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Biomaterials in Dentistry: An Extensive Review from the Atomic Scale to Clinical Applications

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ABSTRACT

This study offers a thorough analysis of dental biomaterials, emphasizing their function from clinical applications to atomic and molecular structure. There includes a thorough discussion of materials like silica, glass-ionomer cements, implants, and composites. Important procedures including molding, casting, and the application of contemporary technologies in the manufacturing of dental prosthesis are also described. Additionally examined are the effects of biomaterials' physical and chemical characteristics on the development of biological scaffolds, the use of advanced polymers for novel therapies, and the enhancement of restorative dentistry performance. The goal of this study is to advance our understanding of biomaterials and provide innovative ways to help dental patients live better lives.

Keywords: Dental biomaterials, biocompatibility, dental polymers and ceramics, dental implants.

1 Introduction

One of the most significant areas of medicine is dentistry, which significantly contributes to raising people's quality of life. The use of more sophisticated materials in the diagnosis, prevention, and treatment of oral and dental illnesses has been made possible by ongoing advancements in materials science, particularly biomaterials. These developments include intricate blends of metallic, ceramic, and polymeric materials that provide notable mechanical performance and longevity in addition to good biocompatibility.

The field of dental biomaterials has seen a large number of studies in recent years, with an emphasis on enhancing mechanical strength, biocompatibility, and minimizing material side effects. But there are still a lot of unanswered concerns about how materials interact with the mouth's acidic or alkaline environment, how to improve clinical processes, and how to develop sustainable and affordable substitutes.

The current study aims to identify the opportunities and difficulties in the field of dental biomaterials by reviewing the body of existing research literature. The purpose of this study is to present a thorough analysis of the different kinds of dental materials, their chemical and physical characteristics, and the procedures involved in clinical applications. The goal of this research is to supply fresh data that will aid in the creation of more sophisticated materials and creative therapeutic approaches.

Stated differently, this study aims to address the following basic question: How can dental biomaterials be optimized in the oral environment to improve their performance, durability, and compatibility? Finding the answer to this query can be a big step in raising patient happiness and the standard of dental care. The significance of materials science in dentistry is examined in this article. The introduction covers

subjects including atomic and molecular structure, dental goals, biomaterials qualities, gypsum and wax products, and sorts of materials. Additionally included are ceramics, resins, adhesives, dental cements, implants, polymer technologies, metals and alloys, casting techniques, investment materials, and impression materials. Lastly, more complex ideas like biomineralization, hybridization, and biological tooth replacement and repair are covered.

1.1 What Materials Science Means in the Field of Dentistry

The study of materials science and engineering encompasses a wide range of engineering materials, including metals, ceramics, electronic materials, and biomaterials. The science of dentistry includes the physical and chemical characteristics of these materials as well as their manipulation and use in the field [1].

1.2 Types of materials utilized in dentistry

Preventive, restorative, and auxiliary materials are the three basic categories into which dental materials are often separated. Bases, liners, and sealants are examples of preventive materials. Sealants are thought to be a rapid and painless way to stop decay in the grooves of teeth's chewing surfaces, particularly in kids and teenagers. The primary purposes of liners are to support dentures and lessen gum sensitivity and irritation. Additionally, bases can be used to replace lost teeth and cover gaps in the teeth with artificial ones.

When there is irreparable tooth damage and the teeth need to have cavities, cracks, or holes filled, restorative materials are utilized. These materials consist of Inlays and Onlays, composites, implants, and silica. In toothpastes, silica serves as a brightening, mild abrasive, and thickening agent. Implants are a long-term solution for missing teeth that are extremely stable and function and look like real teeth. Composites are tooth-colored materials

that are utilized to create restorations that are delicate and nearly identical to actual teeth. When the decay is not severe, inlays and Onlays are also utilized to fix cavities and cracks in rear teeth.

Casts, waxes, and impression materials are examples of auxiliary materials. A diagnostic model of the patient's jaw and teeth is produced during the impression-taking process, enabling accurate treatment planning. Materials like elastomers, silicones, and Polyether's make up Impressions; these are chosen for their hardness, stability, and flavor. Waxes are used to enhance the appearance and condition of teeth while preventing orthodontic issues. Orthodontic wax helps lessen the pain and suffering that brackets and Arch wires produce while shielding the oral tissues from sharp orthodontic elements.

Because of their many uses, these materials are crucial for the diagnosis, treatment, and prevention of dental issues as well as for enhancing oral health [2, 3].

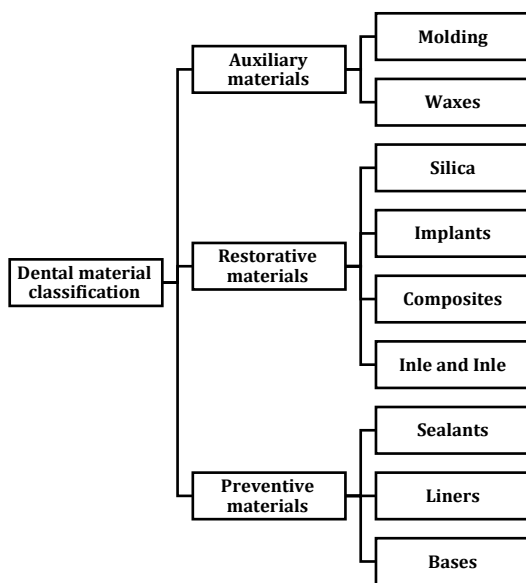


Figure 1: Dental material classification

1.2.1 Which tasks pertaining to materials science should be carried out in the dentistry field?

Understanding the right use of dental materials, identifying their physical and chemical characteristics, and becoming proficient in their manipulation are prerequisites for employment in this sector. Additionally, carrying out additional study in this field can greatly enhance the caliber of materials. It's also important to find pupils who are interested in this subject at both universities and schools. The link between this discipline and physics, chemistry, and other relevant fields should be developed through appropriate and correct teaching [4, 5].

1.3 Dental Goals

The prevention, diagnosis, and treatment of oral and dental disorders, pain management, enhanced speaking and chewing abilities, enhancement of overall look, and smile design correction all contribute to maintaining and enhancing patients' quality of life. In order for each nation to succeed in this area, achieving this on a national and regional level largely calls for appropriate education and learning, research and innovation, and the provision of comprehensive dental care [6, 7].

1.3.1 What branches are there related to dentistry?

Restorative dentistry and dental prosthetics are the two primary subfields of dentistry and oral hygiene. There are two types of restorative dentistry: 1) the branch that handles treatment and prevention, and 2) the branch that concentrates on restoring teeth's natural color and function. Additionally, there are two subcategories of dental prosthetics: 1) the field that deals with restoring the appearance and functionality of teeth, and 2) the field that covers fixed partial dentures to replace a tooth or a tooth fragment [8, 9].

1.4 Properties of biomaterials in relation to dentistry

We'll start by looking at the lexical definition of biomaterials. A biomaterial is a material, either natural or synthetic, that is utilized to replace, repair, enhance, or treat tissue in living things. Dental biomaterials are used in dentistry in an environment that is known to be "hostile" or "aggressive" by science. Significant and quick changes in pH (acidity or alkalinity), moisture content, and continuous mechanical flow and movement are characteristics of this specific habitat. In order to offer solutions for physicians, these difficulties require basic research and development, and a large portion of this work is made possible by the planning and development of fundamental materials concepts and their comprehension in these sciences. Two primary categories can be used to broadly classify this understanding:

1) When it comes to dental restorations, it is crucial to comprehend the characteristics of metals, polymeric ceramics, and design.

2) Understanding the quality of support offered by the specialist and the investment in hard and soft tissues also requires knowledge of the relative values of qualities in different restorative materials [10, 11].

1.5 Examination of Atomic and Molecular Structure

According to the broad and textbook definition of chemistry, atoms and molecules make up all materials. Consequently, it is not unexpected that a material's qualities and its atomic foundation are closely related. The characteristics of the atoms and their locations and configurations are also significant in this context. A primary bond is the bond that forms between two atoms when they come close to one another to form a molecule [12].

¹ CaSO₄·2H₂O

1.6 Dental Gypsum Products

Gypsum is a mineral that is extracted from various parts of mines; it is also used in flue gas desulfurization in some coal-fired power plants. Gypsum is a white powder; the mineral has the chemical name calcium sulfate dihydrate¹, and its product used in dentistry is based on calcium sulfate². Various crystals of gypsum forms, such as selenite and alabaster, exist in nature. Other names for it include dental plaster, dental stone, and high-strength die stone, and its manufacturing process is by casting. These types of gypsum are supplied in the form of hemihydrate; when calcium sulfate is combined with water, it is obtained by dehydration of its dihydrate and is classified into alpha and beta types, with the alpha type typically used in the medical field.

Alpha hemihydrate has long been utilized in dental materials and as a powder to fix cracked areas. The most significant characteristic of this material is its high initial and ultimate strength; it is currently also utilized as a bone transplant and bone regeneration material.

Today, gypsum and its derivatives are employed in a wide range of fields, including building construction, soil aeration, additives, pharmaceuticals, medical devices, and dentistry. Molds, casts, and pouring models are the primary uses in dentistry. The ancient stone blocks of the Egyptian pyramids were previously joined using gypsum, lime, and water [13].

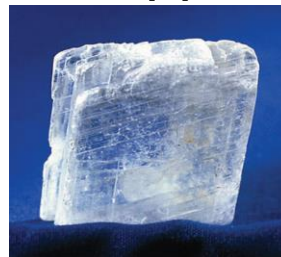


Figure 2: Showing the crystalline form of gypsum

² SO₄·H₂O

1.7 What qualities must to be present in dental mold materials?

Prioritizing dimensional stability, or proportionate and accurate dimensions, is essential while making dental molds. They also need to have the right mechanical characteristics. In order to catch finer details, caution should also be used when pouring the liquid [14].



Figure 3: Molds for teeth

1.8 Dental waxes

Dental waxes can contain resins, oils, fats, and colors and are generally classified as either natural or synthetic. These materials can be combined to produce desired qualities for a range of uses. Waxes are thermoplastic materials, which means that their properties remain unchanged when heated and cooled.

This characteristic enables waxes to solidify after cooling and to become moldable at high temperatures. Numerous other sectors can benefit from this trait in addition to dentistry. Although waxes have poor mechanical and resistance qualities, they are frequently employed in dentistry to make wax patterns and dental appliances like dentures because of their thermoplastic qualities. Inlays, crowns, Pontics, and full and partial dentures are all made using waxes as templates. Additionally, waxes are a crucial tool in the manufacture of complete dentures and the taking of imprints of edentulous areas [15].

1.8.1 Classification and division of dental waxes

Inlay wax, casting wax, and modeling wax are the three primary types of waxes used in dentistry and pattern preparation. Sticky wax, boxing wax, and utility wax—also referred to as beading wax or peripheral wax—are the two primary types of wax processing. Furthermore, bite registration wax is separated into two primary categories: wafer wax and bite registration wax. The purpose of these categories is to make it easier to choose and apply waxes correctly for a variety of dental operations [16].

1.9 Waxing pattern

When dental appliances are being made, wax patterns are created on a stone model or on a prepared oral cavity. The appliances' final size and shape are determined by these patterns. One of the earliest manufacturing techniques, casting, is usually used in this process. It involves melting materials and pouring them into a mold, enabling the mass production of parts with simple to complex shapes, integrated structures, and sizes ranging from small to large, weighing a few grams to several tons.

The lost wax technique is one method employed in the casting process³. Depending on the appliance type and manufacturing method, the final polymer or alloy is used in this procedure to replace the materials that were previously placed in the mold. This procedure is used, for instance, to create metal crowns or entire dentures. It should be noted that the lost wax process needs to fit the exact shape of the wax-fabricated item in order to be used [17].

1.10 Wax pattern types

Generally speaking, these patterns fall into two major categories: those pertaining to dental specialization and those pertaining to the production of materials that are utilized in

³ lost wax

dentistry to create artificial teeth. Generally speaking, there are two primary categories of artificial teeth: porcelain and acrylic. Dental plaster or dental stones and a metal container called a flask make up the mold used to make acrylic prostheses. The gypsum teeth are extracted from this wax after it has been submerged in hot water. Polymeric denture base materials, such as acrylic resin materials, are then used to fill the space that the wax once inhabited. In order to get the correct shape, the wax or carved design is placed in a heat-resistant mold during the production process of different materials. Melted alloy is then used in place of the wax once it has been removed from the mold, either by a burnout procedure or by the lost-wax casting technique [18].

1.11 Overview of refractory molds

The greatest and most accurate reproduction of teeth and surrounding tissues can be obtained by dentists because to impression materials' unique ability to capture details. A negative mold of the teeth and the structures around them is called an impression. Nevertheless, a positive replica of the teeth and surrounding tissues is created when the imprint is filled with plaster to make a model; this model or replica is known as a cast [19].

1.12 Metal and Alloy Use in Dentistry

1.12.1 Crystal Structure of Metals and Alloys

Metals are described as opaque, glossy chemicals that carry heat and electricity well and, when polished, take on the ability to reflect light. Metals are utilized in orthopedic procedures in addition to restorations. Noble metals and base metals are the two basic types of metals. In addition to being resistant to oxidation and corrosion, noble metals like gold, silver, and platinum also have unstable oxide layers. At high temperatures, these metals also exhibit strong resistance to chemical assaults. Alkali metals, alkaline earth metals, transition metals, and rare earth metals are among the different types of base metals, which make up almost 70% of the metals on the periodic table.

Copper, bronze, aluminum, lead, zinc, tin, brass, titanium, chromium, silver, and gold are examples of non-ferrous metals, which do not contain iron in their composition; pure metals, which are composed of only one substance, such as gold, silver, copper, and iron; and ferrous metals, which contain iron, such as steel and cast iron [20].



Figure 4: Metal-fused porcelain crown

1.13 The process of casting dental alloys

Inlays, Onlays, Crowns, Bridges, and Removable partial dentures are among the dental restorative items that are made using the casting technique, which turns a wax model of a restoration into an alloy counterpart. The same fundamental form or variation of the lost-wax process is used for all castings in dentistry. Although the lost-wax process has been around for millennia, it wasn't until 1907 that Taggart popularized it in dentistry by introducing his method using a casting machine.

This procedure entails enclosing the wax pattern in a heat-resistant mold, heating the mold to remove the wax, and then pushing molten metal through a sprue—a channel—into the mold. The final casting used in dentistry needs to be a precise replica of the wax pattern in terms of both surface details and overall measurements. The ultimate quality of dental restorative materials can be greatly impacted by meticulous attention to detail and maintaining technique consistency throughout the casting process. In order to decide whether to alter the technique for a specific procedure that is necessary, it is essential to comprehend the exact impact of each variable in the techniques [21].

⁴ Taggart

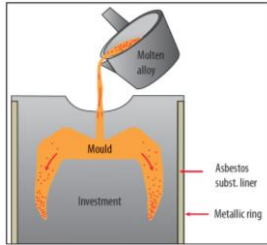


Figure 5: Casting process

1.14 phases involved in the development, repair, and rebuilding of teeth

A dental crown, sometimes referred to as a dental cap, is a covering that is applied over a tooth in order to improve its appearance and restore its size, shape, and strength. Depending on its intended use and the tooth's condition, the dental crown may completely or partially cover the visible area of the tooth up to the gum line after it is cemented into place. Preparing the teeth, making a model, and making a wax-up are all steps in the fabrication process [22].

1.15 Surface alterations of dental implants

A dental implant is a metal device that replaces lost teeth and acts as an artificial root for artificial teeth. The alveolar bone, which makes up the teeth's bony bases, comes into direct touch with these implants. Although the use of implants has been around since the time of the ancient Mayans, Per-Ingvar Brånemark made the accidental discovery of modern implantology. He noticed during his investigation that titanium, which was utilized in an instrument attached to rabbit bone, had fully fused with the bone.

The foundation for the creation of modern dental implant systems was established by this discovery. Modern implants need to be easy to make, stable, biocompatible, and functionally sufficient. Subperiosteal implants, which are made of a cobalt-

chromium framework that is positioned on the bone and beneath the oral mucosa, were utilized before this technique was developed. Because of its drawbacks and significant risks, this design was rendered obsolete. Furthermore, because of the risk of infection and fracture, Osseo integrated implants replaced blade-vent implants, which had one end put into the bone and the other projecting into the mouth cavity. Dental implants are now regarded as one of the most cutting-edge techniques for tooth replacement [23].

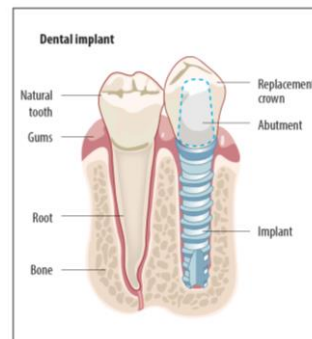


Figure 6: Natural teeth (left) and dental implants (right) are contrasted.

1.16 Osseointegration

Any biomaterial that is introduced into living tissue is nearly instantly covered in cell-adhesive proteins. Wettability and charge of the root surface affect the quality of these protein adsorption processes onto the material and help cells that interact with these proteins adhere to the implant surface. Similar to osteogenesis in the body, this process involves the deposition of osteoblasts, or bone-forming cells, onto the implant surface, which results in a direct structural and functional bond between the implant and bone—a process known as osseointegration.

On the other hand, the implant is said to have failed if the interface between the connective tissue and the bone-implant interface is disrupted. One of the main factors influencing dental implants' success is

the osseointegration process. The osseointegration process depends on bone quality, implant surface shape, implant material, and the surgical technique used for implant placement, according to the idea put forward by Per-Ingvar Brånemark [24].

1.17 Polymer technology's use in dentistry

A branch of materials science that focuses on polymers, particularly synthetic ones, is called polymer science or macromolecular science. One Three primary branches comprise the multifaceted field of polymer science. The chemical synthesis and characteristics of polymers or macromolecules are the focus of polymer chemistry, also known as macromolecular chemistry.

The physical characteristics of polymeric materials and their engineering uses are the focus of polymer physics.

Characterization of polymers involves analyzing their shape and chemical structure as well as determining their physical characteristics in relation to their composition and structural features.

Large molecules known as polymers (poly = many, mer = unit) are created when small molecules, or monomers, are joined by primary covalent bonds in the main backbone of the molecular chain. These molecules are usually made up of C, N, O, Si, and other elements. Most areas of dentistry rely heavily on polymers. Synthetic polymers have been used in medicine for more than 50 years and are now widely used in dental restoration and prosthetics. Examples of their applications in dentistry or dental treatment include disposable devices, dental materials, implants, dressings, bleaching trays, extracorporeal devices, encapsulants, polymeric drug delivery systems, tissue engineering scaffolds, and brackets.

Dentures, restorative materials, relining and repair materials, soft liners, bonding agents, temporary crowns, and bridges are among the application areas for acrylic polymers based on methacrylate

functionality. Among the significant polymer groups, elastomeric materials—also referred to as elastic or pseudo-plastic groups—have the crucial characteristic of elasticity, which allows them to deform under "stress" and revert to their initial condition once the stress is eliminated. Examples include alginates, silicones, and polysulfides, which are used to take imprints of the mouth's soft and hard tissues. These impressions can subsequently be utilized to create extra-oral equipment.

Polymer composites are a crucial component of restorative dentistry, and denture adhesives are likewise a mixture of water and water-soluble polymers in a cement basis. Today, a vast variety of materials used in contemporary dentistry are classified as polymeric materials [25].

1.18 Dental impression procedures and supplies

Collaboration with dental labs is necessary for many dental operations, including the creation of dentures, crowns, laminates, bridges, mouthguards, and night guards. The lab needs precise information on the patient's dental health in order to create this prosthesis. Using specialized putty-like materials that solidify in a matter of minutes, the dentist first makes an imprint of the patient's teeth. This initial mold is then sent to the lab.

Cleaning and drying the teeth is the first step in the process. To gently press the gum tissue away from the teeth, a tiny retraction cable is wrapped around them. The imprint material is put to the teeth and a tray is placed over them once the cord has been removed. A duplicate of the teeth is produced by removing the imprint once the material has solidified. After that, the dental lab receives this mold to create the finished prosthetic [26].

1.19 Dental ceramic items

Although the word "ceramic" comes from the Greek word "KERAMOS," which means "burnt things," it refers to materials that are made by burning or fire.

Earthenware, such as pots for domestic usage, was the earliest pottery created by mankind. These materials are not appropriate for dental applications because they are porous, opaque, and somewhat weak. It was given the term porcelain, often referred to as conventional or feldspathic porcelain, after silica and feldspar were added to increase its strength and translucency, which are necessary for dental usage. Veneer porcelain, a modified kind of ceramic used in dentistry, is used to create veneers, crowns, bridges, and prosthetic teeth [27].



Figure 7: Dental ceramic items

1.19.1 Dental amalgam

Dental materials fall into three categories: restorative, preventative, and auxiliary. They are used in dentistry to repair cavities, replace missing teeth, and reconstruct damaged teeth. These materials should have sufficient biomechanical resistance, dimensional stability, non-toxicity, and biocompatibility. There are two types of restorative materials: direct and indirect. While temporary materials are only utilized temporarily, direct materials—like composites and silver amalgam—are put directly in the tooth cavity. For more than 160 years, amalgam has been utilized to repair posterior teeth, despite questions regarding its safety and look [28].



Figure 8: Dental amalgam

1.20 Overview of composite materials based on resin and their uses

Advances in polymer science have led to the development of a class of materials called resins, which are now widely used in dentistry. Among them, blue light is used to polymerize composite resins, which are made up of monomers and inorganic fillers. They are frequently used to repair carious lesions, improve the aesthetics of damaged teeth, and improve smile design because of their tooth-colored look and advantageous mechanical qualities. Composite resins have superseded older materials like silicate cements and show better performance than unfilled resins like acrylics [29].

1.20.1 Acrylic resins

Composite resins have rapidly supplanted acrylic resins, which were first utilized in unfilled form. These substances have developed into an essential component of dental biomaterials, meeting mechanical and biocompatibility standards. Inorganic fillers and other additives are encased in a polymeric matrix to form dental resins. Each of the fillers' many forms—spherical, fibrous, or porous—has pros and cons of its own. When these fillers are combined in the right way, the composites acquire beneficial qualities. Additives including carbon nanotubes, whiskers, fibers, and nanoclusters are added to improve their mechanical and physical properties even further. Nowadays, dental resins are frequently utilized in temporary crowns, dental bridges, and provisional restorations. They are usually given in liquid and powder form [30].



Figure 9: The process of producing and packaging acrylic

1.20.2 Composites

In materials science, composites refer to products that are composed of at least two distinct phases and are usually created by combining different components with varying structures and properties. These materials are combined to achieve specific characteristics such as increased strength, brilliance, or resistance to electricity. Common engineering composites include composite building materials (such as cement and concrete), fiber-reinforced polymer plastics, metal matrix composites, and ceramic matrix composites [31].

1.20.3 Glass ionomer Cement

Glass ionomer cement has a chemical link to dentin and enamel and is used in dentistry as a luting cement, filling material, and for orthodontic brackets. This substance is used to fill erosions and has anti-cariogenic properties since it releases fluoride. Regular caries and erosion are the two types of dental decay; with erosion, the whole tooth structure is lost. Glass ionomer, hybrid, silicate cement, and polycarboxylate are examples of restorative materials. Alan Wilson and Brian Kent first created glass ionomer in the 1960s. It may be purchased as a liquid and powder or combined with water. Although the new production procedure has produced a more transparent cement with reduced solubility, these cements have less characteristics [32].



Figure 10: Materials for glass ionomer cement restoration

1.21 Dental Adhesive Systems

Dental adhesive solutions serve as a bridge and interface for bonding between the restorative material and the tooth substrate. Dental adhesives made of a mixture of resin monomers, mostly methacrylate's, are what allow a resin-based cement or restorative material to stick to the tooth's hard tissues, such as the enamel and dentin. Surface demineralization is the basic idea behind adherence to dentin and enamel. Demineralization is the term used to describe the everyday, spontaneous healing process of non-cavitated carious lesions in the oral environment. This procedure aids in the restoration of the tooth's outermost covering, or enamel, and helps keep cavities from forming.

Conversely, in cements or composites made of resin, the adhesive creates covalent connections with the monomers. Adhesives, like resin-based composites, go through a polymerization process that can be triggered by light or chemical agents. Light-cured adhesives, which use a light source instead of chemical initiators, are the most aggressive temporary adhesives. Following its placement in the tooth, the composite material is hardened using a light-curing apparatus, also referred to as "light cure." The composite material is quickly polymerized and compacted by this device's ultraviolet (UV) light emission. A different class of adhesives combines chemically and photo-initiated polymerization in a dual-cure mechanism. Dual-cure adhesives are the name given to them [33].

1.21.1 Dental adhesive composition

Resin monomers, solvents, initiators, stabilizers, and maybe fillers make up dental adhesives. Functional monomers, cross-linking monomers, and intermediate monomers are the three general types of resin monomers.

In order to interact with calcium ions, which are essential to the formation of hydroxyapatite, functional monomers must have at least one acidic group. The crystalline structure and chemical makeup of hydroxyapatite, more especially calcium hydroxyapatite, are well-defined. Hydroxyapatite is regarded as one of the most important and extensively utilized materials in biomedical applications because of its chemical resemblance to the mineral component of bone.

Furthermore, because of their superior biocompatibility, bioactivity, and bone-growth-promoting qualities, hydroxyapatite bio ceramics are widely used in orthopedics and dentistry. Consequently, this substance aids in remineralization, often known as bone regeneration.

Additionally, functional monomers improve adherence to the tooth substrate and increase moisture tolerance [34].



Figure 11: Materials for glass ionomer cement restoration

1.22 Dental cements

A substance with a mechanically interlocked and hardened effect is called cement. Cement is defined in dentistry as a substance that solidifies to serve as a base and may also be used as a liner, filler, luting agent, or adhesive to adhere prosthetics to tooth structures. Dental cements are utilized in a variety of dental applications, such as cavity lining materials and pulp-protecting agents. Dental cements come in two varieties: resin cements and acid-based cements. They are hard, brittle substances made by combining a liquid and a powder [35].

1.23 Utilizing Bases and Liners to Prepare Cavities

Certain filling materials should not be put straight into a cavity that has just been prepared. In these situations, a liner is put to the pulpal axial wall and occlusal floor of Class II cavities prior to the cavity being filled. The depth of the cavity, the thickness of the remaining dentin, and the kind of restorative material being utilized all influence whether this surgery is necessary.

There are four primary purposes for which liners and bases are used:

1. The liner serves as a barrier between the dentin and the filling material, preventing dentinal tubules from directly reaching the delicate pulp tissue.
2. Mechanical Support: During the filling process, it offers enough mechanical strength to endure disruptions.
3. The structural foundation provides a solid and secure framework for full cavity repair.
4. Thermal, Chemical, and Electrical Insulation: The liner shields the pulp from potential harm by shielding it from thermal, chemical, and electrical stimuli [36].

1.24 Biomineralization and Hybridization: A Development in Dental Repair

The idea of dentin hybridization, which combines resin materials with essential tooth dentin, was first proposed in the early 1980s. As new generations of dental adhesives were developed, this method changed as well. Conventional composite resins nevertheless have a short lifetime, usually lasting only five to seven years. It has been suggested that bonding agents be used in conjunction with bioactive materials to improve clinical performance and durability.

dental removals, amalgam fillings, gold restorations, and glass ionomer coatings are just a few of the techniques used in dental restoration. Acid etching, according to Dr. Michael Buonocore, may enhance the adherence of acrylic filler materials on enamel. Additionally, to improve bonding performance, Dr. Ray Bowen suggested using less soluble materials in 1963, such as self-cure methyl methacrylates and silicate cements [37].

1.25 Dental Restorative Care

The majority of dental operations have up to now only included replacing broken teeth. Synthetic biocompatible materials are employed for this purpose; these materials must behave and have characteristics that are comparable to those of the host tissue. However, short-term clinical results and the frequent need for retreatment have resulted from discrepancies among researchers about these materials and the impact of the oral cavity environment. Over the past few decades, the multidisciplinary areas of tissue engineering and regenerative medicine have developed to repair damaged tissues and restore healthy ones. In order to support the creation and development of new tissues, these professions rely on biological sciences. Additionally, as material science and engineering have advanced, they have incorporated novel design concepts to create successful tissue engineering techniques [38].

1.26 Biological Replacement and Repair of Teeth

1.26.1 Scaffolds

Scaffolds are a three-dimensional framework or temporary structure used to support biological activity. In order to promote cell adhesion, proliferation, and differentiation for the regeneration of the targeted tissue, their architecture is specially designed. Scaffolds should ideally be placed into the tooth structure.

In addition to facilitating the delivery of bioactive chemicals, the extracellular matrix of natural tissues must facilitate the efficient diffusion of molecules like growth factors or medications. This satisfies the metabolic needs of the participating cells and guarantees a high oxygen supply [39].

1.26.2 Partial Prosthesis

An apparatus that substitutes a missing limb (or the function of that limb) is called a prosthesis. A dental specialty called dental prosthetics uses biocompatible replacements to diagnose, treat, restore, improve, and maintain oral function, comfort, appearance, and health in patients with clinical conditions related to missing or deficient 1 teeth and/or maxillofacial tissues 2 [40].

1.26.3 New Developments in Biological Treatments

Promising developments in contemporary dental care include methods like using stem cells to replace lost teeth, using gene therapy to promote the formation of new dental tissues, and creating biomaterial-based systems that can blend in organically with existing teeth [41].

1.26.4 Dental Tissue Engineering

The creation of new dental tissues using dental stem cells, in vitro dental tissue culture, and the use of three-dimensional scaffolds to support the growth of dental tissues in an environment that closely resembles natural oral conditions are the main focuses of recent developments in dental tissue engineering [42].

1.26.5 Application of Nanotechnology

Novel materials for tooth regeneration and restoration have been developed as a result of advances in nanotechnology. One such material is the use of nanoparticles to improve the mechanical and biological characteristics of restorative materials and to strengthen tooth structure. These

developments are consistent with the more general idea of tooth replacement and repair by biological means [43].

1.26 Conclusion

The quality and efficacy of contemporary dental therapies have been significantly improved by notable developments in the field of dental biomaterials. Damaged teeth have been restored and replaced using a variety of materials, such as glass ionomer cements, implants, composites, and silica-based compounds. Furthermore, new opportunities for enhancing clinical results have been made possible by cutting-edge technologies including bio-scaffolds, sophisticated polymers, and creative prosthetic fabrication techniques. Key characteristics of dental biomaterials include resilience to the extreme acidic and alkaline conditions of the oral environment, biocompatibility, and excellent mechanical performance. Therefore, it is crucial to continuously optimize materials and associated procedures in order to lower treatment costs and potential difficulties as well as to increase the functionality and longevity of restorations.

All things considered, improving the physical, chemical, and biological characteristics of dental biomaterials and creating next-generation technologies have enormous potential to raise the bar for restorative dentistry care and boost patient satisfaction.

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Disclosure of Potential Conflicts of Interest

The author declares that there is no conflict of interest.

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