by mineralizing tiny holes in the dentine and reducing tooth sensitivity.²² The peculiar characteristics of Bioactive glass such as bioactivity, osteoconductivity and osteoinductivity make it the most biocompatible material in the bone regeneration field.²³

Even though the antimicrobial activity is an important requirement of an endodontic sealer, most of them have no capacity to provide complete protection. Various studies have found MTA to possess antimicrobial activity but Sipert et al found MTA and Portland cement to demonstrate no antibacterial activity on *E. coli*.²⁴ Amongst the bioactive materials, Bioglass displays antibacterial activity.

Regenerative approaches in endodontics have received much attention during the last several years in the treatment of vital and necrotic teeth with open apices. White MTA has been used as a material of choice in such treatments.²⁵

CONCLUSION:

The bioceramic materials have wide spread use in dentistry and endodontics in specific, such as pulp capping, pulp amputation,

apexification, root-end fillings, perforation repair, and pulp regeneration. Gradually bioceramics have started to replace traditional materials used in root canal fillings.

Their peculiar properties such as biocompatibility and bioactivity, render them fit for dental applications, especially endodontic use and are facilitating the clinical shift towards these materials. So we can rightly conclude that bioceramics have an extremely promising future and a broad application scope.

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