Materials Science and Engineering C 45 (2014) 519–523

Contents lists available at ScienceDirect

Materials Science and Engineering C

journal homepage: www.elsevier.com/locate/msec

Short communication

Influence of the casting processing route on the corrosion behavior of dental alloys

Rodrigo Galo [a,*], Luis Augusto Rocha [b], Adriana Claudia Faria [a], Renata Rodrigues Silveira [a], Ricardo Faria Ribeiro [a], Maria da Gloria Chiarello de Mattos [a]

[a] Department of Prosthodontics and Dental Materials, School of Dentistry of Ribeirão Preto, University of São Paulo, Brazil
[b] CT2M — Centre for Mechanical and Materials Technologies, Universidade do Minho, Campus de Azurem, Guimarães, Portugal

ARTICLE INFO

Article history:
Received 17 May 2014
Received in revised form 16 August 2014
Accepted 2 October 2014
Available online 9 October 2014

Keywords:
Dental alloys
Corrosion
Casting

ABSTRACT

Casting in the presence of oxygen may result in an improvement of the corrosion performance of most alloys. However, the effect of corrosion on the casting without oxygen for dental materials remains unknown. The aim of this study was to investigate the influence of the casting technique and atmosphere (argon or oxygen) on the corrosion behavior response of six different dental casting alloys. The corrosion behavior was evaluated by electrochemical measurements performed in artificial saliva for the different alloys cast in two different conditions: arc melting in argon and oxygen-gas flame centrifugal casting. A slight decrease in open-circuit potential for most alloys was observed during immersion, meaning that the corrosion tendency of the materials increases due to the contact with the solution. Exceptions were the Co-based alloys prepared by plasma, and the Co–Cr–Mo and Ni–Cr–4Ti alloys processed by oxidized flame, in which an increase in potential was observed. The amount of metallic ions released into the artificial saliva solution during immersion was similar for all specimens. Considering the pitting potential, a parameter of high importance when considering the fluctuating conditions of the oral environment, Co-based alloys show the best performance in comparison with the Ni-based alloys, independent of the processing route.

1. Introduction

From the earliest times until the 1960s, gold was the most commonly used major element in dental alloys [1]. Currently, biomaterials are extensively employed in medicine, and the term "biocompatibility" has gained a wide range of meanings. In the sense of this definition [2], a biomaterial must have the ability to allow a device or construction made from it to accomplish the role for which it was designed. It must also have no undesired systemic or local side effects [2]. The most appropriate host response should be attained, and the material should optimize the clinical performance of the therapy. To satisfy these restrictions, the development of new materials with the desired surface properties is one of the solutions that has been adopted by researchers and specialists [3].

Corrosion of dental alloys can result in biological, functional and esthetic effects. Metal ions and by-products released in the corrosion process can affect cells and tissues in the immediate environment [4] or disseminate into the organism. Depending on the nature and number of metal ions, risks of sensitization and/or toxic effects can occur with harmful effects for the organism [5]. Thus, the clinical use of metal alloys in dentistry requires extensive investigation of their corrosion properties [6].

Casting is one of the methods used to produce shaped pieces built from metallic materials. There are many factors affecting the electrochemical corrosion of dental alloys, one of which is their chemical composition [7]. Additionally, the microstructure, depending on the casting history and the presence of casting defects, is expected to have accentuated effects on metallic ionic release in actual practice. Dental casting alloys can present diverse defects, including shrinkage, porosity, inclusions, micro-cracks and dendritic structures [8]. The literature on the influence of casting procedures on the corrosion resistance of dental alloys has been poor [9–12], and there have been insufficient research studies adequately comparing metal release from dental prosthesis materials in saliva under the same experimental conditions.

In this work, dental alloys were fabricated by 2 different casting methods: centrifugal casting (in contact with air) and electric arc melting induction casting (in an argon-controlled atmosphere). The null hypotheses tested in this study were that there would be significant differences between the different casting methods, and the effects of the process-induced structure and passive film homogeneity on the electrochemical behavior of the dental alloys are discussed.

* Corresponding author at: Department of Dental Materials and Prosthodontics, School of Dentistry of Ribeirão Preto, University of São Paulo, Av. do Café s/n, Monte Alegre, 14040-904 Ribeirão Preto, Brazil.
E-mail address: rogallo@usp.br (R. Galo).

http://dx.doi.org/10.1016/j.msec.2014.10.006
0928-4931/

2. Materials and methods

2.1. Materials and specimen preparation

Six commercially available dental alloys were evaluated, namely Ni–Cr (Vera Bond II; AALBA Dent. Inc.), Ni–Cr–Be (Vera Bond; AALBA Dent. Inc.), Ni–Cr–6Ti (ViStar; Talladium INC), Co–Cr (Remanium; Dentaurum), Co–Cr–Mo (ModellguB; Degussa), and Ni–Cr–4Ti (Tilite Omega; Talladium Inc.). The chemical compositions (wt.%) of the alloys (presented by the manufacturers) appear in Table 1. These materials were used in partial fixed dental prostheses (FDPs), removable dental prostheses (RDPs), or both.

Disk-shaped specimens (13 mm diameter × 4 mm thickness) were mounted in phosphated investments (Rema Exakt; Dentaurum).

Two casting methods were used to produce the specimens: 1) arc melting in a Discovery Plasma machine (EDG Equipamentos e Controles Ltda) by an electric arc in argon atmosphere under controlled oxygen partial pressure and injection of the melted alloy into the mold by vacuum-pressure; and 2) an oxygen-gas flame, in which the alloy was injected into the mold by centrifugation.

The discs were divested after casting, abraded by airborne 100 μm aluminum oxide particles at 80 psi (5.62 kgf/cm^2) and cold mounted with epoxy resin. Each specimen was ground with 1200-grit silicon carbide paper, followed by polishing with 3 and 1 μm diamond suspensions (Struers). Next, the specimens were washed in distilled water and cleaned by ultrasound in ethanol before corrosion testing.

For surface roughness measurements of the polished samples, a profilometer (Perthometer S5P, Feinpruf Perthen) was used at a constant speed of 0.05 mm/s and 0.7 mN of normal force. The height parameter R_a (μm), which was the arithmetical mean of the absolute values of profile departures within the evaluated length, was used for characterization of the surface roughness. The surface roughness statistical calculation, regardless of the polishing protocol, was performed using the average of 3 surface roughness measurements parallel to the diameter of each specimen.

2.2. Electrochemical measurements

The electrochemical measurements were obtained using a potentiostat (PGP201; Radiometer Analytical), controlled with Voltamaster-4 computer software (Voltamaster, Radiometer Analytical). The edge of the specimen area was defined by pressing the specimen against an O-ring, exposing an area of 3.64 cm^2. The potentials were measured against a standard calomel electrode (SCE) (B20B110; Radiometer Analytical) and a platinum plate as the counter electrode, with an exposure area of 1 cm^2 (wire B35M110; Radiometer Analytical).

The electrolyte used was a modified Fusayama artificial solution (AS), consisting of NaCl (400 mg/L), KCl (400 mg/L), $CaCl_2 \cdot H_2O$ (795 mg/L), $NaH_2PO_4 \cdot H_2O$ (690 mg/L), $NaS \cdot 9H_2O$ (5 mg/L), and urea (1000 mg/L) (Sigma Chemical Company, St. Louis, MO, USA). The solution was prepared daily with pure chemical products added to distilled water, and it presented a pH of approximately 5.3. A heated water-bath at 37 ± 1 °C was prepared for immersion of the electrochemical cell for the tests.

Table 1
Chemical composition (wt%) of the alloys used in the study.

Alloy	Composition (wt.%)								
	Ni	Cr	Ti	Co	Si	Nb	Al	W	Mo	Other
Ni–Cr–6Ti	72	17	6	–	–	–	–	–	4.5	0.5
Ni–Cr–4Ti	60–76	12–21	4–6	–	–	–	–	–	4–14	–
Co–Cr	–	25	–	61	1.5	–	–	5	7	0.5
Ni–Cr	75	12	–	–	3.5	4.25	0.25	–	3.5	–
Ni–Cr–Be	77	12.5	–	0.5	–	–	3	5	–	2 (Be)
Co–Cr–Mo	–	28	–	64	–	–	–	–	5	3

For each alloy, the open-circuit potential (OCP) vs. time was recorded over 1 h, and then the OCP was determined and compared with that of other alloys used in dentistry. Next, the potentiodynamic polarization curves were created from −400 mV to +1000 mV vs. SCE, at a scanning rate of 2 mV/s. The test was repeated at least 5 times with each alloy.

2.3. Ionic concentration

After corrosion testing, the metallic ions released by the dental alloys were calculated as a function of the exposed area ($\mu g/cm^2$) considering the volume of the solution. A graphite-furnace atomic absorption spectrometer (AAS) (Model Z-9000, Hitachi) was used to determine the numbers of released Ni, Cr, Co and Ti ions.

2.4. Statistical analyses

The experimental data were statistically analyzed by 2-way ANOVA (dental alloys and casting method) to analyze the influence of the material in artificial saliva. Duncan's test (≤0.05) was chosen for multiple comparisons. The statistical analysis was performed using SPSS software, version 12.0.

3. Results

Fig. 1 (A — plasma; B — oxygen) shows the representative curves of the open-circuit potential evolution over time. In Fig. 2, typical

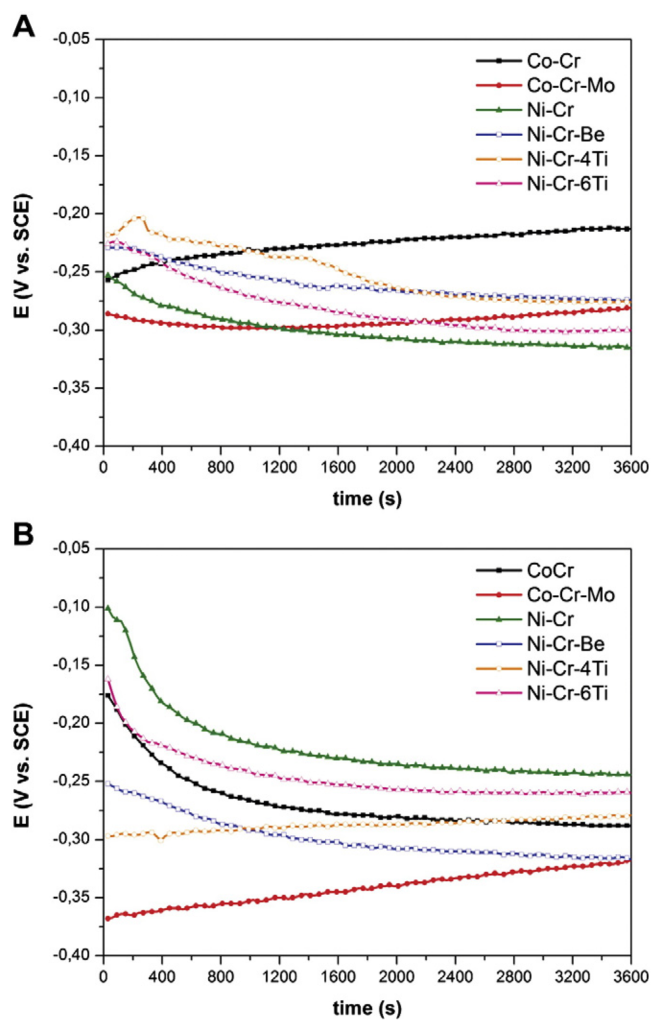

Fig. 1. Curves of the evolution of the open-circuit potential with time (A — plasma; B — oxygen).