

COPPER-ALUMINIUM BRONZE – A SUBSTITUTE MATERIAL FOR GOLD DENTAL ALLOYS?

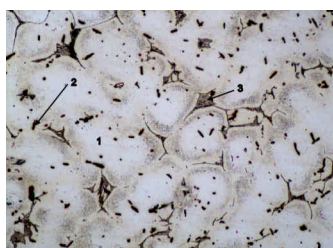
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INTRODUCTION: Since the '80s, copper-aluminium based alloys have appeared on the dental market in the US, Japan, South America and some countries of Eastern Europe. These aluminium bronzes, essentially a substitute for conventional gold-rich alloys, are employed for the fabrication of economical crowns and bridges¹. Alloyed with elements such as iron, nickel, manganese and tin, they show in fact quite a good colour match to gold, and they keep an astonishing brilliance in the oral environment.

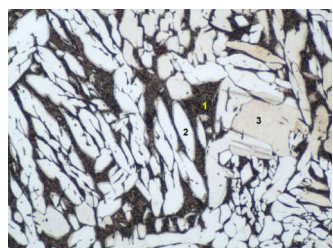
Alloys used in dental restoration must have an appropriate corrosion resistance in order to avoid the release of cytotoxic or sensitising elements into the biological milieu. In this context, we have evaluated two commercial copper-aluminium dental alloys. We here present our results concerning their corrosion and tarnishing behaviour, as well as their release of nickel and copper ions.

MATERIALS AND METHODS: The test samples had the form of discs of diameter 11 mm. They were metallographically polished with diamond paste (granulometry 1 µm).



Phase	Cu	Al	Fe	Ni	Mn	Zn
1	85.2	4.3	1.6	4.7	2.3	1.9
2	59.5	12.1	4.0	20.6	2.8	1.0
3	86.2	4.4	1.6	4.2	2.0	1.6

Fig. 1. Microstructure of alloy # A and phases composition (wt %).



Phase	Cu	Al	Fe	Ni	Mn	Zn
1	84.7	7.4	1.6	4.7	1.6	0.0
2	88.4	4.9	2.1	3.1	1.2	0.3
3	76.5	9.5	4.3	7.0	1.2	1.5

Fig. 2. Microstructure of alloy # B and phases composition (wt %).

Table I. Composition of the tested aluminium bronzes (wt %).

Alloy	Cu	Al	Fe	Ni	Mn	Zn
# A	79.3	7.8	4.0	4.3	1.6	3.0
# B	82	10.7	2.5	3.55	1.2	0.05

Electrochemical measurements were conducted in artificial saliva of the Fusayama type (deaired with nitrogen, temperature 37°C, pH = 5) using the rotating electrode technique. The open-circuit potential (E_{oc}) was measured during 24 h. The polarization resistance (R_p) was calculated from the recorded linear polarization curves (Mansfeld curves). The cathodic and anodic potentiodynamic polarisation curves were measured from - 500 mV to + 1000 mV vs. SCE

A zonal coulometric analysis was derived from potentiodynamic polarization curves (zone I: from open-circuit potential (E_{oc}) up to + 300 mV; zone II: from + 300 mV to + 500 mV vs. SCE).

Tarnishing was evaluated in a thioacetamide test during two days. The test consists in exposure of the samples to the vapours emitted by thioacetamide in an atmosphere with a relative humidity of 75 %, maintained by the presence of a saturated solution of sodium acetate (ISO 4538).

Release tests were done by extraction in an 0.1 NaCl and 0.1 M lactic acid solution (temperature 37°C, pH = 2.3, extraction duration 7 days, sample surface to solution volume ratio: 1 cm² / 1 ml). The copper and nickel ions released during into the solution during the test was quantitatively analysed by inductively coupled plasma spectroscopy (ICP).

RESULTS:

The potentiodynamic curves displayed in Fig. 3 reveal important differences in the behaviour of the aluminium bronze alloys (#A and #B) as compared to a conventional gold and a CoCr alloy.

The electrochemical parameters evaluated in deaired artificial saliva are summarized in table II. All the results consistently show a much stronger corrosion susceptibility of the Cu-Al alloys as compared to conventional dental alloys.

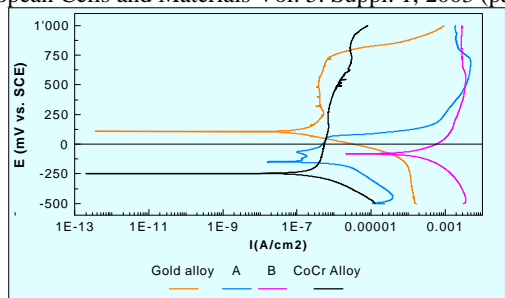


Fig. 3 Polarization curves of alloys # A and # B in comparison with a conventional gold and CoCr alloy.

Table II. Summary of the evaluated electrochemical parameters.

Alloy	E_{oc} [mV] vs. SCE	R_p [kOhm/cm ²]	Breakdown potential E_{bp} [mV] vs. SCE	Zonal coulometric analysis	
				E_{oc} to + 300 mV [mC]	+ 300 mV to + 500 mV [mC]
A	- 144	6.1	97	839	3041
B	- 141	4.3	98	861	3505

During the electrochemical test, the surfaces of both alloys A and B have undergone a significant degradation as evidenced by SEM (Fig. 4). The apparent dendritic microstructure suggests a preferential dissolution of the interdendritic, copper-rich matrix.



Fig. 4. SEM micrograph of alloy # B after the potentiodynamic polarization measurement.

The release tests resulted indeed in high quantities of Cu and Ni in the electrolyte after 7 days (Fig. 5), accompanied by a sample total weight loss of 1.8 mg/cm² for alloy A and of 2.6 mg/cm² for alloy #B.

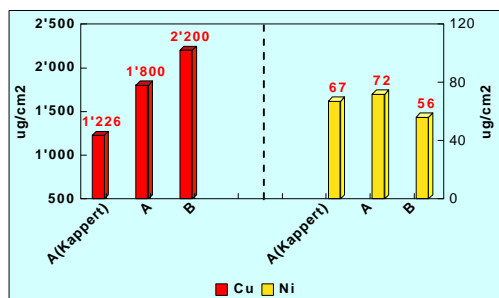


Fig. 5. Quantities of copper and nickel released after 7 days of immersion testing (included are independent results by Kappert²).

DISCUSSION AND CONCLUSIONS

According to our results, the two as-cast aluminium bronzes A and B exhibit a very low corrosion resistance in an oral-type environment. They release significant amounts of nickel and copper, and they tarnish much more than conventional gold alloys.

The release of cations like nickel may induce allergies. For the prevention of contact dermatitis, the European Directive 94/27/EC prohibits the commercialisation of products that come into prolonged contact with the skin, if they release more than 0.5 µg/cm²/week of nickel. As seen in Fig. 5, the two aluminium bronzes release about 100 times this amount.

According to Kappert², the brilliance of these alloys is preserved in the mouth because of their uniform corrosion (i.e. they keep a polished look) and because the cytotoxicity of the released copper ions inhibits bacterial proliferation. On a microscopic level, however, we find a selective rather than an uniform corrosion.

From our results we conclude that this class of non-precious, aluminium bronze type III casting alloys present a very low corrosion resistance and an elevated release of problematic cations.

Reference

1. L. Reclaru, H. Lüthy, C. P. Marinello, P.Y. Eschler, C. Süss, D. Bratu, Corrosion of Non-Precious Type III Casting Alloys, *J Dent Res* 80: 712 (2001).
2. H. F. Kappert, M. Schuster, Dental Labor, XLIII, 3/2001