Precious Metal Alloys for Ceramic Bonding
Introduction

There are a number of different types of alloys used as the metal coping (substrate/substructure) for ceramic bonding. In order to compare their properties for a particular restoration, we first need to analyse what are the desirable properties for such a restoration.
Important Properties needed in an alloy for the PFM technique

1. To be substantially biocompatible and non-toxic.

2. To have sufficient corrosion resistance for permanent use in the mouth.

3. To have sufficiently high a melting range so as not to melt during ceramic firing.

4. To have a sufficiently high a melting range to resist deformation ("sagging") and distortion during ceramic firing.
Important Properties needed in an alloy for the PFM technique

5. To have a coefficient of expansion close to that of available ceramics.

6. To have a **high enough modulus of elasticity and yield point** to act as a support for the ceramic layer during the application of the stresses developed in the mouth.

7. To be able to **develop an oxide layer** which will make a strong bond when fired to the appropriate ceramic.

8. To develop a **strong ceramic bond** without altering the shade or properties of the ceramic applied.
Important Properties needed in an alloy for the PFM technique

9. To be able to be cast by the lost wax method with the **high degree of accuracy** needed for ceramic restorations.

10. To have a **reasonable cost**.

11. To permit **solder joining** where necessary.

12. To allow **easy surface finishing** after casting.

13. To allow **easy adjustment** where necessary.
Important Properties needed in an alloy for the PFM technique

The fact that a number of different alloys are available for this purpose perhaps shows that none of them are perfect for every use. It also indicates that, historically, the movement in prices of precious metals has affected the development of these alloys.

The types of alloys currently available will be analysed in this section, and their major advantages and disadvantages discussed in terms of the properties listed above.
Three Precious Alloys Groups

High Gold Alloys
Modified Gold Alloys
Palladium Based Alloys
The first alloys developed for ceramic bonding came in the late 1950’s. They were based upon the gold alloys available for inlay and partial denture casting at the time, suitably modified for the ceramic application.
High Gold alloys

In particular:

1. These alloys still have a **gold content** ranging from roughly 80-90%.

2. The **copper** content of about 17% needed to provide order hardening in a type IV alloy has been removed because it can **stain** the applied ceramic. Copper is one of the elements, which can diffuse into a silicate glass structure and create ionic bonds. Because the oxide layer produced on copper-bearing gold alloys contains much copper oxide, there is plenty of copper available to diffuse into and stain the ceramic a **greenish** colour.
High Gold Alloys

3. Because there is no copper present, order/disorder transformation hardening on cooling is no longer possible. However, type IV mechanical properties are still desirable, particularly a high yield point, in order to support the ceramic with minimum flex and twist. To keep a high yield point, the alloys have added elements such as iron. These create hardening due to solid solution and due to precipitation hardening by reactions with platinum as the alloy cools from ceramic firing.
4. *Platinum and Palladium* are added to the gold alloy to raise the melting range to a level where the alloy will not melt or sag during ceramic firing.

5. The ceramics used may not bond adequately to pure gold surfaces. The addition of indium, iron, and particularly tin promote the formation of an oxide layer which will bond well with ceramics.

6. *Silver*, because it can diffuse into the ceramic during firing and cause a greenish grey shade alteration can be a problem.
High Gold Alloys

The high gold alloys have compositions typically within the following range:

- Au  80-90%
- Pt  0-15%
- Pd  0-16%
- Ag  0-15%
- Sn  0-3%
- In  0-4%
- Zn  2%
- Fe  0.3-0.5%
High Gold Alloys

The resulting alloys have excellent bio-compatibility and corrosion resistance, good ceramic bonding, and are easy to cast accurately. They are expensive, because of the high gold content. The yield point for a typical alloy is adequate, although the more yellow coloured alloys with gold compositions at the top end of the range are not as strong. The sag resistance of the high gold alloys is not excellent, leading to some deformation during firing. *The elastic modulus is the lowest of available PFM alloys.* As a result of the last two properties, other alloys may be preferred for longer span restorations.
Modified Gold Alloys-Gold/Palladium Alloys

The next stage in developing ceramic alloys came in the 1970’s. Considerable amounts of palladium were added to high gold alloys. Typical compositions were:

- **Au**: 42-55%
- **Pd**: 25-32%
- **Ag**: 6-16%
- **Sn**: 0-4%
- **In**: 0-3%
Modified Gold Alloys-Gold/Palladium Alloys

These additions were made to reduce cost, and improve sag resistance. Palladium is a greyish-white noble metal, of similar corrosion resistance to platinum, though slightly less than gold. Its melting point is 50% higher than that of gold.

The yield point of these gold/palladium/silver alloys was similar to that of the high gold alloys, the modulus of elasticity was higher and the sag resistance was increased due to a higher melting range.
Modified Gold Alloys-Gold/Palladium Alloys

Due to the high silver content, some of these alloys suffered from a tendency to cause diffusion staining of ceramics. This problem could be cured by careful control of the alloy composition and the ceramic composition, or by the use of coupling agents. This is a general term for a material which is painted onto the metal surface in order to improve the properties of the subsequent ceramic layer.

Coupling agents have contained tin compounds, to aid the bonding of high gold alloys.
Modified Gold Alloys-Gold/Palladium Alloys

Coupling agents have contained opaquing compounds, to mask the colour of the metal beneath the ceramic, because light reflection from this metal surface can alter the apparent shade of the ceramic.

Coupling agents can also contain elements which will block, or slow the diffusion of ions such as silver from the metal into the ceramic layer, in which case they are sometimes known as “anti-staining” or “anti-greening” compounds.
Modified Gold Alloys-Gold/Palladium Alloys

Due mainly to problems with ceramic colouration, the modified gold alloys were further developed. The silver content, which is mainly present to lower the price, was removed, and replaced by, for example, a smaller amount of gallium.

Gallium is a metal with a very low melting point, 340 °C. If enough is added to substantially reduce the melting range of another alloy, the amount will still not be enough to seriously reduce the corrosion resistance.
Modified Gold Alloys-Gold/Palladium Alloys

The Silver free modified gold alloys have contents as follows:

- **Au**: 48-53%
- **Pt**: 0-1%
- **Pd**: 36-40%
- **Sn**: 2-5%
- **In**: 3-7%
- **Zn**: 4%
- **Ga**: 3%

The silver free Gold/Palladium alloys have slightly higher yield points and modulus of elasticity than the Gold/Silver/Palladium alloys, similar cost, and similar sag resistance.
Palladium Based Alloys

The success of the Gold/Palladium alloys produced further developments in the later 1970’s. Palladium/Silver, Palladium/Copper and Palladium/Gallium alloys were produced. These had the effect of reducing the price of precious metal ceramic alloys to only 15-20% of that of the high gold alloys.
Palladium Based Alloys

Palladium/Silver Alloys

These high palladium alloys continued to raise the question of silver staining the porcelain. Some ceramic systems were developed which solved the problem, some systems continued to use coupling, or “anti-greening” agents.
Palladium Based Alloys

The yield point was similar to the gold/palladium alloys, and the modulus of elasticity went up slightly. Sag resistance remained good.

Typical compositions were:

- Au 0-4%
- Pd 50-60%
- Ag 30-40%
- Zn 0-3%
- In 0-3%
Palladium Based Alloys

Palladium/Copper Alloys

First introduced in the early 1980’s, these were designed to maintain the price advantage of palladium-based alloys, but remove the possibility of ceramic staining. Although copper in high gold alloys was known to stain ceramic, the copper ions from palladium alloys appear to be less able to diffuse into the ceramics used.
Palladium Based Alloys

Palladium/Copper Alloys

Typical compositions were:

- Au   0-2%
- Pd   75-80%
- Cu   9-15%
- Ga   5-10%
- In   3-7%
Palladium/Copper alloys appear not to stain ceramics, however, the copper produces a darker oxide layer and needs a thorough opaquing treatment. The yield point is by a large amount the highest of the precious metal ceramic alloys, and the hardness is similarly higher, twice that of other precious metal alloys. The modulus of elasticity does not show such an increase, being better than gold based alloys, but less than palladium/silver alloys. The sag resistance of these alloys is also not as good as the palladium silver ones.
Palladium Based Alloys

The higher melting ranges of palladium based alloys in general, and palladium/copper alloys in particular, and a slightly increased susceptibility to contamination during melting means that they are not quite as easy to cast as high gold alloys.