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BIOCERAMICS IN ENDODONTICS – A REVIEW

Endodontide Biyoseramikler: Derleme

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ABSTRACT

Bioceramics are materials which include Alumina, Zirconia, Bioactive glass, Glass ceramics, Hydroxyapatite, resorbable Calcium phosphates, among others. They have been used in dentistry for filling up bony defects, root repair materials, apical fill materials, perforation sealing, as endodontic sealers and as aids in regeneration. They have certain advantages like biocompatibility, non toxicity, dimensional stability and most importantly in endodontic applications, being bio-inert. They have a similarity to Hydroxyapatite, an intrinsic osteo conductive activity and have an ability to induce regenerative responses in the human body. In Endodontics, they can be broadly classified into Calcium Phosphate/ Tricalcium/ Hydroxyapatite based, Calcium Silicate based or mixtures of Calcium Silicate and Phosphates. This review focuses on an overview of Bioceramics, classification and their advantages. It also gives a detailed insight into individual bioceramic materials currently used in the fields of Endodontics along with their properties and applications.

Keywords: *Bioceramics; Bioactive glass; calcium phosphate; calcium silicate; hydroxyapatite*

ÖZ

Biyoseramiklerin içeriğinin bir kısmını alümina, zirkonya, biyoaktif camlar, cam seramikler ve rezorbe olabilen kalsiyum fosfatlar oluşturur. Biyoseramikler, diş hekimliğinde kemik defektlerinin doldurulmasında, kök tamiri ve kök ucu dolgu materyalleri olarak, perforasyonların kapatılmasında, endodontik patlar olarak ve rejenerasyon işlemlerinde kullanım alanı bulmuşlardır. Biyouyumlulukları, toksik olmamaları, boyutsal stabiliteye sahip olmaları gibi avantajları yanında endodontik uygulamalar açısından en önemlisi biyoinert olmalarıdır. Hidroksiapatite benzer özellikler gösterirler, intrinsik osteokondüktif aktiviteye sahiptirler ve insan vücudunda rejeneratif yanıtları indüklerler. Endodontide genel olarak kalsiyum fosfat/trikalsiyum/hidroksiapatit esaslı, kalsiyum silikat esaslı, veya kalsiyum silikat ve fosfatların karışımı olarak sınıflandırılabilirler. Bu derlemede kapsamlı bir biçimde biyoseramikler, sınıflamaları ve avantajları anlatılmaktadır. Endodonti alanında kullanılan bazı güncel biyoseramik materyallerin detaylı açılımının yanında özellikleri ve uygulamaları hakkında da bilgi verilmektedir.

Anahtar kelimeler: *Biyoseramikler; biyoaktif camlar; kalsiyum fosfat; kalsiyum silikat; hidroksiapatit*

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Introduction

The field of Endodontics is constantly changing due to introduction of new techniques and technological advances. Advances in endodontic material sciences contributesignificantly to the exponential growth in endodontics. Bio-ceramics are amongst the recently introduced materials in endodontics which have changed the face of endodontics. Ceramics are inorganic, non-metallic materials made by the heating of raw minerals at high temperatures (1). Bio-ceramics are biocompatible ceramic materials or metal oxides with enhancedsealing ability, antibacterial and antifungal activity applied for use in medicine and dentistry.They have the ability to either function as human tissues or to resorb and encourage the regeneration of natural tissues. They include alumina and zirconia, bioactive glass, glass ceramics, calcium silicates, hydroxyapatite and resorbable calcium phosphates, and radiotherapy glasses (2, 3).Various classifications of bio-ceramic materials used in endodontics were given based on composition, setting mechanism and consistency. One of the simpler ways of classifyingbioceramicsis as follows (4, 5):

Bioinert: non-interactive with biological systems (Alumina, zirconia)

Bioactive: durable tissues that canundergo interfacial interactions with surrounding tissue (bioactive glasses, bioactive glass ceramics, hydroxyapatite, calcium silicates)

Biodegradable: soluble or resorbable, eventually replaced or incorporated into tissue (Tricalcium phosphate, Bioactive glasses).

Advantages of Bioceramics

Excellent biocompatibility properties due to their similarity with biological hydroxyapatite.

Intrinsic osteoinductive capacity because of their ability to absorb osteoinductive substances if there is a bone healing process nearby.

Function as a regenerative scaffold of resorbable lattices which provide a framework that is eventually dissolved as the body rebuilds tissue.

Ability to achieve excellent hermetic seal, form a chemical bond with the tooth structure and have good radiopacity (6, 7).

Antibacterial properties as a result of precipitation in situ after setting, a phenomenon that leads to bacterial sequestration. Bioceramics form porous powders containing nanocrystals with diameters of 1-3 nm, which prevent bacterial adhesion. Sometimes, fluoride ions are constituents of apatite crystals, and the resulted nanomaterial has antibacterial properties (8).

Bioceramics used in endodontics

Calcium silicate based –

Cements- Portland Cement, Mineral trioxide aggregate (MTA), Biodentine (Septodont, France)

Sealers - Endo CPM Sealer (EGO SRL, Buenos Aires, Argentina), MTA Fillapex (Angelus, Brazil), BioRoot RCS (Septodont, France), TechBiosealer (Profident, Kielce, Poland).

Calcium phosphates/ tricalcium phosphate/ hydroxyapatite based

Mixture of calcium silicates and calcium phosphates - iRoot BP, iRoot BP Plus,iRoot FS (Innovative Bioceramix Inc., Vancouver, Canada), EndoSequence BC Sealer (Brasseler, Savannah, GA, USA)/ Total Fill (9), Bioaggregate (Innovative Bioceramix Inc., Vancouver, Canada), Tech Biosealer (6), Ceramicrete (developed at Argonne National Lab, Illinois, USA) (10).

Calcium Silicate based bioceramics

Portland Cement

In 1824, Joseph Aspdin patented a product called Portland cement (PC) obtained from the calcination of the mixture of limestones coming from Portland in England and silicon-argillaceous materials (11). PC is an inexpensive material and except for the absence of bismuth oxide and higher levels of calcium aluminate and calcium sulfate, PC and MTA have a similar main composition. PC like MTA is available as grey and white (12).

Discolouration- Ordinary PC (grey) shows lesser discoloration compared to grey MTA. However there is an equal lack of discoloration seen by white MTA as well as white PC (13).

Solubility-According to Vivaan *et al.*, greater solubility is seen with MTA when compared to white PC (14). It also showed better washout resistance compared to MTA in different solutions (15).

Bioactivity- Maturation of MTA after hydration is more structured than PC hence the former displays better bioactivity (16).Calcium ion release and formation of hydroxyapatite crystals is seen with both grey and white PC (6, 17).

Particle size- The particle size of white ProRoot MTA is significantly smaller than white PC both before and after hydration (18).

Antibacterial properties- PC shows antibacterial and antifungal properties similar to MTA against *Enterococcusfaecalis*, *Micrococcus luteus*, *Staphylococcus aureus*, *Staphylococcus epidermidis, Psuedomonasaeruginosa* and *Candida albicans* (19).

Sealing ability - White and grey MTA had similar sealing ability as a root end filling material when checked by means of dye penetrationwhen compared to white and grey PC (20). However, when checked as a perforation repair material by means of protein leakage, white PC showed better sealing ability compared to white and grey MTA.

Biocompatibility-Cell culture studies have showed variable result as per the cell type. Essentially there was no genotoxicity or cytotoxicity seen associated with PC similar to MTA with respect to fibroblasts (21). However, with respect to human bone marrow-derivedmesenchymal stem cells, MTA displayed greater proliferation and migration compared to PC (22). Biomineralization is greater with MTA compared to PC when observed at 30 and 60 days (23). Pulpotomy performed with PC and MTA was successful both clinically and radiographically,but the root canals showed greater obliteration with PC (24).

Limitations-Higher amount of lead and arsenic released from PC along with reports of its high solubility compared to MTA has raised questions regarding its safety with respect to the surrounding tissues (19).

Higher solubility may jeopardise the long term seal of the restoration (25).

Excessive setting expansion with PC may lead to crack formation with the tooth (19).

Biomineralization with PC is not as effective and as long term as with MTA which is critical for a bioactive material (23).

Mineral trioxide aggregate (MTA)

The first bioceramic material successfully used in endodontics was the MTA cement which was introduced by Dr.Torabinejad in 1993. It is osseoconductive, inductive and biocompatible. This material was developed and recommended initially as a root-end filling material and subsequently has been used for pulp capping, pulpotomy, apexogenesis, apical barrier formation in teeth with open apexes, repair of root perforations, and as a root canal filling material.Up to 2002, only one MTA material consisting of grey colored powder (GMTA) was available.In that year, white MTA (WMTA) was introduced as ProRootMTA(Dentsply Endodontics, Tulsa, OK, USA) to address discoloration of tooth associated with GMTA (26). In the first form, greycolor is given by iron ions, which were later removed to obtain the white form. Setting reaction is by hydration, obtaining hydrated calcium silicate and calcium hydroxide which is released over time. Its biological integration is due to the ions of Ca, which form hydroxyapatite in contact with phosphate ions present in body (8).

Difference between grey and white MTA

WMTAwas found to have 54.9%less Al_2O_3, 56.5% less MgO and 90.8% less FeO than GMTA, leading tothe conclusion that the FeO reduction is most likely the causefor the color change. WMTA was also reported to possessan overall smaller particle size than GMTA (27).

Physical properties

Compressive strength–~40 MPa at 24 hours and ~67 MPa at 21 days.

Setting reaction-MTA sets through an exothermic reaction, requiring hydration of its powder to produce the cement paste that matures over time. Most important reactions are tricalcium silicate and dicalcium silicate reacting with water to produce calcium silicate hydrates (C-S-H) and calcium hydroxide [Ca $(OH)_2$]. The bioactivity of MTA is attributed to hydration of the powder causing Ca^{+2} dissolution and diffusion, reaction product formation (CS-H and $Ca[OH]_2$), and further reactions resulting in apatite formation. Calcium chloride accelerates the setting reaction while sodium hypochlorite hinders the formation of calcium hydroxide.

$2[3CaO.SiO_2] + 6H_2O$ ---->$3CaO.2SiO_2.3H_2O + 3Ca(OH)_2$

$2[2CaO.SiO_2] + 4H_2O$ ---->$3CaO.2SiO_2.3H_2O + Ca(OH)_2$

$7Ca(OH)_2 + 3Ca(H_2PO_4)_2$ ----> $Ca^{10}(PO_4)6(OH)_2 + 12H_2O$ (28)

Setting time-The recommended powder liquid ratio for MTA is 3:1. The setting time of grey ProRoot MTA was reported by Torabinejad *et al.* as 2 hr and

45 min (± 5 min) (28, 29). Islam *et al.* reported final setting times of 140 min (2 h and 20 min) for WMTA, and 175 min (2 h and 55 min) for GMTA (30). The presence of gypsum is reported to be the reason for the extended setting time. In order to reduce the setting time, the effect of accelerators such as sodium phosphate dibasic (Na_2HPO_4) and calcium chloride ($CaCl_2$) have been added to products likeMTA Bio and then used as a rapid-setting material (31).

pH-Hydrated MTA products have an initial pH of10.2, which rises to 12.5 three hours after mixing (27).

Pushout bond strength-The retentive strength of MTA is significantly less than that of glass ionomer or zinc phosphate cement and, thus, it is not considered to be a suitable luting agent. Studies have shown that a 4-mm thickness of MTA (apical barrier) offered more resistance to displacement than a 1-mm thickness (32). Aggarwal V *et al.* found the push-out bond strength of MTA after 24 hours to be ~5.2 ± 0.4 MPa (33). The strength significantly increased to 9.0 ± 0.9 MPa after the samples were allowed to set for 7 days.

Flexural strength- According to Walker *et al.*,placement of moist cotton pelletover the setting MTA for 24 hours showed significant increase in flexural strengthi.e. ~14.27±1.96MPa (34).

Porosity-The amountof porosity in mixed cement is related to the amount of water added tomake a paste, entrapment of air bubbles during the mixingprocedure, or the environmental acidic pH value (35).

Microhardness- Less humidity, low pH values, the presence of a chelating agent and more condensation pressure might adverselyaffect MTA microhardness (36).

Sealing ability-The majority of the dye and fluid filtration studies suggestthat MTA materials overall allow less microleakage than traditionalmaterials when used as an apical restoration whileproviding equivalent protection as a ZOE preparation whenused to repair furcation perforations. GMTA and WMTA wereshown to provide equivocal results compared against guttapercha when used as a root canal obturation material in microleakagestudies.No significant leakage is observed when at least 3 mm of MTAremained after root-end resection. However, significantly more leakage is seen when 2 mm or less thickness of MTA remainedafter root-end resection (27).

Particle size-The physical properties of cement might be influenced by crystalsize. Smaller sized particles increase surface contact with the liquidand lead to greater early strength as well as ease of handling. Some particles of MTA are as small as 1.5 mm, whichis smaller than the diameter of some dentinal tubules. WMTA has finer particles in comparison to GMTA. Particle sizesmight affect the handling characteristics of these materials (19).

Biocompatibility-MTAis non-mutagenic and non-neurotoxic and does not produce a side effect on microcirculation. Both animal and human investigations have confirmed the encouragingrole of MTA on the production of signalling molecules. MTA is found to have anti-inflammatory effects on pulp tissue and cementoconductive, cementoinductive and osteoconductive effects have been confirmed (36).

Advantages-Forms Calcium Hydroxide that releases calcium ions for cell attachment and proliferation

Creates an antibacterial environment by its alkaline pH

Modulates cytokine production

Encourages differentiation and migration of hard tissue–producing cells and

Forms Hydroxyapatite (or carbonated apatite) on the MTA surface andprovides a biologic seal (36).

Limitations-Long setting time (37, 38)

Difficult handling and high cost

Potential tooth discoloration (39).

Absence of a known solvent for this material (40), and

Difficulty of its removal after placement (36).

Biodentine

‘Biodentine’ is a calcium silicate based product which became commercially available in 2009 (Septodont, Saint Maur des Fosses, France). The material is formulated using the MTA-based cement technology and the improvement of some properties of these types of cements, such as physical qualities and handling.

Setting reaction- The setting reaction of Biodentineis similar to MTA with the formation of calcium silicate hydrate gel(C–S–H) and calcium hydroxide. However, calcium carbonate acts as a nucleation siteforcalcium-silicate-hydrate gel, thereby reducing the duration of the induction period, leading to a faster setting time and enhancing the microstructure. The hydrosoluble polymer reduces the viscosity of the cement and improves handling (41).

Setting time-The working time of Biodentine is up to 6 minutes with an initial setting period of 9–12 minutes and final setting time of 45 minutes. This shorter setting time is an improvement compared to other calcium silicate materials. This is due to the addition of calcium chloride to the mixing liquid. Calcium chloride has also been shown to result in accelerated setting time for MTA (42).

Compressive strength-There is a sharp increase in the compressive strength reaching more than 100 MPa in the first hour. The mechanical strength continues to improve to reach more than 200 MPa at 24h which is more than the value of most Glass Ionomers. Biodentine has the capacity to continue improving with time over several days until reaching 300 MPa after one month. This value becomes quite stable and is in the range of the compressive strength of natural dentin (297 MPa) (43).

Elastic modulus - 22.0GPa, very similar to that of dentin at 18.5GPa (44).

Microhardness - After 2 hours, the hardness of Biodentine was 51 VHN and reached 69 VHN after 1 month. The reported micro hardness values for natural dentin are in the range of 60-90 VHN (43).

Sealing ability- The micromechanical adhesion of Biodentine is caused by the alkaline effect during the setting reaction which causes organic tissues to dissolve out of the dentin tubule. The alkaline environment between Biodentine and hard tooth substance clears a path through which the dentin substitute mass can enter the exposed opening of the dentin canaliculi. This enables Biodentine to be keyed to the dentine by means of innumerable microscopic cones, creating a stable anchorage with a sealing, bacteria-tight effect (44).

Push Out Bond Strength–Biodentine has more push-out bond strength than MTA at24 hrs. Blood contamination affected the push-out bond strength of MTA Plus irrespective of the setting time. A favourable feature of Biodentine was that blood contamination had no effect on the push-out bond strength, irrespective of the duration of setting time (44).

Flexural strength-The value of the bending obtained with Biodentine after 2 hours was 34 MPa as compared with other materials such as 5-25 MPa for Conventional Glass Ionomer Cement; 17-54 MPa for Resin modified GIC and 61-182 MPa for Composite resin (19). Hence it was concluded that the bending resistance of Biodentine is superior to conventional GIC, but still much lower than the composite resin (42).

Antibacterial activity and pH- Calcium hydroxide ions released from cement during setting phase of Biodentine increases pH to 12.5 which inhibits the growth of microorganisms and can disinfect the dentin (43).

Biocompatibility-Biodentine is non-toxic and has no adverse effects on cell differentiation and specific cell function. It increases TGF-B1 (growth factor) secretion from pulp cells which causes angiogenesis, recruitment of progenitor cells, cell differentiation and mineralization (42).

Advantages of Biodentine over MTA

Consistency ensures improved handling which is better suited to the clinical use than MTA.

Exhibits better mechanical properties than MTA.

Does not require a two-step restoration procedure as in the case of MTA.

As the setting is faster, there is a lower risk of bacterial contamination than with MTA (42).

Experimental calcium alumino-silicates

EndoBinder (45)

A new calcium aluminate-based endodontic cement, called EndoBinder (Binderware, São Carlos, SP, Brazil), has been developed with the intention of preserving the properties and clinical applications of MTA eliminating its negative characteristics. EndoBinder is produced with high levels of purity, eliminating traces of free magnesium oxide (MgO) and calcium oxide (CaO), which are responsible for the undesired expansion of the material, and ferric oxide (Fe_2O_3), which is responsible for tooth darkening. Among recent materials, EndoBinder presented satisfactory tissue reaction; it was biocompatible when tested in subcutaneous tissue of rats.

Generex A (45)

Generex A (Dentsply Tulsa Dental Specialties, Tulsa, OK, USA) is a calcium-silicate-based material that has some similarities to ProRoot MTA but is mixed with unique gels instead of water used for

MTA. Generex A material has very different handling properties in comparison to MTA. Generex A mixes to a dough-like consistency, making it easy to roll into a rope-like mass similar to intermediate restorative material

Capasio (45)

Capasio (Primus Consulting, Bradenton, FL, USA) is composed primarily of bismuth oxide, dental glass and calcium alumino-silicate with a silica and polyvinyl acetate-based gel. A recent study found that Capasio and MTA promote apatite deposition when exposed to synthetic tissue fluid thus had the mineralization capacity. The same researchers also concluded that when used as a root-end filling material, Capasio is more likely to penetrate dentinal tubules. Another study compared Generex A, Generex B, Capasio along with Ceramicrete-D (magnesium phosphate based) using primary osteoblasts. Generex A was the only new generation endodontic material that supported primary osteoblast growth. No material besides MTA facilitated nodule formation. Only Generex A and MTA allowed cell growth and proliferation throughout the experiment.

Quick-Set (45)

Recently, Capasio powder has been refined and renamed as Quick-Set (Primus Consulting), and the cationic surfactant was removed from the liquid gel component, which was thought to interfere with cytocompatibility. In a contemporary research using odontoblast-like cells, Quick-Set and MTA exhibited similar cytotoxicity profiles. They possess negligible *in vitro* toxicological risks after time-dependent elution of toxic components.

Root-end filling material using epoxy resin and Portland cement (EPC) (45)

EPC, a novel composite made from a mixture of epoxy resin and Portland cement, was found to be a useful material for root-end filling, with favorable radio-opacity, short setting time, low microleakageand clinically acceptable low cytotoxicity.

Calcium phosphate based bioceramics (46)

It was reported that a triple calcium phosphate compound used in a bony defect promoted osteogenesis or new bone formation. In 1971, Hench (47) developed a calcium-and-phosphate-containing glass ceramic, referred to as Bioglass, and showed that it ‘chemically’ bonded with the host bone through acalcium phosphate-rich layer.

Classification-Based on porosity – Dense or porous

Based on resorbability – Non-resorbable (Hydroxyapatite), Resorbable (β-TricalciumPhosphate)

Compressive strength–Porous- 30-170 MPa, Dense- 120-917 MPa.

Uses

Bone substitute or bonegraft material

Pulp-capping materials

Active restorative materials containing ACP as filler encapsulated in a polymer binder was developed which stimulated the repair of tooth structure because of releasing significant amounts of calcium and phosphate ions in a sustained manner (48).

Limitations-The main limitation of the calcium phosphate ceramics is their lack of strength, causing them to have fatigue fracture and to fail in load-bearing situations (46).

Mixture of calcium silicates and calcium phosphates

Bioaggregate

BioAggregate (Verio Dental Co. Ltd., Vancouver, Canada)is composed of nano particle sized tricalcium silicate, tantalum oxide, calcium phosphate, silicon dioxide and presents improved performance compared with MTA.Tricalcium silicate is the main component phase, tantalum oxide is added as a radiopacifier and it is free of aluminium (12).

Setting reaction- On hydration, the tricalcium silicate produces calcium silicate hydrate and calcium hydroxide. The former is deposited around the cement grains, while the latter reacts with the silicon dioxide to form additional calcium silicate hydrate. This results in reduction of calcium hydroxide in the aged cement. MTA Angelus reacts in a similar fashion; however, since it contained no additives, the calcium hydroxide was still present in the aged cement (49).

Biocompatibility-Bioactivity was demonstrated by deposition of hydroxyapatite.The tantalum oxide as opposed to bismuth oxide was inert, and tantalum was not leached in solution (49).

Differences between MTA and Bioaggregate-

As opposed to MTA Angelus, BioAggregate does not contain aluminium and contains additives such as calcium phosphate and silicon dioxide. MTA Angelus exhibited the presence of aluminium, while BioAggregate had phosphorus.

BioAggregate exhibits high calcium ion release early, which is maintained over the 28-day period as opposed to MTA Angelus, which demonstrated low early calcium ion release which increased as the material aged.

Reactivity of Bioaggregate was slower when compared to MTA (49).

BioAggregate is more biocompatible, has bettersealing ability, higher fracture and acidic resistance than MTA (50).

BioAggregateexerts a greater potential to induce odontoblastic differentiation and mineralization than that of MTA in pulp capping (51).

Ceramicrete

Ceramicrete is a self-setting phosphate ceramic developed at the Argonne National Laboratory, Illinois, USA, that sets in an ambient condition formed by acid-base reaction between an acid phosphate (KH_2PO_4) and a negligible soluble basic metal oxide (calcinedMgO). More recently, a biocompatible, radiopaque Ceramicrete-based dental/ bone material has been created by incorporating hydroxyapatite powder and cerium oxide radiopaque filler into the phosphosilicate ceramic.

Setting time-The Ceramicrete-based material has an initial setting time of 6 min and a final setting time of 12 min.It can also be rolled into a sausage-like formation for easier manipulation with dental instruments and sets under water with minimal washout.

Sealing ability-A modified version of the material (Ceramicrete D) was introduced by mixing the powder with deionized water. The sealingability of Ceramicrete D was reported to be favorable. In another study by Leal *et al.* (52), two endodontic bioceramic repair cements (Bioaggregate and Ceramicrete D) displayed similar leakage results to white MTA when used as root-end fillings materials. Ceramicrete D had significantly lower glucose penetration.

Physical and chemical analyses showed that the clinical handling and washout resistant of the Ceramicrete D were superior to those of MTA; however, it was weaker, less radiopaque, and initially more acidic than Generex A and Capasio.

Calcium enriched mixture (10)

Asgary *et al.* introduced new endodontic cement in 2008 to combine the superior biocompatibility of MTA with appropriate setting time (less than 1 h), handling characteristics, chemical properties, and reasonable price (53). This newly formulated biomaterial, named calcium-enriched mixture (CEM) cement (BioniqueDent, Tehran, Iran), was made using different calcium compounds.

Setting reaction-The manufacturer claimed that the mixed paste of CEM is not sticky; it does not tend to adhere to the applicator and can be easily condensed by the operator. In addition, some calcium compounds in CEM such as calcium sulfate and calcium silicate may cause a slight expansion of the material through continuous hydration after initial setting of the material and further crystalline maturation. CEM comprises water-soluble calcium and phosphate ions and forms hydroxyapatite after setting.

Sealing ability-Its sealing ability as a root-end filling material was comparable with MTA. However, CEM showed superior sealing ability compared to MTAin presence of saliva contaminations (54).

Antibacterial activity-Antimicrobial properties of CEM against gram-negative, gram-positive, and cocci/ bacilli bacteria were compared with MTA and calcium hydroxide (CH) using agar diffusion test. Results showed comparable antibacterial effects with CH and significantly better results than MTA (55).

Biocompatibility- In addition, recent studies in cell culture revealed its cytotoxicity to be within acceptable range, suitable biocompatibility and ability to induce hard tissue formation. The results of in vivo studies on dogs showed that as pulp capping materials, MTA and CEM showed similar favorable biological outcomes, and both better than CH especially in terms of inducing the formation of the dentinal bridge (56).

EndoSequence Root Repair Material/IrootSP/ IrootBP (10)

Recently, a new root repair material has been introduced to the market, namely, EndoSequence Root Repair Material (ERRM; Brasseler, Savannah, GA).It is also available as iRoot SP injectable root canal sealer and iRoot BP Plus putty root canal filling and repair material.

Composition- According to the manufacturer, it is composed of calcium silicate, monobasic calcium phosphate, zirconium oxide, tantalum oxide and filler agents and is available as paste in preloaded syringes and also in a moldable putty form.

Setting time- According to the manufacturer's instructions, it has a working time of 30 min and a setting reaction initiated by moisture with a final set achieved approximately 4 hrs thereafter.

Sealing ability- Sealing ability of this novel material was compared with MTA was compared by Hirschberg CS *et al.* using a bacterial leakage model and it was concluded that samples in ERRM group leaked significantly more than those in MTA group (57).

Antibacterial activity- Antibacterial activity of ERRM was compared with MTA, and results demonstrated similar antimicrobial properties during their setting reaction against ten clinical strains of E faecalis (58).

Biocompatibility- ERRM material did not exhibit cytotoxic effects on human gingival fibroblast**s** when compared with MTA Angelus and Intermediate Restorative Material (59).

Uses of Bioceramics

Prosthetic uses- implants, prosthesis, prosthetic devices, coatings to improve the biocompatibility of metal implants (52).

Surgical uses – joint replacements, fill surgical bone defects, alveolar ridge augmentation, sinus obliteration, and correction of orbital floor fracture.

Endodontic uses- sealers, obturation, perforation repair, retrograde filling, pulpotomy, resorption, apexification, regenerative endodontics.

Restorative uses- Dentin substitute, pulp capping, dentin hypersensitivity, dentin remineralization (3, 6).

Conclusion

While MTA was the benchmark in bioceramic materials, material advances have constantly tried to overcome disadvantages and improve its properties. Bioceramics now have a wide array of applications both in endodontics and restorative dentistry. An up-to-date knowledge of these new bioactive materials is essential to ensure the selection of the most suitable material in different clinical situations.

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None declared.

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