Review Article

A REVIEW STUDY OF THE USE OF BIOACTIVE MATERIALS IN MODERN DENTISTRY

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https://doi.org/10.51847/fIenMnlYHT

ABSTRACT

Bioactive materials are substances that affect living tissue, organisms, and cells or their response. The effectiveness of the use of these materials in various fields of dentistry and medicine is approved by many experts. The purpose of this research was to review the application and characteristics of bioactive materials in different fields of dentistry. In this study, several articles that were published on this topic in recent years and had valuable results were examined. In these studies, the use of bioactive materials in tooth remineralization for hard tissue regeneration, pulp capping treatment, and anti-caries and antibacterial properties were studied. Some of these substances have the properties of alkaline and convert acidic pH to neutral pH, while others have adhesive properties and chemical bonding. Dimensional stability, biocompatibility, and bioactivity are also properties of these materials. In this study, the latest bioactive materials used, such as Biodentine (a polymeric material with a nanostructure in combination with protein-replants), as well as well-known and common materials that have bioactive properties (such as MTA and calcium hydroxide) were investigated. In addition, the properties and disadvantages of using these materials in dentistry have been stated. These explanations help us to know all the options and materials in our treatments and make a better choice. Based on the results obtained from different studies, new bioactive substances and their effects can cause transformation in different fields of dentistry and solve many problems ahead.

Key words: Dentistry, Bioactive materials, Application, Modern dentistry.

Introduction

The terms bioactive, bioinductive, biomimetic, and biomaterial are different and are defined separately. A bioactive material is considered a substance that affects the living tissue of organisms, cells, or their response. Inductive bioactivity is considered the ability of a substance to induce a response in a biological system; any material, surface, or structure that interacts with biological systems. Biomimetics studies the formation of the structure or function of biological materials (such as pearls or silk) and biological processes and mechanisms (such as protein concentration with remineralization) so that products and structures with the greatest similarity to the natural process can be imitated and artificially. Therefore, these definitions explain the difference between each term [1].

Different bioactive materials include MTA (Mineral Trioxide Aggregate), calcium hydroxide, bio dentine, calcium-enriched mixture, inert materials (tricalcium phosphate ceramic and isobutyl cyanoacrylate) [2, 3], nanostructured polymer materials with protein-repellent have anti-caries properties of restorative materials such as ActiveTM BioACTIVE, Pulpdent (composite resin that has more bioactive activity and releases more fluoride than glass ionomers), Sol-gel-derived bioactive glass and ceramics containing silver ion (AB-BG), Tetracalcium phosphate, calcium phosphate and novel endodontic cement [4-7].

Bioactive substances have many uses, the most important of which are the following: 1) pulp cupping treatment; 2) permanent restorations; and 3) dentin tubule blockage. Ceramics (Huaxi-BAG (HX-BGC) can be an effective material to reduce dentin permeability and therefore can be utilized in the treatment of dentin hypersensitivity; 4) bioactive materials including BAG as a scaffold act and help to regenerate bone tissue; 5) these substances can increase tooth remineralization and it has been reported that casein phosphopeptide-amorphous calcium phosphate and BAG are effective in tooth remineralization [8-11].

Bioactive materials

Biodentin

This bioactive material is a substitute for natural dentin which has similar properties and has a positive impact on living pulp cells that stimulate the formation of tertiary dentin. Biodentin is available in the market in the form of capsules containing the ideal ratio of liquid and powder. The composition of the powder includes dicalcium silicate, tricalcium silicate, calcium carbonate, iron oxide, and zirconium oxide. While the liquid contains calcium chloride which acts as a reaction accelerator. The performance of water-soluble polymer acts as a water-reducing agent [12, 13]. However, the exact concentration of its components is not provided by the manufacturer. Different researchers have investigated the same plant composition and presented data.

MTA

MTA was introduced in 1369 by Dr. Torabinejad. This is a bioactive substance that is mainly composed of silicate and calcium. MTA is a mechanical composition of three powdered materials: bismuth oxide (20%), portland cement (75%), and gypsum (5%) [14, 15]. Based on the MTA patent, this material is composed of calcium oxide (50-75% by weight) and silicon oxide (20-15% by weight), which together make up 70-95% of cement. After mixing these raw materials, tricalcium aluminate, dicalcium silicate, tricalcium silicate, and tetra-calcium aluminoferrite are produced [15]. There are two commercial types of MTA: gray and white; the difference between the two is because of the presence of iron in the gray type, which makes the tetra-calcium aluminoferrite phase more [16]. These materials containing calcium silicate have common characteristics that contribute to the formation of apatite crystals [15]. This material is the right choice in the treatment of pulp capping and aptal, apexification and apexogen, correction of errors during work, and also as a filling material for the end of the root in apico surgical methods. The exact mechanism of dentin bridge formation when using MTA is not fully understood, and detailed research is required to understand this mechanism. However, it is known that when MTA is used as a pulp coating agent, it causes cytological and functional changes in the pulp cells, which leads to the formation of fibrodetin and restorative dentin on the surface of the mechanically exposed dental pulp. , it becomes When this is placed on the pulp it induces the migration, proliferation, and differentiation of odontoplastic-like cells that produce collagen matrix. This non-mineralized matrix is formed, then it is mineralized by primary dentin, and then by the formation of tertiary dentin [17].

Calcium hydroxide

Calcium hydroxide was introduced to dentistry by Hema, and based on Schroder [18], calcium hydroxide is the gold standard for pulp capping treatment in human teeth. One of the major disadvantages of calcium hydroxide is that they do not flood the exposed pulp properly. Calcium hydroxide failure in bacterial flooding may ultimately lead to treatment failure [19, 20].

Calcium hydroxide decomposes into calcium and hydroxyl ions. These calcium ions decrease capillary permeability, resulting in decreased serum flow and the level of pyrene and inhibitory phosphates that cause mineralization. Hydroxyl acid ions produced by osteoclasts neutralize and maintain the appropriate pH for pyrophosphatase enzyme activity, which leads to an increase in the level of calcium-dependent pyrophosphatase; as a result, inhibitory pyrophosphate decreases, which causes mineralization [21].

An overview of recent bioactive dental materials used in dentistry is presented in **Figure 1**.

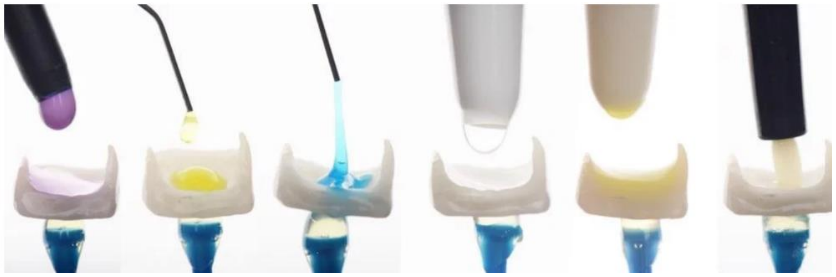

Figure 1. Recent bioactive dental materials used in dentistry.

Comparing the effectiveness of different bioactive materials in the treatment of pulp cupping

A graphical representation of viable pulp therapy treatment options is presented in **Figure 2**.

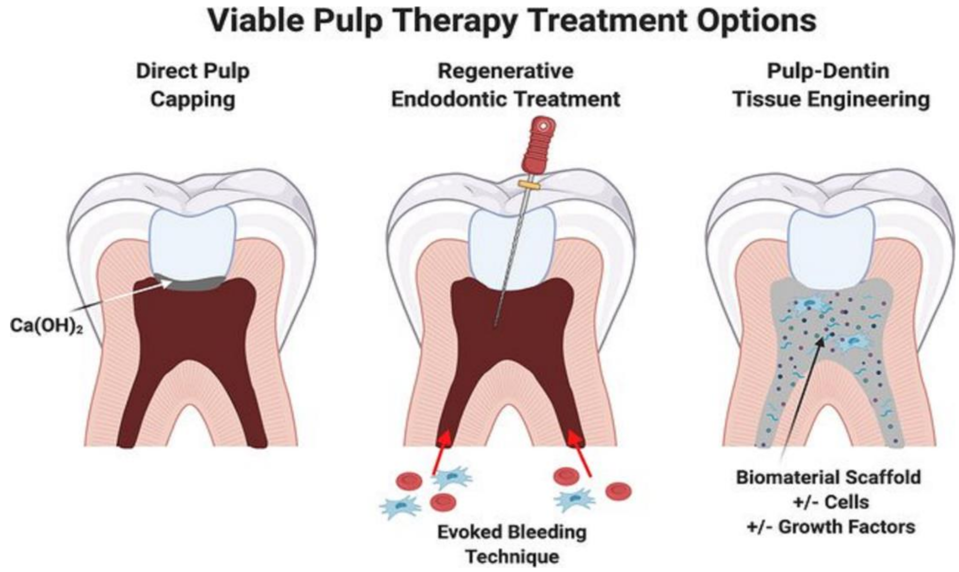

Figure 2. Viable pulp therapy treatment options.

The result of a study revealed that the pulps that were treated with Biodentine were free of inflammation and caused the formation of a better quality dental bridge that was more predictable, uniform, thicker, and more continuous, and the pulp tissue completely flooded compared to Dycal [19].

In terms of the continuity of the fabricated dental bridge, studies have shown that the restorative structures resulting from both calcium silicate cements (Biodentine and MTA) were homogeneous and connected to the primary dentin. In contrast, the repair tissue created after calcium hydroxide treatment had a porous structure. This porosity may eventually facilitate the entry of bacteria into the pulp and endanger the life of the tooth [19, 20].

Various human and animal studies assumed MTA to be superior and a suitable alternative to calcium hydroxide as a pulp-covering agent [22, 23]. However, MTA has certain disadvantages including difficult placement and usage methods, long setting time, the possibility of color change in permanent teeth in aesthetic areas, and high material cost. To deal with these disadvantages, the recently reported Biodentine was introduced as a direct pulp camping agent.

CEM (Calcium Enriched Mixture)

This material is also known as NEC and was reported by Asgary *et al*. [24, 25] and is composed of calcium oxide. While silica and calcium oxide in Portland cement and bismuth oxide, silica, and calcium oxide are the main ingredients in MTA. This cement releases both phosphorus ions and calcium, which leads to the production of hydroxyapatite. This material consists of calcium phosphate, calcium oxide, calcium silicate, calcium carbonate, calcium chloride, and calcium sulfate [24].

Tetracalcium phosphate

It can be utilized for biomedical purposes because it contains a bioabsorbable polylactide composite combined with basic fillers for biomedical applications. It has been proven that it decreases inflammation and the allergic effect caused by acidic substances [5].

Calcium phosphate

It has properties such as high compressive strength, good biocompatibility, and its conversion to hydroxyapatite over time. Without surface tissue necrosis and pulp inflammation, a Dentine Bridge is created [26].

HX-BGC

This ceramic is a new bioactive glass that is available in powder form and contains SiO2-P205-CaO-Na20-Sro. It is used to reduce the permeability of the dentin and this process is done with the help of dentin tubules [27].

Theracal

This material is a resin enriched with calcium silicate, which is cured with the help of light and is utilized to insulate and protect the pulp dentin complex. This material can be utilized in indirect and direct pulp cupping, as a protective base and liner under composites, cements, amalgams, and other base materials. In a study, this material was compared with Dycal and ProRoot MTA and it was reported that it released more calcium and its solubility was lower than the two mentioned materials [27].

Nanostructured polymer materials with the property of rebound protein with anti-decay properties

These polymer materials together with the replant protein have anti-caries properties as part of the dental composite category. In these polymers, 2 substances attracted our attention the most: 1) 2-methacryloxyethyl phosphorylcholine (MPC) and 2) dimethylamino dodecyl methacrylate (DMAHDM).

MPC material was chosen because of its strong ability to repel proteins. The reason for choosing DMAHDM is that compared to other monomers, it had stronger antibacterial properties. The properties of these materials include the following: 1) dental polymer composites with antimicrobial properties and protein replication that are used in tooth restoration; 2) adhesive repairs with rebound protein significantly reduce biofilm acidity; 3) bioactive orthodontic cement can prevent tooth enamel damage; 4) combining the protein of repellants with silver nanoparticles to achieve stronger antibacterial properties; 5) covering the tooth surface with calcium phosphate nanoparticles to achieve remineralization; 6) therapeutic restorations (class V restorations) that are performed in addition to the reconstruction of the dental structure to suppress periodontal pathogens; 7) Longer durability of bioactive dental polymers.

The new generation of substances with strong antibacterial action, which was evaluated in the previous paragraph, can fight caries-causing pathogens and periodontal disease-causing agents and reduce biofilm colony-forming units up to 4 times, provide calcium phosphates for remineralization and tooth structure strength, and increase the pH of the biofilm from a carious pH (4.5) to a safe pH (6.5). These new materials can achieve longer durability that significantly exceeds current commercial control materials. This new generation of bioactive nanostructured polymers seems promising for wide therapeutic applications with longer durability in teeth restoration [28].

Bioadhesive properties of biomaterials

Bioadhesion property is defined as the connection of a natural or synthetic polymer to a biological material and substrate [29]. In this century, biomaterials with bioadhesive properties are considered a series of materials with new and innovative properties that can establish close communication between living tissues [29]. Today, biomaterials are creating a revolution in many aspects of prevention and treatment in the field of health care, which play an important role, especially in the production and creation of new medical devices, prostheses, tissue reconstructions, drug delivery systems, and techniques [29].

Bioadhesive materials are mainly used in wound healing and homeostasis, as well as primarily in other biomedical aspects such as tissue engineering and regenerative medicine [29]. The lack of integration between tissues and biomaterials the method of using tissue bioadhesives in tissue reconstruction is solved [30].

As we discuss the practical application of bioadhesive materials in various aspects of medicine, it is necessary to mention that during the last decade, the amount of attention to bone tissue engineering for research and development in bioadhesive materials and the use of biomaterials has increased all over the world [29]. On the other hand, while defining the use of bio adhesion on a broad scale, it is necessary to state that the term bio adhesion itself can broadly cover the application of adhesion from synthetic components to natural surfaces [29]. Research shows that the use and application of bio adhesion can indicate the connection of two surfaces to each other, such as drug delivery systems and applications related to surgeries and dental treatments [31].

In a review study conducted by Duan *et al*. [32], they stated that the most important applications of bioadhesives in medicine are wound healing, skin closure, wound closure of hard or fragile tissues, preventing bleeding, and preventing subsequent air leakage. Surgery and trauma are used in systems such as drug transfer, as well as stabilization of wound edges relative to each other. Its applications can be used in the field of dental treatments and oral surgeries [32]. In a study conducted by Hasani-Sadrabadi *et al*. [33], they used alginate-based photo-cross-linkable bioglasses for the placement of MSCs and found that the adhesive systems that cause the transfer and placement of cells. It can lead to the complete reconstruction of bone defects around dental implants that are associated with loss.

Bioactive glasses

Bioactive glasses are a group of bioceramics that have a wide clinical application [2]. The characteristics of these materials, including high biocompatibility, and having antimicrobial and bioactive elements inside the body environment, make them suitable for use in various branches of Dentistry and Medicine has made it suitable [34]. Bioactioglasses, having many useful features, such as the ability to support the structure of biological tissues, the ability to use them as suitable scaffolds, and also the property of preventing bacteria growth, are widely used in various branches of dentistry [35].

Bioactive glasses can be used in various dental products, especially toothpaste [36]. It has been reported that the use of bioactive glasses in the formulation of toothpaste can stimulate the remineralization of tooth tissue and decrease sensitivity due to their ability to release antimicrobial agents. In the field of periodontics, studies on dogs have shown that bioactive glass particles can treat periodontal defects by increasing bone mineralization [37]. One of the bioactive glass that affects bone defects is called Perioglass, which has a formulation similar to Bioglass 45S5 and is mainly found in bone grafting materials that are used to reconstruct bone defects [38].

Figure 3 shows the bioactive glass for periodontal regeneration and applications in dentistry.

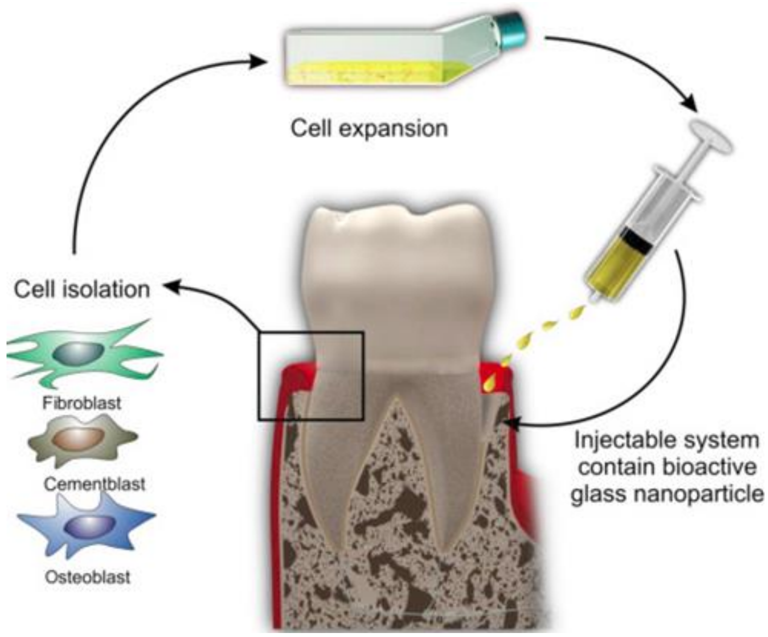

Figure 3. The bioactive glass for periodontal regeneration and applications in dentistry.

Bioglasses are also used in root canal treatments. In pulp diseases, there are various treatments such as pulpotomy, pulpectomy, and pulp cupping, and the materials used for these treatments play a very important role in the prognosis and success of the treatment [39, 40]. In a study conducted on mice, a new bioactive glass was utilized as a pulp-capping material. Then the result showed that bioactive glass was able to stimulate the formation of heavy dentin bridges by inflammatory reactions like MTA [41].

Contrary to the wide use of bioactive glasses in dentistry, there are challenges to their utilization. For example, remaining bone defects in orthopedic and dental surgeries are a major problem. The mechanical limitation of existing bioglass scaffolds along with related strategies and challenges to improve them requires more studies [34]. Also, the use of bioactive glass in the vicinity of soft tissue requires modification of biomechanical factors to adapt delicate and vulnerable collagen tissues [42].

Conclusion

Due to the ever-increasing progress of science in the field of dental materials and equipment, getting to know new materials and their properties helps us to achieve better treatments. Innovation, discovery, and invention of new bioactive materials have created a clear and promising path in dentistry to find a solution for unsolved problems in various fields of dentistry. Also, in conservative dentistry, these materials promise to achieve the least damage to the teeth and the most similar structure to the destroyed tissues.

In this study, the latest bioactive materials used, such as Biodentine (a polymeric material with a nanostructure in combination with protein-replants), as well as well-known and common materials that have bioactive properties (such as MTA and calcium hydroxide) were investigated. In addition, the properties and disadvantages of using these materials in dentistry have been stated. These explanations help us to know all the options and materials in our treatments and make a better choice. Based on the results obtained from different studies, new bioactive substances and their effects can cause transformation in different fields of dentistry and solve many problems ahead.

Acknowledgments: None

Conflict of interest: None

Financial support: None

Ethics statement: None

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