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Review Article

Bioceramics in endodontics – A review

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ABSTRACT

The field of dentistry is constantly changing with the introduction of new materials and techniques that resulted in good treatment outcome.Bio-ceramics are amongst the recently introduced materials which have changed the face of dentistry. Bioceramics are biocompatible, nontoxic, non-shrinking and usually chemically stable within the biological environment.The development of bioceramic based materials has greatly improved the dentist's possibilities to successfully treat cases such as pulp capping, pulpotomy, apexification, apicoectomy and repair of defects caused by accidental perforation and resorption. The application of bioceramic materials has changed both surgical and non- surgical endodontic treatment, providing a promising direction for the preservation of patients' teeth.

1. Introduction

The field of dentistry is ever evolving with the advent of new materials and techniques.Bio-ceramics are amongst the newly introduced materials which have changed the face of dentistry.[1]

Bioceramics are defined as a type of biomaterial with optimal biocompatibility for use for medical and dental purposes. They include alumina, zirconia, bioactive glass, coatings, composites, hydroxyapatite and resorbable calcium phosphate and radiotherapy glasses.[2] In Dentistry, Bioceramic materials were introduced in the 1990's , first as retrograde filling materials , then as root repair cements. Bioceramics are biocompatible, nontoxic, non-shrinking and usually chemically stable within the biological environment.[3] This development of bioceramic based materials has greatly improved the dentist's possibilities to successfully treat cases such as pulp capping, pulpotomy, apexification, apicoectomy and repair of defects caused by accidental perforation and resorption. This review focuses on the physico-chemical, biological properties of current bioceramic materials and their clinical applications that have the ability to either function as human tissues or to resorb and encourage the regeneration of natural tissues.

2. Bioceramics in Endodontics

Bioceramic based materials were introduced to endodontics in the 1990s, first as retrograde filling materials and then as root repair cements, root canal sealers, and coatings for gutta-percha cones. The potential advantages of bioceramic materials in endodontics are related to their physico-chemical and biological properties. Bioceramics are biocompatible, non-toxic, non-shrinking, and usually chemically stable within the biological environment.[4] A further advantage of these materials is their ability to form hydroxyapatite and ultimately create a bond between dentin and the material.

Following the introduction of bioceramic materials into clinical endodontics, mineral trioxide aggregate (MTA) has become recognized as the gold-standard material for a variety of clinical situations and is perhaps closest

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to the ideal reparative material, due to its excellent physico-chemical and biological properties.[5] Bioceramic materials, with their biocompatible nature and excellent physico-chemical properties, are widely used in endodontic applications. They can function as cements, root repair materials, root canal sealers and filling materials, which have the advantages of enhanced biocompatibility, potential increased root strength following obturation, antibacterial properties and sealing ability.

2.1. Classification

Bioceramics have been classified based on:-

2.1.1. Origin

1. Natural
2. Synthetic

2.1.2. Tissue response

1. Bioinert
2. Bioactive- Resorbable, Non-resorbable

2.1.3. Composition

1. Alumina based
2. Zirconia based
3. Carbon based
4. Turbostratic
5. Graphene
6. Diamond like carbon
7. Calcium phosphate based
8. Hydroxyapatite
9. Silica based

Crystallinity- Crystalline, Amorphous

2.2. Properties

Bio ceramics plays a major role in dentistry because of its following properties.[6]

1. Bio ceramics are exceedingly nontoxic, biocompatible do not shrink and are chemically stable within the biological environment.
2. Bioceramics will not result in an inflammatory reaction if over fill occurs during the obturation process or in a root repair.
3. It also has the ability to form hydroxyapatite and to create a chemical bond between dentine and appropriate filling materials.

3. Desirable Properties of Bioceramic Materials[5]

3.1. Physico-chemical properties

3.1.1. Short setting time

Setting time is the length of time for a material to transition from a fluid state into a hardened state. The presence of moisture is usually required for bioceramic materials to set. A short setting time can help facilitate a tight seal between the root canal system and the periodontium, while a long setting time may result in difficulties with maintaining consistency of the mixture.

3.1.2. High mechanical strength

The compressive strength of a material is the value of uniaxial compressive stress reached when the material fails completely. It has been reported that high compressive strength of a root repair material could enable it to withstand loads tending to deformation and shrinkage.[7]

Flexural strength is another type of mechanical strength which is defined as a material's ability to resist deformation under a load.

Push-out strength is an important attribute for materials used in perforation repair, because tooth movement in function may dislodge the material after perforation repair.[8]

3.1.3. High alkaline pH and calcium ion release

It has been suggested, by both in vitro and in vivo studies, that the mechanism of pulp wound healing by the deposition of mineralized apatite depends on pH and the ability of calcium ion-release.[9] Moisture facilitates the hydration reactions of calcium silicates to produce calcium silicate hydrogel and calcium hydroxide, which partially react with the phosphate to form hydroxyapatite and water .

3.1.4. High radiopacity, moderate flow, low porosity and solubility

RADIOPACITY is an essential physical property which allows the viewing of endodontic filling materials by radiographic examination, in order to check the obturation quality. An ideal root canal filling and sealing material should have certain degree of radiopacity to be clearly visible on radiographs.

Flow is the ability of cement to penetrate into the irregularities and accessory canals of the root canal system and is considered to be an important physical property. The greater the flow, the better the ability to penetrate into irregularities. The flow ability is also influenced by the size of the particles—the smaller the particles, the greater the flow. However, if the flow is excessive, the risk of material extravasations to the periapical area is increased, which could damage periodontal tissues and compromise healing. Thus, a moderate flow is preferred for the cement to access the areas that need to be filled.[10]

Solubility is another factor in assessing the suitability of materials used as restorative materials in dentistry. Lack of solubility is a desired characteristic for root- end filling materials and materials used for perforation repair.[7]

3.2. Biological properties

3.2.1. Biocompatibility

Materials used in endodontics are frequently placed in intimate contact with the pulp or periodontium and thus must be non-toxic and biocompatible with host tissues. There are different in vitro and in vivo tests to evaluate the biocompatibility of dental materials. The in vitro tests include evaluating the cytotoxicity profile of potential materials using different cell lines (DC-27, MDPC-23, Od-21 etc.) and the 3-(4,5- dimethylthiazol-2-yl)-2,5 diphenyltetrazolium bromide (MTT) assay , flow cytometry using cell viability staining , and tests for the ability of cells to grow and populate on the surface of a material. The in vivo tests comprises of usage tests in experimental animals, according to accepted clinical protocols, followed by histological examination

3.2.2. Stimulation of biomineralization

An optimal material used for endodontic purposes, such as pulp capping, perforation repair, or root-end filling, not only provides an effective seal, but also induces chemical bond formation and apatite precipitation in dentin over time.[11] Biomineralization is likely to facilitate healing at the material-tissue interface, resulting in the elevation of local pH, the release of mineral ions and formation of apatite-like structures. The apatite crystals grow within collagen fibrils, promoting controlled mineral nucleation on dentin and triggering the formation of an interfacial layer at the material-dentin interface. 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.

3.2.3. Induction of pulp cell differentiation

Severe pulp exposure and the destruction of the underlying odontoblast layer may, under specific conditions, initiate regeneration of the pulp-dentin complex through progenitor cell recruitment and differentiation into secreting cells and the stimulation of reparative dentinogenesis. The main objective in using a bioactive material for this reparative and healing process is to form a barrier of mineralized tissue to protect the pulp from further leakage. Clinically, the objectives of treatments such as direct pulp capping and pulpotomy are to seal the pulp wound, induce odontoblast-like cell differentiation and stimulate dentin secretion in order to build a dentin bridge.

3.2.4. Antibacterial activity

Root canal treatment reduces but usually does not eliminate all microbes. The persistence of microorganisms in dentinal tubules, lateral canals and apical ramifications after root canal treatment have been reported. Therefore, it is considered beneficial if endodontic materials that are permanently sealed in the root canal have long-lasting antibacterial activity. So far, little evidence is available showing that bioceramic materials used for endodontic purposes can kill bacteria in infected dentin canals. However, the standardized dentin infection model has great potential to reveal the antibacterial activity of endodontic bioceramics against dentin infection.

3.3. Applications of bioceramics in endodontic procedures

1. Pulp capping
2. Pulp chamber pulpotomy
3. Apexification procedures
4. Perforation repair
5. Repair of resorptive defects
6. Endodontic surgery procedures
7. Revitalization procedures

3.4. Bioceramic cements

3.4.1. Mineral trioxide aggregate

Mineral trioxide aggregate (MTA) was first described in the scientific literature in 1993 as an aggregate of mineral oxides added to “trioxides” of tricalcium silicate, tricalcium aluminate, and tricalcium oxide, silicate oxide.

Dr. Mahmoud Torabinejad at Loma Linda University and his co-inventor Dean White obtained two US patents for a Portland cement-based endodontic material, which came to be known as Mineral Trioxide Aggregate (MTA).[12]

3.4.2. Mta composition

MTA is comprised primarily of Portland cement[13]

3.4.3. Powder

1. Purified Portland cement
2. Mixture of dicalciumsilicate [Ca2SiO4](75%),
3. Tricalciumsilicate[Ca3SiO5],
4. Tricalciumaluminate[Ca3Al2O6],
5. Calciumsulphate[CaSO4,gypsum], (5%)
6. Tetra-calcium aluminoferrite [4CaOAl 2O 3Fe 2O 3])
7. Bismuth oxide (20%)
8. Small quantities of SiO2, CaO, MgO, K2SO4, and Na2SO4

3.4.4. Liquid

1. Distilled water

3.5. Clinical applications

Many studies have shown successful clinical outcomes with MTA used in direct pulp capping, pulpotomy, rootend filling, apexification, and repair of perforations.

Table 1: Clinicalapplications of MTA

Clinical applications	Related studies
Pulp capping	Permanent teeth: Witherspoon DE[14] concluded that MTA is a good substitute of Ca(OH)2 for vital pulp therapies because it stimulates a higher and greater quality and quantity of reparative dentin and also aids superior long term sealing ability
Pulpotomy	Permanent teeth: Belobrov I et al,[15] 2008 revealed that MTA pulpotomy forms a dentine bridge completely and maintains the vitality of the radicular pulp by limiting the inflammation.
Perforation repair (Furcal or root)	Permanent teeth: Arens DE and Torabinajad M[16] found that MTA promotes bone healing and eliminates the signs of inflammation, hence, MTA can be considered as an alternative option for repair of furcal perforations both in primary and permanent teeth.
Root end filling	Permanent teeth: Christiansen R et al.,[17] 2009 found that healing of teeth treated with MTA as root end filling material had significantly better healing (96%) than those treated with orthograde GP filling (52%).
Root canal filling	Permanent teeth:Bogen G and Kuttler S 2009[18] (obturation with MTA seemed to provide a biocompatible seal of root canal system).
Resorption	Permanent teeth: Silveria FF et al.,[19] treated a double "Pink tooth" with MTA as root canal filling material and found favourable results after 18 months. Hence, MTA may be suitable material for treatment of internal resorption.

3.6. Drawbacks of MTA

1. Long setting time - Torabinajad M et al.,MTA[18] showed longest setting time when compared to that amalgam.
2. Difficult handling - Mooney GC and North S[20] observed that the manipulation of MTA was messy when the moisture was excessive and hence difficult to use
3. Toxic elements in Composition - Asgary S et al.[16] found that MTA contains
4. Elements like arsenic which could potentially cause toxicity).
5. High cost

3.7. Biodentine

"Biodentine" is a calcium silicate based product, specifically designed as a "dentine replacement" material. Biodentine, known as "dentine in a capsule", is a "biocompatible and bioactive dentine substitute" which does not have the draw backs of Calcium hydroxide and Mineral trioxide aggregate. It became commercially available in 2009 by Septodont. The material is actually formulated using the MTA- based cement technology and includes the improvement of some properties, such as physical qualities and handling.

It is quoted by Mark Hargreaves et al[21] that biodentine allows a dentist to achieve biomimetic mineralisation within the depths of a carious cavity. Biodentine has a potential to revolutionise the management of the deep carious cavity in operative dentistry whether or not the pulp is exposed. Appreciable properties of biodentine include good physical properties and its ability to stimulate tissue regeneration as well as good pulp response.

3.8. Composition

3.8.1. Powder

1. Tricalcium silicate ($3CaO.SiO_2$),
2. Dicalcium silicate ($2CaO.SiO_2$),
3. Calcium carbonate ($CaCO_3$),
4. Calcium oxide (CaO),
5. Zirconium oxide (ZrO_2)

3.8.2. Liquid

1. Water
2. Calcium Chloride ($Cacl_2$),
3. Hydrosoluble polymer (Plasticizing agent)

3.8.3. Unique features

1. High purity due to monomer free composition.
2. Highly biocompatible and bioactive.
3. Short setting time of 10-12 minutes.
4. Easy material handling.
5. Versatile to use, requires no preparation or bonding procedure and does not stain.
6. Superior mechanical properties-mechanical properties are comparable to sound dentine.
7. Excellent sealing properties with ability to form mineral tags in the dentinal tubules and outstanding micro leakage resistance, enriched by the absence of shrinkage due to resin free formula.
8. Excellent antibacterial properties-the calcium hydroxide ions released from the set Biodentine result in high alkaline pH which promotes an inauspicious environment for bacterial growth and leads to the disinfection of contiguous hard and soft tissues.
9. Cost effective in contrast to similar material.

3.9. Bioaggregate

Bioaggregate is an endodontic repair calcium silicate cement, which is considered as a modified version of MTA. BioAggregate root canal repair filling material has been successfully developed as new generation of a dental root canal filling material by Innovative BioCeramix Inc. (IBC), which is a fine white hydraulic powder cement mixture for dental applications. It utilizes the advanced science of nano-technology to produce ceramic particles that, upon reaction with water produce biocompatible and aluminum-free ceramic biomaterials. Upon mixing, the hydrophilic BioAggregate Powder promotes cementogenesis and forms a hermetic seal inside the root canal. It is effective in clinically blocking the bacterial infection, its ease of manipulation and superior quality makes BioAggregateis indicated in: repair of root perforation, repair of root resorption, root end filling, apexification, and pulp capping.

3.9.1. Advantages

BioAggregate is new generation of a root canal repair filling materialIt is a contamination-free and aluminum-free ceramic biomaterial.

It has excellent handling characteristics after mixing with water.

It has good radiopaque properties.

3.10. Clinical applications

Bioaggregate is indicated for

Root perforation repair and root resorption repair

Root-end filling

Apexification,

Pulp capping.

3.11. Theracal

Theracal LC is a single paste calcium silicate-basedmaterial promoted by the manufacturer for use as a pulpcapping 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 lightactivated."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.

3.11.1. Composition

1. Light cure paste consists of
2. Type III Portland cement,
3. Strontium glass,
4. Fumed silica,
5. Barium sulfate ($BaSO_4$),
6. Barium zirconate ($BaZrO_3$)
7. Resin-containing bisphenol A glycidyl methacrylate (Bis-GMA) and poly dimethacrylate (PEGDMA)

3.12. Clinical applications

Recommended usage of TheraCal as direct and indirect pulp capping material a restorative liner and base.

As TheraCal is off-white in color, used as a thin layer is recommended to avoid esthetic problems and shading under resin composite restorations.

3.13. Calcium enriched cement

A novel endodontic cement named calcium-enriched mixture (CEM) cement was introduced to dentistry in 2006 by Agsary et al as a tooth-colored, water-based endodontic repair cement with similar applications to MTA, but with a different chemical composition. It has the ability to promote hydroxyapatite formation in saline solution and might promote the process of differentiation in stem cells and induce hard tissue formation. This material has an antibacterial effect comparable to calcium hydroxide and better than MTA or Portland cement (PC).[22]

3.14. Composition

3.14.1. Powder

1. Calcium oxide (CaO),
2. Sulfur trioxide (SO_3),
3. Phosphorous pentoxide (P_2O_5),
4. Silicon dioxide (SiO_2)
5. Trace amounts of aluminum trioxide (Al_2O_3), sodium oxide (Na_2O), magnesium oxide (MgO), and chloride (Cl)

3.14.2. Liquid

1. Distilled water

3.14.3. Clinical applications

1. Direct pulp capping
2. Indirect pulp capping
3. Pulpotomy
4. Root end filling material
5. Furcation perforation repair
6. Apexification
7. Repair of root Resorption
8. Apexogenesis

4. Endosequence Root Repair Material / iRoot BP Plus

EndoSequence root repair material (ERRM) (Brasseler USA, Savannah, GA) is a new bioceramic material delivered as a premixed mouldable putty (also labeled as iRoot BP Plus) or as a preloaded paste in a syringe.

iRoot FS is one of the iRoot series bioceramic materials developed for permanent root canal repair. iRoot FS has improved handling properties and shorter setting times (Brasseler USA, Savannah, GA).[23]

4.1. Composition

Ready-to-use paste or putty Composed of

1. Tri and di calcium silicates (Ca_2SiO_4)
2. Monobasic calcium phosphate ($Ca[H_2PO_4]_2$)
3. Zirconium oxide (ZrO_2)
4. Tantalum oxide (Ta_2O_5)
5. Proprietary fillers, and thickening agents

4.1.1. Clinical applications

Perforation repair, apical surgery, apical plug, and pulp capping have been promoted as suitable uses for ERRM.

4.1.2. Bioceramic sealers

The main functions of root canal sealers are

1. Sealing off of voids, patent accessory canals, and multiple foramina,
2. Forming a bond between the core of the filling material and the root canal wall, and
3. Acting as a lubricant while facilitating the placement of the filling core and entombing any remaining bacteria.

There are two major advantages associated with the use of bioceramic materials as root canal sealers. Firstly, their biocompatibility prevents rejection by the surrounding tissues. Secondly, bioceramic materials contain calcium phosphate which enhances the setting properties of bioceramics and results in a chemical composition and crystalline structure similar to tooth and bone apatite materials, thereby improving sealer-to-root dentin bonding. One major disadvantage of these materials is in the difficulty in removing them from the root canal once they are set for later retreatment or post-space preparation.[24]

4.1.3. Mechanism of action

1. Diffusion of the sealer particles into the dentinal tubules (tubular diffusion) to produce mechanical interlocking bonds.
2. Infiltration of the sealer's mineral content into the intertubular dentin resulting in the establishment of a mineral infiltration zone produced after denaturing the collagen fibres with a strong alkaline sealer.
3. Partial reaction of phosphate with calcium silicate hydrogel and calcium hydroxide, produced through the reaction of calcium silicates in the presence of the dentin's moisture, resulting in the formation of hydroxyapatite along the mineral infiltration zone.

5. Endosequence BC sealer / iroot SP

EndoSequence BC Sealer (also known as iRoot SP root canal sealer) is a premixed ready-to-use injectable bioceramic cement paste developed for permanent root canal filling and sealing applications. EndoSequence BC Sealer is an insoluble, radiopaque and aluminum-free material based on a calcium silicate composition, which requires the presence of water to set and harden.

5.1. MTA fillapex

MTA Fillapex (Angelus SolucoesOdontologicas, Londrina, PR, Brazil) is a recently introduced calcium silicate-based bioceramicsealer . MTA Fillapex was created in an attempt to combine the physico-chemical properties of a resin-based root canal sealer with the biological properties of MTA.

5.1.1. Composition

The composition of MTA Fillapex after mixture is mineral trioxide aggregate, salicylate resin, natural resin, bismuth, and silica.

5.2. BioRoot RCS

More recently, a new tricalcium silicate-based sealer was introduced in 2015, BioRoot RCS (Septodont, SaintMaur-des-Fosses, France). It is a water-based sealer.

5.2.1. Composition

Bioroot is composed of tricalcium silicate and zirconium oxide. BioRoot RCS releases calcium hydroxide after setting, which was absent in MTA Fillapex. BioRoot RCS leaches high levels of calcium exhibiting double the calcium ion leaching compared with EndoSequence BC Sealer. It also forms a calcium phosphate phase when in contact with physiologic solution.

Setting time: As proposed by the manufacturer, working time is 10 mts and setting time is 4 mts.

Manipulation: It has powder and liquid that can be hand mixed on a mixing pad.

5.2.2. Physical properties

1. BioRoot RCS exhibited significantly more percentage of voids than AH Plus.
2. There was no difference in fluid flow and microsphere penetration. BioRoot RCS exhibited a different pattern of sealer penetration and interaction with the dentine walls compared to AH Plus.
3. pH value is greater than 11 .
4. Has 5mm Al radiopacity.

5.3. Biological property

BioRoot RCS has less toxic effects on periodontal ligament cells than Pulp Canal Sealer (SybronEndo, Orange, CA, USA) and induced secretion of angiogenic and osteogenic growth factors indicating a higher bioactivity than Pulp Canal Sealer.

5.3.1. 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. CeraSeal induce a high degree of $Ca2+$ release. This product characteristically cures slowly by absorbing the ambient water inside the root canal. It is white and esthetic. CeraSeal setting time is approximately 3.5 h, material possesses high pH of 12.73, flowability—23 mm, and radiopacity (equivalent to 8 mm of Al).

5.4. Recent developments

5.4.1. The Use of hydraulic calcium silicate cements (HCSCs) for revitalization

MTA has been the material of choice for most cases of revitalization in immature teeth after pulp necrosis and used to cover the blood clot.[25]

Regardless of its clinical success over a long number of years, MTA has several drawbacks. Besides the potential of discoloration of bismuth oxide containing materials, other drawbacks of MTA include a long setting time of up to 3 h, difficult handling, and high cost.

To overcome these disadvantages, optimized formulations of HCSCs have been introduced. Hydraulic cements have specific properties which are not shared with other dental materials, and specifically the setting properties of hydraulic cements are improved in the presence of moisture.

The hydraulic cements available in clinical practice are no longer simple mixtures of Portland cement and bismuth oxide radiopacifier, mixed with water. There have been significant material modifications. The main four components of hydraulic cement systems are the cement, radiopacifier, the vehicle and the additives. Variations to these components create the different types of hydraulic cements.

5.5. Newer sealers

5.5.1. Injectable hydraulic calcium silicate–based sealers

Injectable hydraulic calcium silicate–based sealers have been material developed for sealing during root canal treatment. These are available in a single syringe mode, and the main components include calcium silicates, calcium aluminate, calcium oxide, zirconium oxide, iron oxide, silicon dioxide, and dispersing agents.(Eg ; Well-Root ST, Bio-C Sealer).[26]

Overall, approximately 65% of the material is composed by bioceramic particles, while the polyethylene glycol is used to achieve the viscosity of the material and facilitate its removal and cleaning after obturation procedures. Bioactivity is attributed to the release of calcium ions that stimulate the formation of mineralized tissue. They can be used with different root canal obturation techniques, including a single-cone.

6. Sealers using Active Biosilicate Technology

Sealers have been developed which utilizes the Active Biosilicate Technology. This unique technology allows transforming the raw material to the pure tricalcium silicate, without any presence of aluminate and calcium sulfate in the final product. (BioRoot RCS -Septodont)

These sealers havebeen reported to induce in vitro the production of angiogenic and osteogenic growth factors by human periodontal ligament cells; moreover, it has a lower cytotoxicity than other conventional root canal sealers, may induce hard tissue deposition, and has antimicrobial activity.

These are bioactive by stimulating bone physiological process and mineralization of the dentinal structure. Therefore, they creates a favorable environment for periapical healing and bioactive properties including biocompatibility, hydroxyapatite formation, mineralization of dentinal structure, alkaline pH, and sealing properties.

These simplify the obturation techniques of root canal, by ease of mixing and use, its optimized consistency, and elimination of the need for a warm gutta-percha technique.

They can be used with cold root canal filling techniques, as the heat generated during thermoplastic obturation can negatively affect the flowability and film thickness of the material. In recent times, the single-cone technique was suggested for use with hydraulic calcium silicate cements.

6.1. Bioceramic-coated (bc) gutta- percha points for root canal obturation

There is still the lack of solid scientific evidence that BC gutta-percha points in conjunction with hydraulic calcium silicate–based cements ensure significantly better root canal sealing in comparison to conventional gutta-percha and hydraulic calcium silicate cements fillings. It has been claimed that standard gutta-percha points can be used with BC Sealer or TotalFill, but for a tight, gap-free seal, manufacturers recommend use BC Points . BC Points are impregnated and coated with bioceramic nanoparticles to allow for bonding with BC Sealer producing the uniform monoblock inside the root canal space. The benefit of using BC Sealer and BC Points is that three-dimensional bonded root canal obturation can be achieved at body temperature.[(25)]

6.2. Temporary bioceramic–based root canal dressing materials

The temporary antibacterial root canal dressing materials are widely used during the endodontic treatment of the teeth with pulp necrosis and apical periodontitis as well as management of endodontic complications. The calcium hydroxide was the material of choice for the interappointment root canal filling used to maximize the root canal disinfection.

The BIO-C TEMP is the first ready-to-use bioceramic-based paste for intracanal dressing. According to the manufacturer, the for conventional calcium hydroxide dressing material is recommended to use as a substitute for conventional calcium hydroxide dressing.[27]

The indications for use are intracanal dressing for endodontic treatment in teeth with pulp necrosis and retreatments—intracanal dressing in teeth with perforations,external and internal resorptions, prior to the use of root repair materials or the apexification procedures.

The composition of the material is calcium silicates, calcium aluminate, calcium oxide, calcium tungstate, and titanium oxide. The material is biocompatible and ready for use, has high alkalinity (pH is 12 ± 1), and radiopacity (9 mm of the aluminum). The paste is launched in 0.5 g syringes and can be delivered into the root canal via plastic tip cannula, attached to the syringe as the majority of the premixed bioceramic materials.

7. Conclusion

Potent antibacterial activity, absolute biocompatibility, good osseo-conductivity, ability to achieve excellent hermetic seal in constantly wet environment, formation of chemical bond with dentin, insolubility in tissue fluids, expansion during time of set, very good radiopacity, easy handling are the features that make bioceramic - based materials an up-to-date alternative to other materials.

The application of bioceramic materials has changed both surgical and non- surgical endodontic treatment, providing a promising direction for the preservation of patients' teeth. However, limitations still exist when compared to the criteria for an ideal material used for endodontic purposes. Indeed, it is expected that the presently available bioceramic materials will be further modified and developed to overcome the few remaining challenges and has a long way to go to prove in their clinical outcomes and success.

8. Conflict of Interest

None.

9. Source of Funding

None.

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