

A PROPOSAL FOR THE CLASSIFICATION OF PRECIOUS DENTAL ALLOYS ACCORDING TO THEIR RESISTANCE TO CORROSION BASED ON THE ISO 10271 STANDARD

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INTRODUCTION: A lot of dental alloys are available on the market. Among these alloys, there are the conventional alloys, the so called casting alloys used without ceramics, the bonding alloys used with high fusing ceramics and the universal alloys used without or with low fusing ceramics. It is important to know the physical and mechanical properties of these materials but also their biocompatibility and their resistance to corrosion. Dental alloys are generally placed in the mouth for many years, they must not induce adverse biological reactions such as gingival swelling and erythema, mucosal pain and lichenoid reactions. Although these troubles are often caused not by the materials itself [1, 2], they can be induced by the metallic ions released during their corrosion. In order to decrease the risks to the health, it is necessary to study the corrosion of the dental alloys. Currently, the ISO 10271 Standard [3], describes 3 different corrosion tests: a static immersion test (chemical corrosion), an electrochemical test and a tarnish test. However, there are no indications yet about the possible interpretation of test results. In this paper, we propose a method to compare and classify the dental alloys in relation to their chemical and electrochemical corrosion results.

METHODS: The material tested are pure metals such as gold, palladium, silver, copper and zinc as well as dental alloys which are commercially sold (see Table 1). 54 different materials have been tested. A minimum of four samples of each material were tested by electrochemical corrosion and a minimum of three in chemical test. The samples were cast and prepared as indicated by the manufacturer and by the ISO 10271. For the electrochemical test, the samples are in the form of disks 11 mm in diameter. They are tested with a potentiostat/galvanostat Voltalab Model 21. For the chemical test, the samples are rectangular with the dimensions 35X10X1.7 mm. The solution used and the operating conditions are described in the ISO 10271. The concentration of metallic ions released is measured by Induced Coupled Plasma Spectroscopy.

Table 1. Atomic composition (°/°°) of main elements contained in tested dental alloys

| Alloys | Category | Au | Pt | Pd | Ag | Cu |
|--------------|-----------|---------|---------|---------|---------|---------|
| CONV. | Au-Ag-Cu | 250-605 | 0-75 | 0-60 | 115-505 | 145-315 |
| | Ag-Pd(Cu) | 0-65 | 0 | 180-615 | 240-630 | 0-230 |
| BOND. | Pd-base | 10-35 | 0 | 700-750 | 0-65 | 0-110 |
| | Au-Pt-Pd | 650-780 | 65-95 | 90-160 | 0-40 | 0-6 |
| | Au-Pd(Ag) | 300-620 | 0 | 280-505 | 0-225 | 0-90 |
| | Au-Pt | 800-850 | 110-120 | 0 | 0 | 0 |
| UNIV. | Au-Ag | 420-505 | 0-100 | 0-145 | 200-375 | 0 |

RESULTS & DISCUSSION: Gold is known for its very good resistance to corrosion in contrast to zinc which is easily corroded. We propose to compare the electrochemical values obtained on these two pure metals with the ones of dental alloys. The following parameters are taken into account: Erest, Ecrit, Q1, Q2 and Q3. The rest potential (Erest), which is measured after two hours immersion of the sample into the defined solution against the reference electrode without applying potential (Fig. 1). Then increasing voltage is applied and the resulting current density is measured (Fig. 2), which correlates to corrosion rate. The first section shows typically a flat curve, and from a certain point, the critical potential (Ecrit), the current rises quickly. The integration of the polarization curve between certain defined potentials, Erest and E1*, E1 and E2, E2 and E3, produces the parameters Q1, Q2, Q3 (Table 2).

For classification of the alloys, first the different parameters were compared with the two selected references, gold and zinc, and noted between 0 and 1, the notations of all five parameters were added to the total notation between 0 and 5 (Table 2). After measuring all alloys, one could see that certain composition ranges behave similar, therefore for each alloy category an average note was determined (Fig 3). From these results a classification according to five following classes is proposed: starting with class 1 which is better than the note 5.0, then class 2, 3 and 4 in steps of 0.3 and finally

class 5 below 4.1. According to Metalor standard, an alloy must not be in class 5 to avoid the risk of significant corrosion.

Table 2: A proposal of notation system for a electrochemical classification

| Parameter | Gold note | Zinc note | some alloy m1 note |
|------------|-----------|-----------|---|
| Erest | 1/1 | 0/1 | $n_1 = (E_{rest_{m1}} - E_{rest_{Zn}}) / (E_{rest_{Au}} - E_{rest_{Zn}})$ |
| Ecrit | 1/1 | 0/1 | $n_2 = (E_{crit_{m1}} - E_{crit_{Zn}}) / (E_{crit_{Au}} - E_{crit_{Zn}})$ |
| Q1 | 1/1 | 0/1 | $n_3 = (Q1_{Zn} - Q1_{m1}) / (Q1_{Zn} - Q1_{Au})$ |
| Q2 | 1/1 | 0/1 | $n_4 = (Q2_{Zn} - Q2_{m1}) / (Q2_{Zn} - Q2_{Au})$ |
| Q3 | 1/1 | 0/1 | $n_5 = (Q3_{Zn} - Q3_{m1}) / (Q3_{Zn} - Q3_{Au})$ |
| Total note | 5/5 | 0/5 | $N_{total} = \sum (n_1 + n_2 + n_3 + n_4 + n_5)$ |

*E1=Erest+300 mV/SCE, E2= Erest+700 mV/SCE and E3=Erest+900 mV/SCE

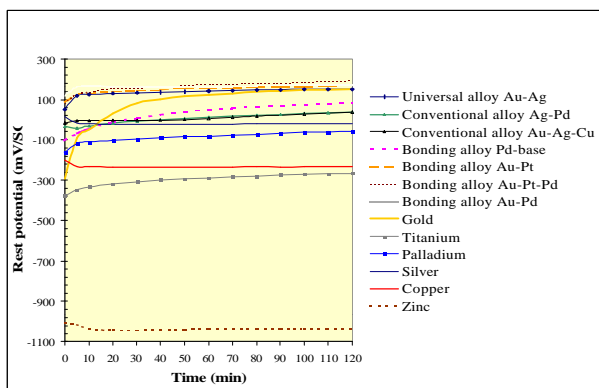


Fig. 1: Rest potential versus time

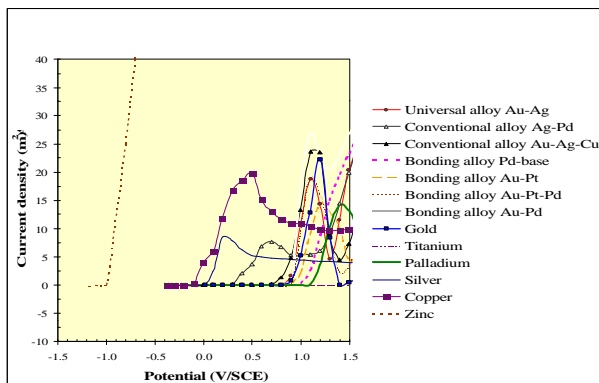


Fig. 2: Examples of polarization curves

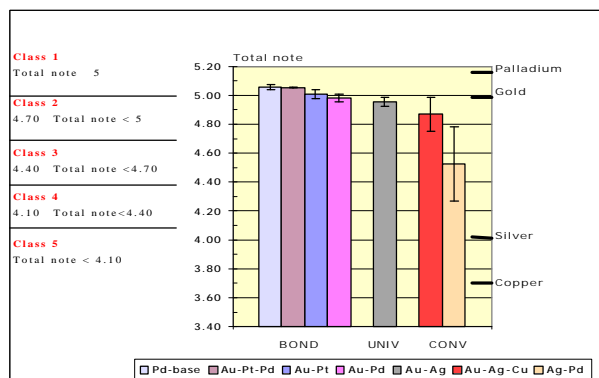


Fig. 3: Electrochemical results

For chemical corrosion the metallic ions released are measured in $\mu\text{g}/\text{cm}^2$ after one week immersion into the defined solution. The results are calculated as an average for each alloy category (Fig. 4). The classification proposed contains three classes: class 1 up to $10 \mu\text{g}/\text{cm}^2$, class 2 between 10 and $100 \mu\text{g}/\text{cm}^2$, and class 3 between 100 and $1000 \mu\text{g}/\text{cm}^2$.

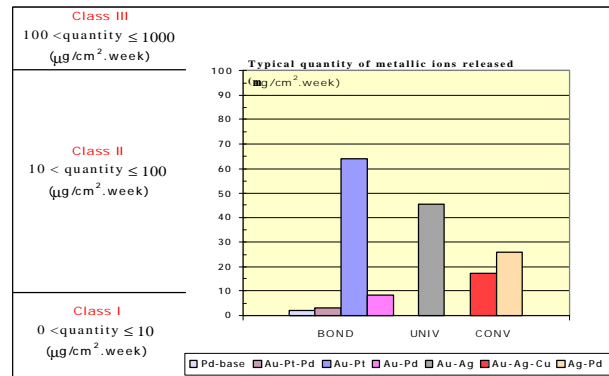


Fig. 4: Chemical results

CONCLUSIONS: In the electrochemical test, the alloys which contain a lot of gold or palladium show a similar behavior as the pure gold and palladium. The conventional alloys contain more silver and copper, they get closer to the values of these metals. In the electrochemical test, typically all alloys were forced to corrode, the values obtained depend strongly on the composition. The corrosion is very significant due to severe conditions (high potentials, aggressive solution). Whereas in the chemical corrosion test, only the phases containing less precious metals were dissolved. This effect can increase strongly when the alloy has an inhomogeneous microstructure or rough surfaces. For these reasons, very good electrochemical results were found for alloys rich in precious metals because it is hard to etch them. As soon as these alloys have a microstructure with several phases they do not necessary have the same classification notes in the chemical test as their homogeneous counterparts. The Pd-base and Au-Pt-Pd dental alloys are the most resistant to electrochemical and chemical corrosion.

REFERENCES: [1] G. Schmalz, P. Garhammer, *Biological interactions of dental cast alloys with oral tissues*, Dental Materials 18, 2002, 396- 406. [2] Environmental Health Policy Comittee, *Biocompatibility of Dental Restorative Materials*, www-health-gov/environment/amalgam1/appendixi-sectioniii.htm, 1-10. [3] ISO 10271 Standard:

Dental metallic materials-Corrosion test methods,
First edition 01/06/2001.