
BIOMATERIALS USED IN ORTHODONTICS

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ABSTRACT

In recent years, orthodontic dental medicine has progressed at a rapid pace as a result of the use and enhancement of biomaterials. Innovations and improvements in biomaterials have a great impact on orthodontic practice, with significant changes in recent years in the types of materials used as well as their biomechanical requirements. Different types of metals, alloys, polymers, composites, self-polymerizing acrylic plastics are used to create orthodontic materials and appliances. Each of the biomaterials used has its advantages over the others in a particular situation. It is extremely important to evaluate the physical and biomechanical properties of biomaterials in order to achieve predictable results that meet the objectives of orthodontic treatment. From the research it has come to the conclusion that orthodontic dental medicine, like other areas of dentistry, is greatly influenced by the improvements and enhancements of the biomaterials used. Digital technologies, computer design and manufacturing are an integral part of modern orthodontics. New technologies have a great impact on biomaterials used in orthodontics. The right choice of biomaterials for making orthodontic appliances is the key to successful treatment.

Keywords: biomaterials, orthodontics, digital technologies

INTRODUCTION

In recent years, orthodontic dental medicine has progressed at a rapid pace as a result of the use and enhancement of biomaterials. Understanding the fundamental principles of the relationship between composition, structure, and properties is extremely important and gives a new incentive to the development of orthodontic biomaterials.

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AIM

The aim of the present study is to investigate the types of biomaterials used in orthodontics.

MATERIALS AND METHODS

For the period September 2021–February 2022, in the available database (PubMed, BioMed Central, ScienceDirect, Scopus, Web of Science, Embase), a systematic analysis of scientific publications examining the types of biomaterials used in orthodontics was conducted.

RESULTS

In recent decades the field of orthodontic biomaterials has expanded substantially with the production of new materials for braces, ligatures, arches, aligners. Innovations and improvements in biomaterials have a great impact on orthodontic

practice, with significant changes in recent years in the types of materials used as well as their biomechanical requirements. Different types of metals, alloys, polymers, composites, self-polymerizing acrylic plastics are used to create orthodontic materials and appliances. Each of the biomaterials used has its advantages over the others in a certain situation. It is extremely important to evaluate the physical and biomechanical properties of biomaterials in order to achieve predictable results that meet the goals of orthodontic treatment.

There are different types of braces based on the material they are made of. They are divided into three large groups: metal braces, plastic braces, and ceramic braces. Metal braces, in turn, are divided into: braces made of stainless steel, braces made of chromium-cobalt, titanium braces, and braces of precious metals. According to the material from which plastic braces are made, they are divided into: polycarbonate braces, polyurethane-composite braces, thermoplastic-polyurethane braces, polyurethane-composite braces. Ceramic braces, in turn, are divided into: monocrystalline aluminum brackets (also known as sapphire brackets), polycrystalline aluminum brackets, and polycrystalline zirconium-yttria partially stabilized brackets.

Metal Braces

Stainless steel braces

Stainless steel braces are characterized by good mechanical properties, corrosion resistance, acceptable aesthetic qualities (1). From the point of view of materials science, stainless steel is an alloy that contains several elements in its composition. Effects of the elements included in the composition of the alloy:

- ◆ Carbon - provides rigidity and strength. It also increases chromium carbide formation due to localized corrosion from oral fluids.
- ◆ Nickel - increases oxidation resistance to corrosion.
- ◆ Molybdenum - increases resistance to pitting corrosion, especially from chlorides.
- ◆ Titanium - stabilizes carbide and increases corrosion resistance.
- ◆ Phosphorus - reduces corrosion resistance and increases sintering resistance.

- ◆ Tantalum - stabilizes carbon and improves corrosion resistance.
- ◆ Selenium - makes stainless steel easier to machine.
- ◆ Chromium - stainless steel braces have a higher resistance to corrosion, especially to chlorides. Chromium is important in increasing corrosion resistance, which maximizes the control of nickel ion release and reduces the possibility of associated hypersensitivity reactions.

Nevertheless, the adverse environment of the oral cavity makes stainless steel susceptible to corrosion, especially in acidic environments and the presence of chloride ions, which can penetrate the outer oxide layer and prevent pitting.

Cobalt-chromium braces

They are a low-nickel alternative to stainless steel braces. Alloys can be categorized as follows: wear-absorbing alloys; high-temperature alloys; corrosion-resistant alloys (2). Due to the relatively higher chromium content, cobalt-chromium braces are characterized by a lower corrosion rate compared to other types of braces (3).

Titanium braces

Titanium (Ti) and its alloys have excellent biocompatibility and increased corrosion resistance, as well as good mechanical properties (4). The advantage of titanium braces is that they are applicable to patients who are hypersensitive to nickel and overcome problems with poor retention. They solve the problem of the sensitivity of stainless steel to corrosion in an acidic oral environment. When tested, they show high purity, corrosion resistance, formability, and high strength. Titanium remains stable during a mechanical sliding process and has friction resistance. It has low thermal conductivity, which relieves the patient's sensitivity to extreme temperature changes; Due to its excellent properties, titanium is used to make space shuttles and rockets. Titanium is the only element that offers a combination of qualities such as: aesthetics, strength, lightness, biocompatibility, corrosion resistance. In recent decades, titanium has been used in the aviation and aerospace industry with great success. Its lightness and strength are the reason why 85% of the space shuttle structure is made of titanium. Today, titanium makes up 6% to 9% of the mass of

aircraft. Due to its exceptional biocompatibility and corrosion resistance, and the highest strength-to-weight ratio, titanium is successfully applied in the fields of medicine and dentistry. The disadvantages of titanium braces are that they are more expensive, grayer in color. They have a rougher surface texture, resulting in a greater amount of plaque and staining.

Braces made of precious metals

The advantage of braces made of gold is that they have good mechanical properties, they are not reactive, and have excellent biotolerance. However, their high price is a disadvantage. Precious metal braces are usually made of steel coated with precious metals, including gold, palladium, or platinum. Gold-plated brackets (16-, 18-, 24-karat) are the ones that are used most often, especially in lingual orthodontics.

Plastic Braces

The advantages of plastic braces are that they are an aesthetic alternative to metal braces; they are more aesthetic than braces made of stainless steel (5). They are more adaptive to the natural color of the tooth surface and chemically inert to oral fluids. The disadvantages include lower bond strength. They show slot distortion and creep deformation, water absorption, discoloration. There is increased friction between the gap and the arch during tooth movement, insufficient strength and rigidity. There are problems with plastic braces coming off (6).

Ceramic Braces

Modern ceramic braces are mainly made of aluminum oxide. According to the manufacturing process, they are categorized into two broad classes with different optical and mechanical properties. Polycrystalline aluminum oxide braces are composed of aluminum oxide particles that are melted by a sintering process.

The advantages are that they are an aesthetic alternative to metal braces; they are more aesthetic than braces made of stainless steel. They are more adaptable to the natural color of the surface of the teeth and are also chemically inert to oral fluids (7,8).

The disadvantage is that they are less radiopaque than metal. They are brittle and have low breaking strength, high levels of hardness, and erode tooth enamel in contact with braces. They are not recommended for patients with defects in the

development of teeth, cracks in the enamel, non-vital teeth, and large restorations (7,8,9).

The biomaterials used for the production of orthodontic arches are: gold, stainless steel, cobalt-chromium (Elgiloy), chromium-nickel, nickel-titanium, thermoelastic nickel-titanium, timolium, titanium-niobium (10). Orthodontic arches made of different biomaterials are characterized by different qualities, have different advantages and disadvantages. Orthodontic arches made of gold have the advantage of being inert, biocompatible, and stable. Golden arcs are made of different percentages of gold, copper, silver, palladium, platinum, nickel, zinc. They have a low modulus of elasticity. Their strength can be increased by heat treatment or cold treatment. They have high formability and excellent biocompatibility. They are characterized by extremely good stability in the conditions of the oral cavity. Another positive quality of theirs is that they can be soldered and welded. Disadvantages of orthodontic arches made of the noble metal gold are the small force field and their high price.

Orthodontic arches made of stainless steel have the advantages of high hardness and elasticity, good formability, high tensile strength, being economical. They can be welded and soldered, are corrosion resistant and biocompatible. Their disadvantage is that, due to the higher modulus of elasticity, more frequent activations are required to maintain force levels. High degree of deviation requires more attention to detail to prevent harmful/unwanted effects on the teeth.

Cobalt-chromium orthodontic arch wires (Elgiloy) have advantages over stainless steel arch wires like excellent corrosion and tarnish resistance, higher elastic efficiency—greater than stainless steel by 20% (11). They remain functionally active for longer when used as an elastic spring. They have great resistance to fatigue and bending. Their modulus of elasticity is comparable to or higher than that of stainless steel. The disadvantages of cobalt-chromium orthodontic arch wires are that the high nickel content may pose a biocompatibility problem. The friction resistance is higher than that of stainless steel arcs. There is need for heat treatment and a demanding soldering process.

Nickel-titanium (NiTi) orthodontic arches have high elasticity and high stored energy. Other advantages are their biocompatibility quality and environmental stability. In certain clinical cases, initial stages of corrosion and damage are observed, which is considered to be a disadvantage. There is higher friction than stainless steel arch wires and less than titanium-molybdenum arch wires (the friction of NiTi orthodontic arch wires can be reduced by coating the surface with a metal coating, chemical vapor coating, ion implantation). They have lower hardness than arches made of stainless steel. It is not recommended for them to be used in the stages of completion of orthodontic treatment. They are prone to easy fractures and cannot be welded or soldered. They are more expensive than arcs made of stainless steel (12). They have poor formability and are not suitable for patients with hypersensitivity to nickel.

Titanium-molybdenum (TMA) orthodontic arch wires have a low degree of deviation, allowing a full bracket engagement with greater torque control compared to stainless steel arch wires. They have good formability, very good strength, and elasticity. The modulus of elasticity of TMA is twice that of NiTi. They are used in all stages of orthodontic treatment from the leveling stage to the final stages of torque equalization. The disadvantages of TMA wires are that they exhibit higher friction than SS and Elgiloy arcs and are not recommended for closing spaces with frictional mechanics. Newer ion shielded TMA arcs are available to reduce friction.

Thymolybium and titanium vanadium orthodontic archwires are nickel-free and can be used in patients with nickel hypersensitivity. They have a smoother surface, compared to TMA, which significantly reduces friction with the braces. Their disadvantage is that they are less rigid than stainless steel arch wires.

Other materials used in orthodontic treatments are: ligatures, elastics, separators with a circular section, chains, and orthodontic elastics. According to the material from which the ligatures are made, there are two types: elastic and wire ligatures. Orthodontic elastics can be made of latex or silicone. Latex-free orthodontic elastics are preferred due to their better biocompatibility. They are successfully used in patients with allergies to latex

protein. Intraoral orthodontic elastics are produced in five diameter sizes and three degrees of elasticity—light, medium and heavy. The strength of a rubber band in g (oz) is measured at three times its size. Sizes and elasticity are color coded for quick identification. Very often in orthodontic practice, elastic orthodontic chains are used. The materials from which they are made have the quality of biocompatibility as well as separators with a round section. Their advantage is that they are biocompatible and radiopaque—for separating the interdental space before placing orthodontic rings. Orthodontic rubber bands are sources of latex allergens in the dental office. Another source of latex allergens can be extraoral appliances—orthodontic treatment caps and chin guards. Sensitized patients are extremely at risk even during dental treatment. Symptoms can range from mild to severe, depending on the degree of sensitivity and the amount of latex allergens to which patients are exposed. Reactions worsen with repeated latex exposures. Anamnestic questions should be strictly directed to determine whether the patient is at risk of developing a latex allergy. When an allergy to rubber products is established, it is necessary to create the so-called latex-free environment in the dental office.

Self-winding orthodontic mini implants are made of stainless steel for surgical use. They are characterized by enhanced strength through heat treatment, which allows for easy removal of the abutment after the end of the orthodontic movement. They are produced in different sizes: with lengths: 6 mm, 8 mm, and 10 mm; diameters: 1.2 mm, 1.4 mm, 1.6 mm, 1.8 mm, and 2.0 mm. **Titanium micro implants** are characterized by excellent biocompatibility. Their disadvantage is that they are more fragile than other micro implants used in orthodontics.

Composite adhesives are most often used materials for fixing braces in orthodontic practice. They can be *chemopolymeric* and *photopolymeric*. Chemopolymers, in turn, are divided into one-component and two-component. All materials for fixing braces are characterized by biocompatibility. The manipulation requirements for chemopolymer composite adhesives include: when working with them, faster positioning of the brackets is required, because the polymerization of the adhesive begins.

The advantage of photopolymers is having longer manipulation time, which allows more precise placement of the brackets and then, with the help of a photopolymer lamp, polymerization of the composite is carried out. Orthodontic rings are made with glass-ionomer cement (GIC), but double-polymerizing composites are also used.

Biomaterials Used for Extralingual Plates and Functional Appliances

Orthodontic laboratory wire made of stainless Cr-Ni steel has a round cross-section and different sizes from 0.5 mm to 1.4 mm. The surface of the wire is treated with a diamond tool for better resistance and smoothness. It is suitable for all orthodontic applications. Self-polymerizing orthodontic plastic is a colorless polymer powder methyl-methacrylate copolymer. The toxicity of the self-polymerizing orthodontic plaster is determined by the presence of a residual monomer—the biologically acceptable norm for the amount of separate monomer in saliva is 0.3–0.5%. In larger quantities, the monomer can cause mucosal lesions (allergic reaction). Allergies to self-polymerizing orthodontic resin have been observed in sensitized patients with a history of allergies. The self-polymerizing orthodontic mesh has extremely good mechanical and aesthetic characteristics. Self-polymerizing orthodontic plastic successfully replaces volcanic and metallic platinum. Colored monomer liquid has a composition that offers excellent processing properties, without priming in the polymerization process (exothermic reaction), eliminating the risk of unwanted evaporation of the monomer.

The biomaterials used for the production of **thermoplastic aligners** are **polyethylene**, **PET-G (polyethylene terephthalate glycol)**, **polyurethane**, **polypropylene**, **polycarbonate**, **ethylene-vinyl acetate**, **copolyester**, **polypropylene/polyethylene copolymer** (14). The properties of thermoplastic aligners include high elasticity, high retention energy, tolerance to the oral environment, biocompatibility, and low roughness (13). Studies show that the most preferred material is PET-G, because it has the best mechanical properties, formability, optical properties, and fatigue resistance (15).

CONCLUSION

From the research we have come to the conclusion that orthodontic dental medicine, like other areas of dentistry, is greatly influenced by the improvements and enhancements of the biomaterials used. Digital technologies, computer design and manufacturing are an integral part of modern orthodontics. New technologies have a great impact on biomaterials used in orthodontics. The right choice of biomaterials for making orthodontic appliances is the key to successful treatment.

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