Metal & Metal Alloys

Metal in dentistry is used either in pure form or in form of alloys. The pure metals that are commonly used are:

1- Gold or platinum in form of foil.

2- Liquid mercury for making amalgam.

3- Electroplated silver and copper for preparing dies.

Classification of metals

- Noble metals like (gold, platinum, palladium, rhodium, ruthenium, iridium, osmium and silver; however in the oral cavity silver in not considered noble because of tarnish).
- Non noble (base metal) like (chromium, cobalt, nickel, iron, copper, manganese, etc…..).

Alloys: an alloy is a metal containing two or more elements at least one of which is metal and all of which are mutually soluble in the molten state.

Requirements of casting alloys:

1. They must not tarnish or corrode in the mouth.
2. They must be sufficiently strong for intended purpose.
3. They must be biocompatible (non toxic-non allergic).
4. They must be easy to melt, cast, cut, grind (easy to fabricate).
5. They must flow well and duplicate fine details during casting.
6. They must have minimum shrinkage on cooling after casting.
7. They must be easy to solder.

Application of dental alloys:

1. Construction of metallic framework of removable partial denture.
2. Construction of metal core of crown & bridge.
3. Making orthodontic wires, bands, brackets, etc……
4. Making endodontic instruments.
5. Construction of dental implants.

Classification of dental alloys:

A. According to number of elements:

1. Binary ⟶ 2 elements.
2. Tertiary ⟶ 3 elements.
3. Quaternary ⟶ 4 elements.

B. According to nobility:

1. High noble alloys: contain 40% gold or more & 60% noble metals or more.
2. Noble alloys: contain 25% noble metals or more.
3. Base metal alloys: contain less than 25% noble metals.

C. According to major elements:

1. Gold alloy.
2. Silver alloy.
3. Palladium alloy.
4. Nickel alloy.
5. Cobalt alloy.
6. Titanium alloy.

D. According to 3 major elements:

1. Gold-palladium-silver alloys.
2. Palladium- silver-tin alloys.
3. Nickel-chromium-molybdenum alloys.
4. Cobalt-chromium-molybdenum alloys.

5. Iron-nickel-chromium alloys.

6. Titanium-aluminum-vanadium alloys.

(GOLD)

Gold foil filling (pure gold)

Pure gold is 24 karat; it is tarnish resistant and very malleable and ductile. Gold foil is in the form of thin sheet or foil about 0.001 mm thickness. It is condensed into the cavity and each layer of foil becomes welded to material already condensed.

Advantages of gold foil filling:

- Perfect corrosion resistance.
- Adequate mechanical properties.
- Very durable.

Disadvantages of gold foil filling

- Highly expensive.
- Not esthetic.
- The technique is time consuming and depends on the skill of operator.

Gold alloys: they are classified according to yield strength & percentage of elongation:

Type I (soft): it is indicated for small inlay, well supported inlay restoration not subjected to mastication stress like gingival cavities (Cl V) cavities and proximal surfaces of incisor and canine (Cl III) cavities.

Type II (medium): it is indicated for large inlay restoration, less ductile and can resist high masticatory stress.

Type III (hard): it is indicated for crown and bridge, low ductility with high content of platinum and /or palladium.

Type IV (extra hard): it is indicated for crown and bridge and removable partial denture frames, has high strength, resilience, low modulus of elasticity.

Composition of gold alloys:

A wide variety of gold alloys may be made by the combination of:

Gold: give the alloy yellow color, increase ductility, corrosion & tarnish resistance and give specific gravity.

Copper: reduce melting point and density, increase hardness and strength, gives red color to gold, reduce corrosion and tarnish resistance.

Silver: whiten the alloys; increase strength and hardness slightly; in large amount reduce corrosion resistance.

Platinum: increase strength and corrosion resistance and melting point, has white color, reduce the grain size.

Palladium: similar to platinum, it hardens and whitens the alloy, raises fusion temp., increase tarnish resistance.

Also there are minor additions such as ***Zinc*** act as scavenger for oxygen, ***indium, tin, iron*** harden the alloy, ***iridium, ruthenium, rhodium*** decrease the grain size.

Properties

1. ***Color:*** it is yellow and there is white gold depending on the whitening elements present (silver, platinum, palladium).
2. ***Melting range:*** 920 ---960.
3. ***Density:*** pure gold is 19.3 gm/cm.
4. ***Yield strength***: type III - 207 Mpa type IV-275 Mpa.
5. ***Hardness:*** type III -121 Mpa type IV-149Mpa.
6. ***Elongation***: type III 30 -40 % type IV – 30 -35%.
7. ***Tarnish and corrosion resistance:*** they are resistance to tarnish and corrosion due to high noble metal content.
8. ***Casting shrinkage:*** it is less than 1.25 – 1.65 %.
9. ***Biocompatibility:*** they are relatively biocompatible.
10. ***Investment:*** gypsum bonded investment.

(Alternative to gold alloys)

Silver – palladium alloys

These alloys are cheaper than gold alloys, whiter in color, their properties is similar to type III and IV gold alloys but:

1. Lower ductility and corrosion resistance.
2. Lower density.

Metal ceramic alloys

They are alloys that are compatible with porcelain and capable of bonding to it, a layer of porcelain is fused to the alloy to give it natural tooth like appearance. Porcelain is brittle so these alloys reinforce porcelain (ceramic). They should have coefficient of thermal expansion (C.T.E.) match that of porcelain.

Requirements of metal ceramic alloys

1. Melting temp. should be higher than the porcelain firing temp..
2. C.T.E. should be compatible with that of porcelain.
3. Should be able to bond with porcelain.
4. Should have high stiffness (high modulus of elasticity).
5. Should not stain or discolor porcelain.
6. It should resist ***creep***. ***(Creep*** can be defined as time- dependent strain or permanent deformation produced by stress**)**.

Types of metal ceramic alloys

1. ***High noble (gold alloys)***

Gold-palladium-platinum, gold-palladium, gold-palladium-silver.

2. ***Noble (palladium alloy)***

Palladium-silver, Palladium- gold, Palladium-copper.

3. ***Base metal alloys***

Nickel-chromium, cobalt-chromium, pure titanium, titanium-aluminum-vanadium, Nickel-chromium-beryllium.

Removable denture alloys

Large structures that require more quantities of alloy can make them quite heavy and expensive. So Besides all requirements of metal, casting denture alloys ***requirements*** are:

- Should have low weight because it is large in structure.
- Should have high stiffness which help in making casting more thinner which is important in the palate.
- Should have good fatigue resistance; it is important for clasp.
- Should not react with denture cleaners.
- Should have low cost.

Types of Removable denture alloys

Cobalt chromium, nickel chromium, aluminum alloys, type IV gold alloys and titanium.

Cobalt chromium alloys

They are also called satellite because of their shiny – star like appearance. Have high strength, excellent corrosion resistance & hard.

Application

1. Denture base.
2. Cast removable partial denture framework.
3. Crown and bridge.
4. Bar connecters.

Composition

- ***Cobalt:*** (35-65%) decrease hardness, strength and rigidity.
- ***Chromium:*** (23 – 30 %) passivity effect, decrease melting point.
- ***Nickel:*** (0-20%) decrease strength and hardness, increase ductility (Nickel cause sensitivity in some patients).
- ***Molybdenum:*** (0-7%) increase hardness.
- ***Carbon:*** (0.4%).

Properties

1. ***Density***: It is half of gold alloys (8-9gm/cm).
2. ***Fusion temp***: Higher than gold alloys (1250-1480 C°).
3. ***Yield strength:*** Higher than gold alloys (710 Mpa).
4. ***Elongation:*** Less than gold (1-12%).

5. ***Modulus of elasticity***: Twice than gold alloys (225*10 Mpa).
6. ***Casting shrinkage:*** It is about 2.3%.
7. ***Hardness***: Harder than gold (432HN) thus cutting, grinding , finishing is difficult ; special hard high speed finishing tools are needed.
8. ***Tarnish and corrosion:*** Passivity affect: the formation of layer of chromium oxide on the surface of these alloys prevents tarnish and corrosion in the mouth. Hypochlorite and other chlorine in some denture cleaning solutions should not be used because it will cause corrosion of the alloy.

Advantages:-

1. Lighter in weight.
2. Better mechanical properties.
3. As corrosion resistance as gold alloys (due to passivity effect).
4. Less expensive than gold.

Disadvantages:-

1. More technique sensitive.
2. Complexity in production of dental appliance.
3. High fusing temp.
4. Extremely hard, so require special equipment for finishing.
5. High harden cause wear of restoration and natural teeth.

Titanium and titanium alloys (Ti-6Al-4V)

Titanium and its alloys are now used in metal – ceramic and for removable partial denture frames and implants. It has excellent biocompatibility, light weight, good strength and ability to passivity.

Application in dentistry

1. Metal ceramic restoration.
2. Dental implant.
3. Partial denture framework.
4. Complete denture.
5. Bar connecters.

Properties

1. ***Color:*** white color metal.
2. ***Density:*** light metal (1-4gm/cm).
3. ***Modulus elasticity:*** 110 Gpa, half rigid as base metals.
4. ***Melting temp.:*** high (1668C°) special equipment is needed.
5. ***Coefficient of thermal expansion CTE***: 8.3*10 cm/cm c. it is low compared to porcelain 12.7 – 14.2 *10, so special low fusing porcelain is used with it.
6. ***Biocompatibility:*** it is non toxic and excellent biocompatibility with soft and hard tissue.
7. ***Tarnish and corrosion resistance:*** passivity effect and formation of oxide layer to protect the metal from further oxidation.
8. ***Investment:*** phosphate and ethyl silicate bonded investment.

Nickel chromium alloys

They are used for metal ceramic crown and bridge.

Composed of:

- ***Nickel:*** 61-81%.
- ***Chromium***: 11-27% passivity effect, decrease melting point.

- ***Molybdenum:*** 2-9% increase hardness.
- ***Minor elements:*** Beryllium, Aluminum, Silicate, Copper.

Properties

1. ***Color:*** white in color.
2. ***Melting range:*** 1155-1304C°.
3. ***Density:*** 7.8-8.4 gm/cm.
4. ***Casting:*** extremely technique sensitive.
5. ***Hardness*** 175-360 VHN, the high hardness make them difficult to cut , grind and polish.
6. ***Yield strength***: 310- 828 Mpa, stronger than gold.
7. ***Modulus of elasticity:*** 150-210Mpa (*10), this mean we can make casting thinner and lighter.
8. ***Elongation:*** 10 – 28% they are ductile but not easily burnishable.
9. ***Porcelain bonding***: this alloy forms adequate oxide layer which bonds to porcelain.
10. ***Aesthetic***: dark oxide layer may be seen at porcelain metal junction.

Shaping the alloys

Alloys used in dentistry are either casting or wrought alloy.

Wrought alloys are defined as alloys which are shaped without applying heat (room temperature) by hammering (cold working).

Cold working: the alloy is hammered, drawn or bent into shape at room temperature. It is called wrought alloy and it is used for making instruments, burs, wires.

Stainless steel is an alloy of iron and carbon that contains chromium, nickel and manganese.