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BIOCERAMICS IN OPERATIVE DENTISTRY AND ENDODONTICS

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ABSTRACT

Many centuries ago, the discovery that fire would eventually transform the clay into ceramics has led to the enormous improvement in the quality of life. Specially designed ceramics have been bought into the field of medicine for the repair and reconstruction of diseased or damaged parts of the body. These speciallydesigned ceramics are termed as bio ceramics. Bio ceramics can be single crystals, polycrystalline, glass, glass ceramics and composites. Bio ceramics are widely used in dentistry as restorative materials, gold porcelain crowns, glass filled cements and dentures. This review deals with bio ceramicsused in operative dentistry and endodontics .

KEYWORDS: Bioactive Glass, Bioaggregate, Bioceramics, Calcium Hydroxide Based Cement ,Mineral Trioxide Aggregate.

INTRODUCTION

New technology and techniques has been developed to produce good treatment results. Recently, we have seen significant development in material science one of which is the use of bioceramics. Bioceramics are ceramic materials specially designed for its use in medicine and dentistry. They include alumina and zirconia, bioactive glass, glass ceramics, coatings and composites, hydroxyapatite and resorbable calcium phosphates, and radiotherapy glasses.[1, 2, 3] There are numerous bioceramics currently used in both dentistry and medicine. Bioceramics are widely used for orthopedic applications, for coatings to improve the compatibility of metal implants, and can function as resorbable lattices which provide a framework that is eventually dissolved as the body rebuilds tissue.[4] In dentistry, they are used for prosthetic dentures, filling bone defects, root repair and for apical retro fills.

HISTORY:

Systematic research of ceramics for use in biomedical applications started in the early 1970s and over the past 40years, the applicationof a variety of ceramics in biomedicine has greatly expanded (Kokubo, 2008). 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.

PROPERTIES:

Bioceramics are exceedingly nontoxic,biocompatible, do not shrink and are chemically stable with in the biological environment. Bioceramics will not result in an inflammatory reaction if over fill occurs during the obturation process or in a root repair. Ithas the ability to form hydroxyapatite and to create a chemical bond between dentine and appropriate filling materials. This property of bioceramics makes them very apt for dentistry. From a clinician'sperspective, the advantages of the bioceramics are its enhanced biocompatibility,potential increased strength of the root following obturation, strongly antibacterial, sealing ability and ease of use.

CLASSIFICATION

Bioceramics can be classified as [1-3,5]

1. BIOINERT: Non interactive with biological systems**.**

- Oxide ceramics

- Silica ceramics
- Carbon fiber
- Diamond-like carbon

2.BIOACTIVE: Durable tissues that can undergo interfacial interactions with surrounding tissue.

- Hydroxyapatite
- Bioactive glass (e.g. Bioglass)

3.BIODEGRADABLE, SOLUBLE OR RESORBABLE:
Eventually replace or incorporated into tissue.

4. IN OPERATIVE DENTISTRY AND ENDODONTICS

A. MINERAL TRIOXIDE AGGREGATE

MTA was introduced by Dr Torabinajed in1993. It is established as Osseo conductive, inductive, and biocompatible. It has been marketed as ProRoot 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, apexogenesis, apical barrier formation in teeth with open apexes, repair of root perforations , and as a root canal filling material.[6] MTA powder contains fine hydrophilic particles that set in the presence of moisture. It is currently available in grey and white forms. The primary difference between the grey and white forms is a lack of potassium and the presence of bismuth oxide. Grey form of MTA comprises of dicalcium and tricalcium silicate and bismuth oxide whereas white form consists of tricalcium silicate and bismuth oxide.[7] When mineral trioxide powder is mixed with water, calcium hydroxide and calcium silicate hydrate are initially formed which later converts into a poor crystallized and porous solid gel. The precipitated calcium forms calcium hydroxide which is the reason of high alkalinity of MTA after hydration.[8] It is an active biomaterial with the potential to interact with the fluids in the tissues. Bismuth oxide provides radioopacity.It is present in both hydrated and nonhydrated MTA. MTA has long setting time when compared to other materials, whichis their major drawback. The compressive strength of mineral trioxide aggregate is less when compared to other materials after 24 hours.[8,9] The compressive strength and push out bond strength reach their maximum several days after mixing because the hydration rate of dicalcium silicate is slower than tricalcium silicate.[8] The pH value of mineral trioxide aggregate is 10.2 after mixing and it rises to 12.5 at 3 hours.[8] A number of biocompatible and mutagenicity studies have confirmed that mineral trioxide aggregate is a biocompatible material. The success of MTA as root repair and apico retro fillingmaterialsis unquestionable but it has its own limitations of use. It does not come premixed, difficult to use on retrofills and large particle size that cannot be extruded through a small syringe. The more research in MTA lead to EndoSequence root repair material which is available as premixed putty or in a syringe. This helps in assuring proper mix and also eases of use. Endosequence root repair material has been created as whitepremixed cement for permanent root canal repairs and retro fillings. The advantages of this material are its high PH, high resistance to wash out,no shrinkage during setting, excellent biocompatibility and good physical properties. MTA has been proposed as a potential medicament for capping of pulps with reversible pulpitis because of its excellent tissue compatibility. [10,11,12]It is much superior to the routinely used calcium hydroxide based on the tissue reaction and the amount and type of Dentin bridge formed. With MTA, Dentin bridge after pulp capping was seen at about 1 week which steadily increased in length and thickness within 3 months of capping whereas following pulp capping with calcium hydroxide, the dentin bridge was less consistent and had numerous tunnel defects.[13]In a histological study by Jabbarifar et al[14]MTA was found to be a better choice aspulpotomymaterial along with bioactive glass when compared to hydroxyapatite and formacresol.Many materials have been used as root-end filling agents but the main disadvantage is their failure to prevent leakage and the lack of biocompatibility. MTA treated teeth exhibited significantly less inflammation, more cementum formation and regeneration of periradicular tissues.[15,16] Conventional management of an immature non vital permanent tooth is apexification with calcium hydroxide.The purpose of apexification is to obtain an apical barrier so as to prevent the extrusion of the obturating material.[17] But the disadvantage of using calcium hydroxide is the extended time taken for the completion of the procedure which may range anywhere between 3 to 54 months. This problem is solved with the use of MTA. An MTA plug of 4mm thickness placed at the apical region is adequate to form a barrier, sealingthe canal from the periapical area.[18,19]Mineral Trioxide Aggregatecan be used to obturate the root canal of aretained primary tooth where the succedaneous permanent tooth is absent. This technique is not recommended for obturation of primary teeth that are expected to exfoliate since it is anticipated that Mineral Trioxide Aggregate would be absorbed slowly. Lee and associates[20]found that MTAhad significantly less leakage and less tendency for overfilling or underfilling, when compared with amalgam and IRM.Torabinejad and Chivianhave suggested the use of MTA for sealing vertical root fractures. MTA can be used to provide coronal seal in a tooth that requires internal bleaching. A thickness of 3-4 mm of MTA placed over the condensed guttapercha in the access cavity prevents the ingress of bleaching agents.MTA is also successful in the formation of a dentin bridge that is thicker with lesser defects and side effects. MTA need to be explored by clinicians so that its beneficial properties can be extracted.

B. BIODENTINE

Biodentine was developed by septodonts research group as a new class of dental material which could conciliate high mechanical properties with excellent biocompatibility as well as a bioactive behavior. Its chemical composition is based on the Ca3SiO5-water chemistry which brings the high compatibility of already known endodontic repair cements,septodont increased the physico-chemical properties which makes biodentine. Clinically biodentine is easy to handle and biocompatible not only for the restorative procedures but also for the classical endodontic procedures. Biodentine turns out to be one of the most biocompatible materials of all the biomaterials in dentistry as demonstrated according to all the ISO standards, as well as in the different preclinical and clinical collaboration. 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 working time of biodentine is upto 6 minutes with a final set at around 10-12 minutes. 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. Biodentine has a consistency after mixing which enables manipulation with a spatula, with an amalgam carrier or with carriers which are used for endodontic cements in retrograde fillings. The superior mechanical property of biodentine is determined by the lower water content in the mixing stage. After the initial setting of biodentine the material continues to improve in terms of internal structure towards a denser material, with a decrease in porosity. There is a sharp increase in the compressive strength of the material in the first hour and reach upto 200Mpa at 24 hours which is more than glass ionomers. The bending resistance of biodentine is superior to GIC but much lower than the composite resins. 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.

C. BIOACTIVE GLASS

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, crushed powders 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}.$PO_4^{-3}$and Si^{+4} takes place at the glass surface. A polycondensated 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 was introduced in dentistry. Many variations in the original composition have made which are approved by FDA and termed bioglass such as 45S5, 58S and S70C30. Recent advances in nanomaterial fabrication have given access to complex materials in the form of amorphous nano particles of 20-60nm size.[21] Bioactive glass nanomaterial could be considered as a good option for the treatment of oral bone defects and root canal disinfection.[22]Bioactive glasses showed strong antibacterial effects for a wide selection of aerobic bacteria.[23] Antibacterial effect of the glasses increases with increasing pH and concentration of alkali ions and thus increased dissolution tendency of the glasses. Bioactive glass can be the material of choice for pulp capping and periapical bone healing because it is biocompatible and has antibacterial property. Studies show that bioactive glass can induce a healing/ recovery period during which restoration of pulpal morphology is attempted. Bioactive glass has the capacity to serve as inductive material for hard tissue formation and mineralization but it has been shown that the microscopic calcified bridge formed by Ca (OH)2does not constitute a continuous seal and may allow bacterial leakage through numerous defects. 45S5 particulate (NovaMin) containing is designed to occlude dentinal tubules and remineralize the surface of teeth, thereby eliminating the cause of dentinal hypersensitivity. In 2011 Glaxo-Smith-Kline acquired the NovaMin technology and has launched a superbly successful over the counter version of bioactive toothpaste called Sensodyne Repair and Protect that prevents dentinal pain sensitivity and inhibits gingivitis. It is an example of the use of bioactive materials as a preventative treatment— the latest revolution in healthcare.

D. BIOAGGREGATE

Bioaggregate root canal repair material is a biocompatible powder consists of ceramic particles.it is also available as DiaRoot root canal repair filling material.it is effective in blocking the bacterial infection. Its ease of manipulation and superior quality makes bioaggregate the most innovative and unique root canal repair material. It is indicated in repair of root perforation, repair of root resorption, root end filling, apexification and pulp capping. Upon mixing, the hydrophilic bioaggregate powder promotes cementogenesis and forms a hermetic seal inside the root canal. 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,[24] strong antibacterial properties against E.faecalis[25] and anti-fungal properties against C.albicans.[26]

E. CALCIUM PHOSPHATE CEMENT

It is a bioactive and biodegradable grafting material in the form of powder and liquid. When mixed, it sets primarily as hydroxyapatite. In vivo and in vitro studies show calcium phosphate cement as a promising material for grafting applications. 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.

F. CALCIUM HYDROXIDE BASED CEMENT

The first clinical use of calcium hydroxide as a root canal–filling material was probably by Rhoner in 1940.[27] It took another 20 years for calcium hydroxide to become popular for apexification, the sealing of perforations, and management of resorption. A ''miracle' material'' Biocalex (Laboratoire SPAD, Dijon, France),developed by French researchers, was believed to make radical changes to endodontic instrumentation methods. [28]Biocalex/Endocal is a root 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. It then goes on to combine with Co2 and become essentially Plaster of Paris. It was most popular in Europe during the 1980's, and although Biocalex 6/9 became available in the United States by the early 1990's, it attracted little attention. The calcium hydroxide based pulp-capping agent, Dycal (DENTSPLY-Caulk, Milford, DE), also became popular as a sealer among some clinicians in late 1970s. Shortly afterward, root canal sealers based on calciumhydroxide became available.[29] The rationale for the addition of calcium hydroxide to root canal sealers is from observations of bases and liners containing the material and their antibacterial and tissue repair abilities. When compared with zinc oxide eugenol (ZOE), AH 26 (Dentsply-Maillefer, Tulsa, OK), and Ketac-Endo (ESPE AG, Seefeld, Germany) sealers in dye leakage studies, Sealapex (SybronEndo, Orange, CA), CRCS (Coltene/Whaledent/Hygienic; Cuyahoga Falls, OH), and Apexit (Vivadent, Germany) showed no significant difference in leakage at 30 days to 32 weeks.[30-34] A recent Enterococcus faecalis bacterial leakage study with Sealapex showed 85% penetration at 30 days and 100% at 60 days. Although not statistically different to results with AH 26, AH Plus, and Ketac-Endo, Sealapex exhibited slower bacterial penetration than AH 26. In an animal study, Sealapex in tissue contact dissolved and was partially replaced by ingrowths of connective tissue.[35]Large quantities of sealer particles were noticed in cells and tissues at some distance from the sample. This was supported in a study by Soares et al[36] who reported the presence of disintegrated Sealapex sealer particles in macrophage cytoplasm away from the root-filling material in the periapical regions of dog teeth. Sealapex, CRCS, and Apexit performed poorly in dentin adhesion experiments irrespective of the presence of smear layer or methods of smear layer removal. At least for Sealapex, this was possibly because of its setting qualities. Sealer 26 showed better adhesiveness to dentin surfaces after the removal of the smear layer with EDTA or using an Er:YAG laser.Calcium hydroxide is effective in the formation of calcific bridges when applied to exposed pulpal tissue. When calcium hydroxide comes in contact with water, it releases calcium ions during ionic dissociation. The quantity of free calcium ions determines its potential to induce mineralized tissue. Free calcium ions are reported to be required for cell migration, differentiation, and mineralization. Torneck and co-workers[37] noted the importance of free calcium ions for the activation of calcium dependent ATPase. In laboratory-based experiments, CRCS showed very little initial release of calcium ions, while Sealapex demonstrated a higher dissociation of calcium but the sample disintegrated in 2 hours. Recently, Sealapex has been recommended as a root-filling material for primary teeth. In prospective clinical studies, Sealapex and Vitapex showed high success rates for pulpectomies.[38,39] The antibacterial effect of calcium hydroxide is based on its ability to release hydroxyl ions and to raise pH. The pH of calcium hydroxide paste has been shown to be as high as 12.5 when used for intracanal medicament purpose. Several studies using a similar test method depicted Sealapex, Dycal, and Apexit as only mildly antibacterial against many anaerobic and aerobic bacteria found in root canal systems. Sealapex was not quite as effective in the elimination of Enterococcus faecalis.[40] Dentinal tubule penetration tests have shown Sealapex and Apexit to be less effective in killing bacteria than resin and eugenol-based sealers. Direct contact tests of sealers and microorganisms concluded Sealapex and Apexit to be mildly effective antimicrobial agents over short duration.[41,42]Beltes et al. did an in vitro evaluation of cytotoxicity of calcium hydroxide based root canal sealers. Dycal has a very short setting time, and in its use as a root canal sealer users recommended first introducing the catalyst paste into the canal with a lentulospiral followed by a gutta-percha cone coated with the base paste. In contrast, Biocalex takes days to set. The setting reactions of calcium hydroxide–containing sealers are complex. CRCS sets within 3 days in both dry and humid environments. Sealapex sets in 2 to 3 weeks in 100% relative humidity and does not set in a dry environment.Apexit has exhibited high water sorption but along with its equally high solubility gives rise to minor overall dimensional change.[43] CRCS was quite stable with volumetric changes in water for 21 days. Sealapex displayed significant sorption in a 100% humid atmosphere with volumetric expansion.[44]Comprehensive studies found difficulties in the assessment of the quality of root canal fillings on radiographs because of the large variance in radiopacifiers. Radiographs of samples of Sealapex showed large voids in their structure, and they were less radiopaque than CRCS for 3 weeks, after which the voids disappeared and there was an increase in radiopacity for Sealapex.[44]The radiopacity for Sealapex was explained by the addition of bismuth trioxide in the recent formulation.

CONCLUSION

Bioceramics has evolved to become an integral part of our modern dental health care delivery systems. The full potential is only beginning to be recognized.The advantages of bioceramics are its biological compatability and antimicrobial properties.Bioceramics offer a new treatment options for improving prognosis in many operative and endodonticprocedures. It surpasses many traditionally used materials such as calcium hydroxide.Research is being done to improve the properties of bioceramics so that it can more widely used.

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