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RESEARCH ARTICLE

REVIEW OF BIOCERAMIC IN CONSERVATIVE DENTISTRY & ENDODONTICS

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ABSTRACT

The use of ceramics has a long history. During the last 200 years, there have been many changes in the way of performing endodontic treatment. Bio ceramics are ceramic materials specially designed for its use in medicine and dentistry. Bio ceramic are inorganic metallic bio compatible materials. They are chemically stable, non-corrosive and interact well with organic tissue. Bio ceramics offers a new treatment options for improving prognosis in many operative and endodontic procedure. Bio ceramics are widely used in dentistry as restorative materials, root canal sealers, and obturation material, for perforation repair, retrograde filling and in regenerative endodontics. This review deals the properties and uses of bio ceramics in operative dentistry and endodontics.

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INTRODUCTION

Endodontic bioceramics are non-toxic substances that are not susceptible to moisture or blood. Thus, they are not technique-sensitive. They have acceptable dimensional stability and have insignificant setting expansion. Thus, they have excellent sealing ability. After setting, their solubility decreases. Therefore, they can provide long-term seal and their pH at the time of setting is above 12 because they release hydroxyl ions during their setting reaction. When their setting is not completed, they have antibacterial effects and after setting, they are biocompatible and bioactive in nature (Trope M *et al* 2015). There are numerous bioceramics currently in use in dentistry and medicine. Alumina and zirconia are bioinert ceramics used in prosthetics. Bioactive glass and glass ceramics are available for use in dentistry under various trade names. In addition, porous ceramics such as calcium phosphate-based materials have been used for filling bone defects. Some calcium silicates (mineral trioxide aggregate [MTA], ProRoot, MTA Root Repair, Dentsply Tulsa Dental Special-ties) and bio aggregates (DiaRoot, Bio Aggregate, DiaDent) have also been used in dentistry as materials for root repair and for apical root filling.

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This review article attempts to compile and compare the properties of various bioceramic for better clinical understanding.

HISTORY: In the 1960s, the idea of using ceramics with special designs for medical purposes such as restoration and reconstruction of injured tissues was suggested (Hench LL 2006).In 1967, some types of glass and ceramics were introduced that could bond to viable bone and named "bioglass" (Malhotra S *et al* 2014).The application of a variety of ceramics in biomedicine has greatly expanded. In 1969 L. L. Hench and others discovered that various kinds of glasses and ceramics could bond to living bone On April 26, 1988 the first symposium on bioceramics was held in Kyoto, Japan.

Classification

Based on tissue reaction: Bioceramics are divided into three groups:

- **Bioinert bioceramics:** These bioceramics do not react with biological systems such as alumina and zirconia, oxide ceramics, silica ceramics, carbon fibres, Diamond like carbon (Hench LL 2006).

- **Bioactive bioceramics:** These bioceramics have a long durability in tissues and only react with tissues at their contact interface such as bioglass and calcium phosphate (Hench LL 2006).
- **Biodegradable bioceramics:** These bioceramics can be dissolved and absorbed by tissues and are eventually replaced with tissue or participate in the composition of tissue (such as tricalcium phosphate) (Malhotra S *et al* 2014).

Bioceramic based sealers: Are categorized into calcium silicate based sealers (Mineral Trioxide Aggregate (MTA) based and non MTA based) and calcium phosphate based sealers.

- **Calcium silicate based** –Cements- Portland cement, Mineral trioxide aggregate (MTA), Biodentine (Septodont, France) Sealers - Endo CPM Sealer (EGO SRL, BuenosAires, Argentina), MTA Fillapex (Angelus, Brazil), BioRoot RCS (Septodont, France), TechBiosealer (Profident, Kielce, Poland).
- **Calcium phosphates/ tricalcium phosphate/hydroxyapatite based:** Bioactive glass.
- **Mixture of calcium silicates and calcium phosphates:** iRoot BP, iRoot BP Plus, iRoot FS (Innovative Bioceramix Inc., Vancouver, Canada), Endo Sequence BC Sealer (Brasseler, Savannah, GA, USA)/ Total Fill , Bioaggregate (Innovative Bioceramix Inc., Vancouver, Canada), Tech Biosealer , Ceramicrete (developed at Argonne National Lab, Illinois, USA).

Bioceramics in conservative dentistry and endodontics.

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 (Caicedo R, Von Fraunhofer J ,1988). 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 (parirokh M *et al* 2014). 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 (Hench LL ,2006).According to Vivaan *et al.*, greater solubility is seen with MTA when compared to white PC (Best S *et al* 2008). It also showed better washout resistance Compared to MTA in different solutions (Wang Z ,2015).Maturation of MTA after hydrationis more structured than PC hence the former displays better bioactivity (Canderio GT 2012).Calcium ion release and formation ofhydroxyapatite crystals is seen with both grey and white PC (Primus CM ,2014). The particle size of white Pro Root MTA is significantly small white PC both before and after hydration (Shen Y *et al* 2015).PC shows antibacterial and antifungal properties similar to MTA against Enterococcusfaecalis, Micrococcus luteus, Staphylococcus aureus, Staphylococcus epidermidis, Pseudomonasaeruginosa and Candida albicans (Camilleri, 2007). White and grey MTA had similar sealing ability as a root end filling material when checked by means of dye penetration when compared to white and grey PC (Asgary S,2006). However, when checked as a perforation repair material by means ofprotein leakage, white PC showed better sealing ability compared to white and grey MTA. 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 (Song JS, 2006). However, with respect to human bone marrowderivedmesenchymal stem cells, MTA displayed greater proliferation and migration compared toPC (Asgary S, 2009). Bio mineralization is greater with MTA compared to PC when observed at 30 and 60 days (Camilleri *et al*., 2005). Pulpotomy performed with PC and MTA was successful both clinically and radio graphically, but the root canals showed greater obliteration with PC (Holland R *et al* 1999). *Limitations*-Higher amount of lead and arsenic released from PC along with reports ofits high solubility compared to MTA has raised questions regarding its safety with respect to the surrounding tissues (Camilleri, 2007).Higher solubility may jeopardise the long term seal of the restoration (Holland R ,2002). Excessive setting expansion with PC may lead to crack formation with the tooth (Camilleri, 2007).Bio mineralization with PC is not as effective and as long term as with MTA which is critical for abioactive material (Camilleri *et al*., 2005).

Mineral trioxide aggregate: MTA was introduced by Dr Torabinajed in1993.It is established as Osseo conductive, inductive, and biocompatible. It has been marketed as Pro Root since its approval by FDA in 1998. It is used primarily to seal lateral root perforations and as a root-end filling material but now a days, It is also used for pulp capping, pulpotomy, a pexogenesis, and apical barrier formation in teeth with open apexes, repair of root perforations, and as a root canal filling material (Torabinejad M, Chivian N 1999).MTA is a mixture of dicalcium silicate, tricalcium silicate, tricalcium aluminate, gypsum, tetra calcium aluminoferrite and 20% bismuth oxide, which is added as radio pacifier to change the physical properties of MTA (Primus CM *et al* 2014). The primary formulation of MTA was based on 75%Portland cement and had a gray color; however, it is different from Portland cement since thePortland cement contains heavy metals (Best S *et al* 2008). Since the gray type causes tooth discoloration, white MTA was introduced to the market in 2002; however, the white type also causes some degrees of discoloration due to the presence of iron oxides in its formulation (Asgray S *et al* 2006). The white MTA has less ironaluminium and magnesium than gray MTA and smaller particles (Wang Z ,2015).When mixed with water, MTA forms calcium silicate hydrate gel and calcium hydroxide (Holland R *et al* 1999).Over time, this hydrated gel dries and forms a calcium ciliate matrix with calcium hydroxide penetrated into its porosities (Gancedo – Caravia L, 2006). The compressive strength is 40 MPa at 24 hours and 67 MPa at 21 days. Torabinejad *et al*, in 1995 stated that the pH of MTA after mixing is 10.2, which reaches 12.5 after three hours .Chang *et al*, in 2005 showed that the pH of white MTA was significantly higher than that ofgray MTA for a longperiod of time after mixing. Thesetting time of MTA is different depending on the measurement method. Primary setting occurs within 45 minutes (Chng HK *et al* 2005) but final setting requires 140 minutes to 250 minutes. It has beensuggested to mix three portions of powder with one portion of liquid. If MTA powder packed in thecanal is given adequate time, it eventually sets by absorbing moisture from the accessory canals andcementum (Budig CG *et al* 2008). However, the performance ofMTA in dry environment is not as good as that inmoist environment (Gancedo – Caravia L, 2006). On the other hand, high amounts of water cause greater porosity

anddissolution (wash out) of MTA at the time of setting and lower strength of set MTA (Walker MP *et al* 2006). Aggarwal V *et al* found the push- out strength of MTA after 24 hours to be ~5.2 ±0.4 MPa. After 7 days the strength significantly increased to 9.0 ±0.9 MPa. The drawback of MTA are difficult handling and high cost, low cohesive strength, potential tooth discoloration and difficulty of its removal after placement.

C.Root MTA: This type of MTA was produced by Lotfi in Tabriz University of Medical Sciences in 1999 and marketed by Salamyfar Company. It is a cheaper type of MTA. It contains 41.64% calcium oxide, 18.58% SiO2, 15.18% bismuth oxide, 3.41% aluminium oxide, 2.08% magnesium oxide and small amounts of iron oxide, sulphur oxide, phosphorus oxide, titanium oxide, sodium oxide, chlorine, water and carbon dioxide. Size of particles ranges between 5-60µ and is smaller than that of gray Pro Root. MTA (Primus CM *et al* 2014). Assessment of biocompatibility of ProRoot MTA and Root MTA showed no cell viability at 48 and 168 hours for ProRoot and 72 hours for Root MTA but the difference was not significant (Moazami F & Shahsiah S, 2006).Assessment of cytotoxicity of Proroot MTA, Root MTA and Portland cement on human gingival fibroblasts showed that these materials had similar biocompatibility in vitro. Root MTA has been used for restoration of strip perforation (Froughreyhani M *et al* 2013) and furcal perforation (Bin CV *et al* 2012).Despite higher inflammatory response of Root MTA compared to ProRoot MTA, these two materials can be used alternately for furcal perforation repair (Jahromi Z *et al* 2006).It has been stated that Root MTA can be used as an alternative to MTA (Sharifian MR *et al* 2007).

MTA ANGELUS (Angelus soluçõesodontológicas, Londrina, PR, Brazil): MTA ANGELUS was launched in Brazil in 2001and received FDA approval in 2011 making it available in United States. MTA Angelus is available in two forms of white (for esthetic regions) and gray containing 80%Portland cement and 20% bismuth oxide. The amount of bismuth oxide in gray MTA Angelus is less than that in gray ProRoot MTA. The amount of aluminium oxide present in MTA Angelus is 237% higher than that in white ProRoot MTA. The amount of magnesium oxide present in grayProRoot MTA is 486% higher than that in MTA Angelus (Asgray *et al* 2009). Homogeneity of MTA Angelus is less than that of ProRoot MTA (Song JS *et al* 2006). Also, it is available in self-cure and light-cure forms. A clinical study showed that light cure MTA Angelus had a similar performance to MTA in a 60-day period but did not cause mineralization (Gomes filho JE 2008).Calcium sulfate is not incorporated in the composition of MTA Angelus in order to decrease setting time (about 10 minutes). The amount of bismuth oxide in MTA Angelus is less than that in ProRoot MTA but its calcium content is higher (about 45%).The pH and release of calcium ions are higher in MTA Angelus than ProRoot MTA, which are probably due to the higher amount of cement and higher calcium content (Hess D *et al* 2011). The gray MTA Angelus has greater release of calcium ions and higher pH than the white type (Amin SA 2012). Both white and gray MTA Angelus have less opacity than ProRoot MTA (Parirokh M & Torabinejad M, 2010).

MTA Fillapex: MTA Fillapex is an endodontic sealer based on MTA developed by angelus & launched commercially in 2010.It has the physical and chemical properties of resin sealers and biological properties of MTA (Silva EJ *et al* 2013). The composition of this material after mixing includes MTA, salicylate resin, natural resin, bismuth and silica (Bin CV *et al* 2012). Highamounts of calcium and carbon are present on thesurface of this material. This material has high solubility and high release of calcium ions (Borges RP *et al* 2012). Its solubility is higher than standard and due to release of calcium during its dissolution, it shows higher antimicrobial activity than some other sealers (Faria Junior NB *et al* 2013). The bond strength of this material is significantly lower than that of AH Plus and iRoot SP and the reason is less adhesion of tag-like structures (Sagsen B *et al* 2011). Comparison of bond of iRoot SP and MTA Fillapex sealers in dry, moist and wet conditions showed that maximum bond of these sealers is achieved in moist conditions and minimum bond strength is achieved in wet conditions. In wet conditions, Fillapex did not bond to canal wall. The bond of iRoot SP in all conditions was higher than that of Fillapex (Nagas E *et al* 2012). Radiopacity (equal to 7.06 mm of aluminium) and flow of this material were higher than those of AH plus sealer (Silva EJ *et al* 2013). Use of calcium hydroxide inside the canal for seven days prior to root canal filling by Fillapex sealer decreased its bond (Amin SA *et al* 2012). Comparison of connective tissue response to Fillapex, iRoot SP and MTA Angelus showed that Fillapex was still cytotoxic for subcutaneous tissues even 90 days after its application. Only one study assessed the reaction of bone to this sealer and revealed that this sealer was biocompatible but presence of MTA in its formulation did not cause regeneration of bone defect. Inflammatory reaction and delayed formation of dentinal bridge in this study was attributed to the presence of silicate resins in sealer composition (Bosio CC *et al* 2014). But it can induce the formation of nucleation sites and apatite (Salles SP *et al* 2012).

BIODENTINE: Bio dentine was developed by septodonts research group as a new class of dental material in the year 2010. Which could conciliate high mechanical properties with excellent biocompatibility as well as a bioactive behaviour. Its chemical composition is based on the Ca3SiO5-water chemistry which brings the high compatibility of already known endodontic repair cements, septodont increased the physicochemical properties which makes biodentine. Biodentine is supplied in the form of powder and liquid. Thepowder contains calcium silicate and zirconium oxides and the liquid contains sodium, magnesium, chlorine and water (Camilleri *et al* 2012). Zirconium oxide serves as a radiopacifier and calcium chloride serves as setting reaction accelerator (Trope M *et al* 2015). Clinically biodentine is easy to handle and biocompatible not only for the restorative procedures but also for the classical endodontic procedures. Biocompatible not only for the restorative procedures but also for the classical endodontic procedures. The calcium silicate has the ability to interact with water leading to the setting and hardening of cement. This is a hydration of tricalcium silicate which produces hydrated calcium silicate gel and calcium hydroxide. The hydrated calcium silicate gel and calcium hydroxide tends to precipitate at the surface of the particle. The CSH (calcium silicate hydration) gel formation is due to the permanent hydration of the tricalcium silicate, which gradually fill in the spaces between the tricalcium grains. The pH of bio dentine is 12.5. The working time of biodentine is upto 6 minutes with a final set at around 10-12minutes. The setting time of biodentine is in the same range as amalgam. When tested according to ISO standard with Gilmore needles, the working time is over 1 minute and setting time is between 9-12 minutes. The bending resistance of biodentine is superior to

GIC but much lower than the composite resins. The compressive strength is 100 MPa in the first hour and 200MPa after 24 hours. The modulus of elasticity is 22 GPa and it is very similar to that of dentin at 18.5 GPa (Saxena P *et al* 2013).It has the surface hardness in the same range as natural dentine. Biodentine contains zirconium oxide for radio opacity. This makes biodentine suitable for endodontics indications of canal repair. Biodentine is used as a dentine substitute under a composite restoration, as a direct pulp capping material and as an endodontic repair material. It exhibits better mechanical properties than MTA. As the setting is faster, there is a lower risk of bacterial contamination than with MTA (Belobrov I *et al* 2011).

PRO ROOT ES canal sealer: ProRoot ES (Endodontic Sealer) from DENTSPLY Tulsa is a new sealer that came to market in May 2016. ProRoot ES represents a continuing paradigm shift in endodontic sealers toward calcium silicates or bioceramics. These new sealers are not just sealers but can also serve as an apical filler. Historically the gutta percha cone is buttered or lightly coated with a thin layer of Thermaseal plus Ribbon Sealer (DENTSPLY Tulsa) or Pulp Canal Sealer EWT (Kerr Endodontics) and then placed in the canal to working length. The ultimate goal is to have a thin layer of sealer between the gutta percha, dentin and any portal of exit (foramen). The sealer serves as a sealer and in this technique it is better to have a tight fitting gutta percha cone that "fits and fills" the apex or the foramen with just a small layer of sealer in between. The various properties of pro root ES are: It causes massive reduction of post-operative sensitivity.it has good Osteogenic/Osteoconductive property & it can promote cementum growth.it has good antibacterial property. The intial Setting pH is 11.6 and final setting pH is 11.7.It is Bonds to the dentin and gutta percha.it has good Hydrophilic property and the sealer will set in moisture.it has excellent Flowability and excellent Coatability the sealer coats the dentinal walls in a 360 degree fashion. It does not promote periradicular inflammation. The working time is 65 min.It has relatively quick set time of12 hours. It can be Re-treatable.Itcan alsoseal the apical perforations.

Experimental calcium alumino – silicates

EndoBinder (Saxena *et al.*, 2013): 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 (Fe2O3), 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 (Saxena P *et al* 2013): 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 (Saxena P *et al* 2013): 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.

D. Quick-Set (Saxena *et al.*, 2013): 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.

Calcium hydroxide based cement: The first clinical use of calcium hydroxide as a root canal–filling material was probably byRhoner in 1940. It took another 20 years for calcium hydroxide to become popular forapexification, the sealing of perforations, and management of resorption. A ''miracle'material'' Biocalex (Laboratoire SPAD, Dijon, France), developed by French researchers, wasbelieved to make radical changes to endodontic instrumentation methods(Hendra L ,1970).Biocalex/Endocal is aroot canal medication/ filler that uses calcium oxide in ethyl glycol. The calcium oxide combines with water in the tooth and becomes calcium hydroxide which is a well-known and long used and documented excellent root canal material. The antibacterial effect of calcium hydroxide is basedon its ability to release hydroxyl ions and to raise pH. The pH of calcium hydroxide paste has beenshown to be as high as 12.5 when used for intracanal medicament purpose. The setting reactions of calcium hydroxide–containing sealers are complex. CRCS sets within 3 days in both dry and humidenvironments. Seal apex sets in 2 to 3 weeks in 100% relative humidity and does not set in a dryenvironment.Apexit has exhibited high water sorption but along with its equally high solubilitygives rise to minor overall dimensional change(Asgray S *et al* 2007). CRCS was quite stable with volumetric changesin water for 21 days. Seal apex displayed significant sorption in a 100% humid atmospherewith volumetric expansion (Caicedo R & Von Fraunhofer J, 1988).

Calcium phosphate based bioceramics: Calcium phosphate cement were proposed by brown and chow and Legeros *et al* in 1980. In 1990, the first calcium phosphate cement was used commercially in treatment of maxillofacial defects and fractures .It is a bioactive and biodegradable graftingmaterial in the form of powder and liquid. When mixed, it sets primarily as hydroxyapatite. Calcium phosphate cement can be used as a complete canal obturation material.Goodell *et al*: recommend CPC as a replacement for calcium hydroxide in apexification cases. The main limitation of the calcium phosphate bioceramics is their lack of strength, causing them

to have fatigue fracture and fail in load bearing situations (LeGeros RZ, 1988).

Bioactive glass: Bioactive glasses were first developed by Hench *et al* in 1969 and represent a group of reactive materials that are able to bond to mineralized bone tissue in physiological environment. Bioactive glasses are characterized by the materials reactivity in water and aqueous fluids. The application of the bioactive glass and glass ceramics has been widely documented over the Past two decades but the high modulus and low fracture toughness has made them less applicable. For clinical use. It is currently regarded as the most biocompatible material in the bone regeneration field due to its bioactivity, osteoconductivity and even osteoinductivity. Bioactive glass is available in bulk, crushedpowders and micron scale fibers. When bioactive glass are brought into contact with body fluids, a rapid leach of Na+ and congruent dissolution of Ca+2.PO4-3and Si+4 takes place at the glass surface. A poly condensated silica- rich layer is formed on the glass bulk, which serves as a template for the formation of a calcium phosphate layer at its outer surface which turns into hydroxyapatite. Because of this phenomenon and good biocompatibility it wasintroduced in dentistry.

Mixture of calcium silicates and calcium phosphate.

Bioaggregate: Lu *et al*. (2006) introduced the High strength, nanoparticulate, bioceramic biological cement that is now marketed as DiaRoot BioAggregate {DB} (Diadent, Canada).DB is a relatively new bioceramic base material which is similar to MTA. It is Easy to handle & setsin the presence of moisture. Antibacterial, non-toxic, aluminum free, hydrophilic white powder with tantalum pentoxide & Promotes cementogenes an excellent seal (double seal). It is indicated in repair of froot perforation, repair of froot resorption, root end filling, apexification and pulp capping. Bioaggregate is more biocompatible than any other root end filling and repair materials. It doesn't produce any effect on microcirculation. It has excellent biocompatibility with the vital periradicular tissue. Bioaggregate has invitro sealing abilities compared to MTA (Holland R *et al* 1999) strong antibacterial properties against E.faecalis(Budig CG, Eleazer PD, 2008) and anti-fungal properties against C.albicans(Gancedo caravia L, 2006).

CEM cement: A novel endodontic material called CEM cements also known as new endodontic cement was introduced to dentistry by Asgary *et al* 2006 for its application in various endodontic procedure. It is produced by Bionique Dent Company in Iran and it is composed of calcium oxide (51.81%), silica oxide (6.28%), aluminum oxide (0.95%), magnesium oxide (0.23%), and sulfur oxide (9.48%), phosphorus oxide (8.52%), sodium oxide (0.35%), chlorine (0.18%), water, carbon dioxide and some other materials (22.2%) [80]. Comparison of CEM and ProRoot MTA shows that they have almost similar pH, working time and dimensional changes but CEM cement has shorter setting time (less than one hour), less film thickness and higher flow (Dreger LA *et al* 2012). One hour after mixing of CEM cement, it releases higher amounts of phosphate compared to Portland cement and white ProRoot MTA. Radiopacity ofthis material is about half of the radiopacity of MTA (Torabzadeh H *et al* 2012), which is lessthan the required amount for endodontic sealers (equal to 3mm ofaluminum). Antimicrobial activity ofCEM cement and calcium hydroxide is significantly higher than that ofwhite and gray ProRoot MTA and Portland cement (Asgray S *et al* 2007).The use of CEM cement are pulpotomy of immature (Nosrat A *et al* 2013) and matureteeth (Asgray S, Eghbal MJ 2010), pulp capping (Ghajari MF *et al* 2010), furcal perforation repair, repair of external root resorption defects , retrograde filling (Asgray S *et al* 2010) and regenerative endodontic treatments (Nosrat A *et al* 2011).

BC Sealer and iRoot SP: EndoSequence BC Sealer and iRoot SP root canal sealer are the same product. In 2007 a Canadianresearch and product development company (innovative bioceramic, Inc., Vancouver Canada) developed a premixed, ready to use calcium silicate based material, iRoot SP. This sealer is premixed and contains zirconium oxide (radiopacifier), tricalcium silicate, dicalcium silicate, colloidal silica, calcium silicate, monobasic calcium phosphate, calcium hydroxide, fillers and plasticizers. This is a hydrophilic sealer and the moisture inside the tubules causes its setting. Its working time is more than 4 hours at room temperature and its setting time depends on the amount of moisture and varies from 4 hours to 10 hours in very dry canals (Hess D *et al* 2011). The solubility of Fill apex and iRoot SP sealers is higher than that of AH Plus and MTA Angelus and is not in agreement with the standards but the solubility ofiRoot SP is higher than that of Fillapex (Borges RP *et al* 2012). Another study found no significant difference in solubility ofiRoot SP and AH Plus, and it was in agreement with the standards. Also, iRoot SP absorbed more water but no difference was noted in the apical seal provided by these two materials [59]. Radiopacity ofthis sealer equals 3.84 mm ofaluminum, which is about halfthe opacity of AH plus but it is in agreement with the standards (minimum of 3 mm of aluminium). BC Sealer has moderate cytotoxic effects on osteoblasts at five weeks [Loushine BA *et al* 2011] but another study showed that iRoot SP and MTA induced differentiation of dental papilla stem cells to odontoblast-like cells and induced biomineralziation (Zhang W *et al* 2010). No difference in inflammatory response to intraosseous and subcutaneous placement of iRoot SP and MTA was noted in rats and both of these materials showed biocompatibility.

EndoSequence: EndoSequence root repair material (ERRM) is produced by Brasseler Company and is supplied inthe form of a mouldable putty (marketed as iRoot BP Plus) and a syringe containing paste with the ability to be injected into the canal. Endo Sequence BC obturation system is another product of this company (comprised of gutta-percha and Endo Sequence BC sealer). All forms of ERRM are composed of calcium silicate, zirconium oxide, tantalum oxide, monobasic calcium phosphate, fillers and plasticizers (Damas BA *et al* 2011). They are comprised of nanospheres that can penetrate into dentinal tubules and set using their moisture. The ERRM putty is similar to gray MTA in terms of crystallographic structure of surface. The compressive strength of ERRM is similar to that ofMTA but due to forming tag-like structures in dentin, it causes micromechanical interlocking and bond to dentin, which are not seen in use of MTA (Wang Z 2015). According to the manufacturer, working time of ERRM is 30 minutes and its setting time is 4 hours. It sets in presence of moisture and its pH is 12.4, which is maintained during its setting. The iRoot products include iRoot SP, iRoot BP and iRoot BP Plus. These products are produced by the Innovative Bioceramix Inc. (Vancouver, Canada). According to the manufacturer, iRoot SP is the same as Endo Sequence BC sealer. The iRoot BP and iRoot BP Plus are insoluble, ready to

use, devoid of aluminum and opaque, and are different from each other in terms of consistency. The iRoot BP is an injectable white paste but iRoot BP Plus has a putty-like consistency. A study showed that ERRM putty is also marketed with the brand name "iRoot BP Plus" (Wang Z 2015). According to the manufacturer, iRoot Plus has a setting time of2 hours but it has been shown that its complete setting takes 7 days (Jiang Y *et al* 2014). No difference was noted in the ability of iRoot BP Plus and MTA for the formation of dentinal bridge in teeth thathave undergone pulp capping.

Comparison ofbiocompatibility ofthese two materials showed that cell viability was less in exposure to iRoot BP Plus compared to ProRoot MTA (De-Deus G *et al* 2012). The iRootSF (Brasseler, Savannah, GA, USA) is another member of this family and is among the permanent restorative materials. It has a base of calcium silicate but does not contain aluminum. Its handling properties are better and its setting time has decreased to one hour (Jiang Y *et al* 2014).

CERAMICRETE: Ceramicrete is a self-setting phosphate ceramic developed at the Argonne National Laboratory, Illinois, and USA that sets in an ambient condition formed by acidbase reaction between an acid phosphates (KH2PO4) 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. The Ceramicrete-based material has an initial setting time of6 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.

A modified version of the material (Ceramicrete D) was introduced by mixing the powder with deionized water. The sealingability ofCeramicrete D was reported to be favourable. In another study by Leal *et al*(Leal F *et al* 2011), 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 thatthe clinical handling and washout resistant of theCeramicrete D were superior to those ofMTA; however, it was weaker, less radiopaque, and initially more acidic than Generex A and Capasio.

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 asthe body rebuilds tissue.

Ability to achieve excellent hermetic seal, form a chemical bond with the tooth structure and have good radiopacity (Prati C *et al* 2015).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 (Jitaru S *et al* 2016).

Uses of Bioceramics

Prosthetic uses: Implants, prosthesis, prosthetic devices, coatings to improve the biocompatibility of metal implants (Leal F *et al* 2011).
Surgical uses: joint replacements, fill surgical bone defects, alveolar ridge augmentation, sinus obliteration, and correction oforbital floor fracture.

Endodontic uses: Sealers, obturation, perforation repair, retrograde filling, pulpotomy, resorption, apexification, regenerative endodontics.

Restorative uses: Dentin substitute, pulp capping, dentin hypersensitivity, dentin remineralisation (Jain P, Ranjan M, 2015).

CONCLUSION

Bioceramics offers a new treatment options for improving prognosis in many operative and endodontic procedures. Bioceramics are non-toxic, non-moisture sensitive materials with optimal dimensional stability, excellent sealing ability, alkaline PH and osteoconductivity. A number of bioceramics have been introduced to the market. Due to drawbacks such as causing tooth discoloration, difficult handling and long setting time, studies are still ongoing on these materials. Thus clinicians must enhance their knowledge about these bioceramics and may cause revolutionary changes in endodontics treatment in near future.

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