REVIEW ARTICLE

Bag: bagged the future

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Abstract

Bioactive glasses are dental materials which are different from conventional glasses and are used in dentistry. Bioactive glasses are made of calcium and phosphate which are present in a proportion that is similar to the bone hydroxyapatite. It has become a adjunct to promote hard-tissue healing in many clinical situations and is of particular interest for endodontic care because of its biocompatibility, regenerative and antimicrobial properties as well as chemical composition that closely resembles the mineral make-up of human bone and dentine so they have a wide range of application in medical and dental field. This article review history, composition, mechanism of action and applications of BAG.

Key Words: Bioactive Glasses, Hydroxyapatite, Biocompatibility, Regenerative, Antimicrobial.

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INTRODUCTION

Bioactive glasses are a group of biomaterials which are used in the fields of dentistry and medicine. A material can be classified as bioactive if the biological response results in formation of a strong chemical bond between the implanted material and a soft or hard tissue[1]. Certain compositions of the silicate-based glasses, with calcium and phosphorus in proportions identical to those of natural bone, can form such a strong bond without an intervening fibrous layer.[2] When the glass contains more than 60% SiO_2, bonding to tissues is no longer observed.[3] On the other hand, it is expected that bioactivity increases with the amount of CaO in the composition, because the dissolution of the calcium ion from the glass plays an important role in formation of the chemical bond.[4]

HISTORY

Hench at the University of Florida introduced the first bioactive glass in 1969.[2] Those days, the available implant materials (metals and polymers) designed to be bioinert had a problem; they initiated fibrous encapsulation after implantation, rather than forming a stable bond with the tissues. Hench began his work to overcome this problem by finding a material that could bond to the bone and survive the harsh environment of the human body. He tried making a degradable glass in the Na_2O-CaO-SiO_2-P_2O_5 system with high calcium content.[2] He discovered such glass with the composition of 46.1 mol.% SiO_2, 24.4 mol.% Na_2O, 26.9 mol.% CaO and 2.6 mol.% P_2O_5 (later termed 45S5 and Bioglass®) which formed a bond with the bone so tightly that it could not be removed without breaking the bone. Various studies were conducted to ensure safety of Bioactive glasses and Wilson et al (1981) reviewed these studies and proposed that BAG are safe for clinical use.[5]

COMPOSITION

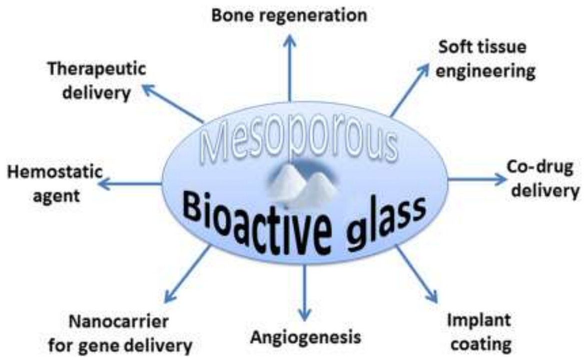
Bioactive glasses have different families and they have different compositions. (Table 1)[6] shows three different types of bioactive glasses.

Table 1: Compositions of three different types of bioactive glasses.

NAME	COMPOSITION
45S5 (Bioglass®)	46.1 mol.% SiO_2, 24.4 mol.% Na_2O, 26.9 mol.% CaO and 2.6 mol.% P_2O_5
58S (Sol-gel derived)	60 mol.% SiO_2, 36 mol.% CaO and 4 mol.% P_2O_5
S53P4	53 mol.% SiO_2, 23 mol.% Na_2O, 20 mol.% CaO and 4 mol.% P_2O_5

MECHANISM OF ACTION OF BIOACTIVE GLASSES

A change in structural and chemical composition of bioactive glass occurs when bioactive glasses react with an aqueous solution, [7]which causes its dissolution and HCAP is formed.[8]Kokubo et al (1990) used glass compositions to study the growth of apatite insimulated body fluid(SBF). It was observed that calcium ions of the glass dissolve and apatite's ion activity product is greater than before. The silica network which acts as a place for apatite nucleation, gets disrupted. The growth of the apatite is therefore based on utilization of calcium and phosphate ions from SBF.[9]



Courtesy-Science Direct Article(Bioactive Glasses)

THE APPLICATIONS OF BIOACTIVE GLASS

In 1986, a bioactive glass was successfully used as middle ear prosthesis to repair conductive hearing lossand it was the first clinical application of such material. In tooth extraction, bioactive glasses have been used to preserve the height of the alveolar ridge.[10]

Bioactive glasses also have been used for spinal fusion, reconstruction of the iliac crest following autograft harvesting, and for filling bony defects in a number of orthopaedic procedures. These early clinical applications confirmed the benefits of this material as highly compatible implants .[11] More recent application of bioactive glasses include coatings for orthopaedic metallic implants, trabecular coatings, bone replacement, periodontology, endodontology, scaffolds for bone tissue engineering, regenerative medicine, and composite based scaffolds .[12,13]

(A) Medical Devices with Monolithic shape

In 1988, a simple cone of Bioglass®, termed the Endosseous Ridge Maintenance Implant (ERMI®), was the commercial Bioglass® device in dentistry. For repairing the tooth roots and to provide a stable ridge for dentures, such devices were inserted into fresh tooth extraction sites. They were highly stable and much better than HAp tooth root implants. But this product did not gain commercial success because surgeons prefer to be able to cut the implant to shape rather than be limited to cones of fixed size. Internationally, products based on particles rather than monolithic shapes are in commercial use .[10]

(B) Particulates of Bioactive Glass

Dentists usually prefer to use particles or granules instead of monoliths, as they can press them easily to fill a defect. In 1993, Perio-Glas® (NovaBone Products LLC, Alachua, Florida) as the first particulate bioactive glass with the particle sizes of 90–710 μm was introduced for the repair of bony defects of the jaw and bone loss arising from periodontal ldisease. In vivo and clinical studies[14,15,16] showed a great success of Perio-Glas® in treatments of defects filled with new bone compared to controls. The regenerative properties for infra-bony defects can be increased with low-level laser therapypostoperatively.[17]Other application of Perio-Glas® is in "guided tissue regeneration", which has been used with polymeric membranes .[18]Perio-Glas® can also be used to produce bioactive glass slurry with applications in root canal sterilization tools prior to insertion of implants and raising pH to bactericidal levels in addition to its bioactive properties.[19]

(C) Bioactive Glass for Treatment of Hypersensitivity

A very fine Bioglass® particulate called NovaMin® (NovaMinTechnology, GlaxoSmithKline, Florida, UK), with a particle size of ~18 μm is used as anrepair agent in toothpaste. This material mineralizes tiny holes in the dentine and helps to reduce the sensitivity of the tooth. Dentin hypersensitivity (DH) is an oral problem which is attributed to the root surface exposure due to periodontal disease, toothbrush abrasion or cyclic loading fatigue of the thin enamel near the cemento-enamel junction[20]. Hydrodynamic theory about DH mechanism proposes that when external stimuli such as cold, hot, tactile or osmotic pressure are applied to the exposed dentin, they cause fluid movement within the dentinal tubules. These open tubules allow the fluid to flow through the tubules, which may result in pressure changes that excite the nerve endings in the dental pulp and DH occurs.[21]When these kinds of toothpastes are used, Bioglass® particles adhere to the dentine and form an HAp layer; therefore, blocking of the tubules relieves the pain for longer periods. In a clinical trial of 100 volunteers who brushed twice daily with a NovaMin®- containing toothpaste over the 6-week period, gingival bleeding and plaque growth reduced 58.8% and 16.4% respectively in comparison with the control groups who used normal toothpaste . [22]Another clinical trial has shown improved pain relief when brushing with a NovaMin®-containing toothpaste for 2-6 weeks compared to brushing with a toothpaste containing potassium nitrate .[23]In fact, the glass dissolutionproducts stimulate the mineralization. Dissolution of the glass in the mouth raises pH, which leads to promotion of HAp deposition .[24]The sol-gel derived bioactive particles are also used in treatment of hypersensitivity. The trials have shown that 24 h after using toothpaste containing the sol–gel and after washing with cola, juice, coffee and further brushing, the tubules remain occluded .[25]Teeth treated with the Bioglass® were also whiter thanthose treated with sodium bicarbonate.[26]

(D) Remineralization Using Bioactive Glass

Bioactive glasses have unique remineralizing properties and are generally introduced into various dentifrices as very fine particles to provide calcium and phosphorus to the tooth surface .[27]The first study on dentin remineralization by a bioactive glass was conducted by Wang *et al.* [28] In this study, after artificial demineralization with EDTA (ethylene-diamine-tetraacetic acid), the treatment with nanoparticulate bioactive glass was compared to the treatment with conventional, micron-sized material (PerioGlas®).The results showed that nanoparticulate bioactive glass resulted in a noticeable growth in mineral content suggested a rapid remineralization of the samples. This result confirmed the critical role of particle size and specific surface area. However, these samples were mechanically unstable, unless the precipitated mineral forms a composite material with the collagen matrix of the samples .[28] Investigations on bioactive glass-containing toothpaste show significant reduction in dentine permeability and excellent resistance to acid challenge which can be beneficial for hypersensitivity and remineralization treatments.[29]In 2014, Mehta *et al.* showed that bioactive glass(Novamin®)andcaseinphosphopeptide-amorphous calcium phosphate (CPP-ACP) successfully remineralized early enamel caries. Novamin® remineralized the carious lesion more effectively. CPP-ACP had an amorphous nature and couldn't properly adhere to the enamel surface. This also led to lower hardness value for CPP-ACP, while Novamin® showed higher values of hardness because it attached to the surface more compactly. [30]In another study, it was confirmed that bioactive glass is an effective remineralizing agent as the effects of bioactive-containing products were investigated onremineralization of artificial induced carious enamellesion .[31]

(E) Bioactive Glass Coatings

The metallic implants are encapsulated with fibrous tissue after implantation and cannot attach to tissue which shows serious need of such implants to bioactive coatings. Hydroxyapatite layer forms on bioactive glass coatings as a result of dissolution and improves the bonding of implants to the host bone. The problem is that a highly bioactive coating may degrade over time and result in instability of the metallic implant in the long span. Perhaps, the dental field is the best application for bioactive glass coatings, e.g. on titanium implants with screw threads. It should be noted that the thermal expansion coefficient of the glass and the metal must match to prevent the glass pulling away from the metal during the processing.[32] For instance, the thermal expansion coefficient of the Bioglass® and titanium doesn't match. In order to address such problem, for example, in the SiO_2–CaO–MgO–Na_2O–K_2O–P_2O_5 system, the Na_2O and CaO are replaced with K_2O and MgO, respectively to modify the thermal expansion coefficient .[33] Another example is coating with the following composition (by weight): 53% SiO_2, 6% Na_2O, 22% CaO, 11% K_2O, 5% MgO, 2% P_2O_5, and 1% B_2O_3 on titanium implants, which were first tested in rabbit femurs. [34]Compared to non-coated implants,more bone grew on the coated implants. By using appropriate compositions, the mismatch of thermal expansion coefficients doesn't make any problem and bioactive glasses can successfully be used as coatings.

CONCLUSION

The realm of dental materials science is continuing to evolve and, in fact, a new day has dawned. The new horizonis the increased use of silicate compounds, including B-G, either as filler materials/coatings for polymer structures or as synthetic bone graft substitutes to elicit specific biological responses. Information on treatment outcomes is essential for the decision-making process. We must adopt stricter controls and performance standards, particularly with the evaluation of new products and technologies, for generating robust data in clinical studies and reaching our goal to implement highest standards of endodontics. Thus, understanding the science, technology and properties of BAG is a very important need for the oral healthcare community.

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