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Biocompactibility and Properties of Alloys in Dentistry-A Review

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Abstract

Alloys have been increasingly used for prosthetic restorations as well as for surgically implanted medical devices. The field of dental alloys is very extensive, encompassing both the materials themselves and the manufacturing methods, which are constantly developing. Their properties, behavior, and corrosion resistance are of great importance for the success of the prosthetic treatment. Dental alloys must have an appropriate corrosion resistance in order to avoid the release of cytotoxic or sensitizing elements into the biological milieu and the presence of a high risk in developing reactions to common or specific allergens. The biocompatibility of dental alloys is of great importance because they are in long-term intimate contact with oral tissues.This article gives a review on various casting alloys ,its properties and biocompatibility with oral tissues.

Keywords: Alloys, Biocompactibility, Metals, Properties, Strength.

Introduction

An alloy is defined as “A mixture of two or more metals or metalloids that are mutually soluble in the molten state; distinguished as binary, tertiary, quaternary etc., depending on the number of metals within the mixture. Over the years various types of dental alloys ranging from nearly pure gold and gold-based alloys to silver, palladium, nickel, cobalt, titanium. Metals were used for variety of dental restorations and full metal fixed dental prostheses such as crown, bridge, coping and fabrication of framework on the basis of their reaction in the oral cavity and their mechanical properties. Dental alloys play a prominent role in prosthetic rehabilitation due to its suitable properties such as strength, modulus of elasticity, wear resistance and biological compatibility required for appropriate function in different types of restorations. Recently,implants made mainly from titanium have been used for the fabrication of dental implants since around 1981. The main alloys are so-called commercially pure titanium (cpTi) and Ti-6Al-4V, both of which give clinical success rates of up to 99% at 10 years and they are found to be biocompactible with the bone and gingival tissues. CAD/CAM milling or 3D printing technologies such as direct metal laser sintering, selective laser sintering, selective laser melting, and electron beam melting are trending to take over traditional casting, which are laborious and time-consuming. Knowledge of basic properties of dental materials is necessary for appropriate selection of the alloy for the specific type of restoration. The present article reviews the literature to analyse the biological behavior of these alloys in the oral cavity and predict their outcome on the patient's health.

Discussion

Alloying elements alter the hardness, strength and toughness of a metallic element, thus obtaining properties not found in a pure metals [1,2]. The term biocompatibility refers to the ability of a material to accomplish its desired function without causing any undesirable local or systemic effects by producing an appropriate beneficial cellular or tissue response with improved clinically performance [3]. Dental alloys when placed intra-orally, is exposed to saliva, beverages, and food, to which it may react and at times cause corrosion [4]. Studies suggest base metal alloys prone to reaction in oral cavity over noble alloys; the literature lacks evidence on the superiotiy in biocompatibility of noble metal alloys over base metal alloys [5,6,7]

Various classification has been put forth in the literatures. In 1927, the Bureau of standards [8,9,10] established Gold casting alloy Type I to Type IV according to dental function, and hardness increasing from Type I through Type IV.

a.Type I – Soft – inlays, Class III and V restorations

b. Type II – Medium – thick 3/4th crowns, pontics etc.

c. Type III – Hard – full crowns, short span fixed partial dentures etc.

d. Type IV – Extra hard – long span fixed partial dentures & partial denture frameworks

The hardness, proportionality limit, heating temperature and strength increase from Type I to Type IV whereas ductility and corrosion resistance decreases in the similar order.

Later, dental casting alloys are classified into several types over the years, the first and foremost being the simple classification given by ADA in 1984 as based on the presence of noble metal

a. High Noble metal alloys – must have a noble metal content of at least 60% by weight and a gold content of at least 40%.

b. Noble metal alloys – must have a noble metal content of at least 25%, but no stipulation exists for gold content.

c. Predominantly Base metal alloys – require noble metal content less than 25 weight%.

Further in 1989, ADA specification No. 5 classified dental gold casting alloys based on their properties as,

a. Type I – Soft – Small inlays, easily burnished and subject to very slight stress.

b. Type II – Medium – Inlays subject to moderate stress, including 3/4 crowns, abutments, pontics, and full crowns.

c. Type III – Hard – Inlays subject to high stress, including onlays, crowns, thin cast backings, abutments, pontics, full crowns, and short span FPD'S.

d. Type IV – Extra hard – Inlays subject to high stresses, including denture base bars & clasps, long span FPD's endodontic posts and Cores, thin veneer crowns and RPD' S.

If the alloy contain 75% of gold, it is named as Gold based alloy and if the alloy carries 60% of Nickel, it is called as Nickel based alloy. Based on three principal elements present, they can be classified as Au-Pd-Ag, Pd-Ag-Sn, Ni-Cr-Be, Co-Cr-Mo, Ti-Al-V, and Fe-Ni-Cr.

Based on the dominant phase present, alloys can be further classified depending on the type of dominant phase as, single phase- isomorphorus, eutectic, peritectic, intermetallic.

Based on their applications in dentistry alloys were categorized into two types as All-metal alloys and metal-ceramic alloys. Metal-Ceramic restoration alloys have paved the gateway of esthetics ,the main function of metal-ceramic alloys is to reinforce porcelain, thus increasing its resistance to fracture. The alloys used for metal-ceramic purposes are grouped further into two categories including noble metal alloys and base metal alloys.On the other hand, All-metal restoration alloys lost its clinical implication over the years in dentistry due to its inert physical and mechanical properties.Depending on the primary purpose of the prosthesis, the choice of casting alloy or metal, dental metal (alloy) characterized by properties namely: Mechanical, Physical, Chemical and Biological property.

Modulus of elasticity [11,12] is a measure of the bending resistance of an alloy. It is evident that higher modulus of elasticity causes lower bending during mechanical load. Elastic modulus is also important for the major connectors of removable partial dentures, which must have enough rigidity to prevent flexure during placement and function of the prosthesis.

Yield strength [13,14] denotes the force which causes a permanent deformation of the material (usually 0.1% or 0.2 %). Lower value of yield strength causes lower resistance to stress thus resulting in easy deformation of the material. Ideally, the alloys should have high yield strength, so that a great deal of stress must be applied before a permanent change in dimensions occurs.

Tensile strength [15] is characterized as maximal traction, which material endures without breaking or damage. High ductility means that the amount of deformation that one can produce by adjusting prosthesis or by burnishing a cast metal margin plastically is higher for the alloy. The shape of the clasps on removable partial dentures often has to be adjusted by bending. Occasionally they fracture during the small plastic deformation that takes place during the adjustment

Hardness [16] indicates the ability of an alloy to resist the local stress during the bite. In case of prosthetic alloys hardness should not exceed the hardness of the enamel and should be between 125 kg/mm^2 −340 kg/mm^2 (hardness of the enamel). Very hard materials are usually quite fragile and may break or chip off by impact or by higher strain on the prosthesis.

For metal-ceramic prostheses, the alloys must have closely matching thermal expansion coefficients [17,18,19] to be compatible with given porcelains, and they must tolerate high processing temperatures without deforming via a creep process. Most base metal alloys melt at temperatures of 1400°C to 1500°C. The addition of 1% to 2% beryllium lowers the melting temperature of Ni-Cr alloys about 100°C. Ceramic (Porcelain) is fired onto the metal substructure and thus the melting temperature range of alloy should be at least 50^o higher than the porcelain firing temperature to prevent any distortion or damage.

The density of an alloy is the amount of mass in grams that take up a volume of one cubic centimeter (g/cm3). Pure Gold and its alloys show a very high density of 18.88 g/cm^3 while titanium and its alloys are the lightest materials with 4.5 g/cm^3. The use of alloys of higher density is better for casting and has an influence on the final weight of the whole construction and also on the cost of the fabricated material.

Corrosion [20,21] is a progressive erosion of the material by chemical or physically-chemical reactions with the surrounding environment. During corrosion in the oral cavity the release of ions or of ion complexes from dental alloys occurs causing a change of color. Corrosion resistance is derived from the use of noble metals that do not react in the oral environment (e.g., gold and palladium) or by the ability of one or more of the metallic elements to form an adherent passivating surface film, a resistant layer which inhibits any subsurface reaction (e.g., chromium and titanium)

Toxicity, allergic reactions, mutagenity and carcinogenetic nature of the living tissues must be monitored to evaluate the biocompatible nature of the alloy [22,23,24]. Moffa et al (1973) reported that high levels of beryllium were accumulating during finishing and polishing when a local exhaust system was not used leading to Berylliosis. When an exhaust system was used, the concentration of beryllium in the breathing zone was reduced to levels considered safe by the authors [25].

Conclusion

Dental alloys have wide application in all-metal fixed prostheses, metal-ceramic prostheses, or removable partial dentures. Alloys for all-metal prostheses are also used as substrates for resin-veneered metal prostheses. It is necessary for the clinician as well as technician to understand the physical, mechanical and chemical properties of dental alloys in various clinical situations.

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