Studies on the Chemical Composition of Welded Base Metal Dental Alloys

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Small variations of the chemical composition of dental alloys may affect the corrosion performance. Experimental studies demonstrated the importance of the content of different components in dental alloys. Chemical analyzes were performed to assess the base metal dental alloys chemical composition of the welded joints in order to be related to the corrosion behaviour. There were no significant differences in chemical composition in the welding between different types of welds. The poor corrosion behaviour is probably due to the high content of iron.

Keywords: chemical composition, welds, dental base metal alloys

The corrosion properties of metal alloys depend on a number of factors: alloy composition, potential values, strain rate, surface roughness, degree of oxidation, acidity (*p*H) and temperature of media, mixing velocity of solution, and the presence of corrosion inhibitors. The oral cavity, on the other hand, is a dynamic environment that often undergoes rapid and substantial changes in temperature and pH, typically instigated by changes in the diet and unconscious regular contact with metal ions. Other factors that place severe demands on restorative materials in the oral cavity include occlusal loading, which results in mechanical wear and corrosion [1,2].

The most important properties of dental alloys are biocompatibility, corrosion resistance, mechanical properties and ease of handling, all determined by the metals contained in the alloy [3 - 5]. The microstructure and chemical composition of alloys have strong influence on the corrosion behaviour, which can be assessed by chemical and electrochemical tests [3,6].

Small variations of the chemical composition of dental alloys may affect the corrosion performance. From this point of view, Be-free Ni-Cr alloys are preferred for dental use and extensive research has been carried out on corrosion resistance of Ni-Cr-based alloys relative to bonding composite . Different studies found that the Ni-Cr-based alloy exhibits significant corrosion and that a high quantity of ions is released, and that, due to the allergic effect of Ni and Cr ions, the use of Ni-Cr-based alloys should be considered carefully [7,8].

Experimental studies demonstrated the importance of the content of different components in dental alloys. The presence of higher Cr (25 wt.%) in the bulk alloy led to higher corrosion resistance compared with a lower Cr (12 wt.%) content. Some changes in microstructure were observed during the study and influenced the corrosion behaviour of the tested alloys. The lower corrosion resistance also led to a greater release of Ni ions to the medium and the quantity of Co ions released from the Co-Cr-Mo dental alloy was relatively small in the solutions [9]

The alloy type has role in the initiation and propagation of corrosion [10].

Chemical analyzes were performed to assess the chemical composition of the welded joint to be related to the corrosion behaviour.

Experimetal part

Studies were carried out on seven alloys, 3 of them Ni-Cr for fixed prostheses frameworks and 4 Co-Cr, 2 for fixed prosthesis and 2 to manufacture frameworks for removable partial dentures. As filler material for welding wires based on Ni-Cr and Co-Cr alloys, with a diameter of 0.35 mm were used.

For the chemical analyzes 68 plates were cast, which were welded similar and dissimilar with mycoplasma and laser, in butt joint configuration, without filler material, bilaterally and with the addition of specific filler material for each weld.

Chemical analyzes were performed with an integrated EDS electron microscope (SEM) type Inspect S + EDAX GENESIS XM + 2i. The Netherlands). EDS is an SEM type detection unit Sapphire crystal Si (Li) and SUTW window for the detection of all chemical elements from beryllium (Z = 4), to uranium (Z = 92).

Results and discussions

Chemical analyzes were performed for all similar and dissimilar welds. tables 1 to 8 show the chemical composition of the welded samples compared to the base materials.

The chemical composition of the Wirolloy NB alloy, for all the samples contents a small amount of Fe or is absent, which may explain the better corrosion behaviour from the three Ni-Cr alloys taken in the analysis. For this alloy changes are larger for microplasma weldings (fig. 1) compared to the laser weldings (fig. 2).

At the other two Ni-Cr analyzed alloys, Wiron 99 and Heraenium NA, not significant differences in the chemical composition in the welded areas of different types of welds were found.

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No.	Alloy	Co (%)	Cr (%)	Ni (%)	Mo (%)	Si (%)	Fe (%)	Nb (%)	Ce (%)	Al (%)	Ca (%)
1	Wiron 99 alloy	-	22.5	65	9.5	<1	<1	<1	<1	-	-
2	microplasma welded, without filler	7.41	21.41	54.45	13.54	1.72	0.34	0.92	0.21	-	-
3	microplasma welded, with filler	-	21.58	63.48	9.32	1.28	0.51	1.78	0.37	1.53	0.17
4	laser welded, without filler	3.89	20.35	60.24	11.69	1.90	0.49	1.44	-	-	-
5	laser welded, with filler	3.58	20.89	61.06	12.18	0.97	0.70	-	-	0.62	-

Table 1
CHEMICAL COMPOSITION OF THE WELDED WIRON 99 ALLOY SAMPLES COMPARED TO THE BASE ALLOY

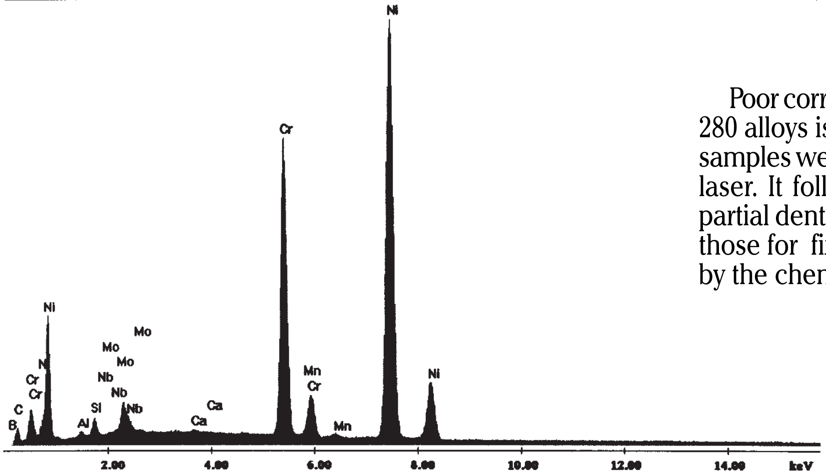
No.	Alloy	Cr (%)	Ni (%)	Mo (%)	Si (%)	Mn (%)	Fe (%)	Nb (%)	C (%)	B (%)	Al (%)	Ca (%)
1	Wirolloy NB alloy	25	67	5	1.5	<1	-	<1	<1	<1	-	-
2	microplasma welded, without filler	17.87	48.40	3.60	1.38	0.54	-	0.68	14.71	12.11	0.59	0.13
3	microplasma welded, with filler	17.17	48.29	4.33	0.65	0.52	-	1.33	12.14	14.16	1.27	0.13
4	laser welded, without filler	23.08	65.95	7.14	2.60	0.72	0.50	-	-	-	-	-
5	laser welded, with filler	22.48	65.37	9.60	1.47	0.56	-	-	-	-	0.53	-

Table 2
CHEMICAL COMPOSITION OF THE WELDED WIROLLOY NB ALLOY SAMPLES COMPARED TO THE BASE ALLOY

No.	Alloy	Co (%)	Cr (%)	Ni (%)	Mo (%)	Si (%)	Mn (%)	Fe (%)	Nb (%)	Ca (%)	Ta (%)	Al (%)
1	Heraenium NA alloy	-	24	59.3	10	<2	<2	<2	<2	-	-	-
2	microplasma welded, without filler	-	21.99	53.65	10.28	2.15	1.50	1.73	1.09		6.07	1.53
3	microplasma welded, with filler	-	20.58	53.00	10.06	1.78	0.93	1.45	2.60	0.29	6.29	3.02
4	laser welded, without filler	-	22.58	60.01	12.04	2.29	1.15	1.95	-	-	-	-
5	laser welded, with filler	0.53	22.22	59.73	12.53	1.57	1.06	1.67	-	-	-	0.70

Table 3
CHEMICAL COMPOSITION OF THE WELDED HERAENIUM NA ALLOY SAMPLES COMPARED TO THE BASE ALLOY

Poor corrosion behaviour of Wirobond SG and Wirobond 280 alloys is probably due to the high content of Fe in the samples welded with filler material, both microplasma and laser. It follows that welded Co-Cr alloys for removable partial denture frameworks corrosion perform better than those for fixed prostheses frameworks. This is supported by the chemical composition.



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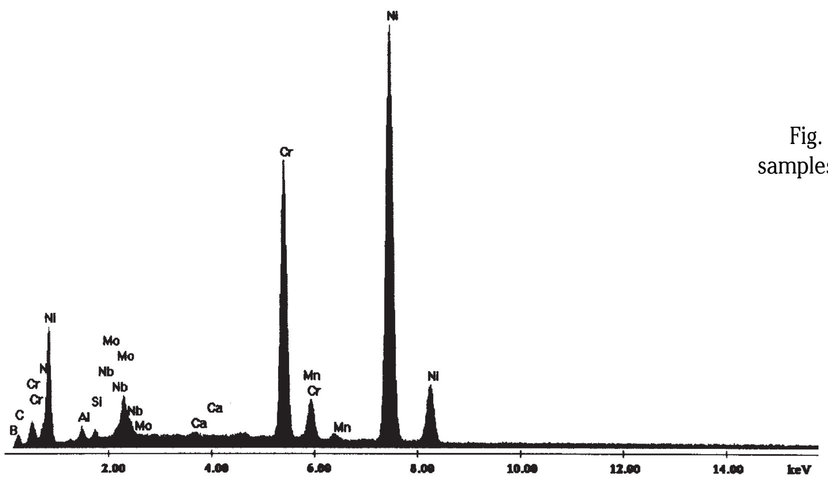

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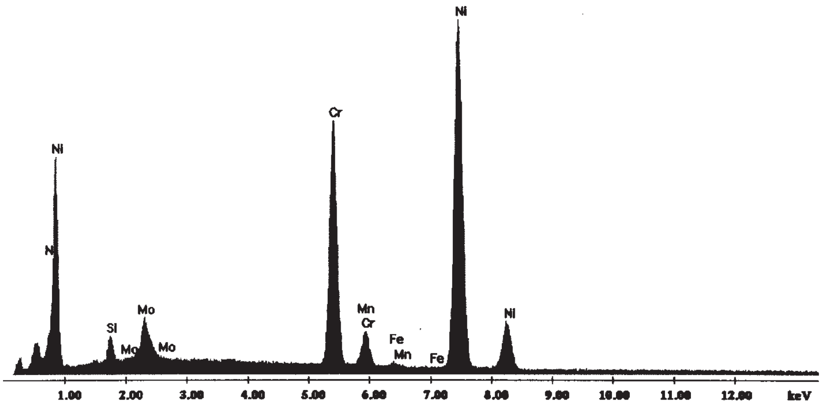
Fig. 1. Chemical composition of the Wirolloy NB alloy samples microplasma welded: a. without filler; b. with filler.



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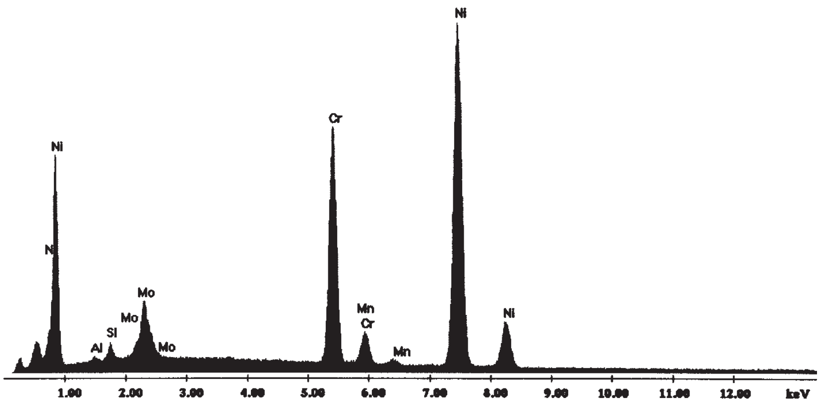

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Fig. 2. Chemical composition of the Wirolloy NB alloy samples laser welded: a. without filler; b. with filler.

Table 4
CHEMICAL COMPOSITION OF THE WELDED WIROBOND SG ALLOY SAMPLES COMPARED TO THE BASE ALLOY.

No.	Alloy	Co (%)	Cr (%)	W (%)	Mo (%)	Si (%)	Mn (%)	Fe (%)	Sn (%)
1	Wirobond SG alloy	63.8	24.8	5.3	5.1	<1	-	<1	-
2	microplasma welded, without filler	62.01	23.27	4.27	6.42	3.69	-	0.33	-
3	microplasma welded, with filler	23.55	17.51	2.43	3.35	1.63	21.39	29.58	0.56
4	laser welded, without filler	65.62	21.45	6.14	6.40	-	0.39	-	-
5	laser welded, with filler	28.82	17.01	2.45	23.06	-	3.99	24.67	-

Table 5
CHEMICAL COMPOSITION OF THE WELDED WIROBOND 280 ALLOY SAMPLES COMPARED TO THE BASE ALLOY

No.	Alloy	Co (%)	Cr (%)	W (%)	Mo (%)	Si (%)	Mn (%)	Fe (%)	Cu (%)	Ga (%)
1	Wirobond 280 alloy	60.2	25	6.2	4.8	<1	<1	-	-	2.9
2	microplasma welded, without filler	59.25	23.45	5.68	5.76	2.23	0.60	-	0.76	2.27
3	microplasma welded, with filler	14.91	17.49	-	2.68	0.77	11.78	41.57	10.78	-
4	laser welded, without filler	59.99	22.44	8.32	5.97	-	0.52	-	-	2.76
5	laser welded, with filler	24.21	19.46	3.26	3.59	1.16	6.49	41.83	-	-

Table 6
CHEMICAL COMPOSITION OF THE WELDED WIRONIT EXTRAHARD ALLOY SAMPLES COMPARED TO THE BASE ALLOY

No.	Alloy	Co (%)	Cr (%)	Ni (%)	Mo (%)	Ga (%)	Si (%)	Mn (%)	Fe (%)	Cu (%)	Ca (%)	Al (%)
1	Wironit extrahard alloy	63	30	-	5	-	1.1	<1	-	-	-	-
2	microplasma welded, without filler	41.56	26.52	22.68	5.43		1.55					2.27
3	microplasma welded, with filler	30.95	22.87	6.37	4.02		1.26		23.78	9.70	0.21	0.82
4	laser welded, without filler	61.09	24.66		6.85	1.41	3.52	0.67	1.80			
5	laser welded, with filler	18.39	16.78	12.12	4.37		1.35	3.89	41.22			1.07

Laser welding has a tendency to form intermetallic particles in the solidified structure, which decrease the corrosion resistance of the joint [11]. Spectrogram of the welding area for dissimilar joints show a combination of both base metal alloys components [12].

Nr.	Alloy	Co (%)	Cr (%)	Ni (%)	Mo (%)	Si (%)	Mn (%)	Fe (%)	C (%)	Al (%)	N (%)
1	Heraenium CE alloy	63.5	27.8	-	6.6	1.0	0.6	-	0.4	-	0.2
2	microplasma welded, without filler	53.95	25.74	8.03	5.68	3.37	-	-	-	-	3.24
3	microplasma welded, with filler	37.62	24.46	-	5.40	2.15	-	30.36	-	-	-
4	laser welded, without filler	57.22	23.69	8.85	7.69	1.88	0.67	-	-	-	-
5	laser welded, with filler	40.61	22.28	23.19	8.65	1.58	0.56	1.52	-	1.61	-

Table 7
CHEMICAL COMPOSITION OF THE WELDED HERAENIUM CE ALLOY SAMPLES COMPARED TO THE BASE ALLOY

Nr.	Alloy	Co (%)	Cr (%)	Ni (%)	Mo (%)	Si (%)	Mn (%)	Fe (%)	Al (%)	Ce (%)	Mg (%)
1	Wiron 99 alloy	-	22.5	65	9.5	<1	-	<1	-	<1	-
2	Wironit extrahard alloy	63	30	-	5	1.1	<1	-	-	-	-
3	microplasma welded, without filler	28.89	24.19	36.95	7.17	1.53	1.27	-	-	-	-
4	microplasma welded, with Ni-Cr filler	7.70	20.63	50.63	9.70	1.24	-	2.22	5.88	-	2.00
5	microplasma welded, with Co-Cr filler	18.78	20.95	15.83	4.79	1.24	8.99	28.69	-	-	0.73
6	laser welded, without filler	30.74	22.21	33.03	8.88	1.97	0.90	-	2.26	-	-
7	laser welded, with Co-Cr filler	20.34	22.10	22.61	8.15	1.49	-	25.31	-	-	-
8	laser welded, with Ni-Cr filler	18.89	22.20	46.28	10.68	1.13	-	-	0.83	-	-

Table 8
CHEMICAL COMPOSITION OF THE DISSIMILAR WELDED SAMPLES COMPARED TO THE BASE ALLOYS

Conclusions

At the Ni-Cr analyzed alloys either not significant differences in chemical composition between different types of welding were observed or modifications were unfavorable to those microplasma welded (higher content of Fe).

The poor corrosion behaviour of Co-Cr alloys for fixed prostheses frameworks compared to those used for removable partial dentures is probably due to the high content of Fe in the samples welded with filler material, both microplasma and laser.

Dissimilar welds combine elements of the two alloys, respectively filler wire. This would lead to virtually a preferential choice of wire-based Co-Cr.

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Manuscript received: 3.11.2014