Short Communication

In Vitro Release of Elements from Prosthodontic Base Metal Alloys: Effect of Protein-Containing Biologic Environments

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Purpose: This study aimed to investigate the release of nickel, copper, zinc, cadmium, magnesium, and lead from prosthodontic base metal alloys into protein-containing biologic solutions. ***Materials and Methods:*** Dissolution experiments were conducted in either 3% Dulbecco's Modified Eagle Medium or 3% bovine serum albumin solutions for 7 weeks. ***Results:*** The protein-containing dissolution solutions and dissolution time did not have a significant effect on release of elements from the alloys (Kruskal-Wallis, $P > .05$). ***Conclusions:*** The amount of the released elements was well below the dietary intake levels of these elements. This study is important given the widespread use of the base metal alloys and the continuing public concerns/questions regarding the health benefits/risks associated with these materials. *Int J Prosthodont 2006;19:250–252.*

Proteins can affect the corrosion behavior of some metals, and their presence can either inhibit or accelerate corrosion.[1] Interaction of base metal alloys with protein-containing solutions is relatively unstudied. Therefore, this study aimed to investigate the long-term release of nickel (Ni), copper (Cu), zinc (Zn), cadmium (Cd), magnesium (Mg), and lead (Pb) from base metal dental casting alloys into protein-containing biologic solutions and to provide baseline data for our prospective clinical study (Table 1). The elements were chosen considering *(1)* their lability and biologic roles (Ni, Cu, Zn), and *(2)* the release of minor or potentially contaminating ions (Cd, Mg, Pb).

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Materials and Methods

Dissolution experiments were conducted in either 3% Dulbecco's Modified Eagle Medium (DMEM) or 3% bovine serum albumin (BSA) solutions for 7 weeks. Element analyses were made using an atomic absorbtion spectrophotometer (AAS) (Shimadzu, AA-680). Ni, Cu, Zn, and Mg were analyzed using air/acetylene flame AAS at the wavelengths of 232.0 nm, 324.8 nm, 213.9 nm, and 285.2 nm, respectively. Cd and Pb were analyzed using graphite furnace atomic absorption spectrophotometry (GFAAS) at the wavelengths of 228.8 nm and 217.0 nm, respectively.

The effect of dissolution solutions on element release was investigated for 3 different time intervals: the first day, the first week until the end of the fourth week, and from the end of the fourth week until the end of the seventh week.

The quantity of the released elements was calculated using the following formula:

(amount of solution) × (element concentration in each test solution) – (mean element concentration in blank controls) / (surface area of specimen)

Element concentration below the blank control was considered zero. Data did not show a normal distribution. Medians of the amounts of the elements released are given in Table 2. Data analyses were made using statistical software (SPSS 11.0 for Windows).

Table 1 Chemical Compositions (% by weight) of the Tested Alloys

Wirolloy	Wiron99	Remanium CS	Remanium 2000
Ni 63.2	Ni 65	Ni 61	Co 61
Cr 23.0	Cr 22.5	Cr 26	Cr 25
Fe 9.0	Mo 9.5	Mo 11	Mo 7
Mo 3.0	Nb 1.0	Si 1.5	W 5
Si 1.8	Si 1.0	Fe < 1	Si 1.5
C ≤ 0.1	Fe 0.5	Ce < 1	Others: Mn,
	Ce 0.5	Al < 1	C, Ce, N
	C max.0.02	Co < 1	

Information provided by manufacturers (Wirolloy and Wiron99, Bego; Remanium CS and Remanium 2000, Dentaurum). Cr = chromium; Fe = iron; Si = silicon; C = carbon; Mo = molybdenum; Ce = cerium; Co = cobalt; Al = aluminium; W = tungsten; Mn = manganese; N = nitrogen; Nb = niobium.

Table 2 Medians of the Quantities of the Elements Released from the Alloy Specimens (n = 6) in Each Dissolution Period

Time/ dissolution solution	Zn (μg/cm²)	Cu (μg/cm²)	Ni (μg/cm²)	Cd (μg/cm²)	Mg (μg/cm²)	Pb (μg/cm²)
Wirolloy						
DMEM						
24 h	0.08	1.48	0.23	0.00103	2.29	0.00068
0–4 wk	0.09	1.71	0.34	0.00028	3.09	0.00104
5–7 wk	0.06	1.85	0.31	ND	3.44	0.00008
BSA						
24 h	0.35	3.06	0.31	0.00039	2.45	ND
0–4 wk	0.26	3.06	0.41	0.00042	2.54	ND
5–7 wk	0.17	1.67	0.14	0.00013	7.23	0.00618
Wiron99						
DMEM						
24 h	0.06	1.76	0.19	0.00048	8.01	0.00048
0–4 wk	0.15	2.22	0.19	0.00006	6.53	0.00201
5–7 wk	0.08	2.22	0.19	0.00048	2.45	ND
BSA						
24 h	0.89	2.59	0.36	0.00014	3.53	ND
0–4 wk	0.32	2.78	0.21	0.00043	7.63	0.00199
5–7 wk	0.14	2.99	0.43	0.00025	7.62	0.00138
Remanium CS						
DMEM						
24 h	0.10	2.47	0.39	ND	6.49	0.00083
0–4 wk	0.11	2.19	0.45	0.00258	8.15	ND
5–7 wk	0.11	2.22	0.37	0.00025	3.84	ND
BSA						
24 h	0.14	2.85	0.60	0.00152	3.19	0.00285
0–4 wk	0.09	2.50	0.51	0.00005	2.28	ND
5–7 wk	0.11	2.92	0.20	0.00027	3.44	0.00217
Remanium 2000						
DMEM						
24 h	0.08	2.96	0.47	0.00057	2.65	0.00178
0–4 wk	0.16	1.85	0.51	0.00006	1.46	0.00361
5–7 wk	0.29	3.47	0.63	0.00006	2.61	0.00200
BSA						
24 h	0.21	3.09	0.43	0.00190	3.37	0.00174
0–4 wk	0.17	2.99	0.65	0.00105	3.50	ND
5–7 wk	0.17	3.06	0.86	0.00291	4.03	ND

ND = not detectable.

Table 3 Average Thresholds* for Toxic Effects and Safe Ranges of Population Mean Dietary Intake for Zn, Cu, and Ni[4]

Element	Average threshold for toxic effects	Safe ranges of population mean intake
Zn	60 mg/d	45 mg/d
Cu	12 mg/d	12 mg/d
Ni	600 μg/d	140–150 μg/d

*For adults aged 18 to 60+.

Table 4 Maximum Tolerable Dietary Intake and Highest Amount Allowed in Drinking Water for Pb and Cd[4,5]

Element	Maximum tolerable intake	Highest amount allowed in drinking water
Pb	2–64 μg/wk	0.01 mg/L
Cd	65 μg/d	0.003 mg/L

According to the statistical results, the protein-containing dissolution solutions and dissolution time did not have a significant effect on the element release from the alloys (Kruskal-Wallis, $P > .05$). Alloys showed similar release behavior in DMEM and BSA dissolution solutions. Amounts of the released elements were almost constant throughout the experimental period.

Discussion

It has been previously reported that protein-containing solutions could accelerate the release of elements from alloys. Proteins can interact with the corrosion reactions in 2 ways: They can bind to metal ions and transport them away from the interface, therefore encouraging further dissolution; or proteins may be absorbed onto the metal surface, thus restricting the diffusion of oxygen to the surface and making it harder for the surface to repassivate.[2] Both of these mechanisms may decrease the corrosion resistance of the alloy. Nelson et al reported that 3% BSA solution caused more elemental release from base metal alloys than the cell culture medium (DMEM) and saline solution.[1] In the present study, BSA solution that contained only proteins did not have an effect on element release when compared with the cell-culture medium that was essentially a saline-protein mixture with a variety of other salts, buffers, and nutrients added for cellular nutrition. Different results may be attributed to the different alloys used in our study. It is known that alloys may have unique responses under the same condition.[3]

All of the alloys released elements throughout the experimental period. Among these Zn, Cu, and Ni are essential elements for the body.[4] The average thresholds for toxic effects and safe ranges of population mean dietary intake for Zn, Cu, and Ni are given in Table 3. On the other hand, the other minor and possibly contaminated elements determined in the alloy extracts Cd, Pb, and Mg are not classified as essential elements. Both Cd and Pb are heavy metals. Cadmium is classified as carcinogen 2A and Pb as carcinogen 2B. Maximum tolerable intake and highest amounts allowed in drinking water for Pb and Cd are given in Table 4.[4,5] Mg is found in the body mainly in the bones, and daily dietary intake is approximately 190 to 420 mg. When the amounts of the elements released from the alloys were compared with the dietary intake levels, none of the released elements reached levels that can cause systemic toxic effects.[4,6] However, all of these elements may have adverse effects locally on the periodontium.[3] Possible contamination sources of the elements that are not found in the nominal compositions of the alloys should be investigated. Additionally, clinical studies are needed to investigate the effects of metal ions on oral and systemic health.

References

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