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Bioactive Glass: The Future of Dentistry

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ABSTRACT

In recent days, spotlight for researchers in biomaterial mainly aims of tissue engineering via initiating various proteins along with body immune cells with bioactive substances. Bioactive glass (BAG) is one of the current biomaterials. Its application in dentistry includes as mineralizing agents, restorative materials, also this material is used in dental implants, root canal treatment, air abrasion and pulp capping. Because of its bioactive qualities, doing wonders by regeneration of hard tissues in dentistry as well as in medicine having variety of clinical applications. The purpose of this review is to give an overview about present applications of bioactive glasses in dentistry.

Key words: Bioactive glasses, Dental implants, Root canal treatment

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INTRODUCTION

Bioactive glass is a beneficent biocompatible material used as an auxiliary to various materials used in dentistry. It has been proved, bioactive glass (BAG) is having beneficent effect in promoting material– tissue bond [1]. Because of its features, such as mechanical biocompatibility, the development of bioactive glasses is landmark in development of biocompatible materials [2].

A substance is said to be bioactive when it interacts with the biological system by building a material tissue link and produces a physiologically active response. Also it has been proven in various studies with no signs of inflammation, no foreign body response or no toxicity when seen interaction between bioactive glass and tissue [3]. When Larry L Hench knew about host rejection of plastic materials or inert metal he came out with biocompatible graft material for human body which turned out to be glass having the potential of making bonds with hard and soft tissues without any rejections [4].

Its bioactive characteristics have resulted in the transformation in healthcare, with applications in dentistry as well in medicine regarding the regeneration of hard tissues [5,6]. Today bioactive glass is able to synthesize on Nano scale which helps in coating orthopedic, spinal implants along with dental implants surfaces [7,8].

Composition

BAG was initially marketed under the brand name Bioglass® 45S5 and was made of [9]

45% Silicon Dioxide.

24.5% Calcium Oxide.

24.5% Sodium Oxide.

6% Phosphorus Pentoxide.

The glass's composition could include [10]

2–8% Phosphorus Pentoxide.

0–25% Calcium Fluoride.

0–10% Boric Oxide.

Bioactive Glass may also contain known bioactive and biocompatible minerals, for example tricalcium phosphate, wollastonite, diopside and fluorapatite [11,12]. The elemental composition can include network modifiers like Calcium Oxide, Sodium Dioxide and phosphorus pentoxide to increase reactivity of the silica network with the surface. Na has been considered as a significant part of the bioactivity since it efficiently destroys the structure of the glass [13,14].

However, sodium-free bioactive glass has been created and demonstrated to have the same level of solubility and bioactivity as conventional sodium-containing bioactive glass, negating the claim that Na is a necessary component. By forming more acid-resistant fluorapatite

preferably of hydroxyapatite, fluoride is particularly important for enhancing the bioactivity of dental treatments [15]. Fluoride associate with bioactive glass may also increase dentin remineralization and reduce danger regarding dentin-matrix deterioration [16].

Properties of bioactive glass

The composition and structure of glass, as well as manufacturing methods along with intensity of ionic dissolution, together influence its bioactive characteristics. The glass with the highest bioactivity has larger surface area and faster dissolution rate, resulting in rapid apatite formation. They have also demonstrated that biomimetic nano - structuration improves cell adherence and also improves its mechanical properties of such composites for natural bones [17].

Bioactive material can interact with biological environment to cause the particular biological response, for example the production of hydroxyapatite layer with the tissue-material bond. Enamel, dentin along with bone and teeth mainly contains (mineralized) hard tissue like hydroxyapatite which is crystalline (Ca3PO4) calcium phosphate [18]. This bioactive materials could be either osteoinductive or osteoconductive in nature [19]. Many a time factors which influences the properties of bioactive material may be due to manufacturing techniques, structure and composition of bioactive glass along with its rate of ionic dissolution.

Bioactivity of BAG

The rate of dissolving between conventional glasses and BAGs is one area of difference. In general, it is anticipated that conventional glasses will last a long time and dissolve slowly. For BAGs to be bioactive, certain dissolving rates are necessary [20]. This is accomplished by adding modifiers, such as sodium oxide and Calcium oxide, to raise the reactivity of the surface and silica network. Bioactive glass experience quick ionic dissolution and glass deterioration upon in contact with natural or simulated bodily fluids through the interchange of H+ ions in the solution and Na+ and Ca2+ from the glass network. The rise in OH- content causes immediate environment to become more alkaline [21].

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 [22]. 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 [23].

Antimicrobial properties of BAG

The development of a bacterial (layer) biofilm on implant's surface leads to infection. In comparison to planktonic bacteria, biofilm is the layer of microbial communities that adheres to a surface using a strong polysaccharide matrix and which is known to be around thousand times more resistant to antibiotic therapy [24]. Quality of life and function are improved by surgically inserting dental implants or prosthetic joints to restore missing tissue. Implants do, however, run the danger of contracting infections like periprosthetic joint disorders or peri-implantitis. These infections increase diseases and mortality while also causing the surrounding bone tissue to resorb and the implant to eventually become loose. Due to inadequate vasculature or sections of devitalized bone, bone infections present the added difficulty of a diminished local effect of antibiotic treatment [25].

Additionally, the use of antibiotic loaded bone substitutes as carriers along with the ineffectiveness of antibiotic therapy for treating bacterial infections due to the rising frequency of antibiotic-resistant bacteria, especially multidrug-resistant bacteria [26]. With no evidence of resistance till date against bioactive glass, especially BAG-S53P4, has demonstrated to have broad-spectrum antibacterial activities. One of the most frequent bacterial strains connected to periprosthetic infections and a significant biofilm contributor is S. aureus. S53P4 has, however, shown to lessen the biofilm bulk under in vitro circumstances [27]. Additionally, it has been noted that the antibiofilm action has an impact on a number of multi-drug resistant strains that were identified from periprosthetic joint disorders [28].

Bioactive glass can incorporate both hydrophilic as well as hydrophobic substances into their structure, indicating several as-yet-unidentified integration of substances may be possible to raise antimicrobial ability, supporting potential antimicrobial role for bioactive glass in dental practice. Similar to hydroxyapatite, the discovered bioactive glass are secure and efficient at promoting osseointegration [29].

LIMITATIONS

It has some drawbacks, one of which is the potential gap formation between material and host tissues as a result of a rapid breakdown rate. In addition to the composition, the applied method and level of particle accumulation should also be considered when determining the cause of the lack of porosity [30].

Because of high rise in pH brought on by high Na+ along with Ca^{2+} leakage and which may prove potential for delayed hydroxyapatite synthesis, bioactive glass may have cytotoxic consequences.

Due to poor mechanical qualities, such as being too

feeble, glass composition may not be ideal for production of porous scaffolds. The mechanical characteristics of bioactive glass require further study to be improved [31].

Dental applications of bioactive glass

Bioactive Glass was initially employed as bone substitutes in dento alveolar and periodontal regeneration, maxillofacial reconstruction along with implants due to their similarities in composition to bone and tooth structure, as well as their bioactive features and antimicrobial properties [32-38]. Following are several clinical applications in dentistry-

Dental adhesives.

Enamel demineralization.

Dentin hypersensitivity.

Air abrasion.

Restorative materials.

Pulp capping.

Root canal treatment.

Bone regeneration.

In periodontics.

In implant dentistry.

In maxillofacial surgery.

CONCLUSION

Bioactive glass has a wide range of uses in the fields of clinical dentistry and medicine due to its unique methods of action and formulation. Bioactive glass's chemistry replicates the make-up of natural hard tissues and conducts a bioactive part in regeneration. Because of its osteoinduction and osteoconduction capabilities, which promote bone regeneration and remineralization, it has led to the formation of numerous products to meet improved treatment goals. Generally, bioactive glass are composed of 45% Silicon Dioxide, 24.5% Sodium Oxide, 24.5% Calcium Oxide and 6% Phosphorus Pentoxide.

Whereas glass is composed of 2–8% Phosphorus Pentoxide, 0–25% Calcium Fluoride and 0–10% Boric Oxide. Na-free bioactive glass shows equivalent bioactivity and avoids the breakup of the glass network. To increase the bioactivity and antibacterial characteristics, several elements, including Sr, P, Si, Cu, Ag, Zn and F are also added.

Either the sol-gel method or quenching are used to create the bioactive glass. The glass's structure and composition, manufacturing processes, and rate of ionic dissolution all have an impact on the bioactivity.

The highest surface area glasses have a higher dissolving rate, which leads to apatite formation more quickly. Bioactive glasses are being used more frequently in several areas of dentistry, such as root canal treatment, dental restorations, desensitizing and mineralizing agents, air abrasion and pulp capping. Dentin remineralization was accelerated and enzymatic degradation at the dentin interface was minimized by resin composites containing bioactive glass and fluoride. Hence, more clinical studies and in vivo research are needed to explore its potential as the perfect biomaterial in the future, which would improve its therapeutic use.

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