INORGANIC CHEMISTRY IN DENTISTRY

Introduction to Sciences of Dental Material

DENTAL BIOMATERIALS

A science that deals with the study of materials used in dentistry, which includes chemical properties, physical properties, manipulation and their applications in dental practice (Fig. 1.1).

Fig. 1.1: Lab analysis.

OBJECTIVES OF THE DENTAL BIOMATERIAL SCIENCES ARE TO: -

- Know the proper usage of dental materials.
- Stimulate further research so we can further improve the quality of the material.
- Introduce the students to the materials used in dentistry.
- Bridge the gap between knowledge from chemistry, physics, etc. with dental materials.

AIM OF DENTISTRY

Maintain or improve the quality of life of dental patients by preventing disease, relieving pain, improving mastication efficiency, enhancing speech and improving the general appearance of patients and the know the physical and chemical properties of dental materials. In terms of quality mastery is replacement of a single tooth or a segment of teeth.

Dental Materials

Metal & Metal Alloys

Metals are defined as "An opaque lustrous chemical substance which is a good conductor of heat and electricity and when polished is a good reflector of light". They are used not only as restorative materials but also as tools and in orthopedic surgeries. They can be base metals or noble/inert metals. In dentistry most frequently used metals are:-

Gold	Au
Silver/Argentums	Ag
Platinum Group metals	Pt

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.

Additives to the gold alloy: -

- **A.** Copper: reduce melting point and density, increase hardness and strength, gives red color to gold, reduce corrosion and tarnish resistance.
- **B.** Silver: whiten the alloys; increase strength and hardness slightly; in large amount reduce corrosion resistance.
- **C.** Platinum: increase strength and corrosion resistance and melting point, has white color, reduce the grain size.
- **D.** Palladium: similar to platinum, it hardens and whitens the alloy, raises fusion temp., increase tarnish resistance.
- **E.** 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.

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.

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.

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%).

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.

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 nontoxic 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.

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.

Dental Amalgam

Dental amalgam is an alloy produced by mixing liquid mercury with solid particles of silver, tin, copper and sometimes zinc, palladium and selenium; this combination of solid metals is known as the amalgam alloy.

In dentistry, the amalgam has been successfully used for more than a century as a restoration material for tooth decay.

(Alloy for dental amalgam A silver-tin alloy containing other metals, usually copper and zinc, that will be mixed with mercury to form dental amalgam).

Classification of amalgam alloys:

1. Based on copper content:

- Low copper alloys: Contain less than 6% copper (conventional alloys).
- High copper alloys: Contain more than 6% copper.

The high copper alloys are further classified as:

- Admixed or blended or dispersion alloys.
- Single composition or unicomposition alloys.

2. Based on zinc content:

- Zinc- containing alloys: Contain more than 0.01% zinc.
- Zinc-free alloys: Contain less than 0.01% zinc.

3. Based on the shape of alloy particle:

- Lathe cut alloys: irregular shape.
- Spherical alloys.

4. Based on number of alloyed metals:

- Binary alloys: e.g. silver-tin.
- Tertiary alloys: e.g. silver-tin-copper.
- Quaternary alloys: e.g. silver-tin-copper-indium.

Manufacture (or Making) of alloy powder:

1. **Lathe-cut alloy powder:** to produce lathe-cut alloys, the metal ingredients are heated and protected from oxidation until melted, then poured into a mold to form an ingot; the ingot is cooled slowly. After the ingot is completely cooled, it is heated for various period of time to produce a more homogenous distribution of Ag3Sn. An annealed ingot of silver-tin alloy is placed in a milling machine or in a lathe and fed into a cutting tool.
2. **Aging:** a freshly cut alloy reacts too rapidly with mercury. If the alloy fillings are stored at room temperature for a few months the reactivity gradually decreases. Such alloys are said to been aged. Aging can be done quickly by boiling the fillings for 30 minutes in water. They can also be treated with acid. Aging also improves the shelf life of product.
3. **Spherical alloy powder:** the spherical alloy is prepared by an atomization process. The liquid alloy is sprayed under high pressure of an inert gas through a fine crack into a large chamber. If the droplets solidify before hitting a surface, the spherical shaped is preserved. Like the lathe-cut powder, spherical powder is aged.

❖ **Composition: -**

Low copper	High copper		
	Admixed		Unicomposition
Lathe-cut or spherical	Lathe-cut	Spherical	Spherical
Silver 63-70%	40-70%	40-65%	40 - 60%
Tin 26-29%	26-30%	0-30%	22 - 30%
Copper 2-5%	2-30%	20-40%	13 - 30%
Zinc 0-2%	0-2%	0%	0 - 4%

Low copper alloys: (Traditional, Conventional):-

Composed of silver 63-70%, tin 26-29%.

Available as:

- ❖ lathe-cut alloys, two types: coarse or fine grain.
- ❖ Spherical alloys.
- ❖ Blend of lathe-cut and spherical particles.

Setting reaction: when alloy powder and mercury are triturated, mercury diffuses into the alloy particles and starts reacting with the silver and tin present in it, forming silver-mercury and tin-mercury compounds.

$$\mathbf{Ag_3Sn + Hg \longrightarrow Ag_2Hg_3 + Sn_8Hg + Ag_3Sn}$$

(Ag_3Sn) gamma (Y) phase a silver-tin compound that forms a substantial part of the amalgam alloy (Ag_2Hg_3) gamma 1 (Y1) phase A silver-mercury compound that is a reaction product in dental amalgam.

(Sn_8Hg) gamma 2 (Y2) phase A tin-mercury compound ***the weakest compound and is least stable to corrosion process.***

The alloy particles do not react completely with mercury; about 27% of the original Ag_3Sn remains as

unreacted particles. Set amalgam consist of unreacted particles (Y) surrounded by matrix of the reaction products (Y1 & Y2). If more (Y) phase is present, the stronger the amalgam.

High copper alloy:

They are preferred because of their improved mechanical properties, resistance to corrosion and better marginal integrity (because the weakest Y2 phase is eliminated in high copper amalgam). High copper alloy is further classified as:

Admixed Alloy

- Made by mixing
- One part of high copper spherical particles (eutectic alloy) silver (40-56%), copper (20-40%)
- 2 part of (low-copper, lathe-cut particles).

Setting reaction

$$Ag_3Sn + Ag\text{-}Cu + Hg \longrightarrow Ag_2Hg_3 + Sn_8Hg + Ag_3Sn + AgCu$$

$$Sn_6Hg + Ag\text{-}Cu \longrightarrow Cu_6Sn_5 + Ag_2Hg_3$$

- **(Cu6Sn5) - Eta phase.**

Single-composition alloys:

Made from particle has the same composition silver (40-60%), copper (13-30%), tin (22-30)

Setting reaction

$$\mathbf{AgSnCu + Hg \longrightarrow Cu_6Sn_5 + Ag_2Hg_3 + AgSnCu}$$

(Y+ ε)

No gamma 2 (Sn_8Hg) will appear in any stage of reaction.

Strength of amalgam

Hardened amalgam has good compressive strength but low tensile or bending strength. Therefore, the cavity design should be such that the restoration will receive compression forces and minimize tension or shear forces in service.

Factors affecting strength:

1. Trituration affect:

Either under or over trituration will decrease the strength for both low and high copper amalgam.

2. Mercury content affect:

Sufficient mercury should be mixed with the alloy to wet each particle of the alloy. Otherwise, a dry, granular mix results which has rough and pitted surface that invites corrosion. Excess mercury in the mix can produce a marked reduction in strength.

3.Condensation affect:

Higher condensation pressure results in higher compressive strength (only for lathe-cut alloy). Good condensation technique will minimize porosity and remove excess mercury from lathe-cut amalgam. If heavy pressure is used in spherical amalgam, the condenser will punch through; however spherical condensed with light pressure produce adequate strength.

4. Porosity affect:

Voids and porosity reduce strength and porosity is caused by:

A. Decrease plasticity of the mix: caused by: low and high Hg/alloy ratio & over and under trituration.

B. Inadequate condensation pressure.

C. Irregularly shaped particles of alloy powder.

D. Insertion of too large increments.

Note/ Increase condensation pressure improves adaptation at margins and decreases the number of voids. Fortunately, voids are not problem with spherical alloys.

5. Rate of hardening affect:

Strength increases with time. Amalgam do not gain strength as rapidly as might be desired. The ADA stipulates a minimum of 80 mpa at 1 hour. Patient should be continued not to bite too hard for at least 8 hours after placement; the time at which at least 70% of strength is gained.

6. Cavity design affect:

The cavity should be designed to reduce tensile stresses. Amalgam has strength in bulk; therefore, increase thickness will increase strength, the cavity should have adequate depth.

Biological properties for Amalgam

- **Certain mercury compounds** are known to have a harmful effect on the central nervous system. The patient is briefly subjected to relatively high doses of mercury during placement, contouring and removal of amalgam fillings. A lower, but continuing, dose results from ingestion of corrosion products. Properly handled dental amalgam should be regarded as safe for general use as a direct restorative material.
- **Mercury is toxic**, free mercury should not be sprayed or exposed to the atmosphere. This hazard can be arising during trituration, condensation and finishing of restoration; also during the removal of old restoration at high speed. Mercury vapors can be inhaled. Skin contact with mercury should be avoided as it can be absorbed. Mercury has accumulative toxic affect. Dentists and dental assistants are at high risk; though it can be absorbed by skin or by ingestion, the primary risk is from inhalation. The clinic should be well ventilated. All excess mercury and amalgam waste should be stored in well-sealed containers.

Application of amalgam

- Permanent filling material.
- For making dies.
- In retrograde root canal filling.
- As a core materials