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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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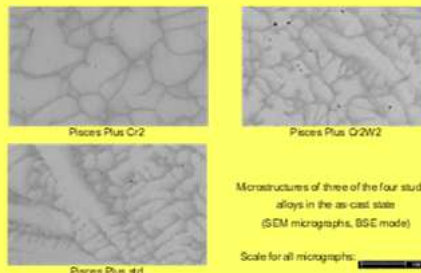
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The frameworks for fixed partial dentures are often composed of noble dental alloys which can be based on gold, platinum or palladium. Alternatively less noble metallic materials can be chosen to replace these expensive parent alloys, as example nickel-based 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 | / | / | / |
| H.-treated "PP W2" | not meas. | not meas. | not meas. | / | / | / |
| As-cast "PP Cr2W2" | 80.6 ± 0.7 | 11 ± 0.1 | 5.4 ± 0.2 | / | / | / |
| H.-treated "PP Cr2W2" | 81.2 ± 0.7 | 11 ± 0.2 | 5.3 ± 0.3 | / | / | / |

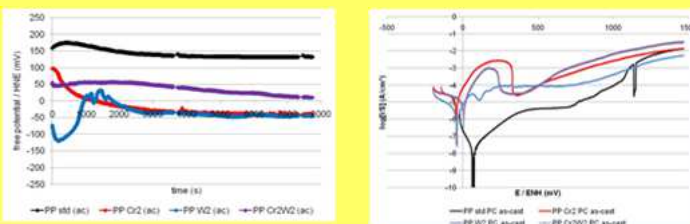


Preparation of the Fusayama saliva

(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) | I _{corr} / NHE (nA/cm²) | E _{corr} ↓ / NHE (mV) | Beta (mV/decade) | |
|----------------------------|---------------------|--|----------------------------------|--------------------------------|------------------|----------------|
| | | | | | β _a | β _c |
| Pisces Plus (heat-treated) | 1 μMol / L | +98 | near 100 | +45 | E ↑: too high | E ↑: 92 |
| | 1 Mol / L | E ↑ Ni ²⁺ Cr ³⁺ WO ₃ E ↓ Ni ²⁺ Cr ³⁺ WO ₃ | | | E ↓: 52 | E ↓: too high |
| PP std As-cast | 1 μMol / L | +70 | 27 | +34 | E ↑: 139 | E ↑: 75 |
| | 1 Mol / L | E ↑ Ni ²⁺ Cr ³⁺ WO ₃ E ↓ Ni ²⁺ Cr ³⁺ WO ₃ | | | E ↓: 151 | E ↓: 254 |
| PP std Heat-treated | 1 μMol / L | +17 | near 10000 | -79 | E ↑: too high | E ↑: too high |
| | 1 Mol / L | E ↑ Ni ²⁺ Cr ³⁺ WO ₃ E ↓ Ni ²⁺ Cr ³⁺ WO ₃ | | | E ↓: too high | E ↓: too high |
| PP Cr2 As-cast | 1 μMol / L | -42 | near 10000 | +23 | E ↑: 88 | E ↑: too high |
| | 1 Mol / L | E ↑ Ni ²⁺ Cr ³⁺ WO ₃ E ↓ Ni ²⁺ Cr ³⁺ WO ₃ | | | E ↓: 121 | E ↓: 250 |
| PP Cr2 Heat-treated | 1 μMol / L | -195 | near 10000 | +74 | E ↑: 42 | E ↑: 138 |
| | 1 Mol / L | E ↑ Ni ²⁺ /Ni ³⁺ Cr ³⁺ WO ₃ /W ₂ O ₅ /WO ₂ E ↓ Ni ²⁺ Cr ³⁺ WO ₃ | | | E ↓: too high | E ↓: too high |
| PP W2 As-cast | 1 μMol / L | -38 | near 10000 | -97 | E ↑: too high | E ↑: too high |
| | 1 Mol / L | E ↑ Ni ²⁺ Cr ³⁺ WO ₃ E ↓ Ni ²⁺ Cr ³⁺ WO ₃ | | | E ↓: too high | E ↓: too high |
| PP W2 Heat-treated | 1 μMol / L | +50 | 4070 | -91 | E ↑: 94 | E ↑: too high |
| | 1 Mol / L | E ↑ Ni ²⁺ Cr ³⁺ WO ₃ E ↓ Ni ²⁺ Cr ³⁺ WO ₃ | | | E ↓: 79 | E ↓: 389 |
| PP Cr2W2 As-cast | 1 μMol / L | +6 | near 10000 | -70 | E ↑: 79 | E ↑: too high |
| | 1 Mol / L | E ↑ Ni ²⁺ Cr ³⁺ WO ₃ E ↓ Ni ²⁺ Cr ³⁺ WO ₃ | | | E ↓: 71 | E ↓: 79 |
| PP Cr2W2 Heat-treated | 1 μMol / L | +7 | near 10000 | -94 | E ↑: 76 | E ↑: too high |
| | 1 Mol / L | E ↑ Ni ²⁺ Cr ³⁺ WO ₃ E ↓ Ni ²⁺ Cr ³⁺ WO ₃ | | | E ↓: 722 | E ↓: 269 |

| Alloys | Corrosion criterion | E _{corr} / NHE (mV) at t = ... | | | Rp (kOhm × cm ²) | |
|----------------------------|---------------------------|---|------|------|------------------------------|-----------|
| | | 0h | 1h | 2h | at t = 1h | at t = 2h |
| Pisces Plus (heat-treated) | val. of E _{corr} | +129 | +154 | +150 | 64 | 89 |
| | 1 μMol / L | Ni ²⁺ Cr ³⁺ WO ₃ | | | | |
| | 1 Mol / L | Ni ²⁺ Cr(OH) ₃ WO ₃ | | | | |
| PP std As-cast | val. of E _{corr} | +160 | +139 | +136 | 441 | 703 |
| | 1 μMol / L | Ni ²⁺ Cr ³⁺ WO ₃ | | | | |
| | 1 Mol / L | Ni ²⁺ Cr(OH) ₃ WO ₃ | | | | |
| PP std Heat-treated | val. of E _{corr} | +109 | +10 | +2 | 4.7 | 4.8 |
| | 1 μMol / L | Ni ²⁺ Cr ³⁺ WO ₃ | | | | |
| | 1 Mol / L | Ni ²⁺ Cr(OH) ₃ WO ₃ | | | | |
| PP Cr2 As-cast | val. of E _{corr} | +97 | -35 | -41 | 0.8 | 0.7 |
| | 1 μMol / L | Ni ²⁺ Cr ³⁺ WO ₃ | | | | |
| | 1 Mol / L | Ni ²⁺ Cr(OH) ₃ WO ₃ | | | | |
| PP Cr2 Heat-treated | val. of E _{corr} | -175 | -178 | -178 | 0.4 | 0.5 |
| | 1 μMol / L | Ni ²⁺ /Ni ³⁺ Cr ³⁺ WO ₃ /W ₂ O ₅ /WO ₂ | | | | |
| | 1 Mol / L | Ni ²⁺ /Ni ³⁺ Cr ³⁺ WO ₃ /W ₂ O ₅ /WO ₂ | | | | |
| PP W2 As-cast | val. of E _{corr} | -82 | -35 | -45 | 4.8 | 2.9 |
| | 1 μMol / L | Ni ²⁺ Cr ³⁺ WO ₃ | | | | |
| | 1 Mol / L | Ni ²⁺ Cr(OH) ₃ WO ₃ | | | | |
| PP W2 Heat-treated | val. E _{corr} | +125 | +37 | +24 | 7.6 | 8.2 |
| | 1 μMol / L | Ni ²⁺ Cr ³⁺ WO ₃ | | | | |
| | 1 Mol / L | Ni ²⁺ Cr(OH) ₃ WO ₃ | | | | |
| PP Cr2W2 As-cast | val. E _{corr} | +46 | +44 | +12 | 1.5 | 1.5 |
| | 1 μMol / L | Ni ²⁺ Cr ³⁺ WO ₃ | | | | |
| | 1 Mol / L | Ni ²⁺ Cr(OH) ₃ WO ₃ | | | | |
| PP Cr2W2 Heat-treated | val. E _{corr} | +73 | +49 | +15 | 2 | 1.7 |
| | 1 μMol / L | Ni ²⁺ Cr ³⁺ WO ₃ | | | | |
| | 1 Mol / L | Ni ²⁺ 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.