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Effect of MRI on structure, roughness, hardness and electrochemical corrosion behavior of biomaterial Protechno® - N dental alloy

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ABSTRACT

Magnetic resonance imaging (MRI) is the newest and perhaps the most available medical imaging technology. No more available research covering the effects of MRI on structure and physical properties of dental alloys. For this reason, the effect of MRI on structure, Vickers hardness, roughness and electrochemical corrosion behavior of Protechno® -N (Ni=63%, Cr=24.6%, Mo=10.77%, Si=1.50%, Mn=0.03% and C=0.01%) dental alloy has been studied. The results show that, Vickers hardness, roughness parameters, corrosion resistance and corrosion rate of Protechno® -N alloy changed after exposure to MRI.

INTRODUCTION

Nickel chromium casting alloys have been used in dentistry since the 1930's[1]. These alloys are characterized as active or passive alloys and rely on a protective oxide coating for corrosion resistance in the oral environment. It has been suggested that 16- 27% chromium provides an adequate protective oxide film for these nickel based alloys[2]. Nickel alloys are harder than precious metal alloys; they provide the required rigid support for porcelain and prevent fracture. They have been the preferred choice in long-span bridge restorations or when strength is of main concern[3, 4]. Because of these advantages, rigidity can be obtained with Cr–Ni alloys without constructing bulky major and minor connectors in cast removable partial dentures[3-5]. Like all non precious alloys, nickel alloy are subjected to corrosion products, which might lead to soft tissue inflammation and contact dermatitis[6, 7]. Ni-Cr wires used for orthodontic bands can influence not only the image quality, but also the diagnostic reliability of MRI of the temporomandibular joint[8]. Hubálková et al[9] described the behaviour of dental alloys during the magnetic resonance imaging procedure. Ni-Cr, Co-Cr and SUS304 expressed small amounts of MR defects, but SUS405, Pd-Co-Ni and Sm-Co expressed large defects. The effects of gamma radiation (10, 20 and 30 kGy) and magnetic resonance imaging on structure, electrochemical corrosion behavior and Vickers hardness value of commercial Co- Cr dental alloy were investigated[10]. The aim of the present study was to investigate the effects of magnetic resonance imaging (MRI) for 10, 20 and 30 mints on structure, hardness, roughness and electrochemical corrosion behavior of commercial Ni- Cr dental alloy.

EXPERIMENTAL WORK

The specimens used in the present work are commercial Protechno® -N (Ni=63%, Cr=24.6%, Mo=10.77%, Si=1.50%, Mn=0.03% and C=0.01%) alloy. The specimens were prepared in convenient shape

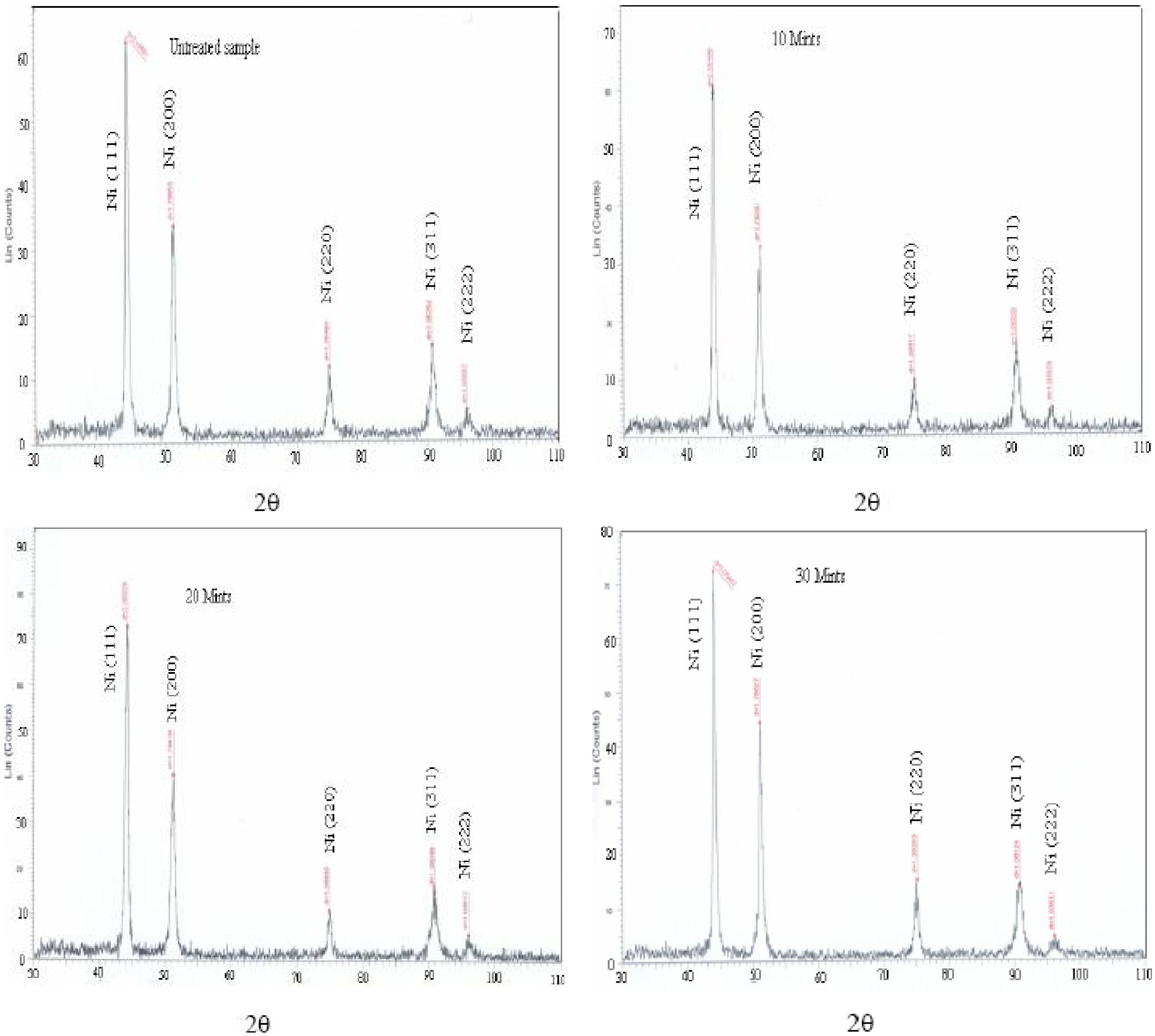

Figure 1 : x-ray diffraction patterns of Protechno® -N alloy before and after exposure to MRI

for all tests such as structure, roughness, Vickers microhardness and electrochemical corrosion behavior. Microstructure of used specimens was performed on the flat surface of all specimens using an Shimadzu X–ray Diffractometer (Dx–30, Japan) of Cu–Kα radiation with =1.54056 Å at 45 kV and 35 mA and Ni–filter in the angular range 2θ ranging from 0 to 100° in continuous mode with a scan speed 5 deg/min. Microhardness test of used specimens were conducted using a digital Vickers microhardness tester, (Model FM–7, Tokyo, Japan), applying a load of 100 gf for 5 seconds via a Vickers diamond pyramid. The roughness of used specimens were measured by using surface roughness measurements device (S.J 201.P). For measuring corrosion parameters, the potentiodynamic current versus potential curves were recorded by changing the electrode potential automatically from -1500 to 500mV at a scan rate of 5mV/s1 using Voltage lab PGZ 100 (Germany PC 3–300) and a computer with Volta Master 4 software (Germany frame work version 7.08) for calculations. MRI is based on the signal of nuclear magnetic resonance (NMR) emitted by the interaction of atomic nuclei that possess spin with incident radiofrequency within a static magnetic field. Magnetic resonance imaging signals (1T for 10, 20 and 30 mints) from a 1 TMR scanner.

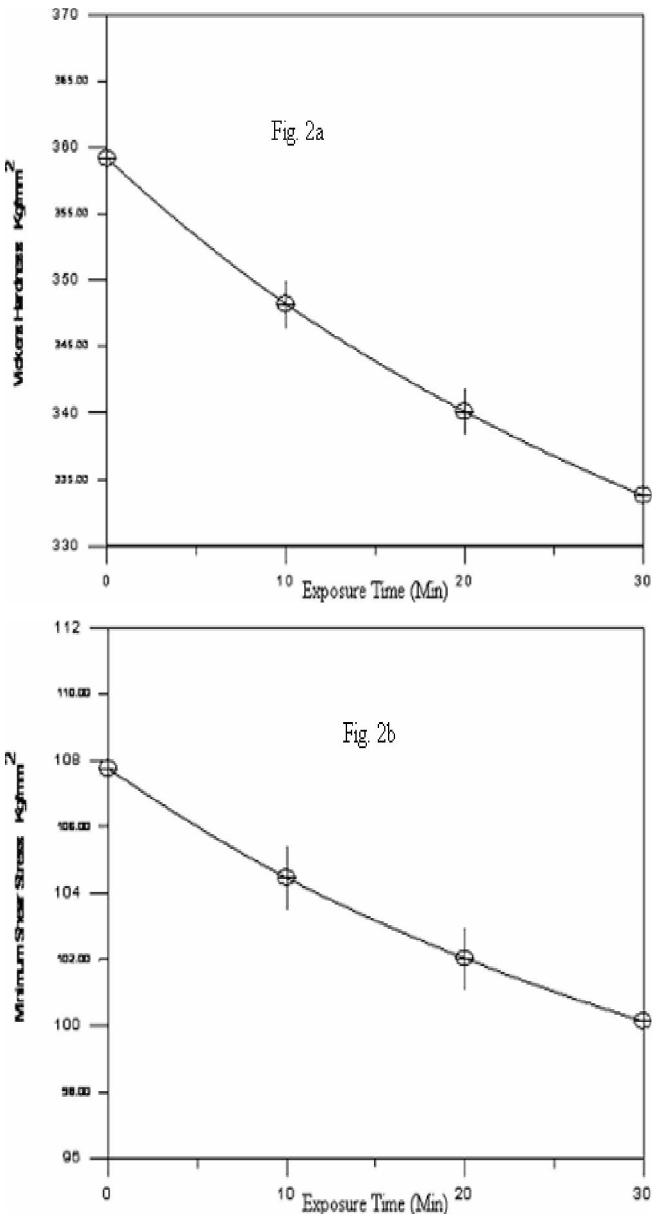

Figure 2 : Vickers hardness and minimum shear stress of Protechno® -N alloy before and after exposure to MRI

RESULTS AND DISCUSSIONS

X-ray analysis

Effect of MRI on microstructure was studied by x-ray diffractometer. Figure (1) shows x-ray diffraction patterns of Protechno® -N (Ni=63%, Cr=24.6%, Mo=10.77%, Si=1.50%, Mn=0.03% and C=0.01%) alloy before and after exposure to MRI for 10, 20 and 30 mints. The analysis of x-ray diffraction patterns show that, Protechno® -N alloy consists of fcc Ni phase. In reality, Ni-Cr-Mo alloy, the fcc matrix phase presents as a metastable phase, fcc Ni phase and a solid solution ϒ (Ni- Cr). After exposure to MRI, the shape of formed crystalline phase, (intensity, broadness and position) is changed due to the interaction of the signal of non-ionizing MRI with the alloy matrix.

Vickers hardness

Hardness is a property with a low coefficient of variation when compared with other mechanical properties tested. In general hardness is defined as "Resistance of material to plastic deformation", usually by indentation. However, the term hardness may also refer to stiffness or temper or resistance to scratching abrasion, or cutting.

The microhardness value was conducted using a digital Vickers microhardness tester, applying a load of 100 g for 5 s, for Protechno® -N alloy. Vickers hardness and minimum shear stress (τ_m) of Protechno® -N alloy before and after exposure to MRI are shown in Figure 2 (a & b). Vickers hardness of Protechno® -N decreased after exposure to MRI that is because non-ionizing MRI cause a movement of metals ions due to heating which affects on matrix alloy microstructure and bonding strength which reduced its hardness value.

Roughness

The roughness profiles of Protechno® -N alloy before and after exposure to MRI are shown in Figure (3). Also the average surface roughness parameter Ra along the total sliding distance and other roughness parameters of Protechno® -N alloy before and after exposure to MRI are listed in TABLE (1). From these results, it found that, surface roughness parameter Ra is increased. That is because non-ionizing MRI cause cracks and/ or pits on the surface alloy.

TABLE 1 : Surface roughness parameters of Protechno® -N alloy before and after exposure to MRI

Roughness parameters	Samples			
	base	10 Min	20 Min	30 Min
Ra μm	0.40±0.03	0.56±0.05	0.45±0.04	0.56±0.02
Rz μm	1.81	2.78	1.88	2.67
Rq μm	0.49	0.70	0.54	0.70
Rt μm	3.35	4.76	2.77	3.94
Rp μm	0.86	1.38	0.93	1.37

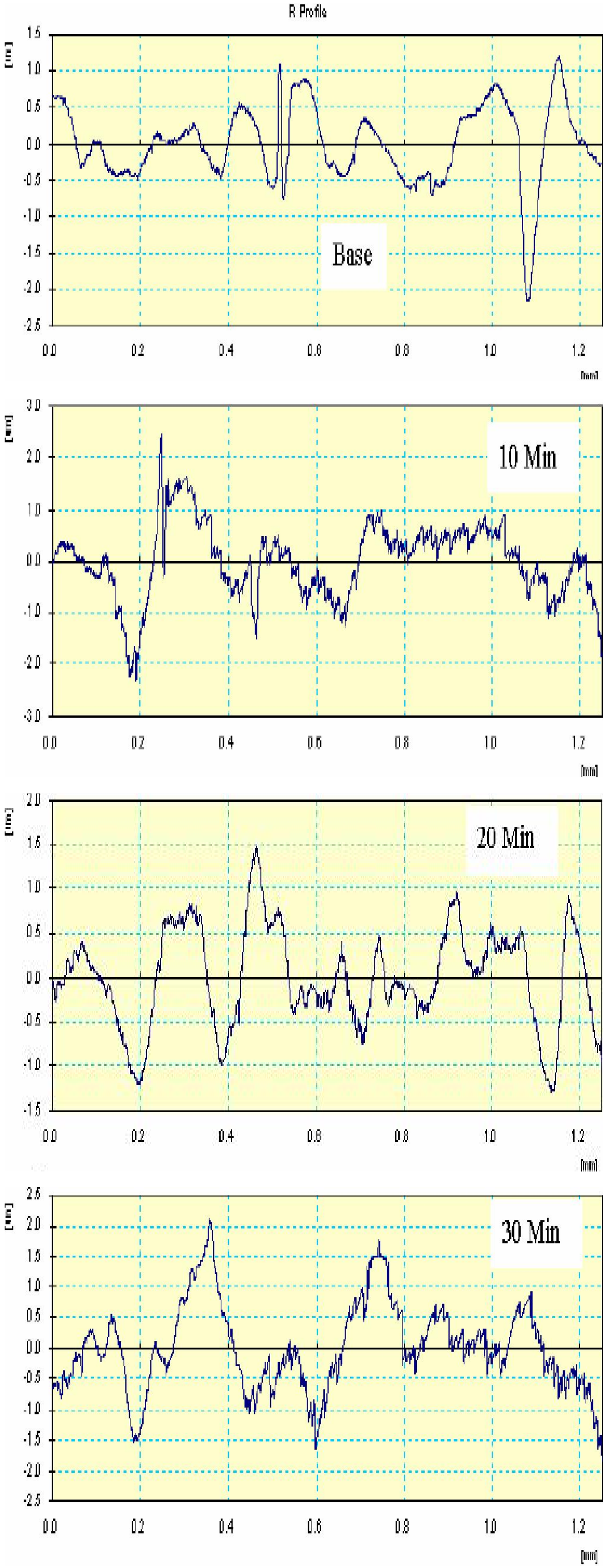

Figure 3 : roughness profiles of Protechno® -N alloy before and after exposure to MRI

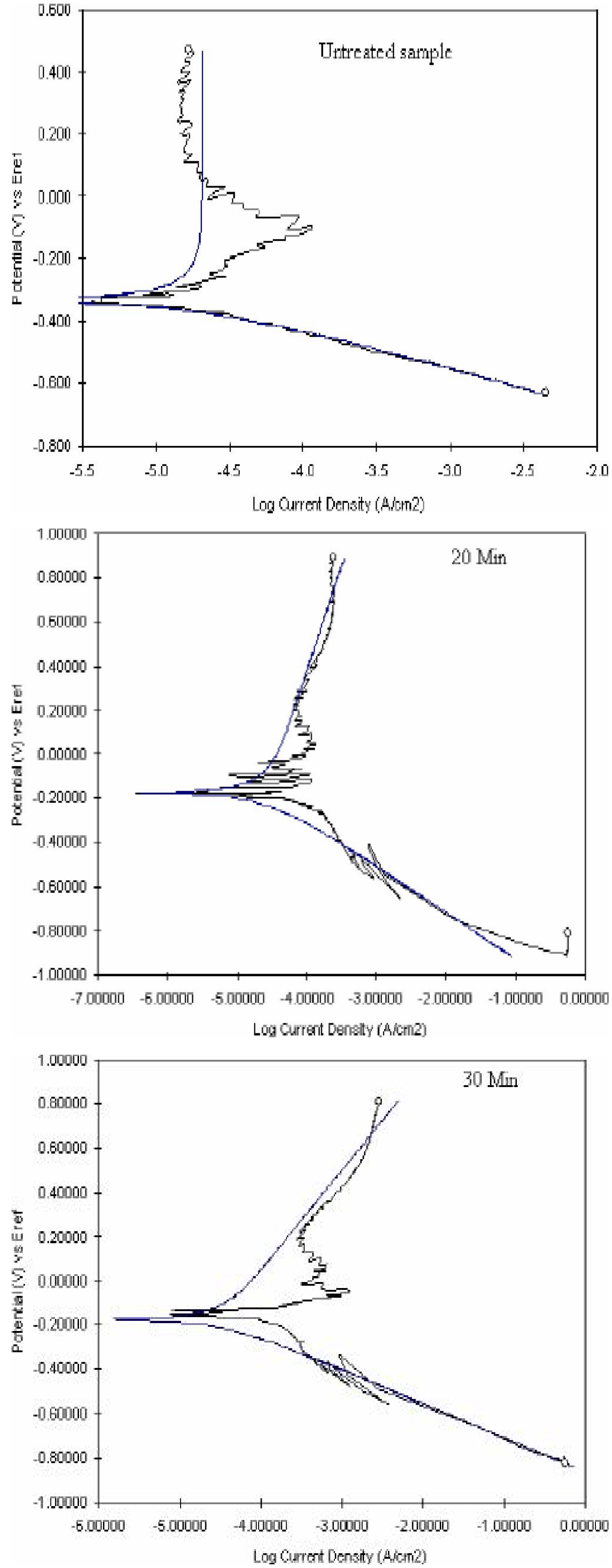

Figure 4 : electrochemical polarization curves for Protechno® -N alloy before and after exposure to MRI

TABLE 2 : Corrosion potential, corrosion current, corrosion resistance and corrosion rate of Protechno® -N alloy before and after exposure to MRI

Samples	E_{corr} (mV)	I_{corr} x10^{-5} (A/cm^2)	R_{Cor} (KΩ. cm^2)	$Corr_{Rate}$ (mm/yr)
Untreated	-333.5	2.023	2.743	0.256
20 Min	-174.9	2.622	2.843	0.332
30 Min	-172.6	3.243	1.534	0.411

Electrochemical corrosion studies

Figure (4) shows electrochemical polarization curves for Protechno® -N alloy in 0.5M HCl before and after exposure by MRI. From this Figure it is obvious that the corrosion potential of the used alloys exhibited a negative potential. Also, the cathodic and the anodic polarization curves showed similar corrosion trends. The corrosion potential (E_{Corr}), corrosion current (I_{Corr}), corrosion resistance (R_{Corr}) and corrosion rate ($Corr_{Rate}$) of Protechno® -N alloy before and after exposure to MRI are listed in TABLE (2). From these results, it is found that the corrosion rate of Protechno® -N alloy with 0.5M HCl is increased but the corrosion resistance in 0.5M HCl is varied due to non-ionizing MRI.

CONCLUSION

1- X-ray diffraction analysis show that, Protechno® -N alloy consists of fcc Ni phase and the shape of formed phase changed after exposure to MRI.

2- Vickers hardness value of Protechno® -N alloy decreased but the surface roughness Parameter Ra value increased after exposure to MRI.

3- The corrosion resistance of Protechno® -N alloy in 0.5M HCl is varied but the corrosion rate with 0.5 M HCl increased after exposure to MRI.

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