Casting alloys used in RPD construction are only one part of a very complicated assembly. In general, the best construction is based on stiff major pieces and flexible (and fatigue resistant) clasps. However, this is a lot to ask for a single cast alloy.

One must “keep in mind” that this entire “assembly” of complicated connections of connectors, clasps, rests, retentive wires, acrylic denture base, and acrylic denture teeth is built on a relatively unstable foundation of changing soft-tissue architecture, resorbing bone, unstable teeth, and changing occlusal relationships. Therefore, the practical clinical lifetime for these “assemblies” is relatively short. For the time being, this lecture will focus on the cast components.
HISTORICAL BACKGROUND

1. Cr-alloys used in dentistry since 1930s -- widely used since 1970s
2. Corrosion resistance; high strength and E; low density; low $$
3. Compositions similar to ones for C&B, MF, and orthopedic implants

RPD ALLOYS CLASSIFICATION

1. Classification by RPD components:
   a. Frameworks (major and minor connectors)
   b. Clasps; Wrought retention wires
   c. Rests
   d. Solders
2. Framework casting alloys:
   a. (Gold Alloys, Type IV)
   b. Co-Cr Vitallium (60Co-31.5Cr-6Mo); Nobillium
   c. Co-Cr-Ni
   d. Ni-Cr (and Ni-Cr-Be) Ticonium (74Ni-15Cr); Howmedica II
   e. (Fe-Cr) Dentillium P-D
   f. (Ti-6Al-4V (cp-Ti)
   g. (Ni-Ti)

Casting alloys have evolved considerably over the last 70-80 years. Before the 1930s, most of the casting alloys used were rigid, high-melting, gold casting alloys. However, since the 1930s more and more Cr-based materials have been used. In the 1970s, there was a significant shift in economics away from gold casting alloys. With a dramatic upward shift in the price of gold, dental laboratories shifted to Co-Cr and Ni-Cr alloys. These alloys offered many advantages including (1) good corrosion resistance, (2) high strength, (3) high modulus, (4) low density, and (5) low cost. The actual compositions used for RPD alloys are remarkably similar to related ones used for crown and bridge, maxillofacial, and orthopedic applications.

Casting alloys can be logically clustered in terms of their roles in RPD assemblies (e.g., frameworks, clasps, retentive wires, solders) or by alloy type (e.g., Gold, Co-Cr, Co-Cr-Ni, Ni-Cr, Fe-Cr, Ti, Ni-Ti). Of all the possible alloys, most include Cr (e.g., Co-Cr, Co-Cr-Ni, Ni-Cr). Two very famous compositions that have been used for both RPD and orthopedic applications have special tradenames, Vitallium and Ticonium. Their compositions are shown in the figure above.

We will focus on three compositions. We will examine Co-Cr and Ni-Cr in comparison to traditional gold alloys.
RPD ALLOY PROPERTIES

1. Physical Properties:
   a. Typical fusion temperatures = 1400 to 1454 °C
   b. Color = lustrous silvery white
   c. Density (lighter weight than gold counterparts) = typically 8-9 gm/cm³
   d. Linear casting shrinkage = 2.05 to 2.33% (vs 1.4 to 1.7% for gold alloys)
   e. Thermal conductivity = high

2. Chemical Properties:
   a. Electrochemical corrosion = good passivation by Cr₂O₃ if Ni-Cr-Co >85%
   b. Passive film attacked vigorously by chlorine -- do not use household bleach

For convenience, we will use the picture of a relatively simple RPD that is shown above to illustrate the following discussions of RPD casting alloys. There are special physical, chemical, mechanical, and biological properties that are key for RPD alloys. While we will discuss the properties for the overall assembly, there are different portions that may have more special requirements for their particular functions. For example, the lingual bar must provide overall rigidity. Clasps require some flexibility.

[CLICK] Most of alloys that can provide excellent rigidity for the RPD assembly are high melting and much more complicated to cast than regular crown-and-bridge alloys. These high melting materials typically have low densities (e.g., 8-9 gms/cm³) that are only half of that of gold alloys). They undergo much more shrinkage due to cooling from higher casting temperatures, and are difficult to finish and polish in the dental laboratory. The materials tend to have a high luster and to some degree reflect or mirror the natural colors of soft tissues and natural teeth that are close to them. A special advantage of most of these alloys is that they do have a relatively high thermal conductivity. Most patients who’s soft tissues are covered by dentures or RPDs complain that their hot or cold foods do not taste as good when the intraoral temperature changes are muffled by the prosthetic appliances. Therefore, having some thermal conductivity is actually a good trait for these alloys.

[CLICK] Of course, the electrochemical corrosion resistance must be excellent for these materials to succeed. There is a large exposed surface area that is impossible to keep clean of intraoral materials. An RPD is potentially susceptible to crevice corrosion and stress corrosion – but is protected in most cases by a passivating film of chromium oxide (Cr₂O₃). However, the passivating oxide is unstable in certain solutions, such as those containing chlorine. Therefore, RPDs should be protected against chlorine containing cleaning solutions.
3. **Mechanical Properties:**
   a. \( E = 200-240 \) GPa (about 2X that of comparable cast dental gold)
   b. Hardness (typically 30% harder than Type IV golds) = R30N (or VHN) = 370;
      \( YS = 414-621 \) MPa,
   c. \( UTS = 621-828 \) MPa
   d. % Elongation (Cr alloys are quite brittle) = 1-2%
   e. Co-Cr alloys not affected by HT; Ni-Cr alloys can be affected by high temp HT

Clearly the mechanical properties of complex RPD assemblies are critical – but are different for different areas of the construction. Remember -- Lingual bars must impart rigidity. Clasps must permit flexibility (or elastic deformation). RPD assemblies are not always cast as a single unit, and can contain soldered portions such as clasps. This often permits more careful control of properties for different sections since different materials can be used in combinations. Let’s start by examining the bulky portions that are required for rigidity.

Let’s compare the stress-strain curves for Co-Cr [CLICK], Ni-Cr [CLICK], and gold alloys [CLICK] for RPD applications. Co-Cr and Ni-Cr have high moduli but undergo much less deformation prior to fracture [CLICK]. We take advantage of the high moduli of Co-Cr and Ni-Cr alloys [CLICK] and use them in thinner cross-sections to produce equivalent rigidity to gold alloys for lingual bars.

Hardness and yield strength measure the same thing – the stress level that produces the onset of plastic deformation. If plastic deformation does occur, then one would hope that fracture could still be avoided -- so having a high ultimate tensile strength is important as well. Look at the stress-strain curves above as a review of these properties. High strength alloys tend to be brittle and do not undergo much deformation prior to fracture (as indicated by the low % elongation).

[CLICK] In practical terms, rigidity is actually a function of three things: (1) the geometry of the part, (2) the thickness, and (3) the modulus. For major connectors, tear-drop shapes offer appropriate thickness, allow comfortable adaptation to tissue, and preserve self-cleansing design. Thickness has a major effect on rigidity. The rigidity is a function of the thickness raised to the fourth power. While you also can increase the rigidity by increasing the modulus, increasing the thickness is a much more effective way to do this. We are always seeking a balance between thickness and modulus – but always remember that a high modulus alloy can not compensate for a design of inadequate thickness.
3. Mechanical Properties: (continued)

f. Fatigue much more important for clasps than connectors

While RPD components must provide rigidity for the major and minor connectors, at the same time they must permit some flexibility for clasps for attachment and detachment. Clasps generally fail by fatigue. Flexibility, like rigidity, is a function of the (1) geometry of the part, (2) the thickness, and (3) the modulus. However, flexibility depends on undergoing elastic deformation easily. Remember from our discussions about dynamic mechanical properties, that even below the elastic limit (i.e., proportional limit, yield strength, hardness, …) that there are small amounts of plastic deformation. The plastic deformation accumulates as a clasp is cycled through attachment and detachment, ultimately leading to fatigue failure. The ultimate strength on a stress-strain curve defines the maximum stress for a single cycle to failure. [CLICK] The fatigue curves exponentially decreased to some fatigue limit or endurance limit. [CLICK] The number of cycles that a clasp can endure depend mostly on the modulus of the material which governs the amount of stress that will be required for the strain necessary to move the clasp. [CLICK] High modulus typically fail under fatigue sooner when modest strains are required for clasps. [CLICK]

Take a second and review what we have just said. Lingual bars require high stiffness – which is achieved through a combination of geometry, thickness, and high modulus alloys. Lower modulus alloys are at risk to exceeding their elastic limit and deforming like the case of the gold alloy shown above. For clasps, the stiffness is also a function of geometry, thickness, and modulus, but now you want a material that gives more easily so that it will not fatigue as quickly. If you cast the clasp then it is generally more likely to fatigue. The alternative is to solder a clasp using a different alloy that is more flexible than the alloy used for the main assembly.
4. **Laboratory Manipulation:**
   a. **Investment** (requires high temperature investments) = PBI or SBI
   b. **Spruing** (entrapped gases may produce voids) = careful venting
   c. **Melting methods** = oxyacetylene, oxygen-gas, or electric induction
   d. **Casting** (broken-arm casting machines not recommended) = use vacuum and/or pressure casting
   e. Sprue removal and finishing/polishing = special lab equipment due to high H
   f. **Soldering** = use care in fluxing, soldering, and heat control (electric soldering)
   g. Solders = usually >800 fine Ag-solders (good corrosion resistance)
   f. **Sterilization** = dilute bleach solutions

5. **Clinical properties:**
   a. **Adjustments** (casts, etc.) = difficult due to high hardness and E
   b. Ni sensitivity = sometimes but probably due to misfit or improper design
   c. Wear = low (but may contribute to excessive wear of teeth or restorations)
   d. **Hygiene** = clean with soap and water or very dilute solutions avoiding chlorine (Use stiff bristle brush; Avoid abrasive dentifrices)

Casting alloys for RPDs are more complicated for a number of reasons. The higher melting alloys require PBI or SBI investment. Spruing is more complex. Melting the alloys requires special techniques. Casting is usually done in a special machine. All the finishing and polishing operations are more difficult due to the high hardness of these materials and the complex shapes involved.

**[CLICK]** The clinical performance is generally quite good except for problems with fatigue. Adjustments are hard to make due to the high modulus and hardness. Nickel containing alloys have a coating of Cr2O3 that imparts corrosion resistance but this coating can be disturbed in areas of tight fit potentially leading to small releases of nickel that might be a problem for a nickel sensitive patient. The wear resistance of the alloy is generally very good but the alloy may abrade tooth surfaces. The best method to clean the metallic surfaces on an RPD is to use a soft bristle brush with soap and water. Chlorine and other cleaning agents may attack and destroy the Cr2O3 passivating oxide film.
In the table above are actual values for Co-Cr and Ni-Cr alloys compared to the ADA Specification. Co-Cr and Ni-Cr alloys have high yield [CLICK] and high ultimate tensile strengths [CLICK] with high moduli [CLICK] and are excellent for rigid portions of the RPD assembly such as the lingual bar. All the same values are lower for Type IV gold alloys and would require greater thickness to accomplish the same job. However, gold and some other alloys have better elongation values and might be better for clasps.
As noted at the beginning, RPD assemblies are very complex. A wide variety of constructions are possible. Everything depends on the stability of the physiological foundation. Because there are so many different things that can go wrong, the half-life for even well-planned RPDs is typically only about 3-5 years with them being redone every 5-8 years.

An RPD can be considered as a rigid platform with potential movements in x, y, z directions along with rotation. [CLICK] If it is effectively connected to remaining hard and soft tissues then it remains stable. However, there are several types of events that can occur to destabilize things: (1) biologic failures include bone resorption, increased tooth mobility, and tissue irritation; (2) functional failures include overloaded PDL or tooth wear due to non-vertical stresses; and (3) materials failures from casting defects, laboratory errors, or adjustment problems. Fatigue failure of clasps is the most common. Distortion or breakage of major and minor connectors may occur as well.

Finally, examine our model for potential problems: [CLICK] (1) clasps and rests can undergo both fatigue and work hardening that will lead to fracture; [CLICK] (2) casting the assembly is difficult due to the low density of the alloy which might permit pores or voids, possible side reactions during casting, and finishing/polishing operations; [CLICK] (3) stiffness depends primarily on thickness but also on geometry and modulus for resistance to flexure; [CLICK] (4) clasps or retentive wires can be soldered to the framework instead of being cast but might increase the corrosion potential at each soldered joints; and [CLICK] (5) the mesh for retention to the acrylic portions may not provide opportunity for the best bonding. This last point will be discussed in more detail in the next lecture.
RPDs are complex assemblies that are at high risk for clinical problems. Thank you.