DENTAL CASTING ALLOY

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Abstract

The compositions and types of casting alloys available to the dental practitioner have changed significantly over the past 25 years. However, today's practitioner may select from alloys based on palladium, silver, nickel, cobalt, and titanium, among others. Furthermore, alloys within each of these groups are diverse, and the practitioner faces a bewildering array of choices. Because of the long-term role, these materials play in dental treatment, the selection of an appropriate alloy is critical from technical, ethical, and legal perspectives. Although uses for pure metals such as gold foil and platinum foil exist in dentistry, the main role for metals in dentistry has been in alloys.

Introduction

Dental casting alloys play a prominent role in the treatment of dental disease. alloys continue to be used as the principal material for fixed prosthetic restorations and will likely be the principal material for years to come. No other material has the combination of strength, modulus, wear resistance, and biologic compatibility that a material must have to survive long term in the mouth as a fixed prosthesis.[(1)] Today's practitioner may select from alloys based on palladium, silver, nickel, cobalt, and titanium, among others. Furthermore, alloys within each of these groups are diverse, and the practitioner faces a bewildering array of choices. Although uses for pure metals such as gold foil and platinum foil exist in dentistry, the main role for metals in dentistry has been in alloys[(2)]. Alloys are used for fixed prostheses rather than pure metals because pure metals do not have the appropriate physical properties to function in these types of restorations.Thus, the use of alloys provides physical and biologic properties that are required for successful, long-term fixed prostheses[(3)].

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Properties of alloys

Color

The color of alloys is often described as being ''yellow'' or ''white.'' These limited terms are inadequate because the range of alloy colors is much greater, encompassing reddish, brownish, and even greenish tints.[(2)] Furthermore, the term ''white'' is a metallurgical term that does not describe the silver color ascribed to these alloys by most clinicians and patients. In any case, the color of casting alloys has little to do with the physical, chemical, dental, or biologic performance of the alloy.[(2,3)]

Phase structure

If most of the components of the alloy dissolve in one another, the alloy is described as a single-phase alloy and has a more or less homogeneous composition throughout. If one or more components are not soluble in the other, then two or more phases form in the solid state, each having a different composition. In this case, the alloy is described as a multiple-phase alloy. Single-phase alloys are generally easier to manipulate (ie, easier to cast) and have lower corrosion rates than multiple phase alloys ; however, multiple-phase alloys may be etched for bonding and may be significantly stronger than single-phase alloys .[4] The phase structure of an alloy is not discernible by the naked eye, so the clinician must rely on laboratory or manufacturer information to know an alloy's phase structure.[3,4]

Grain size

Grains are crystals of the alloy that form upon solidification from small nuclei, much as ice crystals form from water The size of the grains is influenced by factors such as the cooling rate of the alloy, the presence of special nucleating elements such as iridium, heat treatment after casting, and the composition of the alloy.[3,4] For gold-based alloys, a small (\30 *l*m) grain size has been shown to improve tensile strength and elongation . For base-metal alloys, small, dispersed secondary phases (each with a small grain structure) are critical to the strength of the alloys. In other base-metal alloys, the grains are large and may approach 1 mm in diameter..[4]

Strength and hardness

A tensile strength above 300 MPa is necessary to avoid fracture of alloys in high-risk areas such as between pontics of a multiple-unit fixed restoration . Because tensile strength is difficult to measure in practice, most manufacturers cite yield strength instead.[2,4] Information on yield strength is easily obtainable from the manufacturer. The hardness of an alloy must be sufficient to resist wear from opposing teeth or restorations and not so hard as to wear enamel and other materials such as porcelain. In practice, a Vicker's hardness less than 125 kg/mm2 makes an alloy susceptible to wear, and a hardness greater than enamel may wear existing teeth.[3,4]

Alloy solidus and fit

When a molten alloy solidifies from the liquid state during casting, a large amount of shrinkage occurs but is compensated for by the addition of molten metal from the reservoir in the casting ring [4] The higher the solidus temperature, the more shrinkage occurs; these shrinkage values range from about 0.3% to 0.5% for high-gold alloys with solidi of about 950 ^{o}C to nearly 2.5% for nickel- and cobalt-based alloys with solidi of 1300_C to 1400_C. The shrinkage must be compensated for by expansion of the die, application of die spacers, the use of special expanding investment mechanisms, or increasing the burnout temperature of the investment. The risk of ill-fitting crowns is much greater for alloys with high solidi, and this factor is a significant consideration in the choice of alloys.[4,5]

Corrosion

Corrosion may compromise the strength of the restoration, leading to catastrophic failure or the release of oxidized components may discolor natural teeth, porcelain veneers, or even the soft tissues in severe cases.[3] The electrons released during corrosion may be detectable by the patient as a shock (galvanic corrosion) that can be disconcerting and even debilitating. Released metallic components may cause an undesirable metallic taste leading the patient to request that the restoration be removed. Because corrosion generally results in the release of mass from the alloy into the oral environment, it is related in complex ways to alloy biocompatibility .[4]

Biocompatibility

Biocompatibility is best described as how an alloy interacts with and affects biologic systems. Biocompatibility is related to the corrosion of an alloy. However, care must be taken not to assume poor biocompatibility on the basis of elemental release alone because the ability of tissues to tolerate this element release varies widely. [4,5]

Soldering

Soldering of alloys is highly dependent on the type of alloy and may be a significant factor in the clinician's choice of alloy. In general, gold-based alloys are most easily soldered compared with palladium-, nickel-, silver-, or nickel-based alloys. Furthermore, the heating that occurs during soldering is more likely to alter complex phase structures of base–metal alloys than of high-noble alloys.[6]

Elemental Composition of Precious and Non-precious Alloys (Craig, 1997)

Classification of alloys for dental cast restorations and metallic appliances:

(a) High-noble (noble metal content > 60 wt% + gold content > 40 wt%)

(b) Noble (noble metal content > 25 wt%)

(c) Predominantly base metal (noble metal content < 25 wt%)

Noble metals:

Gold (Au), platinum (Pt), palladium (Pd), iridium (Ir), ruthenium (Ru), rhodium (Rh)

Base metals

Silver (Ag), copper (Cu), zinc (Zn), indium (In), tin (Sn), gallium(Ga), chromium (Cr), cobalt (Co), molybdenum (Mo), aluminium (Al), iron (Fe), beryllium (Be), manganese (Mn), titanium (Ti), nickel (Ni), vanadium (V), niobium (Nb), zirconium (Zr)

Classification of casting alloys by physical properties :

ADA designation	Yield strength (MPa, in tension)	Elongation (%)
Soft	<140	18
Medium	140–200	18
Hard	201–340	12
Extra-hard	>340	10

High-noble alloys

High-noble dental casting alloys can be divided arbitrarily into those based on gold-platinum (Au-Pt), gold-palladium (Au-Pd), or gold copper- silver (Au-Cu-Ag). Of these groups, the first two alloy types are appropriate for full-cast or porcelain–metal applications. The latter group is appropriate only for full-cast applications because of its higher silver and copper content and its lower melting range. The Au-Pt alloys are the newest of the high-noble alloys and were designed to avoid the use of palladium, [6,7]These alloys are white (silver) in color and have a moderately high melting range and moderate hardness, modulus, and strength. Because of their high noble metal content ([97 wt %), they are expensive.

Noble alloys

They are comprised of four groups: Au-Cu-Ag, Pd-Cu-Ga, Pd-Ag, and Ag-Pd. The Au-Cu-Ag noble alloys are similar in composition and metallurgy to the high-noble Au-Cu-Ag alloys. Depending on the amount of copper and its high-temperature volatility, the Pd-Cu-Ga alloys are useful for porcelain–metal applications.[(8)] The Ag-Pd alloys are usually only in the noble category by the use of a minimal amount of Pd (25 wt %) or a combination of palladium and gold totaling 25 wt %. The physical and corrosion properties of these alloys are inferior, and they offer few advantages over the base-metal alloys.

Predominantly base-metal alloys

The base-metal alloys can be arbitrarily divided into four groups: Ni-Cr- Be, Ni-Cr, Ni-high-Cr, and Co-Cr. The first three groups are closely related in composition and many physical properties but are fundamentally different in their corrosion properties.[(8)] All alloys in this group may be used for full-cast or porcelain–metal restorations, and all are silver in color. Beryllium is used primarily to lower the melting range of the alloy to a point where gypsum-bonded investments can be used for casting.

Conclusion Alloys are mixtures of metals and non metals. Alloys are used for fixed prosthesis rather than pure metals because pure metals do not have the appropriate physical properties to function in these types of restorations. Thus, the use of alloys provides physical and biologic properties that are required for successful, long-term fixed prostheses.

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