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Influence of the chemical composition of nickel & chromium – based dental alloys on their corrosion behaviour in an artificial saliva

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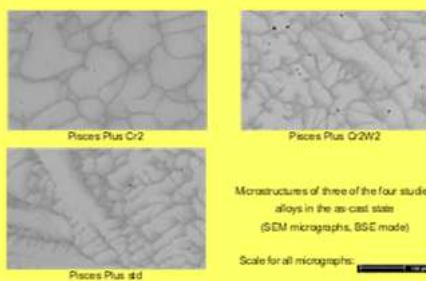
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The frameworks for fixed partial dentures are often composed of noble dental alloys which can be based on gold, platinum or palladium. Alternatively less noble metallic materials can be chosen to replace these expensive parent alloys, as example nickel-based alloys containing around 25wt.% Cr and 11wt.% W or Mo, and also other elements in smaller quantities. Such alloys are almost as resistant as the formers since they can easily enter they passivation domain, which allows them to resist efficiently against corrosion. However their chemical composition needs to be carefully chosen to achieve such good behaviour. The aim of this study is to electrochemically characterize the corrosion behaviours of ternary alloys which are simplified versions of a Ni&Cr-based commercial alloy, for comparison with the latter one, and also to study how the Cr- and W-contents can be important for the corrosion behaviours of these model alloys.

Chemical compositions and microstructures of the studied simple alloys derived from Pisces Plus

elements	Ni	Cr	W	Al	Si	others
Pisces Plus (Ivoclar Vivadent)	61.5	22.0	11.2	2.3	2.6	Misch metal < 1
As-cast "PP std"	64.4 ± 0.5	23.5 ± 0.2	9.9 ± 0.2	/	/	/
Heat-treated "PP std"	63.4 ± 0.4	25.0 ± 0.2	8.9 ± 0.2	/	/	/
As-cast "PP Cr2"	72.7 ± 1.5	11.6 ± 0.2	11.7 ± 0.4	/	/	/
H-treated "PP Cr2"	73.5 ± 0.6	11.7 ± 0.4	11.6 ± 0.5	/	/	/
As-cast "PP W2"	73.1 ± 1.2	23.1 ± 1.5	4.9 ± 1.0	not meas.	/	/
H-treated "PP W2"	80.6 ± 0.7	11 ± 0.1	5.4 ± 0.2	not meas.	/	/
As-cast "PP Cr2W2"	81.2 ± 0.7	11 ± 0.2	5.3 ± 0.3	/	/	/
H-treated "PP Cr2W2"	80.6 ± 0.7	11 ± 0.1	5.4 ± 0.2	/	/	/

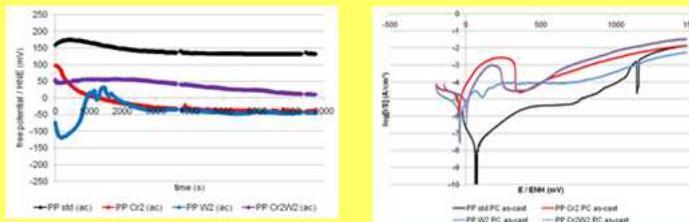


Preparation of the Fusayama saliva

(acidified to pH=2.3 with lactic acid and heated to 37°C)

Components	Conc. (g/L)
KCl	0.4
NaCl	0.4
CaCl ₂ , 2H ₂ O	0.906
NaH ₂ PO ₄ , 2H ₂ O	0.690
Na ₂ S, 9H ₂ O	0.005
urea	1

Evolution, over about 2 hours, of the free potential of the alloys (left), followed by potentiodynamic polarization (right)



Alloys	Corrosion criterion	E _{corr} / NHE (mV) at t = ...			Rp (kOhm × cm ²)
		0h	1h	2h	
Pisces Plus (heat-treated)	val. of E _{corr}	+129	+154	+150	64
	1 μMol / L	Ni ⁺⁺ Cr ⁺⁺⁺ WO ₃			
	1 Mol / L	Ni ⁺⁺ Cr(OH) ₃ WO ₃			
PP std As-cast	val. of E _{corr}	+160	+139	+136	441
	1 μMol / L	Ni ⁺⁺ Cr ⁺⁺⁺ WO ₃			
	1 Mol / L	Ni ⁺⁺ Cr(OH) ₃ WO ₃			
PP std Heat-treated	val. of E _{corr}	+109	+10	+2	4.7
	1 μMol / L	Ni ⁺⁺ Cr ⁺⁺⁺ WO ₃			
	1 Mol / L	Ni ⁺⁺ Cr(OH) ₃ WO ₃			
PP Cr2 As-cast	val. of E _{corr}	+97	-35	-41	0.8
	1 μMol / L	Ni ⁺⁺ Cr ⁺⁺⁺ WO ₃			
	1 Mol / L	Ni ⁺⁺ Cr(OH) ₃ WO ₃			
PP Cr2 Heat-treated	val. of E _{corr}	-175	-178	-178	0.4
	1 μMol / L	Ni ⁺⁺ Cr ⁺⁺⁺ WO ₃ /W ₂ O ₅ /WO ₂			
	1 Mol / L	Ni ⁺⁺ /Ni ⁰ Cr(OH) ₃ WO ₃ /W ₂ O ₅ /WO ₂			
PP W2 As-cast	val. of E _{corr}	-82	-35	-45	4.8
	1 μMol / L	Ni ⁺⁺ Cr ⁺⁺⁺ WO ₃			
	1 Mol / L	Ni ⁺⁺ Cr(OH) ₃ WO ₃			
PP W2 Heat-treated	val. E _{corr}	+125	+37	+24	7.6
	1 μMol / L	Ni ⁺⁺ Cr ⁺⁺⁺ WO ₃			
	1 Mol / L	Ni ⁺⁺ Cr(OH) ₃ WO ₃			
PP Cr2W2 As-cast	val. E _{corr}	+46	+44	+12	1.5
	1 μMol / L	Ni ⁺⁺ Cr ⁺⁺⁺ WO ₃			
	1 Mol / L	Ni ⁺⁺ Cr(OH) ₃ WO ₃			
PP Cr2W2 Heat-treated	val. E _{corr}	+73	+49	+15	2
	1 μMol / L	Ni ⁺⁺ Cr ⁺⁺⁺ WO ₃			
	1 Mol / L	Ni ⁺⁺ Cr(OH) ₃ WO ₃			

Alloys	Corrosion criterion	E _{corr} ↑ / NHE (mV)	I _{corr} / NHE (nA/cm ²)	E _{corr} ↓ / NHE (mV)	Beta (mV/decade)			
					βa	βc		
Pisces Plus (heat-treated)		+98	near 100	+45	E ↑: too high	E ↑: 92		
	1 μMol / L	E↑ Ni ⁺⁺ Cr ⁺⁺⁺ WO ₃ E↓ Ni ⁺⁺ Cr ⁺⁺⁺ WO ₃	52					
	1 Mol / L	E↑ Ni ⁺⁺ Cr(OH) ₃ WO ₃ E↓ Ni ⁺⁺ Cr(OH) ₃ WO ₃						
PP std As-cast		+70	27	+34	E ↑: 139	E ↑: 75		
	1 μMol / L	E↑ Ni ⁺⁺ Cr ⁺⁺⁺ WO ₃ E↓ Ni ⁺⁺ Cr ⁺⁺⁺ WO ₃	151	254				
	1 Mol / L	E↑ Ni ⁺⁺ Cr(OH) ₃ WO ₃ E↓ Ni ⁺⁺ Cr(OH) ₃ WO ₃						
PP std Heat-treated		+17	near 10000	-79	E ↑: too high	E ↑: too high		
	1 μMol / L	E↑ Ni ⁺⁺ Cr ⁺⁺⁺ WO ₃ E↓ Ni ⁺⁺ Cr ⁺⁺⁺ WO ₃	too high	too high				
	1 Mol / L	E↑ Ni ⁺⁺ Cr(OH) ₃ WO ₃ E↓ Ni ⁺⁺ Cr(OH) ₃ WO ₃						
PP Cr2 As-cast		-42	near 10000	+23	88	E ↑: too high		
	1 μMol / L	E↑ Ni ⁺⁺ Cr ⁺⁺⁺ WO ₃ E↓ Ni ⁺⁺ Cr ⁺⁺⁺ WO ₃	121	250				
	1 Mol / L	E↑ Ni ⁺⁺ Cr(OH) ₃ WO ₃ E↓ Ni ⁺⁺ Cr(OH) ₃ WO ₃						
PP Cr2 Heat-treated		-195	near 10000	+74	42	E ↑: 138		
	1 μMol / L	E↑ Ni ⁺⁺ Cr ⁺⁺⁺ WO ₃ /W ₂ O ₅ /WO ₂ E↓ Ni ⁺⁺ Cr(OH) ₃ WO ₃	too high	too high				
	1 Mol / L	E↑ Ni ⁺⁺ Cr ⁺⁺⁺ WO ₃ /W ₂ O ₅ /WO ₂ E↓ Ni ⁺⁺ Cr(OH) ₃ WO ₃						
PP W2 As-cast		-38	near 10000	-97	too high	E ↓: too high		
	1 μMol / L	E↑ Ni ⁺⁺ Cr ⁺⁺⁺ WO ₃ E↓ Ni ⁺⁺ Cr ⁺⁺⁺ WO ₃	too high	too high				
	1 Mol / L	E↑ Ni ⁺⁺ Cr(OH) ₃ WO ₃ E↓ Ni ⁺⁺ Cr(OH) ₃ WO ₃						
PP W2 Heat-treated		+50	4070	-91	94	E ↑: too high		
	1 μMol / L	E↑ Ni ⁺⁺ Cr ⁺⁺⁺ WO ₃ E↓ Ni ⁺⁺ Cr ⁺⁺⁺ WO ₃	79	389				
	1 Mol / L	E↑ Ni ⁺⁺ Cr(OH) ₃ WO ₃ E↓ Ni ⁺⁺ Cr(OH) ₃ WO ₃						
PP Cr2W2 As-cast		+6	near 10000	-70	79	E ↓: 79		
	1 μMol / L	E↑ Ni ⁺⁺ Cr ⁺⁺⁺ WO ₃ E↓ Ni ⁺⁺ Cr ⁺⁺⁺ WO ₃	71	79				
	1 Mol / L	E↑ Ni ⁺⁺ Cr(OH) ₃ WO ₃ E↓ Ni ⁺⁺ Cr(OH) ₃ WO ₃						
PP Cr2W2 Heat-treated		+7	near 10000	-94	76	E ↑: too high		
	1 μMol / L	E↑ Ni ⁺⁺ Cr ⁺⁺⁺ WO ₃ E↓ Ni ⁺⁺ Cr ⁺⁺⁺ WO ₃	722	269				
	1 Mol / L	E↑ Ni ⁺⁺ Cr(OH) ₃ WO ₃ E↓ Ni ⁺⁺ Cr(OH) ₃ WO ₃						

The electrochemical results, in terms of free potential, polarization resistances, corrosion potential, corrosion current and anodic currents in the "passivation" plateau were very dispersed among the alloys, as-cast or heat-treated. Nevertheless it clearly appeared that the decrease in chromium significantly deteriorates the corrosion behaviour of the ternary alloy. For the PP Cr2 and also the PP Cr2W2, the chromium content is obviously under a limit in chromium separating good behaviours and very bad behaviours. The effect of a decrease in tungsten content is less marked in general. A more interesting observation is the detrimental effect of the heat-treatment usually applied in practice: the corrosion behaviour is noticeably deteriorated.

The commercial alloy displayed the best behaviour in corrosion, which can be attributed to the W-rich precipitates present in its interdendritic spaces or to Al and Si present in its more complex chemical composition.