

Biomaterials in Oral Rehabilitation

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Abstract: Ever since dentistry has been evolved dental biomaterials play very important role in every stage of dental treatment. In order to achieve precision and accuracy and to provide high end treatment continuous efforts have been made to introduce newer biomaterials and advances are made in the existing materials. This articles gives a brief description about the biomaterials used now days in dentistry.

Keywords: Amalgams, Zinc phosphate cement, Aluminum oxide ceramics, Pure Titanium (CpTi).

1. INTRODUCTION

During the past few years, the biocompatibility of dental materials has evolved into a comprehensive, complex, and independent discipline of dental materials science⁰¹.

Biomaterials are used in the oral cavity either to restore function, comfort, or aesthetics caused by developmental disorders, disease, or trauma⁰². **Biomaterial** refers to any nonvital material intended to interact with biological systems within or on the human body. Dental materials inserted into the oral cavity therefore belong to the group of biomaterials⁰¹. In dentistry biomaterials are broadly categorized into 1. Auxillary biomaterials which includes impression materials , waxes, gypsum, investment and finishing materials, are utilized during clinical and laboratory steps but will not be covered in this article. 2. Restorative biomaterials, and 3. Prosthetic biomaterials⁰².

2. HISTORY OF DENTAL MATERIALS⁰⁴

Year	Material used
500 B.C	Etruscans used gold to make first dental bridge
1500 A.D	In Italy gold foils used as restorative materials
1700s	In France lead, tin, gold used as restorative materials
Late 1700	Porcelains used to make complete dentures and individual teeth
Early 1800	Amalgam used in France
Late 1880s	Zinc phosphate, silicate cements used to secure gold inlays
1910	Taggert used lost wax technique
1940	Development of synthetic resins like acrylic occurred
1970	Glass ionomer cement and polycarboxylate were developed
After 1990	Simplified dentine adhesive, reinforced ceramics, resin modified GIC, compomers, new root canal fillers were developed

RESTORATIVE BIOMATERIALS:**AMALGAM:**

Silver amalgam has been the most important restorative material in the history of dentistry⁰¹. “amalgam” is derived from the Arabic “almalgham” and the Greek “malagma,” which refer to a soft substance or mass. Silver amalgams are primarily composed of metallic mixtures whose main component is mercury. The alloy powder of modern high copper amalgams comprises silver, tin, copper, and zinc^{01,07}. Amalgam restorations often tarnish and corrode in oral environment. Active corrosion of a newly placed amalgam comes about in the interface between the tooth and the restoration. The empty space permits the microleakage of electrolytes and a concentration cell (crevice corrosion) process results. The build-up of corrosion products gradually seals this space, making dental amalgam a self-sealing restoration⁰³. Several attempts have been made to improve the resistance of amalgam to corrosion and emission of mercury. One direction has been to change the relationship between metals in the alloy. Modern amalgams contain 40–54% mercury, and another approach has been to substitute some of the mercury with gallium⁰¹.

COMPOSITE RESINS:

Resin-based composites are primarily used as anterior and posterior filling materials. Products with similar composition are also applied as pit and fissure sealants, luting composites (e.g., for luting ceramic and indirect composite restorations), and for crown buildups and the bonding of brackets and orthodontic bands. Composite are consists of

- Filler particles
- Matrix resins and corresponding catalyst systems
- Coupling agents between fillers and matrix resins

Filler particles mainly consist of finely ground quartz, boron silicate, lithium–aluminum silicate glasses, and highly dispersed amorphous silicon dioxide. **Matrix resin** consists of a mixture of various monomers, for example, Bis-GMA and/or UDMA as well as various modifications of these molecules. Other ingredients of the composite matrix are comonomers (EGDMA, DEGDMA, and TEGDMA) and various additives such as photoinitiators (e.g., camphorquinone), co-initiators (e.g., DMABEE, DEAEMA), inhibitors (e.g., BHT), ultraviolet absorbers, photostabilizers, and pigments. **Coupling** between filler particles and matrix resin is obtained through trifunctional alkoxy silanes, which are mostly called “silanes” in the literature. Si–OH groups generate the link to the filler surfaces; the unsaturated vinyl or methacryl groups polymerize with base monomers and comonomers. The polymerization of resin-based composites will be either chemically initiated or cured by light initiation^{01,08,09}.

CEMENTS:

The basic components of many types of cement are the following:

- Zinc oxide or silicon dioxide as powder
- Phosphoric acid, polyacrylic acid, or eugenol as Liquid

Setting calcium hydroxide materials are also usually classified as cements. Calcium phosphate cements are a recent development and are considered to be bioactive (osteoconductive and osteoinductive). The main disadvantages of calcium phosphate cements are their poor mechanical properties and washing-out effects, which restrict their actual use to bone regeneration and root canal therapy.

Silicophosphate cements (also called stone cement) are a combination of silicate and zinc phosphate cement in which zinc oxide is mixed with glass powder. They have been used as filling material and for cementing indirect restorations. Silicophosphate cements are usually classified as inappropriate for definitive restorations, particularly because of their ability to cause chronic pulpitis. Also much better alternatives are now available.

Glass ionomer cements (also known as polyalkenoate cements) were introduced in 1972 by Wilson and Kent. Conventional glass ionomer cements are powder and liquid systems. The powder contains finely ground glass (containing, for example,

calcium and sodium fluorophosphoaluminosilicate). The liquid typically consists of a polyacrylic acid (47.5%) and additional polycarboxylic acids such as maleic acid, tartaric acid, and itaconic acid. Conventional glass ionomer cements set through an acid-base reaction. The acid causes an initial release of calcium ions from the glass, followed by a segregation of aluminum ions. These ions replace the protons of the acidic groups, thus generating insoluble calcium and later aluminum carboxylates. Glass ionomers are initially very acidic (pH 1.6–3.7). The completely set cements reveal a pH between 5.4 and 7.3. A significant development was the addition of water soluble monomers, for example, HEMA, and the grafting of methacrylate side groups on the polyacid polymer. By the addition of visible light initiator–accelerator systems these resin-modified glass ionomers (RMGI) can be command set with a light curing unit while also self-curing through the acid–base reaction. These improvements to the conventional GIC and RMGI have made these materials widely used as restorative materials.

Polycarboxylate cements have primarily been used as luting materials. They reveal good pulp compatibility. These materials shrink more extensively than zinc phosphate cements.

Zinc phosphate cement is primarily used for the cementation of indirect restorations, such as crowns and bridges. However, it is also applied for temporary fillings, cavity bases, and buildups of teeth beneath crowns.

The powder is mainly a mixture of zinc oxide and up to 13% magnesium oxide. The liquid is an aqueous solution of phosphoric acid containing 38–59% H_3PO_4 , 30–55% water, 2–3% aluminum, and 0–10% zinc. The aluminum is essential to the cement-forming reactions, and the zinc moderates the reaction between powder and liquid, allowing adequate working time and permitting a sufficient quantity of powder to be added for optimum properties in the cement. A longer exposure time of zinc phosphate cement to humidity will result in release of substances even from well-set cement. The acidity of the cement during application is very high due to the presence of phosphoric acid. The pH is about 2 at 2 min after mixing. Subsequently, it increases to 5.5 within 24 h. Thus, it may be concluded that potential pulp damage caused by acid attacks from the zinc phosphate cement (e.g., by released protons) is possible only during the first hours after application.

Zinc oxide and eugenol cements (ZOE) are primarily used as temporary filling material, for temporary luting of cast restorations, for indirect pulp capping, and as root canal sealers. ZOE consists of two main components: zinc oxide powder and eugenol (2-methoxy-4-allylphenol). When zinc oxide is mixed with eugenol, a zinc oxide–eugenol chelate will form in the presence of humidity. The mixture sets within a period of 12–24 h. Eugenol release depends on the powder–liquid ratio. ZOE with a powder–liquid ratio of 2:1 releases high quantities of eugenol during hydrolysis because of its high share of eugenolate. ZOE materials have antimicrobial properties against a great variety of oral bacteria. ZOE has a pain-relieving effect. When applied in deep cavities, ZOE suppresses the excitability of nerves in the pulpal tissue. This may be due to the capability of eugenol to block transmission of action potentials of nerves^{10,11}.

PROSTHETIC BIOMATERIALS:

METAL AND ALLOYS:

Noble and base metal alloys are used for (1) crowns and bridges with fused porcelain in esthetic areas, (2) inlays, onlays, crowns, and bridges without porcelain veneering in the posterior or nonaesthetic regions of the mouth, and (3) partial and complete removable denture bases. Base metals commonly used in dental alloys include, nickel, chromium, copper, zinc, gallium, silver, indium, and tin. Silver, a “precious” metal, is not considered a noble metal in dentistry due to its corrosion in the oral cavity. The noble metals utilized in dentistry are gold, platinum, palladium, iridium, rhodium, and ruthenium. Cold-worked or wrought noble and base alloys can be cast with or “soldered” Noble and base metal alloys are used for (1) crowns and bridges with fused porcelain in esthetic areas, (2) inlays, onlays, crowns, and bridges without porcelain veneering in the posterior or nonaesthetic regions of the mouth, and (3) partial and complete removable denture bases. Base metals commonly used in dental alloys include, nickel, chromium, copper, zinc, gallium, silver, indium, and tin. Alloys should (1) produce no toxic, carcinogenic, or allergic reactions; (2) resist corrosion and physical changes in the oral environment; (3) possess physical properties, that is, strength, fusing temperature, thermal conductivity, and coefficient of thermal expansion, appropriate for the desired application; (4) be able to be fabricated in a technically feasible manner; and (5) be available and relatively inexpensive. The alloys used for metal-ceramic or commonly termed porcelain-fused-to-metal (PFM) restorations must possess a fusion temperature range that is substantially higher ($>100^{\circ}C$) than the ceramic firing temperature, have

sufficient creep resistance at that temperature, and have the ability to form a good bond between its oxide surface and the ceramic veneer.

Wrought stainless steel alloys are used in orthodontic brackets and wires, endodontic instruments, prefabricated temporary crowns and space maintainers. In addition, wrought cobalt–chromium–nickel, nickel–titanium, copper–nickel–titanium, and beta-titanium alloys are also used as orthodontic wires. Nickel–titanium and copper–nickel–titanium orthodontic wires have a unique superelastic (pseudoeelastic) property that delivers a constant low-level force over an extended range of deformation. Nickel–titanium and copper–nickel–titanium alloys are also the shape memory alloy (SMA), that is, they can be deformed plastically below its transition temperature range (TTR), then after heating through and above the TTR, they will return to their original desired shape due to a crystallographic transformation from martensitic phase into austenitic phase. Titanium and titanium alloys, especially due to their thin stable oxide layers, are very important endosseous dental implant materials and, with the recent refinement in casting techniques, can be used for crowns, partial dentures and complete denture bases^{02,13,15}.

CERAMICS:

Dental ceramics comprise a comprehensive palette of different nonmetallic, inorganic materials. They are primarily used for inlays, veneers, partial crowns, full crowns, and for copings. They are also used for frame works and for veneering of metal/ceramic copings and frameworks (metal ceramics or porcelain-fused to- ceramics), artificial teeth, and for root canal posts. Ceramics are further applied as implant materials, for example as coatings for titanium implants, as full ceramic implants, or as bone replacement materials. Dental ceramics can be classified based on various criteria, for instance, on the raw materials, their chemical composition, the shaping methods, the firing temperature, or the type of clinical application. The classification according to composition is based on the chemistry of the principal components. Accordingly, oxides may be distinguished from nonoxides. Nonoxides, such as silicon carbide, silicon nitride, and aluminum nitride, are of minor importance in dentistry due to their black color. Oxide ceramics used in dentistry are primarily based on silicon oxide (SiO_2), aluminum oxide (Al_2O_3), and zirconium oxide (ZrO_2). Originally, mainly feldspathic ceramics (SiO_2 -based) were used in dentistry; these were obtained from frits of potassium and sodium feldspars and sintered to the desired shape (for example, metal ceramics). Later, glass ceramics and dental ceramics based on Al_2O_3 and ZrO_2 were introduced (for example, metal-free ceramic restorations). The term “titanium ceramic” is used in the literature for a feldspathic ceramic used for the veneering of titanium. Calcium phosphate ceramics are used in dentistry for coating metal implants in order to transform the metallic implant surface into a more bioactive state and thus to accelerate the bone apposition (biofunctionalizing of surfaces) Dental ceramics are commonly regarded as insoluble or only very slightly soluble at best. **Aluminum oxide ceramics** leach only minimal amounts of ions under physiological conditions. **Calcium phosphate ceramics** release calcium and phosphate into adjacent tissues. The leaching rate is determined by the composition, structure, porosity, and other factors, and can, therefore, be controlled within certain limits. Overall, HA and fluorine apatite ceramics are less soluble than TCP. But even HA coatings of implants may be resorbed with time⁰¹. Techniques for fabricating all-ceramic systems include (1) sintering with alumina-based, magnesia- based, and leucite-reinforced ceramics; (2) heat-pressed techniques with leucite-reinforced and lithium-disilicate-based ceramics; (3) slip-casting with alumina-, spinel-, and zirconia-based ceramics; and (4) the machining of manufactured ceramic blocks available in several types of ceramic. One method uses computer-aided designing/computer aided machining (CAD/CAM) technology to fabricate inlays, onlays, veneers, and crowns^{02,16}.

PROSTHETIC RESIN MATERIALS:

Currently, dental polymethylmethacrylates (PMMA) are used primarily for dentures and orthodontic devices. In addition, PMMA are used for individual impression trays and temporary crowns. The application of PMMA as a veneering material no longer plays a major role. According to the setting reaction, PMMA are classified as heat polymerizing, light curing, or chemically (auto)curing. Chemically curing systems require a special catalyst system that initiates the polymerization process without exogenous energy⁰¹. Pigments are added to obtain natural tissue appearance, for example, mercuric sulfide, cadmium sulfide, cadmium selenide, ferric oxide, or carbon black. Various glasses, ceramics and polymer fibers have been added as dispersed phases to various products in an attempt to reinforce the acrylic polymers. The liquid component is methyl methacrylate, modified with various other monomers while including an inhibitor such as hydroquinone to prevent premature polymerization for adequate shelf life. The liquid of cold-, self-, or autocuring resins contain tertiary amine or sulfonic acid

chemical accelerators to allow the polymerization of the monomer at room temperature. Plasticizers for resilience and crosslinkers for hardness and decreased solubility may also be included. Denture base resins can also be fabricated through pressure, heat and light-activated techniques with compositional modifications for the various initiation reactions and physical handling properties during fabrication. Denture teeth are also fabricated from acrylic and modified acrylic materials and are generally preferred over porcelain denture teeth due to wear characteristics, phonetics and technical considerations during fabrication and repair. Temporary or provisional restorations are also fabricated from acrylic based resins. Defects of the head and neck resulting from cancer surgery, accidents and congenital deformities have been corrected with a wide variety of maxillofacial resin materials, including poly(methylmethacrylate), plasticized polyvinylchloride, polyurethane, heat-vulcanized and room temperature-vulcanized (RTV) silicone and a whole host of various other elastomers. It is important to use prosthetic resin materials with color stability, ease of fabrication, dimensional stability, edge strength, flexibility, low thermal conductivity, biocompatibility, and surface texture to achieve clinical success and patient acceptance. The prosthesis can be held in place by tissue undercuts, the patient's glasses or dentures, medical grade adhesives, magnetic attachment to endosseous implant-retained metallic attachments or bars or through a combination of methods^{02,20,22}.

IMPLANTS:

Commercially pure titanium (CpTi) and Ti-6Al-4V are the materials most commonly used for endosseous dental implants. The stable oxides surfaces formed on CpTi and Ti-6Al-4V have proven to successfully biointegrate with bone. The terms osseointegration and functional ankylosis are used to describe the direct bone apposition on the implant surface giving evidence to support a direct biochemical bonding. Many other factors play a role but six biological and technical factors are recognized as key to implant success: (1) implant surface texture, (2) biocompatibility, (3) implant design, (4) host tissue condition, (5) surgical technique, and (6) loading conditions. Lower success is observed in areas of the mouth that may have less cancellous bone or thin cortical plates such as the posterior regions of the maxilla. Two of the most thoroughly investigated and successful surfaces are machined titanium and titanium plasma-sprayed (TPS) surface, with the latter significantly increasing the surface area for bone contact. These rougher surfaces have been shown to require higher forces to be removed from the bone than do smoother surface implants and may allow: shorter healing periods, the use of less invasive shorter implants and may not require bicortical implant engagement. Calcium phosphates or "hydroxyapatite" can also be coated on titanium implants and have been documented to create a very intimate bone to implant contact with a reduced healing period; Macroretentive features are also part of the implant design including: screwthreads, solid body press-fit designs, and sintered bead technology. These macroretentive features are intended to improve initial implant stability and enhanced bone ingrowth. Without the aid of a periodontal ligament (present between the natural tooth root and bone) the bone responds most favorable to compressive loading, which must be accounted for in the implant design^{0226,27}.

3. SUMMARY

This article briefly reviewed those commonly used metal, ceramic, polymer, and composite materials used in dentistry for the restoration of individual teeth or the replacement of missing teeth. The dentist, in consult with the patient, must take several factors into consideration in the selection of restorative biomaterials, to include (1) chewing forces, (2) esthetic demands, (3) strength of remaining tooth structure, (4) diet, (5) hygiene, and (6) cost. No one material type possesses all the desired physical properties; therefore, several biomaterials are required for successful dental restoration. The interplay of biomaterials and biomolecules may also lead to the predictable regeneration of hard and soft tissues, while tissue engineering may someday lead to the induction of whole tooth regeneration.

REFERENCES

- [1] Schmalz G; Bindslev DA: biocompatibility of dental materials, 2009
- [2] Armstrong S: BIOMATERIALS FOR DENTISTRY, Encyclopedia of Medical Devices and Instrumentation, 2006
- [3] Fathi M; Mortazavi V: A Review on Dental Amalgam Corrosion and Its Consequences, Journal of Research in Medical Sciences 2004; 1: 42-51
- [4] Ferracane JL, Materials in dentistry: Principles and application 2nd edition, 2001

- [5] Allen EP, Bayne SC, Becker IM et al: Annual review of selected dental literature: report of the committee on scientific investigation of the American Academy of Restorative Dentistry, *J Prosthet Dent* 82:54, 1999.
- [6] Allen EP, Bayne SC, Donovan TE et al: Annual review of selected dental literature, *J Prosthet Dent* 7632, 1996.
- [7] Halbach S: Amalgam tooth fillings and man's mercury burden [Review]: *Human Exper Toxicol* 13:496, 1994
- [8] Asmussen E: Clinical relevance of physical, chemical, and bonding properties of composite resins, *Oper Dent* 10:61, 1985.
- [9] Bayne SC, Thompson JY, Swift EJ Jr et al: A characterization of first-generation flowable composites, *J Am Dent Assoc* 129:567, 1998.
- [10] Craig RG, Peyton FA: Thermal conductivity of tooth structure, dental cements, and amalgam, *J Dent Res* 40:411, 1961.
- [11] Craig RG, Peyton FA, Johnson DW: Compressive properties of enamel, dental cements, and gold, *J Dent Res* 40:936, 1961.
- [12] A method for assessing the clinical solubility and disintegration of luting cements, *J Prosthet Dent* 40:413, 1978.
- [13] Asgar K, Allan FC: Microstructure and physical properties of alloy for partial denture castings, *J Dent Res* 47: 189, 1968.
- [14] Asgar K, Peyton FA: Effect of casting conditions on some mechanical properties of cobaltbase alloys, *J Dent Res* 40:73, 1961.
- [15] Parmiter OK: Wrought stainless steels. In *ASM metals handbook*, Cleveland, 1948, American Society for Metals.
- [16] Dong JK, Luthy H, Wohlwend A et al: Heatpressed ceramics: technology and strength, *Int J Prosthodont* 5:9, 1992.
- [17] Gray HS: The porcelain jacket crown, *NZ Dent J* 59:283, 1963.
- [18] Hodson JT: Some physical properties of three dental porcelains, *J Prosthet Dent* 9:235, 1959.
- [19] Leone EF, Fairhurst CW: Bond strength and mechanical properties of dental porcelain enamel, *J Prosthet Dent* 18:155, 1967.
- [20] Andreopoulos AG, Polyzois GL, Demetriou PP: Repairs with visible light-curing denture base materials, *Quint Int* 22:703, 1991.
- [21] Arima T, Murata H, Hamada T: The effects of cross-linking agents on the water sorption and solubility characteristics of denture base resin, *J Oral Rehabil* 23:476, 1996.
- [22] Koran A, Craig RG, Tillitson EW: Coefficient of friction of prosthetic tooth materials, *J Prosthet Dent* 27:267, 1972.
- [23] Ogle RE, Davis EL: Clinical wear study of three commercially available artificial tooth materials: Thirty month results, *J Prosthet Dent* 77:145, 1978.
- [24] Dootz ER, Koran A, Craig RG: Physical properties of three maxillofacial materials as a function of accelerated aging, *J Prosthet Dent* 71:379, 1974.
- [25] Pagniano RP, Scheid RC, Clowson RL et al: Linear dimensional change of acrylic resins used in the fabrication of custom trays, *J Prosthet Dent* 47:279, 1982.
- [26] Adell R, Lekholm U, Rockler B et al: A 15-year study of osseointegrated implants in the treatment of the edentulous jaw, *Int J Oral Surg* 10:387, 1981.
- [27] Brunski JB, Hipp JA: In vivo forces on endosteal implants: a measurement system and biomechanical considerations, *J Prosthet Dent* 51:232, 1984