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Polymeric Materials In Dentistry: Properties And Clinical Applications

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Abstract: Polymer materials play a crucial role in modern dentistry due to their wide range of applications, favorable mechanical properties, biocompatibility, and versatility. They are extensively used in restorative, prosthetic, orthodontic, and preventive dentistry, including dental composites, acrylic resins, adhesives, impression materials, and temporary restorations. Continuous advancements in polymer science have led to the development of high-performance dental polymers with improved strength, wear resistance, esthetic properties, and biological safety. The incorporation of digital technologies and novel polymerization techniques has further enhanced the precision and durability of polymer-based dental materials. This paper reviews the classification, properties, and clinical applications of polymers used in dentistry, as well as current challenges and future directions in the development of dental polymer materials.

Keywords: Dental polymers; Polymer materials; Biocompatibility; Restorative dentistry; Prosthetic dentistry; Acrylic resins; Dental composites.

Introduction: Polymers (from poly... + Greek meros — fraction, part) — substances, the molecules (macromolecules) of which consist of a large number of repeating units. Polymers are the basis of plastics, chemical fibers, rubber, paint and varnish materials, adhesives. At the same time, there are 2 main mechanisms for obtaining polymers: through polyaddition and polycondensation.

The creation of polymers for dentistry often leads to the development of materials that have found application in

other fields of medicine and technology. Such an example is the development of epoxy resins, as well as fast-curing compositions of an amine peroxide system, which are now widely used in engineering and medicine.

The main starting compounds for the production of polymeric dental materials are monomers and oligomers [mono-, di-, tri- and tetra(met)acrylates]. Monoacrylates are volatile, so they are used in combination with high molecular weight esters, which reduces polymer shrinkage. Di-[tri-, tetra-](met) acrylates are found in most composite restoration materials, as well as in basic plastics as crosslinking agents.

To facilitate the processing of polymers and give them a complex of required physical and mechanical (impact strength, fracture, bending, stretching, compression, etc.; matching the color of the hard tissues of teeth or oral mucosa, hardness, abrasion resistance), chemical (bond strength with artificial teeth, minimum residual monomer content), technological (simplicity, convenience and reliability of processing) and other properties (see Various components are introduced into their composition — fillers, plasticizers, stabilizers, dyes, crosslinking agents, antimicrobial agents that mix well in the polymer to form homogeneous compositions and have the stability of these properties during processing and operation of the polymer material.

Fillers are introduced to improve physical and mechanical properties, reduce shrinkage, and increase resistance to biological media. Powdered fillers are mainly used in dental copolymers (various types of quartz flour, silica gels, aluminum and lithium silicates, borosilicates, various grades of finely ground glass, hydrosilicates, phosphates).

The introduction of plasticizers into copolymer

compositions makes it possible to give them elastic properties, as well as resistance to ultraviolet rays.

Various dyes and pigments are added to polymer dental compositions to imitate dental tissues and mucous membranes. The main requirements for them are their harmlessness, uniformity of distribution in the copolymer matrix, stability in color preservation under the influence of external factors and biological media, and good optical properties.

To obtain polymers, radical and partially ionic initiators are used (benzoyl peroxide is most often used), that is, substances that, when decomposed into free radicals, begin a polymerization reaction.

The addition of activators in small amounts to the catalyst causes a significant increase in the activity of the latter.

Various quinones, mainly hydroquinone, are most often used as inhibitors. The set of the above components of polymer materials ultimately determines all its physical and mechanical properties.

The deformation and strength properties of polymeric dental materials change significantly under the influence of the molecular weight and branching of macromolecules, cross-links, the content of the crystalline phase, plasticizers and grafting of various compounds.

To assess the basic physical and mechanical properties of dental copolymers, the following parameters are determined: tensile strength, elongation at break, modulus of elasticity, deflection strength, specific impact strength.

The most important characteristic of the base material is its plasticity and impact resistance. Basically, these properties determine the functional qualities and durability of the prosthesis.

One of the main qualities of copolymer materials is water absorption (swelling), which can lead to changes in the geometric shapes of base plastics, impair optical and mechanical properties, and contribute to infection. Water absorption as a physical property is manifested during prolonged exposure of the base plastics (i.e., the base of the prosthesis) in the moist environment of the oral cavity.

An increase in the impact strength and elasticity of brittle copolymers can be achieved by combining them with elastic copolymers.

The thermophysical properties of copolymer materials include heat resistance, thermal expansion, and thermal conductivity. The value of heat resistance determines the maximum operating temperature of the material. For example, the heat resistance of polymethylmethacrylate according to Martens is 60-80 ° C, and according to Vick — 105-115 ° C. The introduction of inorganic fillers increases heat resistance, the introduction of plasticizers reduces it.

Thermal expansion is characterized by the magnitude of linear and volumetric expansion.

Thermal conductivity determines the ability of materials to transfer heat and depends on the nature of the copolymer matrix, the nature and amount of filler (plasticizer). As the molecular weight of polymers increases, the thermal conductivity increases. Since the thermal conductivity of PMMA is very low, it is an insulator. This has a detrimental effect on the physiology of the oral cavity.

The variety of polymer materials used in the clinic of orthopedic dentistry creates certain difficulties for creating a unified classification, since a variety of criteria can be used as a classification feature.

Classification of polymers:

1. By origin:

— natural or biopolymers (for example, proteins, nucleic acids, natural rubber);

— synthetic (for example, polyethylene, polyamides, epoxy resins) obtained by polycondensation and polycondensation methods.

2. By nature:

— organic;

— organoelement;

— inorganic.

3. In the form of molecules:

— linear, in which the structure of polymer or copolymer molecules is represented as a long chain consisting of monomeric units, for example, methyl methacrylate units. Such chain molecules are bent and intertwined, but they can move together when the material is heated. The material is prone to dissolution in the appropriate solvents. The domestic basic material AKP-15 (Ethacryl) should be attributed to this group;

— "crosslinked" polymers in which the polymer structure is represented in the form of chains connected and "crosslinked" in separate places by "bridges", "bridges of a crosslinking agent", for example, glycol dimethacrylate ether. Thus, the polymer structure can be compared to a grid in which the chains cannot move freely relative to each other. Such a material cannot dissolve in any of the solvents, but it can soften when heated and swell in some solvents. A similar material is the basic material Akrel;

— "grafted" copolymers contain a so-called "grafted" polymer capable of copolymerization, i.e. a polymer such as fluorinated rubber, etc., the molecules of which

are chemically attached ("grafted") to linear chain molecules of another polymer, for example polymethylmethacrylate (PMMA).

The structure of materials of this type is heterogeneous, the smallest particles of the "grafted" copolymer make the material opaque, give it increased elasticity and impact resistance, depending on the nature of the "stitching". The basic materials Fluorax, Acronyl, etc. should be attributed to this group of materials.

4. By appointment:

1) the main ones that are used for removable and non—removable dentures:

- basic (rigid) polymers;

— elastic polymers or elastomers (including silicone, thiocol and polyester impression materials);

— polymer (plastic) artificial teeth;

— polymers for replacing defects in the hard tissues of teeth, i.e. materials for fillings, pin teeth and inlays;

— polymer materials for temporary permanent dentures;

— facing polymers;

— restoration polymers (fast-curing);

2) auxiliary;

3) clinical.

As already mentioned, some impression masses should be attributed to auxiliary polymer materials. Polymers are used to make standard and individual impression spoons, standard and individual protective polymer caps, and temporary crowns to protect prepared teeth.

Polymers are part of composite materials and some fixing cements. Many basic and auxiliary polymer materials should be classified as clinical, since they are used by a doctor at a clinical appointment.

In accordance with the above classification, a further presentation of the material will be constructed.

Rigid base polymers. These materials are used for the bases of removable plate and arc (butt) prostheses. Currently, synthetic plastics (plastics) are widely used in dentistry as basic materials.

The basic plastics used in the clinic of orthopedic dentistry can be classified according to generally accepted (traditional) criteria:

— according to the degree of rigidity — plastics are rigid (for the bases of prostheses and their restoration) and soft or elastic, which are used independently (boxing tires) or as a soft lining for a rigid base;

— according to the temperature regime of polymerization, they are divided into "hot" and "cold" plastics ("self—hardening", "fast—hardening");

- according to the presence of dyes, they are divided into "pink" and "colorless" plastics, etc.

At the same time, plastics as polymeric materials are divided into 2 main groups:

1) thermoplastic (thermoplastics) — when they harden, chemical reactions do not occur and the materials do not lose their ability to soften upon repeated heating, i.e. they are reversible. Despite the successful results of a number of studies on the use of thermoplastics as basic materials and methods for creating dentures from them by injection molding, this type of materials has not found wide application in the practice of orthopedic dentistry. Apparently, the hardware difficulties in obtaining a prosthesis, the lack of a reliable connection of the thermoplastic base with artificial acrylic teeth hindered the widespread use of these materials in practice [Poyurovskaya I. Yu.];

2) thermosetting (reactoplastics) — when processed into products, a chemical reaction occurs that leads to hardening, and the material loses its ability to soften upon repeated heating, that is, it is irreversible.

For several decades, basic materials based on derivatives of acrylic and methacrylic acids have held the primacy in dentistry. Acrylic materials have earned a leading role due to their main properties:

— convenience of recycling;

— chemical resistance;

— mechanical strength;

— aesthetic qualities.

Most basic materials currently contain polymethylmethacrylate (PMMA) as the main ingredient.

Acrylic base plastics replaced rubber, which was used as a base material until the mid-40s, and became widespread, among other things, due to a fairly simple application technology available to any dental laboratory.

Much attention was paid by specialists to the improvement of acrylic base materials. The following areas of these works can be distinguished [Poyurovskaya I. Yu.]:

— copolymerization of acrylates;

— changes in the processing regime of polymer-monomer acrylic compositions in the manufacture of dentures;

— complete abandonment of acrylates and the use of injection-molded thermoplastics or other non-acrylic materials, such as polyurethane, for manufacturing bases [Balalaeva N. M.].

The copolymerization method, especially grafted copolymerization, proved to be the most effective for improving the physical and mechanical properties of base materials. The use of this method made it possible to obtain the domestic basic material Fluorax (Batovsky V. N. et al.), and the study of polyacetals in the basic materials led to the development of the Acronyl material (Shteyngart M. 3. et al.).

The intensity of scientific research in the field of new basic polymer materials indicates both the importance and the difficulty of creating a high-strength, convenient, cheap material for dentistry, without fundamental changes in technological techniques.

The creation of more advanced polymer base materials is carried out by the following methods (Shteyngart M. 3.):

— crosslinking of copolymer molecules of methyl methacrylate (for example, Acrel);

— obtaining copolymer compositions (Acronyl, Fluorax);

— the introduction of plasticizing additives (Acronyl). Thus, the modification of acrylic polymers remains the main way to improve the basic materials, which can be used to increase the impact and fatigue strength of the bases of removable dentures. Examples of such a modification are: the addition of a rubber phase to powder particles, the introduction of high-modulus fibers into the composition of the material. The introduction of high-modulus polyethylene fibers into the base material proved to be more effective in achieving increased impact strength of the material and at the same time its aesthetic properties did not deteriorate than the addition of carbon fibers [Poyurovskaya I. Yu.].

The discovery was the use of an electromagnetic field (EPM) of the radio frequency range during plastic polymerization, which significantly reduced the content of residual free monomer in it and improved its physical qualities (Trezuboe V.N., Bobrov A.P., Maksimovsky Yu.M., Zarembo V.N., Shteingart M.Z., Makarov K.A.).

The technology of the plastic base of the prosthesis determines the implementation of physico-mechanical, chemical, etc. the properties inherent in its formulation, and involves the following mandatory manipulations:

— preparation of a plaster model with a wax base, artificial teeth (and clamps) for plastering in a cuvette;

— obtaining a gypsum mold;

— removal of the wax base from the gypsum mold, followed by filling it with a pre-prepared polymer-monomer composition of the base plastic;

— polymerization of the base plastic and subsequent mechanical processing of the base of the prosthesis, grinding and polishing.

A dental technician mainly works with plastics, from which the basis of a removable prosthesis is being created, in a specially equipped production room of the dental laboratory — the polymerization room.

The time factor and the external temperature effect during polymerization are variable and interdependent.

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