

Influence of casting procedures on the corrosion resistance of clinical dental alloys containing palladium [☆]

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Abstract

The aim of this study was to compare the in vitro corrosion resistance in artificial saliva of two palladium–silver alloys (a Pd–Ag (Pors on 4) and an Ag–Pd (Palliag LTG)), with and without casting defects; 1 nickel–chrome alloy and 1 high-gold alloy, cast under recommended conditions, served as controls. For each of the palladium-based alloys, three specimens corresponding to three different casting conditions were used: under recommended conditions, with the use of a graphite-containing investment and crucible, and by reusing the sprues and sprue button. The electrochemical tests were run in Fusayama–Meyer artificial saliva. The open-circuit potential was recorded in mV/SCE at $t = 24$ h. Then, potentiodynamic polarization was performed to measure the polarization resistance (R_p) in $\text{k}\Omega\text{cm}^2$ and the corrosion current (i_{corr}) in $\mu\text{A cm}^{-2}$. Data were evaluated with one-way analysis of variance and multiple comparisons test ($\alpha = 0.05$). In addition, each specimen was examined by scanning electron microscopy. Compared to the control alloys, the electrochemical experiments in artificial saliva indicated satisfactory corrosion resistance for the Pd–Ag and Ag–Pd alloys; these results are related to their high noble metal content and stable substructure. The Pd–Ag alloy displayed superior electrochemical properties to those of the Ag–Pd alloy regardless of the casting condition. The use of the graphite-containing crucible and investment during the cast process did not dramatically reduce the corrosion resistance values, but the reuse of sprues and the sprue button did. The optimal corrosion resistance values were obtained for the alloys cast according to the recommended conditions.

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1. Introduction

From the earliest times until the 1960s, gold was most commonly used as the major element in dental alloys [1].

Nowadays, alloys for dental prostheses differ widely in their compositions and their most abundant elements. The properties of base metal alloys have been improved and costs considerably reduced [2]. Studying the corrosion properties of an alloy is important in order to evaluate its biocompatibility in clinical use [1]. According to Mülders et al. [3], the use of base metal alloys is limited by their susceptibility to corrosion, since corrosion products can be both toxic and allergy-provoking in the biological environment. This observation had previously been made by other authors,

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resulting in the development of a range of noble and semi-noble palladium-based alloys. Being classified as a noble metal according to the American Dental Association, palladium could form the base of a large variety of alloys. Semi-noble alloys are an excellent alternative to gold-based ones for full-cast and metal ceramic restorations due to their high resistance to corrosion [4,5], good porcelain adherence [4], as well as excellent mechanical properties.

Most electrochemical studies use Fusayama artificial saliva as a test solution close to the clinical conditions, to study the *in vitro* corrosion of dental alloys [6–8]. Under these conditions, palladium-based alloys display satisfactory corrosion resistance [4,5,9], with the formation of a protective passive film against oxidation and corrosion on the surface of the alloy [10]. Studying the influence of casting procedures and defects on the corrosion resistance of such alloys as reported by many researchers [3,11], it seems that the conclusions are controversial; this may be because of the differences in the parameters and conditions used.

To cast dental alloys in the laboratory, investment wax patterns and the lost-wax process are commonly used [12,13]. A phosphate-bonded investment is required in the case of palladium-based alloys (also used for base metal alloys and titanium-based alloys) whereas a gypsum-bonded investment is used for gold-based alloys. Graphite and vitrified graphite crucibles are used only for gold-based alloys. The palladium-based alloys require the use of a silica or ceramic crucible: some authors such as Böning and Walter [14] have identified surface porosity in palladium-based alloys when graphite was present during fusion, resulting in a ceramic bond of poor quality. On the other hand, some laboratories recast sprues and sprue buttons after being recovered by adding 50 wt.% of new alloy pellets. Thus, depending on the dental laboratory, problems due to casting defects could appear in the short or medium terms. The dental prosthesis may be unsuitable or corrosion may occur after cementation, as discussed by Cohen et al. [11].

The present study was designed to compare the *in vitro* corrosion resistance of Pd–Ag and Ag–Pd alloys, being cast under three different conditions, with those of a high-gold alloy and a nickel–chrome alloy being cast under recommended conditions and serving as controls. Three casting conditions were tested: one series produced under recommended conditions and two other series involving commonly found casting errors, pointed out by the

manufacturers. Open-circuit potential (OCP) and potentiodynamic curves were recorded for each alloy to measure the corrosion potential, the polarization resistance (R_p) and the corrosion current (i_{corr}). The results will be discussed in order to determine whether the corrosion resistance of a palladium–silver alloy could be influenced by the laboratory casting procedure or not. In addition, as silver-based dental alloys have a poor reputation because of their high silver content [15], this study reports the results for the Pd–Ag and the Ag–Pd alloys, to study the influence of silver content on the corrosion resistance and to compare results with the same alloy family [16]. Finally, surface observations using a scanning electron microscope (SEM) were conducted.

2. Material and methods

2.1. Specimens

2.1.1. Composition of alloys

Two palladium-based alloys were selected: a Pd–Ag one (Pors on 4) and an Ag–Pd (Pallig LTG) (both manufactured by Dentsply France Corp., Montigny le Bretonneux, France). As controls, a high-noble Au–Pt alloy – Degudent H (Dentsply) and a Ni–Cr alloy – Wiron 99 (Bego, Atlantic Codental Corp., Fontenay sous Bois, France) were used. The composition of the four alloys is listed in Table 1. These four alloys are commonly used for porcelain-fused-to-metal restorations.

2.1.2. Preparation of specimens in different casting conditions

For each alloy, five specimens were prepared ($N=5$). They were cylindrical, 4 mm in diameter and 8 mm in length. Each polymethyl methacrylate pattern was sprued and invested individually; care was taken to ensure that the diameter and position of the sprues were correctly placed according to standards. Each alloy was melted individually with a conventional propane/oxygen blowtorch following the manufacturer's instructions to avoid overheating. Alloy casting was performed in air using a broken-arm centrifugal casting machine (Kerr/Sybron Dental Specialties Inc., Romulus, USA).

Three different casting conditions were used to obtain the specimens (Table 2). Specimens of series 1, featuring the studied alloys and controls, were obtained following the

Table 1
Composition of alloys (wt.%)

	Alloy element (wt.%)										
	Au	Pt	Pd	Ag	Zn	Ni	Cr	Mo	In	Sn	Other
Pors on 4 ^a (Pd–Ag)			57.8	30	2				4	6	Ru 0.2
Pallig LTG ^a (Ag–Pd)			36.9	56	4					3	Ir 0.1
Degudent H ^a (Au–Pt)	84.4	8	5						2.5		Ta 0.1
Wiron 99 ^b (Ni–Cr)						65	22.5	9.5			Nb 1, Si 1, Fe 0.5, Ce 0.5, C 0.2

Alloys composition was obtained from product information literature.

^a Degudent, Dentsply France Corporation, Montigny le Bretonneux, France.

^b Bego, Atlantic Codental Corporation, Fontenay sous Bois, France.

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