Dental materials

Sheet #13+14

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**Cast metal alloys**

**\*\* the Dr said that it is enough to study these lecs from his slides so I tried to put here what he said in the lec and what’s in the slides to make it easier to study**

**\*\* do not memorize any % of elements, I put them for better understanding.**

In our region, the major elements that are used in dentistry nowadays are metallic but the ceramics are increasing in use. Here we still have room for porcelain-fused-to-metal restorations, RPDs, amalgam restorations,.. but in some western countries they are tending to have metal-free dentistry. What is preventing the complete elimination of using metals ‘till now is that there are some conditions that we can’t use ceramics in: for ex, zirconium-based restorations need minimal thickness of 3\*3 mm (9mm2) so if a pt has reduced interarch space there won’t be enough space for zirconia so it can’t be used. In addition; the metal restoration are proved clinically to have better results than ceramics if used on the last teeth in the arch especially in pts with bruxism.

Notes:

\* When constructing a long span bridge, the only material that is indicated is zirconia.

\* Zirconia have enough strength and enough fracture toughness that we can use it on posterior teeth up to 5units bridge but we can't use it from lateral to 7.

\* The best material to oppose natural tooth is Gold because its wear properties is just like enamel so in full mouth rehab it's better to put gold on the last tooth to preserve occlusal stability.

***An alloy*** is a mixture of metals or a mixture of a metal and another element. We use alloys rather than pure metals in dentistry, why?

1. Pure metals have properties that are undesirable in the oral cavity. In the very beginning of restorations they start with pure gold and they noticed that upon heavy occlusal forces the crowns may bend or deform.
2. Pure metals have melting points but ceramics have melting range. So we use alloys, which have melting range, rather than pure metals to ease the fabrication of PFM crowns.
3. Bonding of ceramics to the metal when corporating other elements will be better than with pure metals. For ex; gold doesn’t produce an oxide but in order for the ceramics to bond there must be an oxide.

**Metallic bonding:**

Metallic bonds are mainly ionic bonds unlike the bonds in ceramics which are covalent bonds and have intermolecular or interatomic spaces; these spaces are not present btw metallic bonds. Metals are loosely attached to each other which make them electric and heat conductors. This will have affects in the oral cavity in 2 ways:

* They have corrosion properties; like amalgam esp. in Gamma2 phase (Tin + Mercury); which may affect the oral environment leading to toxicity or lichenoid rxn or staining “amalgam tattoos”.
* They could irritate the tissues or the pulp by electricity or heat conducting.

When is the electricity generated?

Only if you have 2 opposing restoration that are from the same metal (amalgam and amalgam. Gold and gold, ..) So one of them will act as cathode and the other as anode (not sure about this)

**Crystal structure:**

The metals have this distinctive feature and there are 14 types of these structures. The most common ones in dentistry are:

1. Body centered cubic
2. Face centered cubic
3. Hexagonal close packed



If we build ideal metal blocks (with no impurities and undergoes no structural changes when cooling off), we will have 100 times stronger metals than what we use now. What happens is that when the metal cools off, impurities could interrupt the crystals arrangement and make voids which will decrease the strength or induce deformity or cause brittleness of the metal alloys.

Deformation of metal:

1. Vacancies (فراغات)
2. Interstitial
3. Dislocations:

- Edge dislocation

- Screw dislocation

\*\* Metals and all material we use in general become weaker with voids.

How to improve strength (decrease the voids and vacancies)?

1. By Alloying: as we said that alloying will increase metal strength by increasing the metal %
2. Precipitation hardening: we do hardening by special salts that remove the debris of metals that affect the strength
3. Grain refining: grains are groups of crystals that are formed from nuclei. The smaller the crystals, the better the strength (mechanical properties). The grains work basically by closing the spaces and vacancies between metallic crystals which will improve the strength.
4. Cold working: we reduce voids by hammering; forming sheets or wrought wires.

**Alloys**

A blend of two metals or more, and we have three types of alloys:

1. Solid solutions: Two metals completely miscible (we can’t separate them from each other)
2. Intermetallic compounds: need chemical reactions btw the metals to be “ready” (most dental amalgam faces like).
3. Eutectic mixture: Miscible in liquid state but separate in the solid state. Each metal will be in specific percentage.

\*\* Solid solutions:

They have **melting range** not point and this melting range is between the melting points of the two metals that are miscible to each other, and it depends on the grain size and the number of molecules and the percent of each metal. That’s why we always try to have alloys in solid solution form (having a melting range).

Corrosion resistant of this material depends on the type of material we add, for ex it increases when we add metals to the Iron to make Iron alloys (Stainless steel) but decreases with gold bcuz any type of metals that are added to the noble alloys (Titanium, Palladium & sometimes Silver) will increase the metallic oxide production which will decrease the resistance (as we said the gold does not produce an oxide)

\*\* Eutectic mixtures:

Harder and stronger but must be in certain percentages like (HgSn 72% -82%) in gamma 2 phase of amalgam.

Brittle; specifically ceramics

 They have melting point

Prone to galvanic action 🡪 Poor corrosion resistance

\*\* Intermetallic compounds:

Very hard and brittle

**Strength& hardness**

In most materials the compressive strength is higher than tensile strength. In ceramics the compressive strength is higher 10 times than tensile strength. Metals in compression with ceramics have higher tensile strength (in metals the tensile strength is higher than compressive strength), so they can resist deformation better until they get fractured.

The hardness and stiffness of metals and ceramics are same

The hardness and stiffness of the base-metal alloys are higher than that of gold,

\*\*How all that can affect the type of metal to be used in construction of the restoration?

* If we want to put a restoration on the terminal tooth (a second molar for ex), it is better to use gold because it has the same wear as the natural teeth to preserve occlusal stability (Physiological tooth wear: 10 microns per year & the gold resemble it).
* When we want minimum preparation on the teeth, we use Resin bonded bridges. So it will have a thin section of base- metal so we need a metal that is very hard and stiff to resist deformation and fracture underneath the porcelain, so we use base- metal alloys not noble metal alloys (gold). This is applied for ex when using bridges on the anterior areas to replace congenitally missing laterals, the best treatment option is using Resin bonded bridges

*Note:*

Resin bonded bridges could be metallic (as we said), ceramic or other. And if it is metallic it is better to use noble metals but if the base-metal alloys can compensate it will be used because it is much cheaper. Rarely we are forced to use noble metals like in war victims that are presented with difficult situations.

**Solidification shrinkage:**

Every material; except water; when it transform from liquid stage to solid stage, it shrinks.

When we want to make a crown, we start by preparing the desired tooth. After that we make an Impression (which is an accurate negative replica of the prepared tooth and the arch). Then we send it to the lab to pour it and get a working cast and a die (the positive replica). Then the technician will wax-up the die in the exact dimensions of the final crown. Then it will be replaced by the metal. But how to compensate the solidification shrinkage of the metal to get the exact size that we want?

1. By using investment materials that have the same expansion as the metal shrinkage
2. Or we can make the wax-up larger by the same amount of the metal shrinkage

**Corrosion**

The corrosion is the reason of the changing in color of old restorations like amalgam to blackish or greenish color.

Tarnish: is when the outer surface of the material gets corroded only.

Corrosion: the whole structure of the material gets corroded.

The noble materials are less prone to corrosion and tarnish. The base-metal alloys are more prone to corrosion so they have less strength but they are less brittle as will. الفولاذ for ex is much stronger than pure iron and do not get corroded but they are more brittle (they don’t bend, rather they get fractured in one piece).

Types of corrosions:

1. Dry
2. Wet (what we care about because the oral cavity is a wet environment):
	* 1. Generalized
		2. Localized
			+ 1. Pitting corrosion
				2. Crevice corrosion
				3. inter granular corrosion

**Biocompatibility**:

1. Nickel alloys

Nickel allergy is found in minority of people; in Females 10 times more than Males.

1. Silver and Copper alloys

Here we are concerned more about it compatibility with porcelain itself.

*\* We don’t use copper alloys with porcelain bcuz it will cause a greening effect on it.*

\* Silver alloys underneath porcelain reflect a dull color of the crown, so we will not get the desirable color instead we will have the grayish appearance. This happens with all base-metal alloys to some extent but in gold base it will reflect a more natural color--> better appearance.

1. Palladium

Some say that it has a mutagenic effect; not very much used.

**\*\* Types and classifications of metal alloys**:

The first classification depending on "**The crystal configuration**":

1. Body centered cubic
2. Face centered cubic
3. Hexagonal close packed

The second classification depending on “**the elements used**” // ADA (American dental association) classification 1984: (memorize these numbers)

1. High noble metal alloys:

Contains > 60 wt% of noble metal alloys; 40 wt% at least should be gold.

1. Noble metal alloys:

Contains > 25 Wt% metal alloys (Au,Pd,Pt).

1. base metal alloys (Predominantly):

Contains less than 25 wt% of the noble metal alloys

The third and new classification depends on “**the type of the fusing temperature**”:

1. Normal Fusing Temperature :

They are used in full metal crowns. They cannot tolerate higher temperatures than their fusing ones, so they cannot be used beneath the porcelain (Porcelain needs very high Temp).

Examples:

1. Medium-gold
2. Low-gold
3. Silver-palladium
4. Silver-indium
5. High Fusing Temperature Alloys :

They introduced this type of Alloys in the 50s due to the need of their use beneath the porcelain, in order not to go under any dimensional changes.

Examples:

* 1. Gold-Platinum- Palladium Alloys. "The most expensive".
	2. Gold-Palladium-Silver Alloys.
	3. Gold-Palladium Alloys.
	4. Palladium-Silver Alloys.
	5. Base Metal Alloys :

- Ni/Cr

- Co/Cr.

\* Titanium is a new material that is introduced and mostly they are used with implants.

\* Casting of gold is easier than base metal alloys

***\*\* The Elements:***

* **Noble alloys:**

\* ***Noble*** means that it doesn’t undergo any oxidation reaction forming no oxides; and this means that it won't bond reliably to the porcelain.

1. Gold :
* Soft, (most) malleable and ductile

(Malleable means: Capable of being shaped or formed, as by hammering or pressure/Ductile means: Easily drawn into wire or hammered thin)

* Relatively low strength, so it cannot be used in a long span bridge because it will move and the porcelain will break SO "Palladium & Platinum can be used instead".
* Tarnish resistant in air and water at any temp.
* Insoluble in sulfuric, nitric, or hydrochloric acids but soluble in a combination of nitric and sulfuric acids called “Aqua ragia”
* impurities (i.e. lead, mercury, base metals) have usually detrimental effect on its properties
* Expensive
1. Platinum:
* Malleable.
* Very high cost; this limits its use.
* High corrosion resistance.
* High melting Temperature “More than that of the porcelain"; so it's easier to use it with the PFM crowns, so they were used before the introduction of base metal alloys
* It is not used in dentistry only in the casting alloys; it can be used as a catalyst with the additional type Silicon "Impression Material" that’s why it is more expensive than condensation type Silicone.
1. Palladium
* Not used in the pure state dentistry
* It replaced Platinum, it is cheaper.
* Prevents the corrosion.
* Absorbs H2 when heated 🡪 increasing the voids 🡪 decreasing the strength.
1. Silver:
* Some people consider it one of the noble alloys, but the truth that it is not, because it forms oxides but those oxides do not lead to any structural deterioration.
* Malleable and Ductile.
* Harder than gold.
* Absorbs the O2 so it leads to weaker casting strength.
* Unaltered in clean dry air. However, combined with sulfur, chlorine and phosphorus can cause severe tarnish; that’s why we avoid using chlorine when silver restorations are used.
* It has a big problem that it shows from beneath the porcelain so it is harder to mask it in comparison with the gold and needs more "Reduction".
1. Minor Alloying Elements “rare elements”:
* Iridium (Ir)
* Ruthenium (Ru)
* They are extremely expensive and are not readily available
* They are used in grain refining
* ***Grain refining***: The addition of as little as 50 ppm (0.005%) of Ir and Ru results in a 100x increase in the no. of grains per unit volume. It Increases the alloy’s tensile strength and % elongation by >30%. Increases tarnish resistance, slightly increases yield strength. No appreciable effect on hardness.
* **High noble- and noble-metals Alloys** :
1. Gold-Silver-Copper-Palladium Alloys: only used with full metal
* (High Noble alloys) containing > 90% "noble metals"; “Gold, Silver and Palladium", considering the silver as a noble metal.
* Its most important disadvantage is the greenish color resulting from the presence of the *copper*, **So it cannot be used beneath the porcelain**.
* **Gold (Au)** :
* Tarnish and corrosion resistance
* Tarnish is an inverse function of gold content.
* Contributes burnishability, ductility
* **Silver (Ag):**
* Helps control the color of the alloy, neutralizing the red color imparted by Cu
* Promotes ductility 🡪 Au/Cu alloys (75% Au) break apart at grain boundaries during heat treatment if no Ag is present.
* **Platinum (Pt):**
* Very expensive ingredient
* Contributes strength
* Whitens the alloy
* Increases the fusion temperature
* **Palladium (Pd):**
* Like Pt but more effective and less expensive than Pt
* Alloying metal of choice v.s. Pt
* **Copper (Cu):**
* Principle hardener in gold alloys
* Conc. >12% of Au amount 🡪 alloy can be heat treated
* Conc. >18% 🡪 decrease the melting temp of the alloy
* When alloyed with Ag, Cu increases the alloy’s hardness and decreases melting temp.
* Cu imparts a reddish color to the metal and contributes most to the corrosion of gold alloys.
* Ag/Cu ratio is important to tarnish resistance (but not as important as the Ag/Pd ratio).
* **Zinc (Zn):**
* O2 scavenger
* 1-2% helps to counteract the absorption of O2 by silver.
* Increases the castability, decreases porosities, and increases the hardness and brittleness of the alloy
* **Indium (In), Tin (Sn), Iron (Fe)**:
* Hardens the alloy (Provides oxides for ceramic bonding in PFM alloys)
* **Iridium (Ir), Ruthenium (Ru), Rhenium (Rh):**
* Grain refining
* **Gallium (Ga)**:
* Added to high Pd alloys or non-silver Au/Pd metal ceramic alloys to compensate for a decrease in the TCOE caused by the elimination of the Ag.
* (Also provides oxides for ceramic bonding)
* Not found in PFM alloys due to its tendency to discolor the porcelain (greenish effect).

\*\* How the metals bond to porcelain:

1. Chemical Bonding 🡪 between the oxides of the metals and the oxides of the porcelain; In the presence of noble alloys there must be another source for the oxides.
2. Mechanical bonding 🡪 Sandblasting (roughness of the surface) of the metals; so it can accept the porcelain in a better manner; for this purpose, we use aluminum oxides (110 micron for the metals and 50 microns for the porcelain).
3. Physical bonding 🡪 **Coefficient of thermal expansion** between the 2 Materials, the porcelain should be put under compression so it becomes stronger.

***\*\* Some important Requirements must be in the metals to insure good bonding with ceramics:***

* Must have the potential to bond to dental porcelain 🡪 need oxide-forming elements (small amount of base metals)
* Posses coefficient of thermal contraction COMPATABLE with those of dental porcelains not equal 🡪 the alloy should have slightly **higher** coefficient of thermal contraction than the porcelain; the porcelain must shrink more than the metal (مشان يشد الporcelain على الmetal) … exam question
* Sufficiently high solidus temp (fusing temp) to permit the application of low- fusing porcelains 🡪 >100°C than the firing temp of the ceramic

\*\* All the following alloys could be used in Ceramo-metal restorations \*\*

1. Silver- Palladium alloys:
* They are noble metal alloys not high metal alloys; contain 25% Pd and 60-70% Ag
* Can be used with the PFM.
* Both Ag and Pd absorb gases during heating, casting is very technique sensitive
1. Gold-Platinum-Palladium Alloys (Au-Pt-Pd):
* Composition Au (84-86%); Pt (4-10%); Pd (5-7%); Ag; Fe, In, Sn
* (high noble) 🡪 Au > 40%; noble > 60%
* Advantages:
* Excellent bonding to porcelain
* Reproduces fine margins and occlusal detail
* Easily finished and polished
* Corrosion resistant and non-toxic
* Adequate yield strength and MOE (most cases)
* Disadvantages:
* Low creep resistance
* Not strong enough for long span FPDs
* High cost
1. Gold-Palladium-Silver Alloys (Au-Pd-Ag):
* Composition Au (45-52%); Pd (26-31%); Ag; In, Sn
* (high noble) 🡪 Au > 40%; noble > 60%
* The most high noble alloys that are used because it has the same advantages with less cost
* Advantages:
	+ - Higher melting range
		- Better creep resistance
		- Higher yield strength for long span FPDs
		- Good castability 🡪 we want that because if it was poor then the margins of the restoration may be deficient.
		- Easily finished and polished
		- Non-toxic and lower cost vs. Au-Pt-Pd alloys 26
* Disadvantages:
	+ - Ag may cause grayish color of porcelain.
		- White color may show through tissues as gray and may not be as acceptable as gold collars.
		- High Pd content may increase the risk of H2 gas absorption during casting, and bonding of porcelain may be affected by oxidizing procedures.
1. Gold-Palladium Alloys (Au-Pd):
* Here we don’t have Ag, so we eliminate the disadvantages of it.
* Composition Au (45-52%); Pd (38-45%); In; Ga
* (high noble) 🡪 Au > 40%; noble > 60%
* Advantages:
* same as for Au-Pd-Ag alloys with the addition of potentially better porcelain color due to lack of Ag
* Disadvantages:
* same as for Au-Pd-Ag alloys
1. Palladium-Silver Alloys (Pd-Ag):
* Composition Pd (53-88%); Ag ;In ;Sn
* (noble) 🡪 > 25 Wt% metal alloys
* Advantage
* High yield strength
* Better creep resistance
* Non-toxic and low cost
* Disadvantages
* Castability < gold alloys
* High Ag 🡪 porcelain grayish, ↓bonding
* High Pd 🡪 ↑gas absorption and poor color
1. High Palladium Alloys:
* Composition Pd (74-88%); Cu; Ga ;Au (0-2%); Co; In
* (noble) 🡪 < 40 wt% AU
* Advantages:
* High yield strength and sag and creep resistance
* Non-toxic, low cost
* Castability = gold alloys (easy)
* Excellent porcelain color because of its white metallic color
* Disadvantages:
* Porcelain bond strength may be variable. And can’t be used with porcelain bcuz it contains Cu (greening effect)
* High Pd content 🡪 ↑ H2 gas absorption, poor solderability
* Can’t be used with carbon investments or crucibles (Carbon or Silicon contamination will cause brittle castings which may crack or tear at grain boundaries under stress).

*What we can do to enhance the bonding btw those alloys and porcelain?*

1. **We can add Palladium**. So in general, Palladium has these advantages in PFM Alloys:
2. Hardens the alloy
3. Whitens the alloy
4. Increases the alloy’s casting temp.
5. Renders silver tarnish resistant
6. Decreases the alloy’s density
7. Decreases the alloy’s thermal coef. of exp.
8. **We can add Minor Elements**. Advantages of Minor Elements in PFM Alloys (These elements are added to all the alloys esp. when using porcelain):
9. provide metallic oxides for porcelain bonding and harden the alloy (In, Sn, Fe, Ga)
10. Increases the thermal coef. of exp. to compensate for decreased or absence of Ag.( Ga)
11. **Heat Treatment:**
* This is done with high noble alloys (Gold) to increase the metallic oxide content to bond with porcelain. This is done by heating the alloy to 600 degrees for few mins before adding the ceramic.
* **Base Metal Alloys:**
* They're either (Co/Cr or Ni/Cr).
* They produce metallic oxides so they bond with porcelain better than the gold alloys.
* The cobalt-chromium alloys have better castability, but they have a problem in the bonding with porcelain so we add a bonding agent btw the metal and the porcelain
* The Nickel-chromium alloys have a better bonding to the porcelain, but some people have allergy toward the nickel.
* The nickel-free alloys are not recommended to use with pt with no nickel allergy.
* Composition:
* Chromium (11-20%)

Responsible for tarnish and corrosion resistance due to its passivity “passivation”

If >30% 🡪 difficult to cast and brittle

* Cobalt or Nickel (65-78%)

 Co and Ni are pretty much interchangeable.

Ni alloys have decreased strength, hardness, fusion temps and increased ductility and %elongation vs. Co alloys.

* Minor alloying elements:

🡪 Control the majority of the physical properties

1. Carbon
* Increases strength, hardness, and brittleness.
1. Molybdenum
* increases strength, hardness, and %elongation
1. Aluminum
* Forms a Ni3Al in NiCr alloys which contributes to precipitation hardening resulting in increased tensile and yield strength.
1. Beryllium
* decreases the fusion temp by approx 100°C
* increases fluidity during casting
* allows for electrolytic etching (with resin bond prosthesis)
1. Manganese and Silicone
* increases fluidity and castability of the molten alloy so they’re important in preventing the shortness of the casting
1. Iron and Copper
* increase hardness

\* The base metal alloys in general cause discoloration at the margins, so some dentists to by- pass this problem makes the margins subgingval; but it's like putting the rubbish beneath the carpet because it leads to gingival inflammation, so the solution is either using high noble alloys "very expensive" or creating porcelain shoulder by making the metal shorter by 1mm and putting porcelain instead.

* **Titanium alloys:**
* They have a high melting point (> 2700 degrees)🡪 they need very high temp for casting; so they have special casting machines.
* They are the best material to be used in implants as the “screws” that goes inside the bone or the abutments that we will put a crown on it
* Advantages:
* It is a light material
* Disadvantages:
* Their bond to the porcelain is not reliable.

This is the last dental material sheet forever, so enjoy it to the max *=)*

*Good Luck*