Corrosion of orthodontic archwires in artificial saliva in the presence of Lactobacillus reuteri

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Abstract
Dental materials such as orthodontic archwires should be corrosion resistant to saliva but also to other compounds that can come in contact with them like agents for oral hygiene. Lately, it has been recommended that, in addition to improved oral hygiene, orthodontic patients should use probiotic supplements to decrease the incidence of caries and gingivitis as the most frequent side effects of long-term orthodontic therapy. For this reason, the objective of this work was to examine how the use of probiotic supplements affects corrosion stability of orthodontic archwires made of nickel-titanium alloy (NiTi). Studies have been conducted in artificial saliva and in saliva with dissolved tablets of commercial oral probiotic. Electrochemical measurements (electrochemical impedance spectroscopy, potentiodynamic polarization) showed that probiotic tablets increase the possibility of localized corrosion. However, it was not clear if the localized corrosion was caused by microorganisms or due to the deposits of insoluble tablet components. For that reason samples were exposed to artificial saliva containing Lactobactilus reuteri. After 2 weeks of exposure they were characterized by electrochemical methods and electron microscopy in order to evaluate the impact of studied microorganisms on their corrosion stability.

Keywords: dental material; localized corrosion; microbially influenced corrosion, probiotics.

Introduction

The excellent corrosion resistance of the metallic materials that are in contact with human body is one of the main requirements they should fulfil in order to be considered as biocompatible. Otherwise corrosion products can be toxic to human body or result in allergic reactions. For example, it has been found that the corrosion in the oral cavity causes tooth discoloration, and in some cases allergic reactions as a consequence of metal ions being released into the organism [1-3]. Orthodontic appliances make maintenance of adequate oral hygiene more difficult, whereby conditions are created for the development and maturation of biofilm and for propagation of pathogenic microorganisms around the appliance. Probiotics are microorganisms that have a beneficial effect on human health. The use of probiotic bacteria in the oral cavity has shown good results in treatment of periodontitis, gingivitis and cavities. However, there is no relevant research on how probiotic supplements affect corrosion stability of orthodontic archwires. It is known that different bacteria and fungi can cause metal corrosion, either directly through their metabolic influence, or by creating locally corrosive conditions.

Experimental

Two types of nickel-titanium orthodontic wires were studied (chemical composition Ni - 50.4%, Ti - 49.6%) Dentsply GAC Int, Islandia, USA:

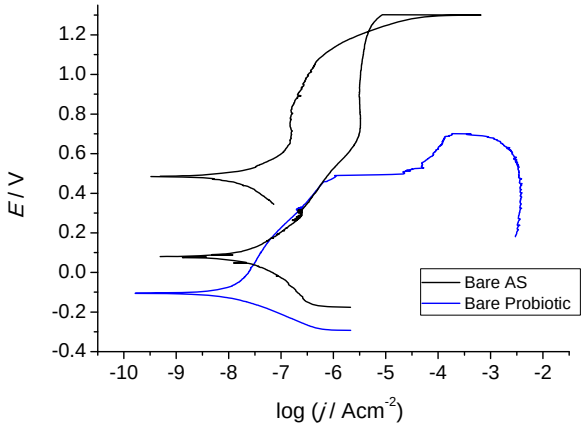
- bare surfaces (Bioforce Sentalloy)
- nitrided surfaces (Bioforce Sentalloy IonGuard)

Orthodontic wires were cut in halves and part of the wire was isolated with a lacquerer in order to expose only 0.61 cm^2 of surface area to corrosive medium.
Corrosion studies were conducted in the artificial saliva (AS) with the following composition: 1.5 g/L KCl; 1.5 g/L $NaHCO_3$; 0.5 g/l NaH_2PO_4 x H_2O; 0.5 g/L KSCN; 0.9 g/L lactic acid, pH 4.8. In the first set of measurements addition of probiotics was studied in a way that commercial oral product – BioGaia Prodentis, containing Lactobacillus Reuteri, was dissolved in AS (2 pastilles/100 mL of AS). After two hours of exposure to corrosive medium at 37±2°C electrochemical measurements were conducted [4]. In the second set of the measurements part of the wires were exposed for 2 weeks to AS with Lactobacillus Reuteri (without other components of commercial oral probiotic) while the other part of the wires was exposed only to AS. Afterwards samples were transferred to fresh AS and electrochemical measurements were performed. Again, all the steps were conducted at 37±2°C.
Electrochemical studies were conducted in a three electrode cell with saturated calomel electrode as a reference electrode and platinum wire as a counter electrode. Electrochemical impedance spectroscopy (EIS) was then carried out at the open circuit potential with a 10 mV amplitude and a frequency range from 100 kHz to 10 mHz. Afterwards, the cyclic polarization was carried out from the initial potential of -300 mV from the open circuit potential to the 700 mV potential or the potential where the current density reached 100 μAcm^{-2}. Polarization was then continued in the cathodic direction to the open circuit potential The potential sweep rate was 1 mVs^{-1}.

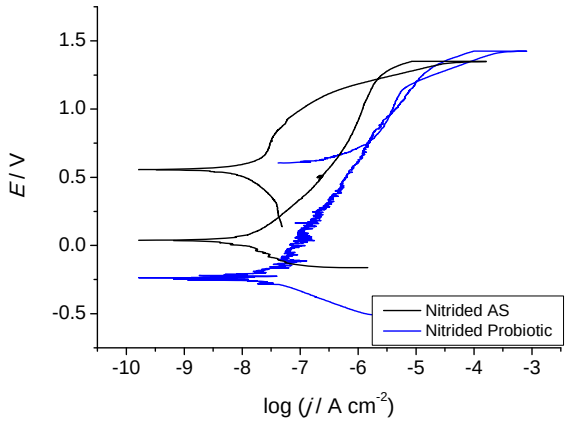
Results and discussion

Results of the polarization measurements conducted after 2 hours of exposure to AS with or without the commercial probiotic are presented in Figure 1.[4] It can be seen that the addition of the probiotic resulted in increased susceptibility towards pitting corrosion for bare NiTi wires while for nitride samples the corrosion resistance was not significantly changed. However, it is not clear if the localized corrosion of bare wires can be related to the presence

of microorganisms or it is due to the deposition of insoluble pastile components on the wire surface. For that reason wires were exposed to AS with Lactobacillus Reuteri for two week and afterward were conducted electrochemical measurements (Fig. 2.).



a)

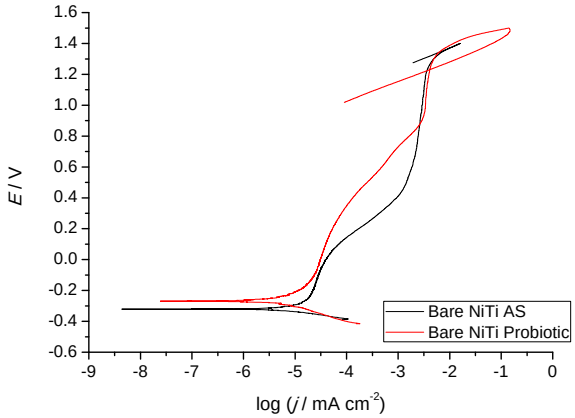


b)

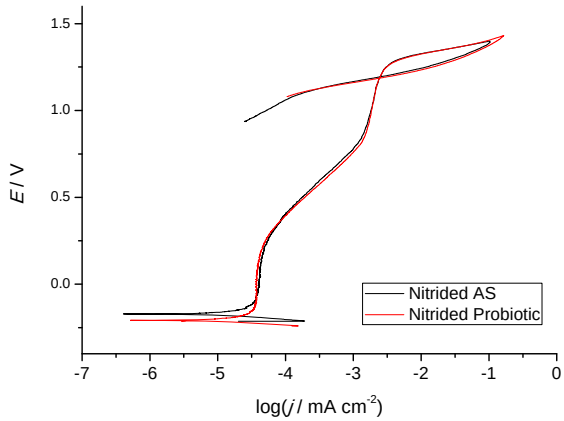
Figure 1. Polarization curves for bare (a) and nitrided (b) wires in artificial saliva and saliva containing oral probiotic

It can be observed that exposure to bacteria alone resulted in less significant changes of corrosion parameters than the exposure to the probiotic pastilles. Only very small decrease of the corrosion and passivation current density is observed for samples exposed to Lactobacillus Reuteri. However, for bare NiTi wires slight increase in localized corrosion possibility was observed.

Results of the electrochemical impedance measurements are presented in Figure 3. It can be seen that the samples that were exposed to bacteria show slightly higher impedance values than those exposed only to AS, especially in the case of bare NiTi wires. Thus it can be concluded that exposure to bacteria actually resulted in slightly increased general corrosion resistance of studied wires.



a)

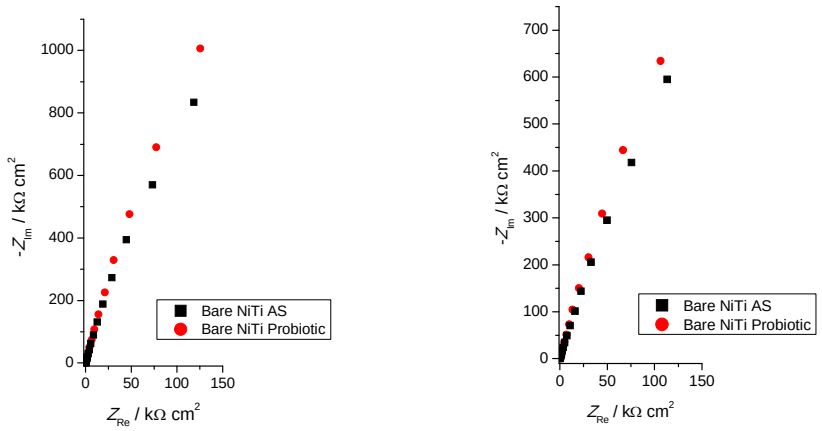


b)

Figure 2. Polarization curves for bare (a) and nitrided (b) wires that were exposed for two weeks to artificial saliva or saliva containing oral probiotic

Table 1.Corrosion parameters determined from polarization curves in Fig.2.

Sample	j_{corr} / nA cm^{-2}	E_{corr} / mV	j_{pas0V} / nA cm^{-2}	E_{bd} / V	E_{rp} / V
Bare AS	4.9	-322	39.3	1.350	1.350
Bare-Probiotic	3.3	-269	31.1	1.342	1.233
Nitrided AS	9.8	-174	41.1	1.300	1.193
Nitrided-Probiotic	8.2	-210	37.6	1.305	1.187



a) b)

Figure 3. EIS spectra for bare (a) and nitrided (b) wires that were exposed for two weeks to artificial saliva or saliva containing oral probiotic

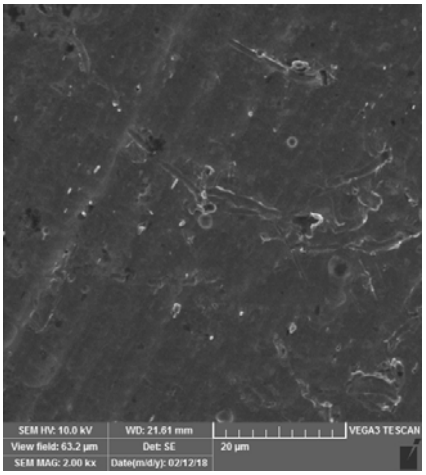


Figure 4. SEM image of bare NiTi sample that was exposed to AS with Lactobacillus reuteri

SEM images of the bare sample exposed to Lactobacillus reuteri show traces of localized corrosion as well as the white structures that resemble to microbial organisms. However the trace of complete biofilm formation was not observed.

Conclusions

Studies performed in this work show that corrosion behaviour of nitrided NiTi wires is less influenced by the presence of Lactobacillus reuteri itself, or oral probiotic pastilles containing this bacteria than the corrosion behaviour of bare NiTi wires. The bare wires showed significantly increased tendency towards localized corrosion in the solution containing commercial probiotic product while bacteria alone only slightly increased this tendency. Thus it can be concluded that the corrosive influence of other components of commercial probiotic product is more significant than that of the bacteria alone.

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