Metallographic Observation to Determine a Low-content Gold Alloy Castability

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Low gold-content dental alloys nowadays represent viable alternatives to high nobility alloys. The casting techniques and equipment used for low-gold content alloys are similar to those used for conventional gold alloys. This, coupled with their acceptable properties, good clinical performance and lower cost, has lead to their widespread use. The alloy performance in the dental laboratory is an important factor affecting alloy selection. One of the main properties of alloys is their capacity to very accurately reproduce the wax pattern, therefore resulting in a fine structure, with minimum internal porosity and no surface defects. These performances represent what we call castability. The aim of our study is to determine castability for a low gold-content dental alloy.

Keywords: castability, low-content gold alloy, metallography

Commonly there are three different types of dental alloys: conventional casting alloys used without ceramics or polymers, bonding alloys used with high and medium fusing ceramics and polymers and universal alloys used without or with low-fusing ceramics and polymers [1].

A most accurate classification of dental alloys is given in table 1.

In the past, the use of high-nobility alloys (those with a high content of gold or other noble metals) generally ensured quality for fixed partial dentures. However, later, the use of low-nobility alloys has become widespread due to economic pressures. As a consequence of this trend, problems regarding chemical stability of this type of alloys have emerged. Accordingly, more attention was paid to the quantification of the chemical stability of dental alloys in terms of their tarnish and corrosion behaviour. [2].

In time the necessity to introduce a large number of alternative casting alloys of low cost has become obvious. These alloys containing silver, palladium, copper, nickel, chromium, etc., also had to be accompanied by the continuous check of tarnish and corrosion resistance in order to assure a long term durability and good aesthetic result [1].

The microstructure of low gold content alloys can be manipulated through heat treatments. For example, grain size can be altered by varying the solidification rate and by post-solidification anneals. The degree of segregation in a casting also depends on homogenization anneals, alloy composition, and casting conditions. Furthermore, low-gold alloys in particular exhibit both precipitation and ordering reactions which affect chemical stability.

However, the desirable features of low gold content alloys are large grains, a minimum of segregation, and the absence of precipitates and ordered phases.

The alloy performance in the dental laboratory is an important factor affecting alloy selection. Properties as castability, surface roughness, sag resistance (deformation during heating) affect the usability of an alloy [3].

The density of gold provides excellent castability at a relatively low temperature. Silver is a common constituent that has been used as a lower alloy cost component [4].

Silver improves castability and forms solid solutions with gold and palladium, although it is less dense. Palladium was also introduced as a lower alternative to gold [5].

It has a considerably higher melting point and reduced castability. Other metals present in lesser quantities optimize the alloy properties. Gold, silver and palladium are miscible and are usually single phase, copper being a common addition [6].

The casting techniques and equipment used for low-gold content alloys are similar to those used for conventional gold alloys. This, coupled with their acceptable

Class	Type and area of use
A	High gold-content alloys for the metalo-ceramic technique
B	High precious metals content alloys for the metalo-ceramic technique
C	Pd-based alloys for the metalo-ceramic technique
D	High gold-content alloys for the conventional technique
E	Low gold-content alloys for the conventional technique
F	Ag-Pd-based alloys for the conventional technique
1	Co-Cr base alloys for the metalo-ceramic technique
2	Ni-Cr base alloys for the metalo-ceramic technique
3	Fe-Ni-Cr base alloys for the conventional technique
4	Co-Cr base alloys for cast partial denture frameworks
5	Ti 4th grade for implants and the metalo-ceramic technique
6	Ti-6Al-4V for implantology pieces
7	Ti-Ni alloys for wires and endodontic use

Table 1
CLASSES OF DENTAL ALLOYS

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Composition % wt	Au 54,8	Ag 26,0	Pt 0,0	Pd 6,2	Cu 10,9	Zn 2,1
Type	ISO DIS/8891 low gold content alloy					
Melting range	880-915°C					
Preheating temperature	650°C					
Casting temperature	1065°C					

Table 2
COMPOSITION AND GENERAL PROPERTIES OF THE ALLOY USED FOR MANUFACTURING THE CROWNS

properties, good clinical performance and lower cost, has lead to their widespread use [7].

Experimental part

A type E low-gold content alloy is used for casting three crowns, using the conventional technique (table 2) using an induction melting/casting device. After adapting and polishing, all three crowns show major surface porosity (fig. 1). This defect cannot be repaired, being impossible to give the surface the necessary homogeneity for corrosion resistance.

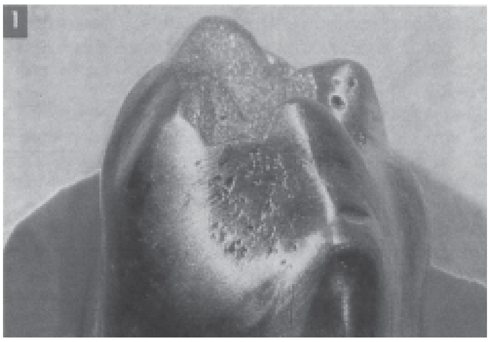

Fig. 1. Porosity present at the first upper molar level

Independent of the porosity observed at the crown surface, the S shaped casting shaft is characterized by a strong surface porosity along the shaft and a concave and perturbed aspect of the base surface (fig. 2).

In order to compare the crown structure to that of the alloy melted in optimal conditions, using a propane-oxygen burner, metallographic samples were used. A high degree of internal macroscopic porosity in the crown alloy, at a depth order of 100 μm (fig. 3) is notable. After the chemical attack, an enlargement of 100x reveals intergranular porosities in the whole crown alloy (fig. 4). On the other hand, the alloy structure, after melting by flame, in proper conditions, shows a fine, homogenous and porosity-free structure (fig. 5).

Results and discussions

In order for the alloy casting to be complete, certain rules should be observed, especially concerning the choice of thermal conditions: the stabilising temperature of the cylinder and the alloy temperature at injection.

Fig. 2. S shaped casting shaft characterized by a high porosity and a concave and perturbed aspect of the base surface

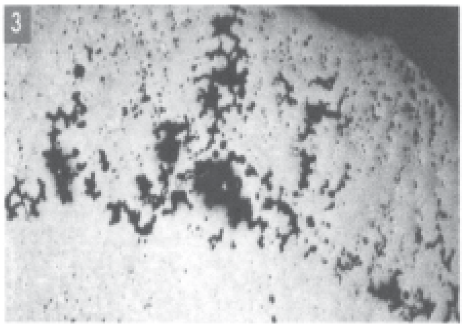

Fig. 3. Metallographic sample of the crown alloy, at a 50x enlargement. Significant internal porosity

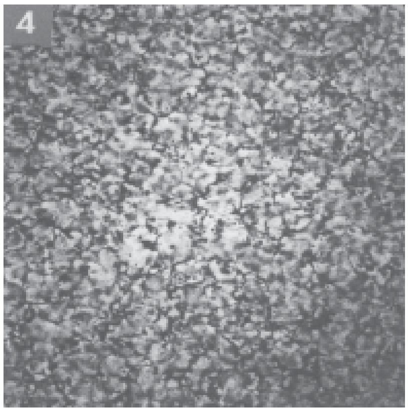

Fig. 4. Metallographic observation of the crown alloy, at a 100x enlargement, after the chemical attack. The internal structure is fine and porous

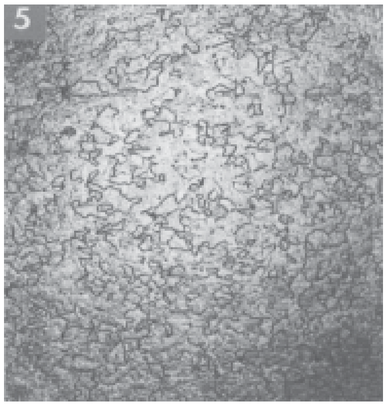

Fig. 5. Metallographic observation of the same alloy, correctly casted, at a 100x enlargement, after the chemical attack. The internal structure is fine and not porous

The importance of these two elements may be emphasized by casting evaluation of the alloy (liquid temperature 920°C), using a certain pattern.[8] The castability expresses in percentages multiplied with 25, the areas completely melted. It is notable that for a very low cylinder temperature (500°C) the melting will not reach its peak, regardless the alloy temperature at injection. On the contrary, for deliberate very high temperatures (900°C) the pattern is always complete, even if the alloy temperature is close to that of its melting interval.

One may also notice that the associated porosity, metallographically determined in the narrowest area of

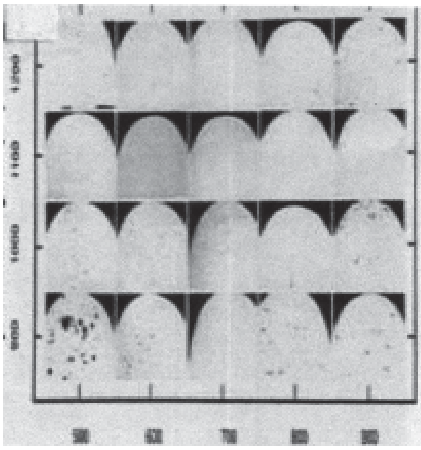

Fig. 6. Internal porosity rate of the cylinder center by metallographic observation, depending on cylinder and alloy temperature at the injection moment

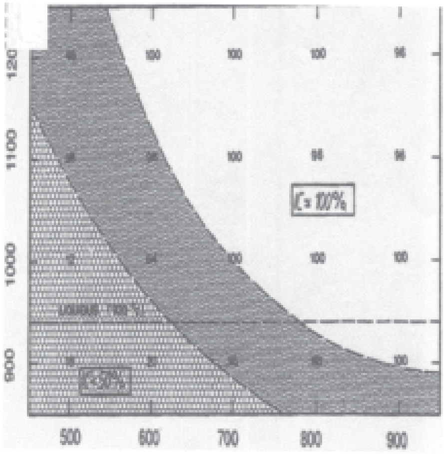

Fig. 7. Diagram illustrating the castability index depending on the characteristic temperatures. The bright area is characterized by a 100% castability

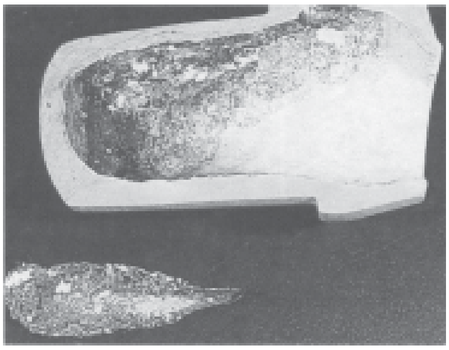

Fig. 8. Melting alloys for the conventional technique by induction, in a silica crucible is difficult because of the oxide layer formed at the surface which leads to scoria formation

the disc, is macroscopically noticeable and quite significant in the case of the lowest characteristic temperatures (fig. 6).

These correlated remarks (fig. 7) permit to define an area for which the alloy melting is 100%, and the internal porosity minimum.

One of the main properties of alloys is their capacity to very accurately reproduce the wax pattern, therefore resulting in a fine structure, with minimum internal porosity and no surface defects. These performances represent what we call castability.

There have been many experimental designs for comparing castability of alloys or efficiency of casting techniques. Some studies attempt to evaluate castability based on fit of restorations. Even though their results may be significant, they expand the definition of castability to include coefficients of thermal expansion and roughness factors. Other studies have evaluated the ability to fill special designed mold forms. These forms include different designs (razor blades, wedges, specially machined saucer design etc). We used special designed patterns, made in our own laboratory [8].

Casting defects can be classified into:

-distortion: caused by the distortions of the wax pattern caused by wrong handling or as a result of the setting and hygroscopic expansion of the investment;

-asperities, irregularities and color alterations: caused by air bubbles, water film between the pattern and the investment, fast heating, insufficient preheating, water/ powder ratio, prolonged heating, melting the alloy at a too high temperature, elevated casting pressure, investment material composition, contamination with foreign bodies or sulphur, incorrect application of the casting shafts, investing multiple patterns too close, carbon inclusions. -porosities: caused by the contraction at solidification, gas inclusions, gas retention in the mould;

-incomplete casting: due to the fact that the architecture of the mould does not allow gases to evacuate quickly enough or to the high viscosity of the melted alloy.

The occurrence of these defects increases the needed finishing time, or if they occur in areas of major importance, a recasting is necessary [8, 9].

In our case, we decided that the defects were not compatible with quality fixed prosthodontics, so recasting was decided.

We had to deal with a situation in which the thermal parameters could not be respected. When melting alloys in the conventional technique by induction, in a silica crucible, it is not easy to determine the alloy's temperature at injection, because of the oxide layer which prevents observation (fig. 8). Furthermore, it is important to respect the time the cylinder is maintained at stabilization temperature (650°C), to assure the homogeneity of the temperature within the cylinder.

Conclusions

Internal and external porosity is the consequence of poor judgement in choosing the thermal parameters of melting the alloy.

The two fundamental parameters are the cylinder temperature and the alloy temperature at injection.

In case of temperatures usually used for cylinder stabilization (650-700°C), the alloy temperature at injection must be at least 150°C above the liquid temperature of the alloy.

The cylinder maintenance time at stabilizing temperature must be sufficient enough to provide the entire cylinder temperature homogenization.

A proper melting of precious dental alloys for the conventional technique is easier to obtain by flame than by induction.

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