Metal and Alloys in Dentistry

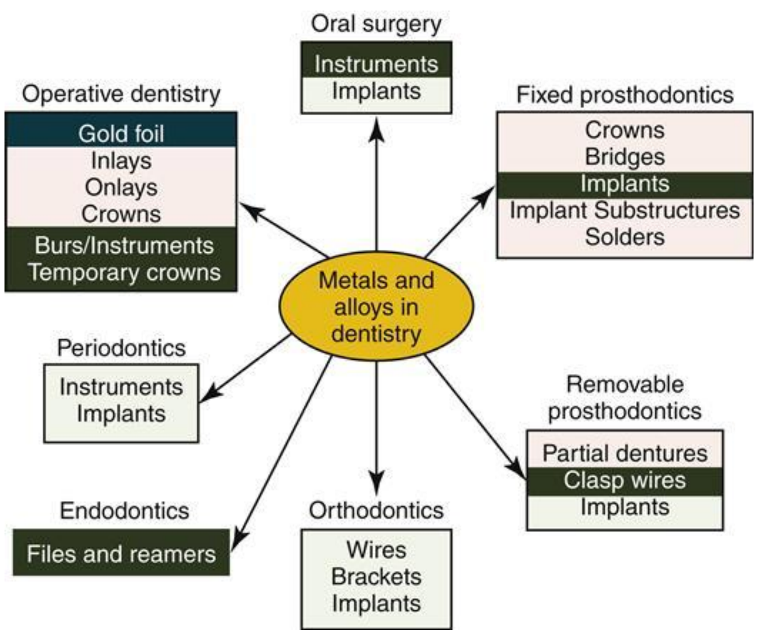
Metals are defined as “An opaque lustrous chemical substance which is a good conductor of heat and electricity and when polished is a good reflector of light”.
In dentistry most frequently used metals are:

1- Noble metals: This group of metals consists of mainly anticorrosive metals. like (gold, platinum, palladium, and silver; however, in the oral cavity silver in not considered noble because of tarnish).

2- Base metal: Base metals are usually used with combination of other metals. These metals are prone to oxide layer formation which does not make them suitable for dental applications. Once oxide layer is formed these metals lose their integrity and become dangerous for dental applications. To increase their anticorrosion behavior, they are used in combinations like (chromium, cobalt, nickel, iron, copper, manganese, etc…..).

Nobility is related to tarnish and corrosion resistance
Tarnish: is loss of luster from the surface of metal or alloy due to the formation of a surface coating of metal oxide.
Corrosion: is the gradual destruction of materials (usually metals) by chemical or electric-chemical reaction with their environment.

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 (nontoxic and no 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.

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.

Shaping the alloys

Alloys used in dentistry are either wrought alloy or casting alloy.

1-Wrought Alloys. Defined as alloys which are shaped without applying heat (room temperature) by hammering, drawn or bend into shape (cold working). Stainless steel is a wrought alloy of iron, carbon, chromium, nickel and manganese. it is used for making dental instruments, burs, wires.

2-Casting Alloy Defined as alloys which are shaped by heating the material until it becomes molten, when it can be forced into an investment mold which has been prepared from a wax pattern.

GOLD

Gold foil filling (pure gold)

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*** decreases 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 are 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 match that of porcelain.

Requirements of metal ceramic alloys

1. Melting temp. should be higher than the porcelain firing temp.
2. coefficient of thermal expansion 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 is the physical property of dental material; it is **time-dependent plastic deformation** of a material under static or dynamic loading. **A sag** is a form of **creep** that occurs in metal at high temperature under its own weight. For example, metals used for long-span bridges should have high sag resistance, so that when porcelain is fired onto them, which requires high temperature for fusing porcelain, these metals should not sag.

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 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 (220–230 GPa).

6. ***Casting shrinkage:*** It is about 2.3%.

7. ***Hardness***: Harder than gold (432HN) thus cutting, grinding, and 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. 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*: 8.5 X 10-6;0 0 at room temperature it is low compared to porcelain 12.7 – 14.2 X10-6, 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:*** 150-210 Gpa, 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.

Stainless steel Alloy:

* Composition: Iron (70%), Chromium (18%), Nickel (8%), and Carbon (the rest).

* Uses: Mostly used to form wrought wire used in prosthodontics as removable partial denture clasps and in orthodontic wires.

* Advantages: Its product is thin, light, conducts heat rapidly, strong and has good resistance to corrosion.

Wrought Alloy: It is the alloy when it is shaped without applying temperature (in room temperature) by hammering, drawn or bent into shape (cold working).

Filling material

Filling material: the material that is used to replace a missing part of the tooth which may result from dental caries, trauma or abrasion. It can be divided in to:

1. Direct filling materials: it placed directly into a cavity on a tooth, and shaped to fit it.

2. **Indirect filling materials** the dental impression is taken after tooth preparation and sent to a dental technician who fabricates the restoration that place in the prepared tooth.

Requirement of an ideal Filling material:-

1. Working time should be sufficiently long, to enable manipulation and placement of material before setting.

2. Setting time should ideally be short for comfort and convince of both the patient and clinician.

3. The material must withstand large variation in PH and a variety of solvents which may be taken into mouth.

4. Filling should be good thermal insulator, protecting the dental pulp from the harmful effect of the hot and cold stimuli (low thermal diffusivity).

5. Materials should have values of coefficient of thermal expansion similar to those of enamel and dentine.

6. Metallic material should not undergo excessive corrosion, or be involve in the development of electrical currents which may cause " **Galvanic pain** " .

7. Should have satisfactory mechanical properties to withstand the force applied, abrasion resistance, compression and tensile strength, modulus of elasticity.

8. It should adhere well to the tooth walls and seal the margins to prevent ingress of fluid and bacteria.

9. It should be harmless to the operator and to the patient and should not be irritant to dental pulp and soft tissue.

10. It should be radiopaque.

11. It should bacteriostatic and anticariogenic.

12. It should be easily polished.

No single restorative material is suitable for all cases. For some situations, the strength and abrasion resistance of material may be the prime consideration. In other situation, appearance and adhesive properties may become more important.

Classification of filling materials:

1. **Metallic**

a. Amalgam.

b. Direct Gold filling.

c. Indirect cast restorations.

2. **Non metallic which include**

a. Polymeric

- **Unfilled resin (acrylic) (** not used now)
- **Filled resin (composite, compomers)**

b. Non polymeric

- **Silicate cement (**not used now**)**
- **Glass ionomers cement**

Other classifications:

1. Anterior filling material (tooth colored filling).

2. Posterior filling material.

Composite materials

The term composite may be defined as a compound of two or more distinctly different materials with properties that are superior or intermediate to those of the individual constituents.

Composite is polymeric filling material reinforced with filler particles used as restorative materials. The proper term is polymer matrix composite or resin composite. It has higher mechanical properties than of acrylic filling and of silicate cement.

Modern composite materials have excellent esthetics that mimics the natural teeth and excellent durability, wear-resistance, high mechanical properties for stress bearing areas (used as anterior and posterior filling materials).

Composition:

A resin composite is composed of four major components:

1. **Organic resin matrix**. (Bis- GMA or urethane dimethacrylate).

2. **Inorganic filler particles** (Quartz, colloidal silica glasses or ceramic containing heavy metals).

3. **Coupling agent** (organo silanes).

4. **The initiator-accelerator system**.

Also they contain

1. **Hydroquinone -** inhibitor to prevent premature polymerization

2. **UV absorber -** to improve color stability

3. **Opacifiers** - e.g. titanium dioxide and aluminum oxide.

4. **Color pigments** - to match tooth color

Organic resin matrix (binder):- The nature of it may alter slightly from one product to another; essentially The monomers used for the resin matrix are **dimethacrylate** compounds. Its properties were superior to those of acrylic resins. The two monomers that have been commonly used are (**Bis-GMA**) and **urethane dimethacrylate (UDMA**). Both contain reactive carbon double bonds at each end that can undergo **addition** polymerization initiated by free-radical initiators. Both of Bis-GMA and UDMA are viscous and sticky so, **TEGDMA** 'triethylene glycol dimethacrylate' with low molecular weight added as a dilute monomer to control the consistency of composite paste.

Inorganic Filler particles: Composite resins use 3 types of fillers:

1. **Ground quartz filler**: They are obtained by grinding or milling the quartz. They are mainly used in conventional composites. They are chemically inert and very hard. This

make restoration more difficult to polish and can cause abrasion of opposing teeth and restoration. The quartz filler is harder than the glass filler.

2. **Colloidal silica:** Referred to as **microfillers**, they are added in small amount (**5 wt %**) to modify the paste viscosity. Colloidal silica particles have large surface area thus even small amount of micro fillers thicken the resin. It used in microfilled composites.

3. **Glasses / ceramics containing heavy metal**: There filler provide radiopacity to resin restoration. ex. Barium ;Zirconium. The most commonly used is barium glass. It is not as inert as quartz some barium may leach out.

The function of the addition of filler particles into resin matrix are

1. Reinforcement (Improves mechanical properties). Increased filler loading generally increases physical and mechanical properties such as compressive strength, tensile strength, modulus of elasticity.

2. Reduction of polymerization shrinkage/contraction. (less resin is present so the curing resin is reduced).

3. Reduction in coefficient of thermal expansion and contraction. (Fillers thermally expand and contract less than the polymers).

4. Decreased water sorption. Increased filler loading decreases water sorption. Absorbed water softens the resin and makes it more prone to abrasive wear and staining.

5. The radiopacity are improved

6. Control of workability/viscosity. The more filler, the thicker is the paste

Factor with regard to filler that determine the properties and clinical application of composite

a- *Amount of filler added.*

b- ***Size of particles and its distribution:*** In order to increase the amount of filler in the resin, it is necessary to add the filler in a range of particles size. If a single particle size is used, a space will exist between particles, smaller particles can then fill up these spaces.

c- ***Index of refraction*****:** For esthetic, the filler should have a translucency similar to tooth structure. To achieve this, the refractive index of filler should closely match that of the resin. Most glass and quartz filler have a refractive index 1.5, which much than that of bis-GMA.

d- ***Its hardness***

e- ***Radiopacity***

The Coupling agents: the composite to have successful properties, a good bond must form between the inorganic filler and the organic resin, The most commonly used coupling agents are organosilanes (often referred to as silane). It is applied to the inorganic filler particles to surface-treat the fillers before being mixed with the monomer. They called coupling agents, because they bond the filler particles to the resin matrix. This allows the more plastic resin matrix to transfer stress to stiffer filler particles. Function of coupling agents.

1. They improve the physical and mechanical properties of resin.

2. They prevent water from penetrating the filler - resin interface. (Micro leakage of fluids into filler resin interface led to surface staining).

3. Prevent the filler from being dislodged from the resin matrix.

The initiator-accelerator system: is to polymerize and cross-link the system into a hardened mass. The polymerization reaction can be activated by

1. light-activation
2. self-curing (chemical activation)
3. dual curing (chemical and light-curing).

Properties of the composite

1. Low polymerization shrinkage

2. Low water sorption

3. Coefficient of thermal expansion similar to tooth structure

4. High fracture resistance

5. High wear resistance

6. High radiopacity

7. Good bond strength to enamel and dentin (by using bonding)

8. Good color match to tooth structure

9. Easy to manipulation

10. Easy of finishing and polishing

Types of composite

Classification of composite based on curing mechanism

1. Chemically activated composite or self cured composite.

2. Light activated composite.

3. Dual cured composite

Classification of composite based on size of filler particles:

1. Conventional or traditional composite.

2. Small particles composite.

3. Micro filled composite.

4. Hybrid composite.

5. Nanocomposites.

Chemically activated composite resins (self cured composite):

This is two paste system (base and catalyst) two tubes.

- **Base paste**: contains benzoyl peroxide initiator.

- **Catalyst paste**: tertiary amine activator.

Setting: When the two pastes are mixed the tertiary amine reacts with the benzyl peroxide to form free radical which stats the polymerization. The correct proportions of the base and catalyst pastes are dispensed onto a mixing pad and combined by rapid spatulation with a plastic instrument for **30 seconds**. (Metal instrument should be avoided as it may discolor the composite) it can be inserted in the cavity with a plastic instrument or syringe. The cavity is slightly overfilled; a matrix strip is used to apply pressure and to avoid inhibition of air.

The properties of self cures composite are:

1. Activated by peroxide-amine system.
2. Chemical activation is accomplished at room temperature
3. Cures throughout its bulk.
4. Working time is limited.
5. Supplied as two component system.
6. Air may get incorporated during mixing resulting in reduction of properties.

Light activated composite resins:

UV activated systems: The earliest system used Ultra Violet light. Not used now a day because of the

1. Limited penetration of the light into the resin,
2. Lack of penetration through tooth structure
3. it Irritant to the soft tissue.

Visible Light activated resins: They are widely used than the chemically activated resins. These are single paste system containing Photo initiator (**camphoroquinone**) and **Amine accelerator**.

Under normal light they don't interact.but when exposed to light of the correct wave length the photo initiator is activated and reacts with amine to form free radical.

Camphoroquinone has an absorption range between ***400-800 nm***. This is in the blue region of visible light spectrum. In some cases inhibitors are added to enhance its stability to room light or dental operatory light.

The properties of light cures composite are:

1. Supplied as single component (light tight syringes) or unit-dose capsules.
2. Working time under control of Operator.
3. More Homogenous mix
4. Required light of correct wave Length for its activation.
5. Cure only where sufficient Intensity of light is received.
6. Less chance of air entrapment during manipulation

Light activated	**Chemically activated**
1. Required light of correct wave length for its activation.	1. Activated by peroxide-amine system.
2. Cure only where sufficient intensity of light is received.	2. Cures throughout its bulk
3.Working time under control of operator.	3. Working time is limited.
4. Supplied as single component in light tight syringe.	4. Supplied as two component system.
5. Less chance of air entrapment during manipulation, more homogenous mix.	5. Air may get incorporated during mixing resulting in reduction of properties.
6. More Homogenous mix.	6. Less homogenous mix.

Dental Amalgam

Dental amalgam is a powder of silver-tin alloy mixed with mercury. Previously, it is the most popular filling material used till nowadays to restore posterior teeth and core build up.

In 1833 amalgam introduced in USA by mixing silver coins with mercury, the problem was a high setting expansion of silver cause fracturing of restoring tooth. The best scientific, beginning of amalgam as a restorative material was in 1855 by using Silver-Tin- mercury of equal parts.

Composition

The composition, of alloy powder is varies from one product to another.

I) Conventional amalgam (Traditional)

Produced by early dental manufactories in 1900.

Basic composition:

a) Silver (Ag) 65%: strength, promoting setting when mixed with mercury.

Disadvantage: high degree of setting expansion.

b- Tin (Sn) 25-29%: aids in amalgamation process of alloy with mercury at room temperature and decrease expansion within practical limit.

Large amount of tin cause decrease strength, prolong the setting time and decrease corrosion resistance of amalgam.

c- Copper (Cu) 6%: increase strength and hardness and setting expansion but decrease flow.

d- Zinc (Zn) 1-2 % max: aid in process of manufacturing by acting as a scavenger for oxygen and minimize the oxidation of other metals.

Increase in Zn cause delayed expansion.

-Alloy which contain > 0.01% ——————Zinc- containing alloys

-Alloy which contain <0.0l% —————non zinc (Zinc free; alloys). (Require inert atmosphere during manufacturing)

II) High copper amalgam:

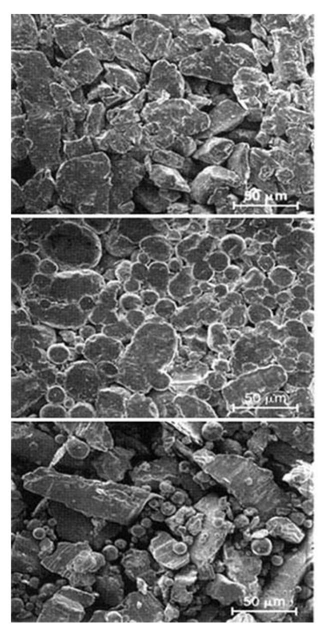
The copper content is increase from 6% up to 10-30%.

a- Unicompositional system: either lathe - cut or spherical

b- Disperse alloy (admixed): a mechanical mixture of lathe-cut alloy with spherical alloy (c).

Two methods of production of alloy powder:

1- Lath - cut
2- Spherical
3- Admixed



Lathe cut

Spherical

Admixed

Setting Reaction

The reaction is take place when alloy powder and mercury is mixed, mercury diffused in alloy particles. The reaction products crystallize to give new phases in the set amalgam. A considerable amount of initial alloy remains unreacted.

The reaction of conventional amalgam is given by this equation:

$$Ag_3Sn + Hg \longrightarrow Ag_2Hg_3 + Sn_7Hg + Ag_3Sn$$

$$\gamma + Hg \longrightarrow \gamma 1 + \gamma 2 + \gamma$$

For high copper amalgam:

$$Ag_3Sn + Cu + Hg \longrightarrow Ag_2Hg_3 + Cu_6Sn_5 + Ag_3Sn$$

$$\gamma + Cu + Hg \longrightarrow \gamma 1 + Cu_6Sn_5 + \gamma$$

Properties

1- Dimensional changes: The setting reaction of amalgam is associated with dimensional changes.

A small contraction takes place in the first *1/2* hr as mercury still diffusing in alloy powder, then when crystallization begun the outward thrust of growing crystals cause expansion. The overall effect of the final set material may cause slight final expansion (curve a) or slight final contraction (curve b).

Factors which affect a final expansion or contraction:

1- Type of alloy

2- Particle size and shape.

3- Pressure used to condensed amalgam (most significant).

A standard test permit a slight expansion typically (0.2%) max. or slight contraction of. 0.1% max. a large contraction would result in a marginal gap down which fluids could penetrate. A large expansion would result in the protrusion of the filling from the cavity.

Delayed expansion**:** for zinc containing amalgam when contaminated with moisture during condensation zinc will react with water, hydrogen will produced as products of such reaction, hydrogen will be collected internally, this cause pressure which may cause expansion. This occurs after 3-4 days and may be after a month. This confirms the need for adequate moisture control when using this material.

2- Strength : The strength of amalgam developed slowly it may takes 24 hrs after mixing to reach reasonable high value, and continue to increase slightly for some time after that.

{*Why* we instruct the patient not to press on amalgam after 20-30 minutes}

Spherical alloy and high copper amalgam develop strength more rapidly than conventional lathe-cut material, in which fine grain develops strength faster than coarse grain.
High mercury affect the strength (weaken the final properties of the set material)

PROPERTY	INGREDIENT			
	Silver	Tin	Copper	Zinc
Strength	Increases			
Durability	Increases			
Hardness			Increases	
Expansion	Increases	Decreases	Increases	
Flow	Decreases	Increases	Decreases	
Color	Imparts			
Setting time	Decreases	Increases	Decreases	
Workability		Increases		Increases
Cleanliness				Increases

Table 1-1. Effects on properties of an amalgam restoration imparted by ingredier

3) Creep: Is a plastic deformation of amalgam when subjected to intraoral stresses. It is measured using "Static Creep Test".
Creep causes protrusion of amalgam out of the cavity , the protruded edges are unsupported and weak and may be further weakened by corrosion this lead to fracture , as a result a ditch will happened around the margin of amalgam restoration which will cause a gap and microleakage (Ditching of amalgam)
The gamma 2 phase is primarily responsible for high value of creep in conventional amalgam but it is not the only factor involved, while high copper amalgam has lower value of creep because it has a little or no gamma 2 phase .

4) Tarnish and Corrosion:
Tarnish: is a loss of luster from the surface of metal or alloy due to the formation of a surface coating. The amalgam is usually tarnished due to the formation of sulphide layer on the surface. This causes no change in the mechanical properties of the alloy.

Corrosion: The multiphase structure of amalgam makes it prone to corrosion. The different phases from the anode and cathode and saliva (provides the electrolytes), electrolytic cell is readily setup.
The gamma 2 phase of conventional amalgam is the most electrochemically reactive and readily forms the anode, gamma 2 will break down to tin containing corrosion products and mercury, some of mercury will combine with unreactcd alloy (gamma). Small quantity of mercury will be ingested by the body.
For higher copper amalgam the $Cu6Sn3$ phase forms the anode but less corrosion occurs than conventional amalgam because absence of gamma 2 phase.

*The rate of corrosion is accelerated when the amalgam filling is contact with gold restoration. *Why?*

*Corrosion will cause roughness of the amalgam which may lead to plaque and bacterial accumulation and inflammation of the soft tissue also will cause poor appearance of the filling surface and may affect the mechanical properties of amalgam.

*Level of corrosion may be minimized by polishing, surface of restoration.

*Corrosion has one advantage that corrosion products thought to be gathered at the restoration - tooth interface (seal the gap) to prevent or decrease microleakage.

5-Thermal Properties:

*Dental amalgam has a high value of thermal diffusivity so requires insulating material (cement base).

*The Coefficient of thermal expansion and contraction is three times greater than that of dentine this cause more expansion and contraction of the restoration than the surrounding tooth when patient takes cold and hot food and drinks. This leads to microleakagc around the filling. So replacement of the restoration is a must every 5 years.

6- Biological properties

The mercury has a bad effect on CNS also may cause contact dermatitis.

Some studies showed a higher concentration of mercury in blood and urine in patients with amalgam fillings than those without fillings, but the levels was within acceptable limit.

Mercury Toxicity

People are exposed to mercury in daily life by the way of foods, vaccines, antiseptics, ointments, amalgam or occupation.

The symptoms of mercury poisoning are:

1. Ataxic gait
2. Convulsions
3. Numbness in mouth and limbs
4. Constriction in visual field.
5. Difficulty in speaking.

Harmful effects of mercury from the dental amalgam could be in the form of

1. Toxicity.
2. Hypersensitivity

Mercury has been found to be a causative agent of various sorts of disorders, including alterations of motor function and neuroendocrine secretion at very low exposure levels of inorganic Hg, Nephrological (Kidney injury from mercury is known to cause dose-related tubular dysfunction An immunological effect has also been observed in studies on clinically asymptomatic workers with low level exposure, cardiac, motor, reproductive and even genetic. Recently heavy metal mediated toxicity has been linked to diseases like Alzeihemer's, Parkinson's, Autism, Lupus, Amyotrophic lateral sclerosis, etc.

Quantitative diagnostic procedures are done to decide whether the problems are due to mercury poisoning or not.

Mercury Exposure in Dental Practice

Various means of exposure to mercury

- Storage of mercury
- Preparation and placement of amalgam restoration.
- Polishing silver amalgam restoration
- Removal of amalgam filling.
- Storage of waste silver amalgam.

Exposure of mercury may be either in the form of vapour or particulate amalgam dust (Hg^{2+}).

-The dentist and assistants should take precautions:

A) Freshly mixed amalgam and mercury should not be touched by hands, because mercury will be absorbed by skin.

B) Dentist: and assistant subjected to the vapor of mercury in atmosphere which increases with increasing temp, especially when sterilizing the instruments with mercury contamination. So Instruments should be cleaned well.

C) Wearing a mask and gloves will protect the dentist and the assistant from mercury toxicity.

Manipulation of dental amalgam fillings

1- Proportioning and Dispensing

2- Trituration

3- Condensation

4- Caving

5- Polishing

1- Proportioning and Dispensing

Alloy-mercury ratios vary between 5:8 and 10:8. Those mixes containing greater quantities of mercury are wetter and are generally used with hand mixing

For optimum properties, the final set amalgam should contain less than 50% mercury. Those materials used at alloy/mercury ratios at or approaching 5:8 require the removal of excess mercury following trituration and during condensation.

Various methods of dispensation are available:

1- the most accurate method is to weight the mercury and alloy components using balance. This method is rarely used however, and is commonly proportioned using volume dispenser.

2- Amalgamator.-: the device typically has 2 hoppers, one filled with alloy and the other with mercury, the alloy /mercury ratio is set by the operator and the required amount of each component is released in to a mixing chamber by pressing a button.

3- Using capsulated materials: both alloy and mercury in proportion have been determined by manufacturer. The two component is separated by impermeable membrane, which is readily shattered using a capsule press or starting vibrate the capsule in a mechanical mixer which is called self- activating capsule which is the most applicable to use nowadays.

2-Trituration:

1- By hand using a mortar and pestle: a glass mortar with pestle

2- Mechanically by amalgamator: The time of mixing-vary from 5-20 seconds this depend on the speed of amalgamator and the type alloy used.

Advantages:

a) uniform mix is produced

b) shorter time .

c) less mercury / alloy ratio is used.

3-Condensation: -

The material should be placed into the prepared cavity and should be condensed in increments by using one of the following techniques

1- Hand condensation by using a flat -ended steel hand instrument (amalgam condenser) ,

2- Many mechanical devices are available for condensing amalgam. These devices are more useful for condensing irregularly shaped alloys when high condensation forces are required. With the development of spherical alloys, the need for mechanical condensers was eliminated.

3- Ultrasonic condensers are not recommended because during condensation they increase the mercury vapor level to values above the safety standards for mercury in the dental office.

4- Carving and burnishing:-

When an amalgam restoration has been properly placed, with adequate condensation, and the excess mercury has been removed from the final surface layer of the restoration, it will be sufficiently hardened within a few minutes to permit careful carving. If the restoration is not well condensed, it will not harden promptly, and the carving operation must be delayed. Usually the amalgam is sufficiently well set and hardened that carving with sharp instruments can be started almost immediately after condensation. Burnishing, the newly condensed amalgam with a metal instrument having a broad surface contact, can be employed to smooth the surface, thereby making the amalgam more susceptible to finishing and polishing.

5- Finishing and polishing

If final finishing and polishing are to be done at a second appointment, the restoration should be left undisturbed for a period of at least 24 hours. The patient should be cautioned that the freshly inserted restoration is relatively weak and that heavy biting forces should be avoided for a few hours after the time of insertion.

Preventive materials

1. Chemotherapeutic agents

a) Dentifrices

b) mouth washes

c) fluoride varnishes

2. Resin sealants

a) self cure

b) light cure

3. Glass ionomer sealants and resin modified glass ionomer sealants

<u>Dentifrices(tooth paste)</u>

<u>Function of tooth pastes</u>

1. Enhance cleaning of exposed tooth surfaces
2. Removal of pellicle ,plaque ,and debris
3. Carrier for fluoride, detergents, abrasives and whitening agents to improveesthetic of teeth.

<u>General composition of tooth pastes</u>

1. Colloidal binding agents: they act as carrier for the active ingredients ex:sodium alginate.
2. Preservatives to inhibit bacterial growth within the paste.
3. Flavouring agents: peppermints, wintergreen, cinnamon
4. Abrasives: aid in the removal of heavy plaque and adhered stains and calculus ,like calcium pyrophosphate.
5. Humectants :to stabilize the composition and reduce the water loss byevaporation
6. Detergents: like sodium lauryl sulfate to reduce surface tension and enhanceremoval of debris
7. Therapeutic agents: like stannous fluoride to improve resistance to caries0.025-0.15%
8. Other chemicals: minor amounts to reduce corrosion, give color, removediscoloration.

<u>Mouth washes:</u> They are composed of three main ingredients:

1. Active agents which is selected for specific health care benefit such as anticarious activity, anti-microbial effect, fluoride delivery or reduction of

plaque adhesion

2. Solution of water or alcohol to dissolve the active agents
3. Surfactants: help to remove debris and dissolve other ingredients, flavoring agents to breath freshness like eucalyptol, menthol and thymol.

The main active ingredients are Chlorhexidine and fluoride

Disadvantages :

1. high ethanol content produce softening effect on resin restoration
2. Staining effect of chlorhexidine and euogenol in some mouth washes
3. Toxicity with high ethanol content

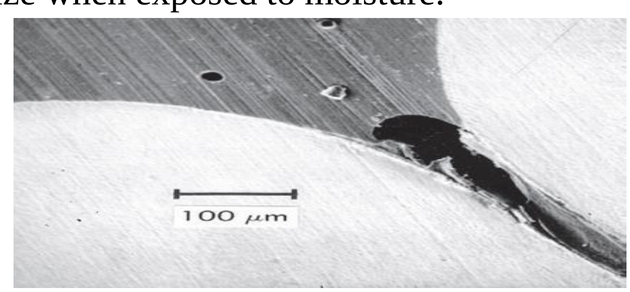
Fluoride varnishes: The fluoride is dissolved in organic solvent that evaporate when applied or sets when exposed to moisture leaving thin film of calcium fluoride deposited on the tooth surface which later converted to fluroapatite by remineralization reaction. It differs from mouth wash its action last for several hours before vanish wears while the mouth wash for seconds.

It is used in young children with high risk of caries ,also in old patientsto prevent root caries

- ***Disadvantages***: bitter taste and tooth discoloration which is transient.

Pit and fissure sealants: Deep pits and fissures are difficult to clean andmore susceptible to caries and fluoride treatment was least effective in prevention of caries.

In 1965 the first technique was called occlusal sealing. Methyl -2-cyanoacrylate mixed with polymethyl methacrylate and inorganic powder. Then placed in the pits and fissures and cyanoacrylatepolymerize when exposed to moisture.



<u>Glass ionomer sealants</u>

<u>Requirements of dental sealants:</u>

1. high flow and good wetting to the surface
2. good wear resistance
3. high compressive strength and rigidity
4. tooth colored
5. less solubility
6. good bond to tooth
7. coefficient of expansion and contraction compatible with thetooth

Root canal filling materials

<u>Sealers</u>

They are paste like material that is essential to seal the space between the dentinal wall and the gutta percha.

Functions of the root canal sealer

1- Cementing the core material to the canal wall.

2- Filling and marking irregularities that can not be filled by gutta percha (lateral and accessory canals).

3- Act as a lubricant to ease the placement of the master cone.

4- Act as a bactericidal agent.

Properties of an Ideal Sealer

1- Exhibits tackiness when mixed to provide good adhesion.

2- Produce a hermetic seal.

3- Radiopaque.

4- Very fine powder to get a smooth mix with the liquid.

5- No shrinkage on setting.

6- No staining of tooth structure.
7- Bacteriostatic.
8- Exhibits a slow set.
9- Insoluble in tissue fluids.
10- Tissue tolerant.
11- Soluble in common solvents.

Zinc Oxide and Eugenol

Zinc oxide–eugenol sealers have been used for many years. They have certain properties as:

1- Exhibit a slow setting time.
2- Shrinkage on setting.
3- Solubility especially when extruded outside the root canal.
4- Stain tooth structure.
5- It has antimicrobial activity.

<u>Types of zinc oxide eugenol sealers</u>

1- Rickert sealer. This powder/liquid sealer contains silver particles for radiopacity. It stains tooth structure if not completely removed. This sealer is popular when using thermoplastic techniques.
2- Procosol sealer. It is a modification of Rickert’s formula in which the silver particles have been removed.
3- Roth's sealer. This is a modification of the Rickert' sealer as it is nonstaining.
4- Tubli-Seal. It is a catalyst/base zinc oxide–eugenol sealer. It has a faster setting time when compared with the liquid/powder sealers.

Calcium Hydroxide Sealers.

They were developed for their antimicrobial activity and osteogenic–cementogenic potential. These actions were very limited. From the types of this group are Sealapex (catalyst/base system), Apexit and Apexit Plus.

Noneugenol Sealers.

They are root canal sealers without the irritating effects of eugenol.

Glass Ionomer Sealers.

The glass ionomers have been developed in root canal obturation because of their dentin-bonding properties. An example from this group is Ketac-endo.

<u>Properties of this group:</u>

1- It enables adhesion between the material and the canal wall.
2- It is difficult to properly treat the dentinal walls in the apical and middle thirds with modifying agents to receive the glass ionomer sealer.
3- It has minimal antimicrobial activity.

Resin resin sealers.

These sealers provide adhesion, and do not contain eugenol.

Types of this group are:

1- Ah-26. It is a slow-setting epoxy resin that releases formaldehyde when setting.

2- Ah Plus. It is a modified formulation of Ah-26 in which formaldehyde is not released. It exhibits a working time of approximately 4 hours.

3- EndoreZ. It is a methacrylate resin with hydrophilic properties. When used with endoreZ resin-coated gutta-percha cones the dual cure endoreZ sealer bonds to both the canal walls and the core material.

4- Diaket. It is a polyvinyl resin sealer.

5- Epiphany and RealSeal. They were introduced for use with the resilon filling material.

Silicone Sealers.

1- RoekoSeal is a polyvinylsiloxane that is supposed to expand slightly on setting.

2- GuttaFlow is a cold flowable matrix that is triturated. It consists of gutta-percha added to roekoSeal. Sealing ability is comparable to other techniques.

Bioceramic sealers.

It is composed of zirconium oxide, calcium silicates, calcium phosphate monobasic, calcium hydroxide, and various filling and thickening agents.

Properties of this group:

1- It is a hydrophilic sealer it utilizes moisture within the canal to complete the setting reaction.

2- It does not shrink on setting.

3- It is biocompatible.

4- It exhibits antimicrobial properties during the setting reaction.

Semi Rigid types materials for obturation of the root canal

1- Gutta-Percha

Gutta-percha is the most commonly used root canal filling material. It is a linear crystalline polymer that melts at a set temperature, with a random but distinct change in structure resulting. It occurs naturally as 1,4- polyisoprene and is harder, more brittle, and less elastic than natural rubber.

The crystalline phase has two forms, the alpha phase and the beta phase. The alpha form is the material that comes from the natural tree product. The processed, or beta, form is used in gutta-percha for root fillings.

When heated, gutta-percha undergoes phase transitions. The transition from beta phase to alpha phase occurs at around 46° C. An amorphous phase develops at around 54° C to 60° C. When cooled very slowly gutta-percha crystallizes to the alpha phase.

Normal cooling returns the gutta-percha to the beta phase. Gutta- percha cones soften at a temperature above 64° C.
These cones can easily be dissolved in many solvents as chloroform, halothane and xylene. Modern gutta-percha cones that are used for root canal fillings contain only about 20% gutta-percha. The major component is zinc oxide (60% to 75%). The remaining 5% to 10% consists of various resins, waxes, and metal sulfate.
Antiseptic gutta-percha with various antimicrobial agents as chlorhexidine and calcium hydroxide may be seen. Gutta-percha cannot be heat sterilized, therefore NaOCl can be used to disinfect the cones by dipping them for 1 minute.
Pressure applied during root canal filling procedures does not compress gutta-percha, but rather compacts the gutta-percha cones to obtain a more three- dimensionally complete fill of the root canal system. After heating, while cooling, there is a slight shrinkage of approximately 1% to 2% when the gutta-percha has solidified.
Gutta-percha cannot be used alone as a filling material; it lacks the adherent properties necessary to seal the root canal space. Therefore, a sealer is always needed for the final seal. Gutta-percha cones are available in tapers matching the larger tapered rotary instruments (#.02, #.04, and #.06).

Advantages of gutta percha

1- Inert
2- Dimensional stability
3- Non allergic
4- Antibacterial
5- Non staining to dentin
6- Radiopaque
7- Compactable
8- Softened by heat
9- Softened by organic solvents

Disadvantages of gutta percha

1- Lack of rigidity
2- No adherence to dentin
3- No complete adaptation to narrow areas.

2- Resilon

It is a thermoplastic, synthetic, polymer-based root canal filling material. It was developed to create an adhesive bond between the solid-core material and the sealer. Resilon can be supplied in the same ISO sizes and shapes (cones and pellets) as gutta-percha. When manufactured in cones, Resilon’s flexibility is similar to that of gutta-percha. Based on polyester polymers, Resilon contains bioactive glass and radiopaque fillers (bismuth oxychloride and barium sulfate) with a filler content of approximately 65%. It can be softened with heat or dissolved with solvents such as chloroform.

Mineral trioxide aggregate (MTA)

It was developed for use as a dental root repair material and was formulated from commercial Portland cement combined with bismuth oxide powder for radiopacity.

MTA is used for:

1- Creating an apical plug during apexification.
2- Repairing root perforations during root canal therapy.
3-Treating internal root resorption.
4- Root-end filling material.
5- Pulp capping material.

Composition

MTA is composed of:

1- tricalcium silicate.
2- dicalcium silicate.
3- tricalcium aluminate.
4- tetracalcium aluminoferrite.
5- calcium sulfate.
6- bismuth oxide.

The later 4 phases vary among the commercial products available.

Characteristics and products

1. Biocompatible with periradicular tissues
2. Non cytotoxic to cells, but antimicrobial to bacteria
3. Non-resorbable
4. Minimal leakage around the margins.
5. Very basic AKA alkaline (high pH when mixed with water).
6. As a root-end filling material MTA shows less leakage than other root-end filling materials, which means bacterial migration to the apex is diminished.
7. Treated area needs to be infection free when applying MTA, because an acidic environment will prevent MTA from setting.
8. Compressive strength develops over a period of 28 days, similar to Portland cement. Strengths of more than 50 MPa are achieved when mixed in a powder-to-liquid ratio of more than 3 to 1.

Originally, MTA products required a few hours for the initial and final setting but newer materials are available that set more quickly and have added characteristics.

Solid type materials for obturation of the root canal

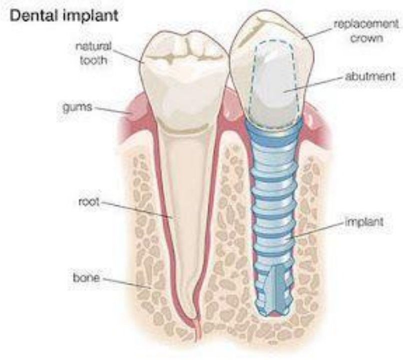
1- Semi rigid materials as silver cones which are not used now. They are flexible and fill narrow curved root canals. When silver cones contact tissue fluids or saliva, they corrode. The corrosion products are cytotoxic.

2- Rigid materials as Vitalium cones which are inflexible and were used as endodontic implants.

Relining mat
Finshing mat

Implant Materials

Dental implants are fixtures that serve as replacements for the root of a missing natural tooth. Implants may be placed in the mandible or maxilla. When properly designed and placed, dental implants bond with bone over time and serve as an anchor for dental prostheses. Dental implants are used to replace a single missing tooth or many teeth, or to support a complete removable denture.



Osseointegration was initially defined on the light microscopic level as “a direct structural and functional connection between ordered, living bone and the surface of a load-carrying implant.

CLASSIFICATION

Dental implants fall into 1 of the following 3 primary groups: ***(1) metals, (2) ceramics, and (3) polymers***. In addition, biomaterials can be classified based on the type of biologic (tissue) response when implanted and the interaction that develops with the host tissue (bone) . Three major types of dental implants : ***(1) biotolerant, (2) bioinert, and (3) bioactive***.

Bioinert Biomaterials

• The term bioinert refers to any material that once placed in the human body has minimal interaction with its surrounding tissue, examples of these are stainless steel, titanium, alumina, zirconia, and ultra high molecular weight polyethylene.

• Bioinert materials allow close apposition of bone on their surface, leading to contact osteogenesis.

Bioactive Biomaterials

• Bioactive refers to a material, which upon being placed within the human body interacts with the surrounding bone that is chemically equivalent to the mineral phase in bone.

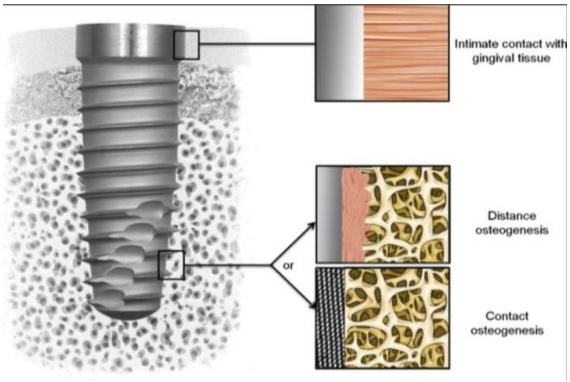
• Examples of these materials are synthetic hydroxyapatite [$Ca_{10}(PO_4)_6(OH)_2$], glass ceramic and bioglass.

• Bioactive materials also allow the formation of new bone, active carbonate apatite (CHAp) layer on the implant by ion exchange with host tissue leads to the formation of a chemical bond along the interface (bonding osteogenesis)

Biotolerant

• Gold ,Co-Cr alloys , Polyethylene ,Polyamide Polymethylmethacrylate

• Biotolerant materials are those that are not necessarily rejected when implanted into living tissue, but are surrounded by a fibrous layer in the form of a capsule.

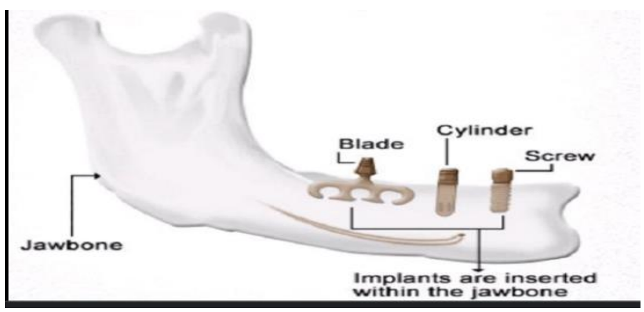


Historically, dental implants have been classified according to their design and placement within the tissues. The three types of implants commonly used are :

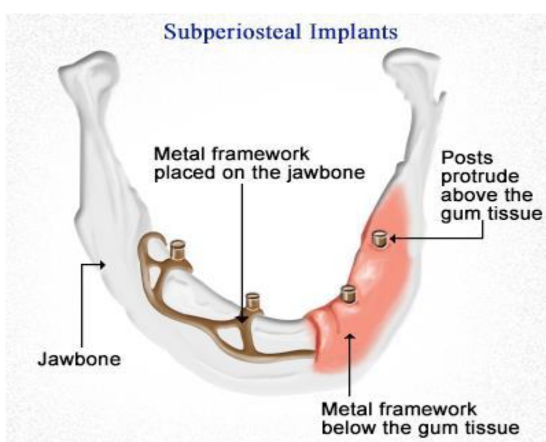
The subperiosteal implant, the transosteal implant, and the endosseous implant .

Endosseous Implant

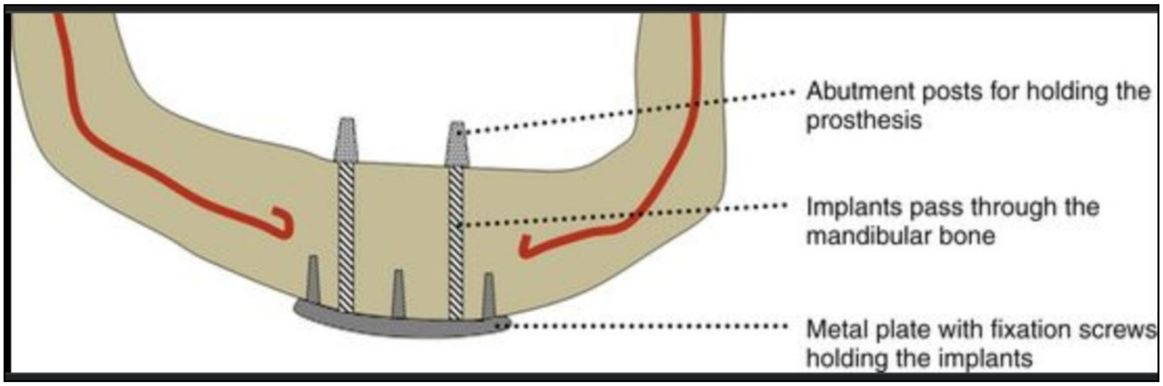
Endosseous implants are the most common type of implant placed today. Implants are placed directly into the mandible or maxilla.



Subperiosteal implant: is a type of implant where the artificial tooth is placed beneath the periosteum that overlies the cortex.



Transosteal implant: This type of implant can, also, be referred to as staple bone implant, mandibular staple implant or transmandibular implant. This type of implant is a combination of both the endosteal components and those of subperiosteal. The implant penetrates the two cortical plates.



Properties of an implant biomaterial

Modulus of elasticity: Implant material with modulus of elasticity comparable to bone (18 GPa) must be selected to ensure more uniform distribution of stress at implant and to minimize the relative movement at implant bone interface.
Metals possess high strength and ductility, whereas the ceramics and carbons are brittle materials.
Tensile, compressive and shear strength: An implant material should have high tensile and compressive strength to prevent fractures and improve functional stability. Improved stress transfer from the implant to bone is reported interfacial shear strength is increased, and lower stresses in the implant.
Yield strength, fatigue strength: An implant material should have high yield strength and fatigue strength to prevent brittle fracture under cyclic loading.

Ductility: According to ADA a minimum ductility of 8% is required for dental implant. Ductility in implant is necessary for contouring and shaping of an implant.
Hardness and Toughness: Increase in hardness decreases the incidence of wear of implant material and increase in toughness prevents fracture of the implants.

Metallic implants

Titanium
• Bioinert
•Light weight
•biocompatible
•corrosion resistant (dynamic inert oxide layer , $TiO2$)

•It is 6 times stronger than compact bone
•Its modulus of elasticity is 5 times greater than that of compact bone (102-110 GPs) (thus equal mechanical stress transfer)
•Most commonly used –Commercially pure (CP) titanium –Titanium-aluminum-vanadium alloy (Ti-6Al-4V) - stronger & used with smaller diameter implants.

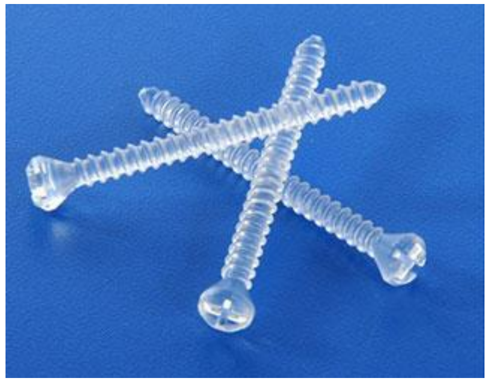
Cobalt-chromium-molybdenum alloys generally consist of 63% cobalt, 30% chromium, and 5% molybdenum with small amounts of carbon, manganese, and nickel. Molybdenum is a stabilizer and provides strength; chromium provides the passivating effect to ensure corrosion resistance through the oxide surface; and carbon serves as a hardener.
Co-Cr-Mo alloys have a high elastic modulus and resistance to corrosion.
Co-Cr-Mo and stainless steel alloy continue to be used for some implants, such as subperiosteal and transosteal implants and ramus frames, because of their castability, mechanical properties, and lower cost.

Ceramic implant

Ceramics are inorganic, nonmetallic materials . Ceramic implants can withstand only relatively low tensile or shear stresses induced by occlusal loads, but they can tolerate quite high levels of compressive stress.
Aluminum oxide (Al_2O_3) is used as a standard biomaterial for ceramic implants because of its inertness (biostability).
Zirconia (ZrO_2) has also demonstrated a high degree of inertness.
These types of ceramic implants are not bioactive in that they do not promote the formation of bone. They have high strength, stiffness, and hardness and function very well for some designs of dental implants.
Hydroxyapatite (HA), or $Ca_{10}(PO_4)_6(OH)_2$, and tricalcium phosphate (TCP), $Ca_3(PO_4)_2$ promote and achieve a direct bond of the implant to hard tissues, they are classified as bioactive.

POLYMERS

The early work with the methyl methacrylate resin implants met mostly with failures .
There are some disadvantages:
(1) inferior mechanical properties;
(2) lack of adhesion to living tissues; and
(3) adverse immunologic reactions.



Peek (Polyetheretherketone) as dental implants

The major beneficial property for peek is its low elastic modulus (3-4 GPs) being close to human bone , good resistance to degradation, lack of toxicity, good chemical and sterilization resistance, lighter in weight, PEEK combines high strength with a relatively low Young’s modulus which is closer to that of human bone than titanium. This property may minimize the stress by distributing it in more physiological manner thus supporting bone formation around the implant and reducing osteolysis.