Dental Casting Alloys
Applications

All metal restoration

Removable Partial Denture (RPD)

Metal-ceramic or Porcelain-fused to metal restoration
General application of dental alloys.

1) Inlay.
2) Onlay
3) Crown
4) Bridges
5) Ceramo-metallic restoration.
6) Resin bonded- metallic restoration (Maryland bridge)
7) Post and core system
8) Dental implants
The evolution of new dental alloys and the development of the present alloy have been influenced by:

1. *Technological changes of dental procedures.*
2. *Metallurgic advancements.*
3. *Price changes of Nobel metals*
Choice of an alloy will depend on:

1. Clinical situation.
2. Operator.
3. Properties of the alloy
   mechanical, corrosion resistance, compatibility with porcelain, castability, ease of finishing and polishing.
Terminology

• **Noble metals**
  – Elements with good metallic surfaces that retain their luster in clean dry air
  – Indicate the relative inertness of the element in relation to the standard.
  – Resist oxidation, tarnish and corrosion during heating casting and soldering
    • Platinum group (6 metals)
      – Platinum, Iridium, Osmium (atomic wt 190, density 22 g/cc)
      – Palladium, Rhodium, Ruthenium (atomic wt 100, density 11-12 g/cc)
    • Gold (atomic wt 196, density 19.3 g/cc)
    • (Silver?)
**Terminology**

- **Precious metals**
  - Indicates how expensive a metal is based on supply and demand.
  - **The descriptors *precious* and *semiprecious* should be avoided because they are imprecise terms.**
Terminology

- Gold content of a dental alloy
  - Karat, Carat (K)
    - Parts of pure gold per 24, e.g. 18K, 24K
  - Fineness
    - Parts of pure gold per 1,000
      - e.g. a 650 fine alloy has a gold content of 65%
    - Primarily used for gold solders
Classification

ADA's Specification #5

Principal Elements

Descriptive Classification
Mechanical Properties
Specific Use
Noble Metal Content
The Cost
### ANSI/ADA Specification #5

- **Referred to** Gold-based alloys
  - Alloys can have any composition as long as they pass the tests for *toxicity, tarnish, yield strength, and percent elongation.*

<table>
<thead>
<tr>
<th>Type</th>
<th>%Au &amp; Pt</th>
<th>VHN</th>
<th>Restoration</th>
</tr>
</thead>
<tbody>
<tr>
<td>I (soft)</td>
<td>83</td>
<td>50-90</td>
<td>Inlay</td>
</tr>
<tr>
<td>II (medium)</td>
<td>78</td>
<td>90-120</td>
<td>Inlay/onlay</td>
</tr>
<tr>
<td>III (hard)</td>
<td>78</td>
<td>120-150</td>
<td>Onlay/Crown&amp;Bridge</td>
</tr>
<tr>
<td>IV (extra-hard)</td>
<td>75</td>
<td>150-250</td>
<td>Crown&amp;Bridge/RPD</td>
</tr>
</tbody>
</table>
Mechanical Properties:

In the past this classification referred to gold-based alloys only.

Since 1989, ADA approved that casting alloys can have any composition as they pass the tests for toxicity, tarnish and corrosion, yield strength as well as percentage elongation based on this old classification, the minimum values for yield strength and % elongation determine whether an alloy is classified as:
**Type 1:** Low strength for castings subjected to very slight stress, e.g. inlays. Their maximum yield strength is 140 Mpa and their minimum % elongation is 18 %.

**Type II:** medium strength for casting subjected to moderate stress, e.g. inlays and onlays. Their yield strength is 140-200 Mpa and their minimum % elongation is 18 %.

**Type III:** high strength for castings subjected to high stress, e.g. onlay, thin cast backing, pontic full crowns and short span bridges. Their yield strength is 200-340 Mpa and their minimum % elongation is 12 %.

**Type IV:** extra high strength for castings subjected to very high stress and thin in cross section, e.g. saddles, bars, clasps, crowns, long span bridges and partial denture frame works. Their yield strength in equal to or greater than 340 Mpa and their minimum % elongation is 10 %.
1. High noble (HN)
2. Noble (N)
3. (Predominantly) Base metal (PB)

<table>
<thead>
<tr>
<th>Alloy Type</th>
<th>Total Noble Metal Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>High noble metal</td>
<td>Contains ≥ 40 wt% Au and &gt; 60% of the noble metal elements</td>
</tr>
<tr>
<td>Noble metal</td>
<td>Contains ≥ 25 wt% of the noble metal elements ((Au, Pd, Pt))</td>
</tr>
<tr>
<td>Base metal</td>
<td>Contains &lt; 25 wt% of the noble metal elements</td>
</tr>
</tbody>
</table>

*No discrimination among alloys within a given category*
Contain less than 25 % noble elements like:

1. **Nickel based alloys**: These alloys contain Ni-Cr with or without Beryllium (Br). **Beryllium is sometimes added to improve the castability** of the alloy but its inhalation during casting or finishing is **hazardous**.

2. **Cobalt base alloys (Coa-Cr)**.

3. **Iron base alloys (Fe-Cr)**: Many elements may be added as Cr.C, Al, Mg and silicon.

**Titanium base alloys**: cast in vacuum or Argon gas or machine duplicated and spark erosion (like procera) due to its high melting temperature during casting and also to increase its adaptability specially at the margin of the preparation.
• **N.B.** *The noble metal content determines the corrosion resistance and inert properties of the alloy.*
Principal Elements

- When an alloy is identified according to the elements it contains, the components are listed in **declining order of composition**, with the largest constituent first followed by the second largest constituent.
  - e.g. Au-Ag-Pt (Au ~ 78%, Ag ~ 12%, Pt ~10%)
- **Exception**: Certain elements that significantly affect physical properties or that represent potential biocompatibility concerns are often designated (regardless of their small amounts).
  - e.g. Au-Cu-Ag-Pd (Au ~40%, Cu ~7.5%, Ag ~47%, Pd~4%)
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
Classification According to the Specific Use:

- Alloys for metal restorations that cannot be used with porcelain.
- Alloys for ceramo-metallic restorations that have certain requirements to be compatible with porcelain.
- Alloys for partial denture frame work.
<table>
<thead>
<tr>
<th>Alloy Type</th>
<th>Restoration Type</th>
<th>All-Metal Restorations</th>
<th>Metal-Ceramic and All-Metal Restorations</th>
<th>RPD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High Noble</strong></td>
<td>≥ 40 wt% Au and &gt; 60% of the noble metal elements</td>
<td>Au-Ag-Cu-Pd</td>
<td>Au-Pt-Pd</td>
<td>Au-Ag-Cu-Pd</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Au-Pd-Ag (5-12 wt% Ag)</td>
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<td></td>
<td></td>
<td>Au-Pd-Ag (&gt;12 wt% Ag)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Au-Pd (no Ag)</td>
<td></td>
</tr>
<tr>
<td><strong>Noble</strong></td>
<td>≥ 25 wt% of the noble metal elements</td>
<td>Ag-Pd-Au-Cu Ag-Pd</td>
<td>Pd-Au (no Ag)</td>
<td>Ag-Pd-Au-Cu Ag-Pd</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pd-Au-Ag</td>
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<td>Pd-Ag</td>
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<td>Pd-Cu</td>
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<td></td>
<td>Pd-Co</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Pd-Ga-Ag</td>
<td></td>
</tr>
<tr>
<td><strong>Base Metal</strong></td>
<td>&lt; 25 wt% of the noble metal elements</td>
<td>Pure Ti Ti-Al-V Ni-Cr-Mo-Be Ni-Cr-Mo Co-Cr-Mo Co-Cr-W</td>
<td>Pure Ti Ti-Al-V Ni-Cr-Mo-Be Ni-Cr-Mo Co-Cr-Mo Co-Cr-W</td>
<td></td>
</tr>
</tbody>
</table>
Classification According to The Cost:

Precious, semiprecious and non-precious alloys

The noble alloys are sometimes referred to as precious, but the terms are not synonyms. The term precious refers to the cost of the metal while “noble” refers to its chemical behavior.

This classification is less preferable than the classification of noble and base metal as it is sometimes confusing.

The elements gold and platinum are both noble and precious. On the other hand palladium is noble, but is much less expensive. However, silver is precious, but not noble.
Requirements of Dental Casting Alloys:
Biological requirements.

Functional requirements

1. Working requirements

2. Mechanical requirements

3. Physical requirements
1. **Biological Requirement:**

- *Dental alloys*, as any dental materials are functioning in close contact to various human oral tissues for short or long periods of time. **So, they must meet the following requirements:**
  
  1. They should **not be harmful** to the soft tissues.
  2. They should **not contain toxic diffusible substances** that can be released and absorbed into the circulation to **cause a systemic toxic response.**
  3. They should be **free of potentially sensitizing agents** that are likely to **cause an allergic response.**
  4. They should **not have any carcinogenic potential**
Functional requirements

1. **Working requirements.**

2. **Mechanical requirements.**

3. **Physical requirements**
1. Working requirements.

I-Ease of Casting of Dental Casting Alloys

II-Ease of Finishing and Polishing

IV-Ease of Soldering

III-Ease of Burnishing
I-Ease of Casting of Dental Casting Alloys:

The accuracy and completeness of a casting depends on:

1. alloy selection,
2. melting and
3. casting techniques,
4. pattern design and
5. investment material.

Castability is used to describe the ability of an alloy to faithfully reproduce sharp details and fine margins of a wax pattern.
• Regarding to the alloy type, there are many contributing factors that are related to the ease of casting such as:
**Density of the alloy:**

*High density* is considered as an *advantage* in casting technology as it means that there is *no need for an expensive complicated casting machine* to drive the molten alloy in to the mold to ensure *complete casting.*

From this point of view *Au-based alloys are superior* to the lower density base metal alloys.
Melting range of the alloy:

The lower the melting ranges of the alloy, the easier the casting process.

This is due to the fact that, high melting temperature alloys require special melting methods, investment materials as well as adequately controlled atmosphere to guard against excessive oxides and carbides formation due to increased reactivity of the alloys at higher temperature.

That’s why base metal alloys and specially titanium alloys are difficult to be cast when compared with Au-based alloys.
Coefficient of thermal expansion of the alloy:

This physical property will affect greatly

1. The amount of casting shrinkage, which in turn will affect

2. The dimensional accuracy of the cast restoration. 

The lower the value of the coefficient of thermal expansion and/or contraction, the greater the dimensional accuracy of the final cast restoration provided that the proper investment material is used.

Au-based alloys are superior to base metal alloys. However, the degree of fit of base metal restorations has been greatly improved through advancement in casting technology.
II-Ease of Finishing and Polishing:

- The hardness of an alloy represents the ease of finishing and polishing of the cast restorations.
- The lower the hardness value of the alloy, the more easy its finishing and polishing as in Au-based alloys.
- However, they cannot maintain such polished surface for long period of time.
- On the other hand, base metal alloys require special devices to obtain satisfactory surface finish and polish. Sandblasting and electro-polishing are effective methods.
Recasting:

- From the economical point of view, recasting is considered as an advantage. Dental gold casting alloys may be recast without loss of properties if the casting procedure is properly conducted. Gold alloys used for metal-ceramic restorations may be recast if 50% new alloy is added.

  to ensure that minor elements required for bonding with ceramics and hardening of the alloy have not been burned out and are in an adequate concentration.
On the other hand, base metal alloys cannot be recast as the casting technique is sensitive and most of their ingredients have high affinity for carbide formation especially at higher temperatures. These carbides can adversely affect the mechanical properties of the alloys.
Ease of burnishing is related to the ductility of the alloy.

Generally speaking, gold-based alloys are easy in burnishing when compared to base metal alloys.
IV-Ease of Soldering:

Soldering: is used to overcome distortion that may occur during cooling of the large metallic restorations.

Soldering is also important in joining metal components formed from different alloys.

Generally speaking, soldering of Au-alloys is much easier than base metal alloys that require special precautions to guard against excessive oxide formation and incorporation of carbides during heating.
Functional requirements

1. Working requirements.
2. Mechanical requirements.
3. Physical requirements
2. Mechanical requirements

**Hardness:** the Vickers hardness-number (VHN) a measure of resistance to indentation.

*Hardness:* is important in relation to *occlusal wear resistance,* *finishing* and affects *polishing properties.*

**Yield strength:** a measure of the stress required to cause permanent deformation under tension.

*Yield strength:* is necessary in determining *load bearing,* especially in fixed partial dentures.

**N.B. Yield strength measure with increasing hardness.**

**Elongation:** The amount of *permanent deformation* the metal undergoes when loaded *to its fracture point.*

*Elongation relates to margin-finishing properties,* especially important in partial veneer crowns and abutments.

*It is important to remember that* the *elongation value* for an alloy may be clinically *irrelevant if the yield strength is high.*
Selection of a casting alloy for porcelain fused to metal (PFM) restorations should be based on the following:

**A- Color** is one of the most obvious physical properties of an alloy. When the gold content of an alloy is decreased less costly metals such as silver and palladium are substituted → yellow color is lost.

The products contain more than 80 % gold, yet no yellow color is seen because of the strong whitening effects of palladium and platinum.

Color can be misleading indicator of composition,

**B- Fusion temperature:** the approximate temperature at which an alloy separates under its own weight from partial melting.

Fusion temperature is important in relation to solder melting ranges and correlates with sag resistance.
Fundamental Properties of Noble Metals

- Gold (Au)
- Platinum (Pt)
- Palladium (Pd)
- Silver (Ag)
- Minor alloying elements
Gold (Au)

- Soft, (most) malleable and ductile
- Relatively low strength
- Tarnish resistant in air and water at any temp.
- Attacked by only a few of the most powerful oxidizing agents
- Insoluble in sulfuric, nitric, or hydrochloric acids
- Soluble in a combination of nitric and sulfuric acids (aqua-regia)

- Small amounts of impurities (ie. lead, mercury, base metals) have a pronounced and usually detrimental effect on its properties.

Fusion temp = 1063°C
Density = 19.3 g/cm³
Thermal coef. of exp. = 14.2x10⁻⁶/°C
MOE = 80 GPa
Platinum (Pt)

- Tough, malleable and ductile
- Very high cost (usually replaced by Pd in most modern alloys)
- High corrosion resistance
- Higher melting temp than porcelain

Fusion temp = 1755°C
Density = 21.37 g/cm³
Thermal coef. of exp. = 8.9x10^-6/°C
MOE = 147 GPa

> Au > Au
< Au > Au
Palladium (Pd)

- Not used in the pure state dentistry
- Has replaced Pt in dental casting alloys
- Decreased cost v.s. Pt
- Helps prevent corrosion of silver in the oral environment
- Absorbs H₂ gas when heated improperly

Fusion temp = 1555°C
Density = 11.4 g/cm³
Thermal coef. of exp. = 11.1x10⁻⁶/°C
MOE = 112 GPa
Silver (Ag)

- “Noble?”
- Malleable and ductile
- Best known conductor of heat and electricity
- Harder than gold
- Unaltered in clean dry air, however, combines with sulfur, chlorine and phosphorus resulting in severe tarnish in the oral environment

- Occludes large quantities of O₂ in molten state
- O₂ gas will evolve during solidification resulting in pits and porosities.

Fusion temp = 960.5°C
Density = 10.4 g/cm³
Thermal coef. of exp. = 19.7x10⁻⁶/°C
MOE = 120 GPa
Minor Alloying Elements

- Iridium (Ir) - grain refining
- Ruthenium (Ru) - 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.
  - Increases the alloy’s tensile strength and %elongation by >30%
  - Increases tarnish resistance, slightly increases yield strength
  - Does not appreciable affect hardness
End of Dental Casting Alloys