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Bioceramics in Endodontics: A Literature Review

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Abstract

Alumina, Zirconia, Bioactive Glass, Glass Ceramics, Hydroxyapatite, and Resorbable Calcium Phosphates are a few examples of materials that fall under the category of Bioceramics. They have been employed in dentistry as endodontic sealers, bone defect fillers, root repair materials, apical fill materials, perforation sealers, and regeneration aids. They offer some benefits, including biocompatibility, non-toxicity, dimensional stability, and most significantly, being bio-inert for endodontic applications. They are comparable to hydroxyapatite, have intrinsic osteoconductive activity, and can trigger the body's healing processes. They can be broadly categorised in endodontics as either calcium phosphate/tricalcium/hydroxyapatite based, calcium silicate based, or calcium phosphate and silicate based mixtures. This paper concentrates on a summary of bioceramics, their classification, and benefits. Additionally, it provides a thorough understanding of the various bioceramic materials currently employed in the field of endodontics, as well as their characteristics and uses.

Keywords: *Bioceramics, Endodontics, Application of Bioceramics.*

Introduction

With the introduction of new materials and techniques, the discipline of dentistry is constantly expanding. One of the recently developed materials that has transformed dentistry is bio-ceramics.[1] A form of biomaterial having the best biocompatibility for usage in medical and dental applications is referred to as bioceramics. They consist of radiotherapy glasses, coatings, composites, hydroxyapatite, zirconia, bioactive glass, and resorbable calcium phosphate.[2] In dentistry, bioceramic materials were originally introduced in the 1990s as root healing cements and then as retrograde filling materials. Within the biological environment, bioceramics are typically chemically stable, non-toxic, and biocompatible.[3] The success rate of dental procedures such pulp capping, pulpotomy, apexification, apicoectomy, and restoration of defects brought on by unintentional perforation and resorption has significantly increased as a result of the introduction of bioceramic-based materials. This study focuses on the physico-chemical, biological, and therapeutic applications of modern bioceramic materials that can either operate as human tissues or resorb and promote the regeneration of natural tissues. [4,5]

In the 1990s, endodontists began using bioceramic-based materials as retrograde fillings, root healing cements, root canal sealers, and coatings for gutta-percha cones. The physico-chemical and biological characteristics of bioceramic materials have the potential to be advantageous in endodontics. Within the biological environment, bioceramics are typically chemically stable, non-toxic, and biocompatible.[4] These materials also have the benefit of forming hydroxyapatite, which leads to a connection between the substance and the dentin.

Mineral trioxide aggregate (MTA) has been acknowledged as the gold-standard material for a variety of clinical situations since the introduction of bioceramic materials into clinical endodontics. Because of its exceptional physico-chemical and biological properties, MTA may be the closest thing to the ideal reparative material. With their high physico-chemical qualities and biocompatibility, bioceramic materials are frequently used in endodontic treatments. They have the advantages of improved biocompatibility, potential increased root strength following obturation, antibacterial qualities, and sealing ability. They can be used as cements, root healing materials, root canal sealers, and filler materials.[6]

Classification: In addition to being nontoxic, bioceramics can be classified as:[7-10]

1. Bioinert: Noninteractive with biological systems (zirconia and alumina)
2. Bioactive: Interactive with surrounding tissues to encourage the growth of durable tissues (glass and calcium phosphate)
3. Biodegradable, soluble, or resorbable: Eventually replaces or gets incorporated into tissue. Particularly important with lattice frameworks.

Bioceramics in Endodontics

Calcium Silicate Based Bioceramics

Portland cement: Portland cement (PC), which was created in 1824 by Joseph Aspdin, was patented. It was made by calcination a mixture of limestones from Portland and silicon-argillaceous minerals. Except for the absence of bismuth oxide and higher concentrations of calcium aluminate and calcium sulphate, PC and MTA have a similar main composition. PC is also a cheap material. PCs with MTA-like features come in grey and white.[11,12]

According to Vivaan et al., greater solubility is seen with MTA when compared to white PC. [13] It also showed better washout resistance compared to MTA in different solutions.[14] Bioactivity-Maturation of MTA after hydration is more structured than PC hence the former displays better bioactivity.[15]

Mineral trioxide aggregate (MTA):

The MTA cement, which was created by Dr. Torabinejad in 1993, was the first bioceramic material to be successfully employed in endodontics. It is biocompatible, inductive, and osseoconductive. This substance was initially created and suggested for use as a root-end filling substance, but it has since been utilised for pulp capping, pulpotomy, apexogenesis, the construction of an apical barrier in teeth with open apexes, the healing of root perforations, and as a root canal filling substance.There was just one MTA material made of grey coloured powder (GMTA) available until 2002. In order to remedy the tooth discolouration brought on by GMTA, white MTA (WMTA) was released as Pro Root MTA (Dentsply Endodontics, Tulsa, OK, USA) in that year.[16]

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. [17,18]

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).[17] 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. The presence of gypsum is reported to be the reason for the extended setting time.[19]

Biodentine:

In 2009, Septodont, Saint Maur des Fosses, France, introduced "Biodentine," a calcium silicate-based product. The material is created utilising MTA-based cement technology, which has improved some of the handling and physical characteristics of these types of cements.[20]

With the development of calcium hydroxide and calcium silicate gel, Biodentine's setting reaction is comparable to MTA. However, calcium carbonate serves as a nucleation site for calcium-silicate-hydrate gel, shortening the induction period and enhancing the microstructure as a result. The hydrosoluble polymer makes the cement less viscous and easier to handle.

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. Better handling, which is more suitable to clinical application than MTA, is ensured by consistency. superior mechanical characteristics than MTA. Not necessitate a two-step restoration process like the MTA. As the setting is faster, there is a lower risk of bacterial contamination than with MTA.[21,22]

Theracal LC:

Theracal LC is a single paste calcium silicate-based material promoted by the manufacturer for use as a pulp capping agent and as a protective liner for use with restorative materials, cement, or other base materials. This material has been classified as a 4th generation calcium silicate material. According to ISO 9917-2017-part 2 clause 4.1, TheraCal LC is a class 2 cement material "in which the setting reaction of the polymerizable component is light activated." TheraCal is a radiopaque light-cure, resin-modified calcium silicate cement, promoted as a pulp-capping cement with an ability to stimulate apatite-like precipitates and dentinal bridging.[5]

Ceraseal:

CeraSeal (Meta Biomed Co., Cheongju, Korea) is a newly launched premixed endodontic sealer containing calcium silicates, zirconium oxide, and thickening agent. According to the manufacturer, CeraSeal is hydraulic calcium silicate– based sealer, which possesses superior sealing ability. Moisture in the dentinal tubules and calcium silicate's chemical reaction produce crystallization of calcium hydroxide. The material guarantees the hermetic seal of the root canal and prevents the influx and propagation of bacteria.The material is dimensionally stable, does not shrink or expand in the root canal, and prevents from root infractions or fractures by keeping its stable volume. The single-cone obturation technique can be used with this material. Due to the shorter setting time, the material is highly resistant to the washout.[5]

Calcium Phosphates/Tricalcium Phosphate/Hydroxyapatite Based Bioceramcis: Triple calcium phosphate, when used in bony defects, promotes osteogenesis. In 1971, calcium-and-phosphate-containing glass ceramic, referred to as bioglass, was developed, and it showed that it “chemically” bonds with the host bone. [10]

Mixture of Calcium Silicates and Calcium Phosphates: EndoSequence Root Repair Material (ERRM) or Bioceramic Root Repair Material (BC RRM) [trade names- iRoot BP, iRoot BP plus, iRoot FS] (Innovative Bioceramix Inc., Vancouver, Canada).[10]

Experimental Calcium Alumino Silicates [23]

- EndoBinder: It is a new calcium aluminate-based endodontic cement, seen as presenting a satisfactory tissue reaction.
- Generex A: It is a calcium silicate-based material that mixes to a dough-like consistency, making it easy to be rolled into a rope-like mass similar to an intermediate restorative material.
- Capasio: It comprises bismuth oxide, dental glass, and calcium alumino-silicate with a silica and polyvinyl acetate-based gel, showing mineralization properties.
- Quick-set: Capasio powder has been refined and renamed as Quick-set (Primus Consulting), and it possesses negligible in vitro toxicological risks after time-dependent elution of toxic components

Desirable Properties of Bioceramic Materials

Short Setting Time:

The amount of time it takes for a material to change from a fluid condition to a hardened state is known as the setting time. For bioceramic materials to set, moisture is typically needed. While a long setting time may make it difficult to maintain the mixture's consistency, a short setting time can aid in creating a tight seal between the root canal system and the periodontium.[5]

High Mechanical Strength:

The amount of uniaxial compressive stress that a material can withstand before fully failing is its compressive strength. According to reports, a root healing material with high compressive strength may be able to endure loads that cause deformation and shrinking.[17]

Another sort of mechanical strength is flexural strength, which is the capacity of a material to withstand deformation under a force. Because tooth movement during function may cause the material to come loose after perforation repair, push-out strength is a crucial property for materials used in perforation repair.[24]

Antibacterial effect

Root canal therapy typically decreases but does not always completely eradicate all germs. There have been reports of bacteria remaining following root canal therapy in the dentinal tubules, lateral canals, and apical ramifications. Therefore, it is advantageous if the endodontic materials used to seal the root canal have enduring antibacterial activity. The ability of bioceramic materials used in endodontic procedures to eradicate bacteria in diseased dentin canals has received scant attention thus far. The standardised dentin infection model, on the other hand, provides a great deal of promise to demonstrate the antibacterial activity of endodontic bioceramics against dentin infection.[5]

Biomineralization:

An ideal biomaterial used in endodontics should stimulate and modulate the biomineralization process to properly seal the margin of a tooth defect, so that the newly formed barrier of mineralized tissue can protect the root canal from bacteria and toxins.23

Application of Bioceramics in Endodontics [25-27]

- Sealers
- Obturation
- Perforation repair
- Retrograde filling
- Pulpotomy
- Resorption
- Apexification
- Regenerative endodontics
- Restorative uses- Dentin substitute, pulp capping, dentin hypersensitivity, dentin remineralization

Conclusion

While MTA served as the industry standard in bioceramic materials, improvements have been made in an ongoing effort to address its drawbacks and enhance its characteristics. There are now numerous uses for bioceramics in restorative and endodontic dentistry. To ensure the selection of the most appropriate material in various clinical settings, it is crucial to have up-to-date understanding of these new bioactive materials.

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