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Comparative Electrochemical Behavior of NiTi and 316L Stainless Steel

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Introduction: Nickel-titanium (NiTi) is now used in a wide variety of biomedical applications ranging from minimally invasive devices such as stents to metallic rods used in orthopedics.[1] The unique combination of mechanical and surface properties of NiTi (shape memory, superelasticity and biocompatibility) is the reason for its success and increased popularity as a biomaterial. In particular, the good biocompatibility of NiTi has been associated with its excellent corrosion resistance that minimizes bio-degradation of the material in the body. Many authors have reported that the good corrosion behavior of NiTi[2,3] can be related to its surface layer.[3,4] Nevertheless, very few studies demonstrate the effect of disruption of this surface layer on NiTi corrosion behavior.

Aim: The objective of the first part of this research was to compare the potentiodynamic polarization behavior of NiTi and 316L stainless steel (SS). The second part of the study consisted of step-polarization potentiostatic testing of both materials after damaging their surface to determine their ability to repassivate/repair such damage.

Materials and Methods: NiTi (50.8 at.% Ni, balance Ti) and 316L stainless steel discs were passivated and sterilized according to ASTM F86 standard practices for metallic implants.

Potentiodynamic polarization testing was conducted per ASTM G5 on the discs in de-aerated Hanks salt solution at 37°C. The corrosion potential (E_{corr}), the corrosion current density (I_{corr}) and also the breakdown potential (E_{bd}) were obtained using Tafel extrapolation and Stern-Geary fits. NiTi and SS disc samples were subject to scratch damage using a diamond stylus during step polarization experiments (variation of ASTM F746) and the current density profiles over time obtained. The samples were scratched before the potentiostatic holds (P-Hold) at 0 mV, 200 mV, 400 mV and 600 mV with reference to SCE. A decreasing current density trend indicated that the material was able to repassivate the scratch damage while an increasing current density trend indicated that the sample was not able to repassivate scratch damage at that P-hold. Current density > 500 $\mu A/cm^2$ was used as a threshold to define total loss of ability to repassivate scratch damage.

Results: The values from the Tafel extrapolation are listed in Table 1. NiTi exhibited more active E_{corr} values, but greater E_{bd} values compared to SS. The I_{corr} values for SS and NiTi alloys were similar.

Table 1: Potentiodynamic polarization test results.

Sample	E_{corr} mV	I_{corr} nA/cm^2	E_{bd} mV
NiTi	-457±59	8.72±4.87	888±20
SS	-265±33	8.51±0.54	213±50

The test results from step polarization scratch testing are summarized in Table 2. The SS alloy exceeded the 500 $\mu A/cm^2$ threshold values faster than the NiTi alloy at both the 400 mV and 600 mV potentiostatic holds.

Table 2: Step polarization scratch test results.

P-Hold mV	I > 500 $\mu A/cm^2$ SS	I > 500 $\mu A/cm^2$ NiTi	Description
0	No	No	Total repassivation by SS and NiTi
200	*No	No	Total repassivation by NiTi. *SS exhibited an increasing current density.
400	Yes	Yes	No repassivation by SS and NiTi
600	Yes	Yes	No repassivation by SS and NiTi

Discussion: NiTi exhibited superior resistance to primary breakdown of the passive layer compared to the SS during potentiodynamic polarization testing. Step polarization scratch testing indicated that the resistance to scratch damage using the absolute 500 $\mu A/cm^2$ threshold was equivalent for both NiTi and the SS. However, while the SS did not exceed the 500 $\mu A/cm^2$ threshold, it exhibited an increasing current density trend compared to the decreasing trend exhibited by the NiTi at the 200 mV P-Hold. Thus, the region of repassivation capability after scratch damage for the NiTi alloy could be 200 mV greater than the SS alloy.

Conclusion: Based on the results from this study:

- NiTi exhibited more active E_{corr} values than SS
- NiTi and 316L SS exhibited similar I_{corr} values
- NiTi exhibited a greater resistance to primar breakdown than SS and also a repassivation range greater than SS once its surface was damaged

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