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Bioceramic Technology in Endodontics

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Authors' contributions

This work was carried out in collaboration between all authors. Author MNH wrote the first draft of the manuscript. Authors SM and CS managed the analyses and literature searches. All authors read and approved the final manuscript.

Review Article

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ABSTRACT

Bioceramics include ceramic materials specifically designed for use in medicine and dentistry. These materials are mainly alumina, zirconia, bioactive glass, glass ceramics, coatings, composites, hydroxyapatite and resorbable calcium phosphates. Dental applications include dental implants, in periodontal treatment, alveolar ridge augmentation, maxillofacial surgery, pulp capping and apexification. The use of alumina and zirconia can be seen for prosthetic devices although calcium phosphate based materials are used for filling bone defects. Bioceramics are biocompatible, non–toxic, do not shrink and are chemically stable within the biological environment. Bioceramic sealers allow the enhanced use of bioceramics. The future of bioceramics is very promising. Recently, bioceramic putty has been introduced for primary teeth along with other fast repair materials.

Keywords: Bioceramics; hydroxyapatite; bioglass; zirconia.

1. INTRODUCTION

In 1969 L. L. Hench and others had seen that several glasses and ceramics could bond to living bone and thus found a new material which he called Bioglass [1]. Significant evolution has been seen in endodontic material sciences over the past decade. In this continuously

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evolving field the start of bioceramic technology can be treated as a new beginning. Bioceramics can be used for dental as well as medical applications [2,3,4]. Bioceramics has made endodontic treatment more efficient due to their osteoconductive properties and multiple uses like in cases with perforation. They include substances such as bioactive glass, glass ceramics, alumina, zirconia, coatings and composites, hydroxyapatite, radiotherapy glasses and resorbable calcium phosphates [5,6,7].

Bioceramics are classified into three categories, namely, bioinert, bioactive and biodegradable [5-8]. Alumina finds its application in orthopaedics due to its low coefficient of friction, wear rate and biocompatibility [9, 10]. Bioceramics used in dentistry also include bioactive glass, glass ceramics [7] and calcium phosphate based materials that can be used to fill bony defects. Apical retro fills and root repair can be carried out using bio aggregate and calcium silicate. Benefits associated with bioceramics can be easily used using bioceramic sealer. Bioceramics are known to be nontoxic, chemically stable in the biologic environment and biocompatible [14].

2. CLINICAL PROPERTIES

A premixed sealer of bioceramics (Endosequence BC Sealer) is available in a syringe. It has a working time of approximately four hours at room temperature and is introduced immediately into the root canal. It has a shelf life of two years and does not require refrigeration for storage. It can be stored at room temperature. They act by creation of a bond between the appropriate filling material and dentin and can form hydroxyapatite [3,4].

Presence of moisture in the dentinal tubules affects the setting time of the bioceramic sealer. This moisture availability in the root canal is by the dentinal tubule which is needed for the setting reaction. Thus prior to obturation addition of moisture is not required. The highly alkaline pH (12.9) enhances its bactericidal properties [11]. A very small capillary tip or a cannula can be used for its delivery owing to its small particle size.

3. RETREATMENT

Piezoelectric ultrasonic and conventional treatments are two techniques that are used to remove bioceramic sealer in combination with gutta percha. Bioceramic sealer is known to be bioactive because of the presence of hydroxyapatite and calcium silicate in it. These sealers have the advantage of enhanced sealing ability and the ease of use. Treatment of endodontic cases using glass ionomer has difficulty in retrieval during retreatment cases; similar condition is seen during retreatment with bio ceramics [12]. As a sealer glass ionomer has definite use in retreatment. Bioceramics should be used as sealers instead of complete filler; they can be used with a central core material that facilitates retrievability in cases where retreatment is indicated. Treatment can be facilitated by the continuous taper of the canal helps in minimising the use of endodontic sealer. During retreatment of bioceramic cases copious amounts of water should be used with ultrasonic [3].

4. MECHANISM OF ACTION

Bioceramic sealers use the water inherent in the dentinal tubules for the setting reaction thus beginning the hydration reaction of the material and by this reducing the setting time. The setting time is reduced. Dentin is believed to contain about 20 percent water (by volume) [13]. This water is responsible for the setting of the material. These sealers are available as

premixed endodontic cement and have the advantage of improved convenience. Problems that are associated with mixing of cement such as insufficient and non-homogenous mix can be prevented and also helps in saving time. Bioceramic sealers have the property of hardening only when exposed to moist environment such as dentinal tubules [14].

Upon hydration, calcium silicate gel and calcium hydroxide are produced by the calcium silicates in the powder. The calcium hydroxide reacts with phosphate ions and produces the precipitation of hydroxyapatite and water. The hydroxyapatite that is produced can be used for reconstruction material and in bone repair as is non toxic. The continuous interaction of calcium silicate and water leads to production of calcium silicate hydrate.

The hydration reactions (A, B) of calcium silicates and precipitation reaction (C) of calcium phosphate are [15,16]:

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

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

(C) $7Ca(OH)_2 + 3Ca(H_2PO_4)_2$ ----> $Ca_{10}(PO_4)_6(OH)_2 + 12H_2O$

A critical factor in controlling the rate of hydration and setting reaction is the water through the setting reactions. When compared to the setting reaction of calcium hydroxide, similarity is seen and is related to its pH. It is affected by release of hydroxyl ions and their concentration. Dissociation is altered by the vehicle used. The pH of dentin also altered after by the release of hydroxyl ions when it is treated with it [17].

5. BIOCERAMIC AS ENDODONTIC SEALER

Bioceramics are highly successful endodontic sealers and have several advantages such as improved biocompatibility, sealing ability, anti-bacterial, ease of application and an increase in strength of root following obturation. The extreme biocompatibility of bioceramics can also be observed in cases of root repair where there is absence of inflammation and pain or minimal pain following an overfill during obturation [14,18]. The bioceramic sealer can be used in the root canal by the use of a premixed syringe. Thus the need for mixing of the sealer is not required which avoids problems such as insufficient and non homogenous mix. Bioceramics are hydrophilic in nature and have the ability to form hydroxyapatite. They lead to the formation of a chemical bond between the filling material and dentin walls [18]. This eliminates the presence of any space between the dentinal walls and sealer which enhances the seal [18]. The bioceramic sealer has a particle size of 2 µ aiding in its delivery by the means of a capillary tip [3]. Bioceramics have shown radiopacity and flow in accordance with ISO 6876/2001 recommendations [21]. Ghoneim et al had shown in an *In vitro* study that bioceramic sealer (iRoot SP), particularly with activ gutta percha cones, have increased resistance of the fracture of the endodontically treated roots [19].

A study [20] comparing the bioceramic sealer (iRoot SP) with other sealers such as AH plus, Epiphany and MTA Fillapex was done. It showed that the former had greatest bond strength to root dentin. The degree of residual moisture has been shown to affect the bonding ability of the sealers. Although with regard to the studied sealers the presence of slightly moist canals is preferable. This can be due to the hydrophilicity of the sealers.
Synchronised hydraulic condensation is feature of some bioceramic sealers. This involves the formation of a true bonding between the root canal wall and the master cone. Bioceramic

sealer can be placed by the use of intracanal tip. These tips are flexible and allow the user additional benefits such as better access to the root canal. Capillary tips can also be used to place the sealer. The sealer is inserted slowly and the tip should not be inserted further than coronal one third. After the removal of the tip, the thin sealer is coated on the master cone. Sufficient material can be carried and placed in the apex till the final working length by using the synchronised gutta percha [14].

The constant taper of the canal combined with the precise fit of the gutta percha helps in achieving excellent hydraulics. During setting reaction of bioceramic material there is presence of creation of chemical bonding to the canal wall by hydroxyapatite and other between the ceramic particle in sealer and the ones on the sealer coated cones [3].

6. BIOCERAMICS AS A ROOT REPAIR MATERIAL

Bioceramics are used in root repairs and they can be used in two forms either as premixed putty or in a premixed syringe. As root repair materials they are easy to use and provide a proper mix. Bioceramics have many advantages such as biocompatibility, high resistance to wash out and lack of shrinkage. It also displays good physical properties. The syringe eliminates need of hand instruments and also need for mixing. The bioceramic particle size is less than 2 µ thus can be delivered by a 0.012 capillary tip which allows premixed material to be placed by syringe. Thus the syringe eliminates the need for hand instruments. These materials have a compressive strength of 50-70 MPa [3].

7. BIOCERAMICS IN PERIAPICAL SURGERY

Endodontic surgery is indicated for teeth with persistent periradicular pathologies that do not respond to non-surgical treatment. Periradicular surgery is indicated when non-surgical retreatment is impractical or unlikely to improve on the previous result. Surgery is done to remove the etiological agent and to restore functional health in tissues. Following curetting the defect in the bone can be filled by the use of graft material to promote bone formation [22].

The human hard tissues such as dental enamel (98%) and bone (60%-70%) have hydroxyapatite as their natural mineral component [23]. Tri calcium phosphate is not a natural component of the bone but is similar to hydroxyapatite clinically. Due to its partially bio resorbable nature it is considered desirable for repairs of morphologic site [24].

Calcium phosphate biomaterials are nontoxic and also have the advantage of becoming functionally integrated with bone with no fibrous encapsulation [25]. They promote bone to extend in areas that it would occupy due to their growth guiding properties. It provides a suitable physical matrix for deposition of new bone [26].

Biphasic calcium phosphate includes both β- tricalcium phosphate and hydroxyapatite. These two together by their properties allow control over bioactivity [27,28,29]. Biphasic calcium phosphates maintain both the osteoconductive potential of hydroxyapatite along with the control over resorbability of tricalcium phosphate [24].

It is hypothesized that biphasic ceramic phosphates have two main functions that include initiation of cell growth and differentiation and have the property of osteoinductivity [30].

8. PULP CAPPING WITH BIOCERAMICS

Bioceramic sealers are convenient to use owing to the premixed syringe as it helps in reducing working time, also problems associated with mixing of cement such as non homogenous or inadequate mix can be avoided. Bioceramic sealers can be used by syringe having a capillary tip due to its small particle size. Thus pulpal therapies or pulp caps in young patients can be better managed and with ease. It can also be used for direct pulp cap. The procedure begins with the isolation of the tooth by the rubber dam. After this disinfection of the exposure site is carried out by NaOCl and cotton. The exposure site can be covered by bioceramic in putty form or in the premixed form. The bioceramic material can then be covered by glass ionomer restoration or Compomer. Finally the restoration is done. Etching if required can be carried out. Single visit pulp capping may be carried out [3].

9. BIOCERAMICS IN COMPARISON WITH OTHER ENDODONTIC CEMENTS

Some bioceramic cements have several applications such as those with Mineral trioxide aggregate [31,38]. They are believed to be having cytotoxicity levels comparable with mineral trioxide aggregate [32,33]. De-Deus and colleagues [34] found biocompatibility of mineral trioxide aggregate and bioceramic cement to be similar. Bioceramics have also demonstrated to be having antifungal and antibacterial activity [35,36]. Bioceramics induced secretion of IL-1b, IL-6 and IL-8 as is seen with mineral trioxide aggregate [37]. Mineral trioxide has also been used in cases with immature apices to complete pulp space therapy by acting as a scaffold for dentin formation when placed over the blood clot in cases of immature apices with parallel walls [38]. Bioceramics also have similar biocompatibility and sets in presence of moisture thus may also be used.

Internal and external resorption can be managed with non-surgical pulp space therapy using calcium hydroxide [39]. Calcium hydroxide points were used in non-surgical treatment of large periapical lesions [17]. These repeated appointments in such cases are eliminated by use of bioceramics.

Bioceramics has antibacterial and antifungal activities [35,36]. Calcium hydroxide was often used in treatment of external resorption because of its high calcium ion concentration and alkaline pH of 12.5. Several theories attempt to demonstrate its activity. One such theory attributes its alkaline pH as essential for formation matrix by formative cells [40].

Vitapex (Calcium hydroxide and iodoform paste) was used to successfully complete pulp space therapy in reimplanted tooth having external root resoprtion with apical and lateral radiolucency [41]. The advantage of bioceramics over vitapex is the lack of recall of patient and change of dressing. Thus reducing the chair side time and advantage of the sealing ability of bioceramics.

Thus mineral trioxide aggregate [38] and calcium hydroxide [42] have been successfully used for obturation in patients with incompletely formed apex. Bioceramics the newer endodontic cement can be used in similar cases with advantages of decreased chair side appointments and ease of placement of the material.

10. OTHER APPLICATIONS

Dental applications include dental implants, in periodontal treatment, alveolar ridge augmentation [1], sinus obliteration [43], maxillofacial applications include pulp capping [44] and in correction of orbital floor fracture [45].

Bioceramics such as Bioglass have been seen to be useful for implants to maintain alveolar ridge of edentulous patients. Bioceramics like Bioglass devices have also been used for maxillofacial reconstruction to correct conductive loss of hearing by means of replacing the bones of the middle ear (Hapex). They are also used following tooth extraction to provide stable ridge for construction of denture and can also be used to support labial and lingual plates in natural tooth loss [1].

In periodontics, bioceramic products such as PerioGlas have been used in cases of bone loss caused by infrabony defects seen in periodontal diseases. Bioceramics have also shown to be useful in treatment of dentinal hypersensitivity. Bioglass materials of fine particle size can be incorporated in the toothpaste or can be used with the help of an aqueous vehicle and used on tooth surface over the exposed surfaces thus the pain is removed [1].

11. CONCLUSION

Bioceramics have an extremely promising future and a broad application scope. A wide variety of bioglass products are used in medicine and dentistry. This technology can also be used in other fields of dentistry such as prosthodontics, maxillofacial surgery and others. They offer several advantages when compared to the other available sealers. They also help preserve the natural tooth structure by allowing the user to be more conservative during the endodontic shaping. Bioceramics (Brasseler Endosequence Root Repair Material) have shown cytotoxicity similar to that of ProRoot MTA and MTA angelus [46]. *In vitro* studies on bioceramics (DiaRoot BioAggregate) have shown compatibility to MTA [47]. Bioceramics such as BioAggregate and iRoot SP have acceptable biocompatibility as has been demonstrated on human fibroblasts (MRC-5) cells [48]. Thus their properties, such as biocompatibility, render them fit for endodontic use. Further research would open newer avenues for research in different fields.

CONSENT

Not applicable.

ETHICAL APPROVAL

Not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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