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Elemental ion release from four different fixed prosthodontic materials

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ABSTRACT

Objective. Elemental release is important because it plays a significant role in material biocompatibility. The aim of this study was to investigate the release of metal ions from four fixed prosthodontic materials.

Methods. Specimens were prepared using the conventional lost wax technique for gold and nickel–chromium (Ni–Cr) alloys, and by cutting blocks and bar for CAD–CAM ceramic and stainless-steel (St-St) alloy, respectively. All specimens were polished (600 grit SiC paper), and ultrasonically cleaned with ethanol for 5 min. After they were immersed in 0.9% sodium chloride (NaCl) and 1% lactic acid, and were kept at 37 °C for 7 days, the elemental release ($\mu g/cm^2$) from each material was analyzed by using inductively coupled plasma mass spectroscopy. The rate ($n = 5$) was statistically analyzed by ANOVA/Tukey test ($p < 0.05$). Two immersion blank solutions were used as a negative control group.

Results. Higher elemental release (mean ± S.D.) of all elements from all materials was evident into the lactic acid solution except for Ag. In the gold alloy, there was significant difference ($p < 0.05$) between Zn and other released elements in the NaCl solution, and it also revealed significant difference between Pd or Ag and Cu which detection value was more than Zn (but no statistical difference) into lactic acid solution. The Ni was significantly more released from Ni–Cr alloy than the other elements into both NaCl and lactic acid solutions. The same was observed for Fe released from St-St alloy. There was more significant release of K than Al from CAD–CAM ceramic in only NaCl solution.

Significance. Transient exposure of tested materials to an acidic environment is likely to significantly increase the elemental release from them. The significant higher release of Ni from Ni–Cr alloy, and Zn, Cu from gold alloy was evident.

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1. Introduction

Many different types of alloys are now available in the market to be used for fixed prosthodontics. In the developed countries like the United States, Europe and Japan, cast gold alloy and all ceramic materials are the most widely used. In developing countries like the Middle East and South America, base metal alloys and prefabricated stainless-steel crowns are the most prevalent types. However, the common criterion for all these fixed prosthodontic materials is the permanent existence of them in the oral cavity for prolonged time without the ability to be removed by the patient. Therefore, knowledge about the elemental release from these materials into the oral cavity in regards to quantification is of great importance.

The release of elements from dental casting alloys was mainly measured using either atomic absorption spectroscopy

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(AAS), inductively coupled plasma atomic emission spectrometry (ICP-AES), or inductively coupled plasma mass spectrometry (ICP-MS). All of these have been used to measure the elemental release from dental casting alloys in different environments. Atomic absorption spectroscopy has been used with cell culture medium [1–3], different biological media (saline, saline with 3% bovine serum albumin, or complete cell culture medium with 3% serum) [4], or pH 7 phosphate buffer solution [3]. While inductively coupled plasma mass spectrometer was used with artificial oral saliva [5], inductively coupled plasma atomic emission spectrometry was used with artificial oral saliva [6], cell culture medium [7], pH 3.5, pH 6 phosphate buffer solution, or pH 3.5 mixture of lactic acid and sodium chloride [8].

Accordingly, several findings had been stated about the elemental release from many different dental casting alloys that have different compositions. However, generalization of these statements for all dental casting alloys cannot be applied because of different facts. First, multiple phases will often increase the elemental release from alloys [9]. Second, certain elements have an inherently higher tendency to be released from dental alloys, regardless of the alloy composition [2,9]. Third, certain environmental conditions around the alloy will affect the elemental release. For example, a reduction in pH will increase elemental release from some dental alloys [1,10].

Regarding dental ceramics, the evaluation of mass release from ceramics is not common in the literature, although several studies demonstrated such mass release. The leakage of inorganic ions from ceramics was found to occur in aqueous media [11]. Under more severe conditions (as the concentration of alkali ions increases), the Si–O–Si bonds may be broken, and the entire glass structure may be impaired [12]. Generally, the elemental release from ceramic materials may be influenced by many factors, such as the composition of the ceramic material, the chemical character of the corrosive medium, the exposure time, and the temperature [13]. In addition, the multiphase microstructure of many dental ceramic materials results in complicated corrosion modes, as each phase is likely to react individually to the corrosive medium [12]. In a previous study [14], different dental ceramic materials did not respond uniformly to a specific corrosive environment. Therefore, the same chemical durability cannot be generalized for all types of ceramics.

Generally speaking for all fixed prosthodontic materials, elemental release from these materials plays a great role in their biocompatibility because the release of elements from these materials is mandatory for adverse biological effects such as cytotoxicity, mutagenicity, and allergy. Occasionally, the host response to the elemental release differs according to the nature and amount of the released elements. Thus, the objective of this study is to evaluate the ion release from four different commonly used fixed prosthodontic materials (type IV gold alloy, CAD–CAM ceramic material, nickel–chromium alloy and stainless-steel alloy) into two different immersion solutions (0.9% sodium chloride and 1% lactic acid).

2. Materials and methods

2.1. *Preparation of samples*

The materials tested are listed in Table 1. Specimens of each casting alloy (gold and nickel–chromium alloys) were prepared in the form of rectangular plates (10 mm × 15 mm × 1.2 mm). The wax plates were invested in molds with a phosphate-bonded investment material (Formula 1, Whip Mix Corp., Louisville, KY). The mixing procedures and burnout schedules (gold alloy: 700 °C; nickel–chromium alloy: 900 °C) followed the manufacturer's instructions. Then, both alloys were cast using a conventional broken-arm centrifugal casting unit (Kerr Centrifico, Kerr Manufacturing Company, Orange, CA). To cast the nickel–chromium alloy, oxygen gas was used in conjunction with an oxyacetylene gas torch. After casting, the specimens were air-abraded with 50 μm Al_2O_3 to remove the investment material. The specimens of the tested stainless-steel alloy were prepared as discs (14 mm in diameter and 2 mm in thickness) by cutting a bar using a cutting machine (Allied, High Tech Products Inc., Rancho Dominguez, CA). The composition of this stainless-steel alloy is similar to that of prefabricated stainless-steel crowns (3M stainless-steel crown, 3M ESPE, St. Paul, MN). In addition, rectangular plates (12.5 mm × 14.0 mm × 1.8 mm) of CAD–CAM ceramic material were prepared by cutting the IPS Empress CAD blocks. Surfaces of all specimens were polished using silicon carbide paper starting at Nos. 120, 240, 320, and 400, and finished by No. 600. The specimens were ultrasonically cleaned with 95% ethanol for 5 min and in distilled water for another 5 min.

2.2. *Immersion (extraction solutions)*

Two different immersion solutions for elemental extraction were prepared: (1) 0.9% sodium chloride (NaCl) (Alfa Aesar,

Table 1 – Materials used.

Material	Manufacturer	Product	Composition (wt.%)
Type IV gold alloy	Dentsply, Konstanz (Germany)	Ney-Oro 60	56 Au, 19.9 Ag, 4 Pd, 17 Cu, and 3 Zn
Machinable ceramic	Ivoclar-Vivadent, Liechtenstein (Germany)	IPS Empress CAD blocks	>98 SiO_2, Al_2O_3, K_2O, CaO, BaO <2 TiO_2 and pigments
Nickel–chromium alloy	Ticonium Comp., Albany, NY (USA)	T-3 C&B	76.5 Ni, 14 Cr, 4.5 Mo, 2.5 Al, and 1.6 Be
Stainless-steel alloy	B&L Metals Inc., Huntington, NY (USA)	St.St 321	67–70 Fe, 9–12 Ni, 17–19 Cr, 0.08 C, 2 Mn, and 0.75 Si

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