Original Article

An Investigation on Metallic Ion Release from Four Dental Casting Alloys

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Abstract:

Statement of Problem: Element release from dental casting alloys into the oral environment is of clinical concern and is considered to be a potential health problem to all patients.
Purpose: The aim of this study was to investigate the metallic ion release of four base metal alloys.
Materials and Methods: Two Ni-Cr (Minalux and Supercast) and two Co-Cr alloys (Minalia and Wironit) were examined. Nine specimens of each type were prepared in 13×11×1.4 mm dimensions and each of the four alloys (3 specimens per group) were conditioned in artificial saliva at 37˚c for one, three and seven days.
The conditioning media were analyzed for element-release using Inductive Coupled Plasma Atomic Emission Spectrophotometer (ICPAES). Collected data were statistically analyzed using ANOVA and Duncan multiple range test ($P< 0.05$).
Results: The greatest amount of element release was seen after seven days (134.9 ppb Supercast, 159.2 ppb Minalux, 197.2 ppb Minalia, and 230.2 ppb Wironit). There was a significant difference between the released elements from the alloys after the three conditioning times ($p<0.001$).
Conclusion: Element release from the studied alloys is proportional to the conditioning time. The Ni-Cr alloys tested in this investigation were more resistant to corrosion as compared to the Co-Cr alloys in artificial saliva. Supercast had the highest corrosion resistance.

Key Words: Corrosion; Ion release; Base metal alloys; ICPAES; Biocompatibility; Dental alloys; Nickel chromium alloys; Cobalt chromium alloys

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INTRODUCTION

Corrosion is a chemical process with adverse effects on other dental alloy properties such as esthetics, strength and biocompatibility. Identification and quantification of the released elements is the most relevant measure of biocompatibility. Systemic and local toxicity, allergy, and mutagenecity all result from elements in the alloy being released during corrosion. The biologic response to released elements depends on their type and quantity, the duration of tissue exposure and other factors [1].
The quantity of corrosion is related to alloy composition, manipulation, pH of environment, surface roughness, alloy

microstructure, and other factors [1-8].
Prediction of alloy corrosion based on its composition is sometimes not accurate because multiple phases often increase the released elements. In addition, certain substances have an inherently higher tendency to be released from dental alloys regardless of the composition of the alloy. Elemental release may be affected by certain environmental conditions [1], for example, pH reduction can cause an increase in the release of certain elements in dental alloys [8,9].
Noble metal alloys have been found to be ideal for dental restorations, because of their corrosion resistance and biocompatibility [10-13]. The rise in the price of gold led to a widespread use of base metal alloys. The base metal alloys (excluding the titanium based system) generally have superior mechanical properties compared to noble or high-noble alloys including hardness, high elastic modulus, etchability for resin bonding and high melting range. These alloys also have several negative characteristics such as markedly higher corrosion in an acidic environment, difficult finishing and polishing features, dark and thick oxides, risk of patient allergy and difficult soldering and casting [14].
The aim of this study was to evaluate the metallic ion release from four base metal alloys. The hypothesis was that there were differences between the quantities of ion release from these four base metal alloys.

MATERIALS AND METHODS

The dental casting alloys used in this experimental study consisted of two nickel-chromium alloys, Supercast (Thermabond alloy MFG, LosAngeles, CA) and Minalux (Mavadkaran Iran Co, Tehran, Iran) and two cobalt-chromium alloys, Wironit (Bego, Bremen, Germany) and Minalia (Mavadkaran Co, Tehran, Iran). The chemical compositions of these alloys are given in Table I. Nine rectangular specimens (11×13×1.4 mm) from each casting alloy were fabricated.

Table I: Alloys composition used in this study.

Alloy	Composition (wt %)
Minalux	Ni: 75 %; Cr:12 %; Mo:3.5 %
Supercast	Ni: 75 %; Cr:14 %; Mo:5 %; Be: 1.6 %
Minalia	Cr: 31 %; Co: 62 %; Mo: 5%
Wironit	Cr: 28 %; Co: 64 %; Mo: 5%

The wax pattern was constructed using base plate wax (Modelling wax, Dentsply Ltd, Weybridge, UK). The wax was sprued, invested and cast in phosphate bonded investment material (Accufit, Prevest Co, Cleveland, OH) using a conventional lost-wax technique. All processes of wax pattern, investment, burn out and casting were carried out according to the manufacturer's instructions. The specimens were sandblasted using 250 µm aluminum oxide to remove the investment material. The sprues were removed and the specimens were finished and polished using finishing stone burs, brown, green, pink and black respectively, followed by green rubber polishing wheels (Bego, Bremen, Germany). Finally iron oxide rouge polishing compound (Bego, Bremen, Germany) was applied. All types of alloy specimens were finished and polished separately using separate instruments.
The specimens were soaked in a detergent solution for 5 minutes, scrubbed using a soft brush and rinsed under tap water for 5 minutes and distilled water for another 5 minutes. The specimens were then placed in 95% ethanol and cleaned by sonication for 5 minutes, then removed and placed in distilled water and cleaned by sonication for another 5 minutes. Finally the specimens were autoclaved at a temperature of 121ºC for 16 minutes.
The conditioning media used in this test was artificial saliva made in the laboratory (pH=6.7) [13]. The nine specimens of each type of alloy were divided into three groups

and each specimen was immersed in 4.7 ml artificial saliva at 37°C for one, three and seven days. In the present study, the ratio of surface area of specimens to the volume of conditioning media is standardized according to ISO 10271 [15].

The conditioning media was analyzed for release of Ni, Cr, Co, Mo, and Be ions using an Inductive Coupled Plasma Atomic Emission Spectrophotometer (ICPAES; Maxim, Fisons Co, USA). Triplicate absorbance readings per element were made for each sample. Each reading was used to determine the mean concentration of the different elements in part per billion (ppb) released from the alloys.

The mean concentrations of elements released from the specimens were presented in ppb with a detection limit of 6 ppb. Two-way analysis of variance followed by Duncan test was used to analyze the mean (standard deviations) of the elements released from the tested alloys. Statistical differences were defined at $P<0.05$ level of significance.

RESULTS

The results of the elements released from the tested alloys in artificial saliva for the three conditioning times measured by ICPAES are shown in Table II.

Overall, after 7 days of conditioning time, Wironit had the highest amount of element release (Co) followed by Minalia (Co). Supercast showed the least amount of element release (Ni).

Statistical analysis of the elements released for the three conditioning times, showed that the type of alloy and the conditioning time had a statistically significant effect on the amount of element release ($P<0.001$).

Analysis of the Ni levels released from the tested Ni-Cr alloys at the studied time intervals, revealed a statistically lower amount of release from Supercast as compared to Minalux ($P<0.001$). Similarly, the Cr ion levels released by Minalux and Minalia were higher than those released by Supercast and Wironit on the first day ($P<0.001$).

There was no statistically significant

Table II: Mean values (standard deviation) of element release in ppb from the tested alloys in artificial saliva after either one, three or seven days of conditioning.

Alloy	Conditioning time(day)	Ni	Cr	Co	Mo	Be	Total element released
Minalux	1 day	63.6(1.5)	10.6(1.1)	-	-	-	74.2
	3 days	40.6(1.1)	10(0)*	-	15.6(0.5)	-	116.2
	7 days	126(2)	14.6(1.1)**	-	18.6(1.1)	-	159.2
Supercast	1 day	55.3(1.1)	-	-	-	-	55.3
	3 days	83.6(3)	8.8(0.76)*	-	7.6(0.5)	-	100
	7 days	110.6(1.1)	12(1)	-	12.3(0.5)***	-	134.9
Minalia	1 day	-	9.6(0.5)	103.3(1.1)	15(1)	-	127.9
	3 days	-	10.3(0.5)*	106(2)	12.6(0.5)	-	128.9
	7 days	-	17.6(0.5)	165(5.5)	14.6(1.1)***	-	197.2
Wironit	1 day	-	-	83.3(1.1)	-	-	83.3
	3 days	-	9.3(1.1)*	96.6(1.1)	17(1)	-	122.9
	7 days	-	13.6(0.5)**	190.3(5.8)	26.3(2)	-	230.2

Most data showed significance difference (P<.001); – = not detected or below detection limit (6 ppb), * No significance difference (p=0.143), ** No significance difference (p=0.195), *** No significance difference (p=0.068)

difference in the amount of Cr released from the alloys tested after the third day (P=0.143).
After 7 days, Minalia and Supercast released the significantly highest and lowest amounts of Cr ions, respectively (p<0.001). The difference in Cr release was not significant between Minalux and Wironit during the same time period (P=0.195).There was a statistically significant difference in the amount of Co released from Co-Cr alloys over the three test periods (p<0.001). Minalia alloy released statistically significant different and increasing levels of Co ions after days 1 and 3, but on the seventh day, Wironit released a higher amount of Co ions (p<0.001).
Mo ions were released only from Minalia alloy on the first day. Wironit released the significantly highest and Supercast released the lowest quantity of Mo ions after three days (p<0.001). There was a significant difference in the amount of Mo ions released from the tested alloys after 7 days (p<0.001). Wironit followed by Minalux released the highest amount. There was no significant difference in the release of Mo from Supercast and Minalia after 7 days (p=0.068). Release of Be from Supercast was not detected in any of the conditioning periods.

DISCUSSION

Corrosion is measured in a number of ways. It can be determined visually by observing the alloy surface, by many forms of electrochemical tests that measure elemental release through the flow of the released electrons or indirectly by tests that measure the released elements by spectroscopic methods [1]. Although the alloys are considered to have good corrosion resistance, both in vitro and in vivo studies have shown that metallic ions can be released into the surrounding environment [1, 16].
In this study chemical corrosion and ion release of four dental casting alloys were studied. The results of ICPAES showed an increase in the amount of elements released in relation to conditioning time. The increase in release is associated with the corrosion susceptibility of the alloys [11]. The greater amount of element release (especially Ni) from Minalux (P<0.001) as compared to Supercast, could be related to the lower content of Cr and Mo in Minalux. Supercast alloy has more Cr and Mo in its composition, thus it was less susceptible to corrosion. Cr is added to nickel-based alloys to improve their ability to form a protective oxide film on the surface. It has been suggested that a chromium content of approximately 16 to 27 percent can provide an optimum corrosion resistance for the nickel-base alloys. In addition, Mo plays an active role in the formation of the oxide layer [17, 18]. Thus, an increasing concentration of Cr and Mo on the surface layer may synergistically lower the dissolution rates of metals [11].
The phase structure of an alloy is critical to its corrosion properties and its biocompatibility. The interaction between the biologic environment and the phase structure is what determines which elements will be released and therefore how the body will respond to the alloy. An alloy does not necessarily release elements in proportion to its composition. Multiple phases will often increase the elemental release from alloys [1]. For corrosion resistance, in addition to nobility, an alloy requires a homogenous microstructure. It has been shown that Ni-Cr alloy microstructure is not single phase and accordingly does not present chemical homogeneity. This means that there are plates one beside the other with a different composition that act as electrochemical cells [16].
Regarding the studied Co-Cr alloys, the element release was higher in Wironit than Minalia. This could be due to Wironit's lower content of Cr.
Berelium increases the corrosion of dental

alloys, but its release from Supercast was below the determined detection limit of 6 ppb for all tested periods.

Cr release from the studied Ni-Cr and Co-Cr alloys were much lower in comparison to the release of Co and Ni. Other studies have also reported similar low Cr release in artificial saliva, lactic acid and saline solution [11, 19].

In the present study the Co-Cr alloys were more corrosion-susceptible than the Ni-Cr alloys. This finding was in agreement with the results of Al-Hiyasat's et al study [11]. Geis-Gerstorfer et al [20] showed that the Co-Cr-Mo alloys were more corrosion-resistant as compared to the Ni-Cr-Mo alloys, which may be related to the conditioning media. Different types of conditioning media such as cell culture media, artificial saliva, saline and diluted acids have been used in pervious studies [11,19,21-24]. The media contains various minerals or organic constituents that may have an effect on the corrosion susceptibility of alloys. Varying pH, salt and protein contents may result in greater element-release of the alloy [11]. Different studies have used different conditioning media: artificial saliva was used in the present study, Al-Hiyasat et al [11] employed distilled water and Geis-Gerstorfer et al applied a combination of lactic acid and sodium chloride [20]. The artificial saliva used in this study is a less aggressive environment [25].

CONCLUSION

Within the limitation of this study, the following conclusions were drawn**:**

1- The Ni-Cr alloys tested in this study were more resistant to corrosion in artificial saliva conditioning media, as compared to Co-Cr alloys.

2- The Supercast alloy had the least amount of element release and Wironit was the most susceptible to metallic ion release among the four tested dental alloys.

3- The amount of element release increased with increasing conditioning-time.

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بررسی میزان رهاسازی یونهای فلزی از چهار نوع آلیاژ کستینگ

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چکیده

بیان مسئله: رهاسازی عناصر شیمیایی از آلیاژهای کستینگ دندانپزشکی از اهمیت کلینیکی به سزایی برخوردار است و به عنوان تهدیدی بالقوه برای سلامتی بیماران به شمار می‌رود.

هدف: هدف از مطالعه حاضر تعیین میزان رهاسازی یونهای فلزی از چهار نوع آلیاژ بیس‌متال است.

روش تحقیق: دو نوع آلیاژ نیکل- کروم (مینالوکس و سوپرکست) و دو نوع آلیاژ کرم- کبالت (Minalia و Wironit) مورد بررسی قرار گرفتند. نُه نمونه از هر نوع آلیاژ به ابعاد ۱۴ × ۱۱ × ۱۳ میلی‌متر در سه زیرگروه سه تایی به مدت یک، دو و هفت روز در محلول بزاق مصنوعی غوطه‌ور شدند، سپس میزان رهاسازی عناصر با استفاده از روش Induction Coupled Plasma Atomic Emission Spectrophotometer (ICPAES) اندازه‌گیری شد. آزمون آماری Duncan multiple range و با در نظر گرفتن سطح معنی‌داری کوچکتر از ۰/۰۵ استفاده گردید.

یافته‌ها: حداکثر میزان رهاسازی یون‌ها در روز هفتم مشاهده شد (۱۳۴/۹ PPb در Supercast، ۱۵۹/۲ PPb در Minalox، ۱۹۷/۲ PPb در Minalia و ۲۳۰/۲ PPb در Wironit) میزان رهاسازی آلیاژها در زمانهای مختلف با هم اختلاف آماری معنی‌داری نشان داد. (P<۰/۰۰۱)

نتیجه‌گیری: میزان رهاسازی عناصر از آلیاژهای تحت مطالعه، متناسب با زمان قرارگیری در محیط تغییر می‌یابد. آلیاژهای نیکل- کروم در مطالعه حاضر مقاومت بیشتری در برابر خوردگی در مقایسه با آلیاژهای کرم- کبالت از خود نشان دادند. آلیاژ Super cast بالاترین میزان مقاومت را دارا بود.

واژه‌های کلیدی: خوردگی؛ رهاسازی یون؛ آلیاژهای بیس‌متال؛ ICPAES؛ زیست سازگاری؛ آلیاژهای دندانپزشکی؛ آلیاژهای نیکل- کروم؛ آلیاژهای کرم- کبالت

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