Casting alloys II

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Aims &Objectives

- Classification of casting alloys
- Elements roles
- Clinical considerations

Descriptive Classification

- Normal-fusing alloys
  - Medium-gold
  - Low-gold
  - Silver-palladium
  - Silver-indium
- High-fusing alloys
  (mostly for PFM)
  - Gold-platinum-palladium
  - Gold-palladium-silver
  - Gold-palladium
  - High-palladium
  - Palladium-silver
  - Base-metal
    - Cr/Co; Cr/Ni

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Noble alloys

- Gold (Au)
- Platinum (Pt)
- Palladium (Pd)
- Silver (Ag)

Gold (Au)

- Soft, (most) malleable and ductile
- Relatively low strength
- Tarnish resistant in air and water at any temp.
- Insoluble in sulfuric, nitric, or hydrochloric acids
- Soluble in a combination of nitric and sulfuric acids
- impurities (ie. lead, mercury, base metals) have usually detrimental effect on its properties.

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Platinum (Pt)

- Tough, malleable and ductile
- Very high cost
- High corrosion resistance
- Higher melting temp than porcelain

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Palladium (Pd)

- Not used in the pure state dentistry
- Has replaced Pt in dental casting alloys
- Helps prevent corrosion of silver in the oral environment
- Absorbs H_2 gas when heated improperly

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Silver (Ag)

- "Noble?"
- Malleable and ductile
- Harder than gold
- Unaltered in clean dry air, however, combined with sulfur, chlorine and phosphorus can cause severe tarnish.
- Contains large quantities of O_2 in molten state

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Minor Alloying Elements

- Iridium (Ir) – grain refining
- Ruthenium (Ru) – grain refining

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- 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.
  - Increases the alloy's tensile strength and % elongation by >30%
  - Increases tarnish resistance, slightly increases yield strength
  - No appreciable effect on hardness

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Au-Ag-Cu-Pd Alloys

- Primarily ternary alloys of Au, Ag and Cu, with minor amounts of Pt, Pd and Zn.
- Approx. >90% of the total alloy content is Au, Ag and Pd

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Au-Ag-Cu-Pd: Composition

- 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.

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Au-Ag-Cu-Pd: Composition

- 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

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Au-Ag-Cu-Pd: Composition

- 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

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Au-Ag-Cu-Pd: Composition

- Copper (Cu)
  - 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).*
  - Cu is not found in PFM alloys due to its tendency to discolor the porcelain.

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Au-Ag-Cu-Pd: Composition

- Zinc (Zn)
  - O_2 scavenger
  - 1-2% helps to counteract the absorption of O_2 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)*

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Au-Ag-Cu-Pd: Composition

- 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)*

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Alloys for Ceramo metal restorations

Silver-Palladium Alloys (Ag-Pd)

- Ag:Pd ratio approx 3:1 (60-70% Ag, 25% Pd) to render silver tarnish resistant in the oral cavity.
- Both Ag and Pd absorb gases during heating, casting is very technique sensitive.
- ≠ Pd-Ag alloys (for PFM restorations)

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Ag-Pd: Composition

Alloy Type	Main Elements	Cu/ Au	Au	Cu	Ag	Pd	Sn, In, Fe, Zn, Ga
III	Noble (Ag base)				70	25	Balance
IV	Noble (Ag base)		15	14	45	25	Balance

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some important Requirements

- Must have the potential to bond to dental porcelain
  - need oxide-forming elements (small amount of base metals)
- Posses coefficient of thermal contraction compatible with those of dental porcelains
- Sufficiently high solidus temp (fusing temp) to permit the application of low-fusing porcelains
  - >100°C than the firing temp of the ceramic

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Ceramic-Metal Bond

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Gold-Platinum-Palladium Alloys (Au-Pt-Pd)

- Composition
  - Au (84-86%); Pt (4-10%); Pd (5-7%); Ag (0-5%); Fe, In, Sn (2-3%)
  - (high noble)
- 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)

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- Disadvantages
  - low creep resistance
  - not strong enough for long span FPDs
  - High cost

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Gold-Palladium-Silver Alloys (Au-Pd-Ag)

- Composition
  - Au (45-52%); Pd (26-31%); Ag (6-16%); In, Sn (5-7%)
  - (high noble)
- Advantages
  - Higher melting range
  - Better creep resistance
  - Higher yield strength for long span FPDs
  - Good castability
  - Easily finished and polished
  - Non-toxic and lower cost v.s. Au-Pt-Pd alloys

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- Disadvantages
  - Ag may cause greening 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 H_2 gas absorption during casting, and bonding of porcelain may be affected by oxidizing procedures.

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Gold-Palladium Alloys (Au-Pd)

- Composition
  - Au (45-52%); Pd (38-45%); In (8.5%); Ga (1.5%)
  - (high noble)
- 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

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Palladium-Silver Alloys (Pd-Ag)

- Composition
  - Pd (53-88%); Ag (30-37%); In (4-7%); Sn (4-7%)
  - (noble)
- Advantages
  - High yield strength
  - Better creep resistance
  - Non-toxic and low cost
- Disadvantages
  - Castability < gold alloys
  - High Ag → porcelain greening, ↓bonding
  - High Pd → ↑gas absorption and poor color

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High Palladium Alloys

- Composition
  - Pd (74–88%); Cu (10–15%); Ga (9%); Au (0–2%); Co (4–5%); In (0–5%)
  - (noble)
- Advantages
  - High yield strength and sag and creep resistance
  - Non–toxic, low cost
  - Castability = gold alloys (easy)
  - Excellent porcelain color

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- Disadvantages
  - Porcelain bond strength may be variable.
  - High Pd content → ↑ H_2 gas absoption, 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.

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Palladium in PFM Alloys

- Hardens the alloy
- Whitens the alloy
- Increases the alloy's casting temp.
- Renders silver tarnish resistant
- Decreases the alloy's density
- Decreases the alloy's thermal coef. of exp.

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Minor Elements in PFM Alloys

- In, Sn, Fe, Ga – provide metallic oxides for porcelain bonding, and harden the alloy.
- Ga – increases the thermal coef. of exp. to compensate for decreased or absence of Ag.

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Heat Treatment

- PFM alloys can be heat tx however clinical condition is dependant on ceramic application.

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Co-Cr and Ni-Cr alloys

Composition of Major Co... Alloy... in Dentistry

Elements	Co-Cr Vitallium†	Ni-Cr Ticonium†	Beryllium-Containing* Nickel-Chromium Alloy	Boron-Containing* Nickel-Chromium Alloy
	Alloys (% of Weight)			
Chromium	30.0	17.0	11	20
Cobalt	Balance	-	0.5	0.01
Nickel	-	Balance	Balance	Balance
Molybdenum	5.0	5.0	2	6
Aluminum	-	5.0	2	-
Iron	1.0	0.5	2	0.12
Carbon	0.5	0.1	0.02	0.02
Beryllium	-	1.0	1.6	-
Silicon	0.6	0.5	0.5	4
Manganese	0.5	5.0	0.02	-
Gallium	-	-	-	-
Boron	-	-	-	3

*Alloys for porcelain-fused-to-metal restorations.
†Data from Asgar K: An overall study of partial dentures, USPHS Research Grant DE-02017, NIH; and Baran G: The metallurgy of Ni-Cr alloys for fixed prosthodontics, *J Prosthet Dent* 50:539, 1983.

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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 v.s. Co alloys.

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Composition

- Minor alloying elements

  control the majority of the physical properties
  - Carbon (0.1-0.5%)
    - increases strength, hardness, and brittleness.
    - increased by 0.2% → alloy too hard and brittle for dental use
    - decreased by 0.2% → decreases yield strength and UTS to unacceptable levels.
  - Molybdenum (3–6%)
    - increases strength, hardness, and %elongation

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Composition

- Aluminum (4-5%)
  - forms a Ni_3Al in NiCr alloys which contributes to precipitation hardening resulting in increased tensile and yield strength.
- Beryllium (0.5-2%)
  - decreases the fusion temp by approx 100°C
  - increases fluidity during casting
  - allows for electrolytic etching (with resin bond prosthesis)

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Composition

- Manganese (5%) and Silicone (0.5%)
  - increases fluidity and castability of the molten alloy
  - + Boron → deoxidizers (essential in Ni containing alloys)
- Iron and Copper
  - increase hardness

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Titanium & Titanium alloys

- What for
- Mostly used alloy
- Advantages and disadvantages

Thank you