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Review Article

Bioactive Glass in Dentistry: A Review

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ABSTRACT:
Currently, biomaterials researchers are concentrating on the oral hard and soft tissue engineering with bioactive substances by triggering body immune cells or various proteins. Natural ground substance, tissue components, and durable tissues grow as a result of this practise. Bioactive glass (BAG), one of the contemporary biomaterials, is well-known. BAG is suitable for a variety of clinical applications requiring the regeneration of hard tissues in both medicine and dentistry due to its bioactive characteristics. It has applications in orthopaedics and soft-tissue repair in medicine, as well as dental restorative materials, mineralizing agents, coating materials for dental implants, pulp capping, root canal therapy, and air-abrasion. The purpose of this paper is to give a summary of applications for bioactive glasses in dentistry.

Keywords: Biomaterial, Bioactive Glass, Application in Dentistry

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INTRODUCTION

A beneficial biocompatible material called bioactive glass is utilized as an adjuvant to other dental materials. It has been demonstrated that bioactive glass is beneficial in promoting the bond between the material and the tissue.[1] The creation of bioactive glasses is a turning point in the development of biocompatible materials due to its characteristics, such as mechanical biocompatibility.[2,3]

Tissue engineering and tissue regeneration are the current areas of interest for biomaterials researchers.[4] Dentine, pulp tissue scaffold templates, periodontal membranes, and bone cements are only a few examples of dental products where the notion of tissue engineering has been successfully used to regenerate oral tissue.[5-7] Bioactive glass is one of the materials that can be accessed. When Larry L. Hench learned about the host rejection of inert metal and plastic materials often employed in amputation cases and dentistry, he set out to design a graft material that was compatible with the human body.[8]

Due to its bioactive properties, which have uses in both dentistry and medicine addressing the regeneration, healthcare has undergone a revolution regarding the regeneration of hard tissue. The ability to synthesize bioactive glass on a nanoscale nowadays aids in covering the surfaces of orthopaedic, spinal, and dental implants.[9] The purpose of this paper is to give a summary of applications for bioactive glasses in dentistry.

COMPOSITION OF BIOACTIVE GLASS

The most significant finding was a glass that included 46.1 moles of silicon dioxide, 24.4 moles of sodium oxide (Na_2O), 26.9 moles of calcium oxide (CaO), and 2.6 moles of phosphorus pentoxide (P_2O_5), which was later known as Bioglass 45S5, makes a strong link with bone that could only be broken to release the binding. The original 45S5 formulation was sold under the trade name "Bioglass" by the University of Florida. As a result, the name "Bioglass" is only used to describe the 45S5 composition and not bioactive glass as a whole. Besides above content, it may also contain some of biocompatible and bioactive minerals like: Fluorapatite, Wollastonite, Diopside, Tricalcium phosphate.[10,11]

PROPERTIES OF BIOACTIVE GLASS

MECHANICAL PROPERTIES

Due to their intrinsic fragility and low mechanical strength, bioactive glasses have only been used on non-load-bearing structures, including the ossicles in the middle ear. The issue of poor strength in glasses can be solved by adding nitrogen to the silicate network. Elastic modulus and hardness in alumino-silicate glasses increase linearly with nitrogen content when oxygen is substituted; nevertheless, glass transition temperature also rises. Additional benefits of nitrogen incorporation include improved slow crack development resistance, moderate increases in fracture resistance, and higher viscosities. Both fluorine and nitrogen can be added to materials to increase their mechanical properties. Fluorine significantly lowers the glass transition and melting temperatures while nitrogen increases the elastic modulus and hardness without having any effect on either. Fluorine also aids in the solubility of nitrogen into the glass melt.[12,13]

ANTIMICROBIAL PROPERTIES

BAGs, in particular BAG-S53P4, are demonstrated to have broad-spectrum antibacterial activities, and no resistance has yet been noted. One of the most frequent bacterial strains linked to peri-implantitis (PI) or periprosthetic joint diseases (PJI) and a significant biofilm contributor is S. aureus. S53P4 has, however, shown to lessen the biofilm bulk under in vitro circumstances. Additionally, it has been noted that numerous multi-drug resistant bacteria recovered from PJIs are adversely affected by the antibiofilm action. Antimicrobial compounds added to the BAG are also seen to have a stronger antibiofilm action. Alkalinity of Bioactive glass is considered the primary antimicrobial mechanism; Bioglass® 45S5 is considered more effective.[14-17]

BIOACTIVE PROPERTIES

One area of distinction between BAGs and ordinary glasses is the rate of dissolution. Conventional glasses are expected to generally last a long period and degrade gradually. Certain dissolving rates are required for BAGs to be bioactive. To achieve this, modifiers like sodium oxide and calcium oxide are added in order to increase the surface and silica network's reactivity. When in contact with real or simulated physiological fluids, bioactive glass experiences rapid ionic dissolution and glass degradation due to the exchange of H+ ions from the solution and Na+ and Ca2+ from the glass network. The local environment becomes more alkaline as OH- concentration increases.[18]

As the pH raises, silica network deteriorates even more, producing orthosilicic acid on the surface. With precipitation sites, gel layer serves as the matrix for hydroxyapatite. On top of the bulk glass is decreased alkaline surface layer that lies beneath gel layer. That layer of amorphous calcium phosphate develops over the gel layer. Growth factors can bind to the surface of newly generated hydroxyapatite, which also facilitates osteoprogenitor cell adhesion, proliferation, and differentiation through cytokines and extracellular matrix contents expressed by activation of numerous genes. Glycoproteins and Collagen are thought to combine surrounding bone tissue into hydroxyapatite layer, even if the precise tissue bonding characteristics of the bioactive glass are still unknown. Once absorbed into the growing bone, osteoclasts break down bigger particles, extending the time between resorption and formation of stronger Bone.[18,19]

CLINICAL APPLICATION OF BIOACTIVE GLASS IN DENTISTRY

Due to its composition resembling that of bone and teeth, as well as its bioactive characteristics and antibacterial capabilities, bioactive glass was initially used as a substitute for bone in procedures such as dentoalveolar and periodontal regeneration, maxillofacial reconstruction, and implants.

ENAMEL REMINERALIZATION

With routine plaque removal and fluoride application, early caries lesions that have not yet cavitated, such as white spot lesion, may be stopped and remineralized; operational treatment may then be avoided. Bioglass® 45S5 has been extensively studied regarding the remineralization of WSLs. Taha et al. evaluated the effectiveness of bioactive glasses in inducing remineralization compared to topical fluoride and CPP-ACP treatment. They concluded that bioactive glasses may enhance enamel remineralization more effectively and earlier. However, clinical research is lacking.[20]

Novamin®, which is utilised as the active ingredient in the commercial toothpaste Sensodyne® (GlaxoSmithKline), has a composition that is identical to Bioglass® 45S5, but with an average particle size of 18 m, for remineralization and lowering hypersensitivity. Calcium and phosphate ions are released by the calcium-sodium-phosphate silicate glass known as Novamin®. These ions cause the calcium phosphate to precipitate and mineralize into hydroxyapatite, which is the common BAG. They also cause the pH to rise. While Novamin® demonstrates a continual calcium release, CPP-ACP or other calcium-based solutions only offer an initial calcium burst. However, the availability of only in vitro and in situ studies and lack of randomized clinical trials (RCTs) precludes the clinical use of Novamin® for enamel remineralization.[21,22]

BIOACTIVE GLASS IN ORAL SURGICAL PROCEDURES

For maxillofacial applications, Biogran (Biomet 3i, Palm Beach Gardens, Florida, United States) is commercially available. It is frequently used to fix or treat maxillofacial defects. Commercially available NovaBone (NovaBone Products LLC) can be used to create putty using blood from the site of the defect.

Bioglass with strontium oxide has proven to lessen bone resorption. The alkali-free Bioglass is more suited for dental and oral maxillofacial applications because it is more biocompatible, resorbs bone slowly, and has higher osteoconductive property.[11,23]

IMPLANTOLOGY

Dental implants are man-made, screw-shaped devices used to hold replacement or bridges in the periosteum or alveolar socket. Dental implants are used in prosthodontic constructions to enhance their functionality and appearance. In order to achieve appropriate retention in bone, or osseointegration, the implant surface must remain in continuous contact with the bone tissue. For dental implants, titanium-based alloys are frequently used; they are biocompatible and osteoconductive but bioinert materials. The inclusion of Bioglass overcomes its bioinert characteristic. Bioglass and titanium-based alloy implants offer active bonding and antibacterial qualities, cutting down on overall treatment time.[24,25]

BIOACTIVE GLASS IN DENTAL ADHESIVE

Dental adhesives enable the adhesion, or bonding, of a substance or material, such as dental composites or brackets, to the tissue of the natural tooth. The adhesive joins two materials together.

The use of orthodontic brackets frequently results in cases of white spot lesions. Since the orthodontic bracket sticks to the tooth surface, a favourable environment for microbial flora growth is created. Regular teeth brushing and the use of fluoride dentifrices, mouthwash, or varnishes become essential for the prevention of white spot lesions, which increases the expense of care. By encouraging the remineralization of mineral-deficient areas and simultaneously increasing the modulus of elasticity, the bonding mechanism in bioglass minimises micropermeability. This characteristic qualifies Bioglass as a dental adhesive. Biosilicate is a bioactive glass ceramic that, when used beforehand, improves the bond strength system in both mineralized and unmineralized dentins.[26]

BIOACTIVE GLASS IN PERIODONTICS

According to studies, using bioactive glass was more efficient than other materials like hydroxyapatite and tricalcium phosphate at delaying epithelial down growth and allowing the regeneration of a normal periodontium. The increased rate of reaction in vivo that bioglass possesses in comparison to other materials due to its release of silicon and its apparent ability to bond with connective tissue collagen are two characteristics that seem to have contributed to these positive results. The response layers seem to form minutes after it is implanted due to its strong bioactivity, and the osteogenic cells liberated during surgery can quickly colonise the particles. The combination of these two processes is known as osteoinduction, and it serves as a complement to the bone's osteoconduction from the alveolus. This causes the faults to fill more quickly than they would with other, less active minerals, including hydroxyapatite. This could also happen as a result of bioactive particles' surface rapidly amassing bone morphogenic proteins and other growth factors. Additionally, bioglass particulate has been utilised to promote bone growth in extraction sockets and hence preserve alveolar ridge height.[27]

CONCLUSION

There are presently several uses for bioactive glasses of different compositions. Researchers are now interested in bioactive glasses, and work on many features of these glasses is still ongoing. With considering their existing uses, these glasses have a promising future in the fields of medicine and dentistry.

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