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TRIBOCORROSION IN DENTAL IMPLANTS: AN IN-VITRO STUDY

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Abstract: The relative motion between the zirconia abutment and the titanium implant in the presence of saliva might lead to tribocorrosion and consequently metal ion release and ion contamination of peri -implant tissues. In order to study this issue tribocorrosion, tests were performed in open circuit potential (OCP) and during anodic polarization in two different configurations: titanium ball pin on zirconia plate and zirconia ball pin on titanium plate. For both configurations, the OCP decreases and the anodic current increases during the wear testing. The results showed different tribocorrosion response between configurations. The higher OCP drop and anodic current was obtained for the configuration titanium ball pin on zirconia plate.

Keywords: Implant wear, Ti6Al4V, Tribocorrosion

1. INTRODUCTION

Nowadays, dental implants are a very successful surgical practice in dentistry. However, there are some concerns about implant rejection, as a result of relative motion between abutment and implant. The dental implants are usually made of titanium alloys [1], while abutment and dental crown are made of zirconia. Titanium alloys are recognized by their excellent biocompatibility among metal alloys [1]. Zirconia is a ceramic material that gives to the dental restoration a similar appearance to the natural teeth [2]. This ceramic has the highest tenacity among the ceramic materials, reducing the probability of dental failure due to fracture. The relative motion between the ceramic abutment and the metal implant in the presence of saliva might lead to tribocorrosion and consequently metal ion release and ion contamination of peri - implant tissues.

The main objective of the present work is to investigate the corrosion wear behavior of the system titanium alloy-zirconia under different geometries.

2. MATERIALS AND METHODS

Pin-on-plate reciprocating tribological tests were performed using a nanotribometer (Nanosurf Easyscan 2) in dry conditions and in artificial saliva at room temperature. The contact stress and sliding distance were chosen in order to simulate the mastication conditions. Two tests configuration were studied: titanium ball pin on zirconia plate and zirconia ball pin on titanium plate.

The tribocorrosion tests were performed in a corrosion cell with a reference calomel electrode and a platinum counter electrode. The metal titanium sample was the working electrode in both configurations. The electrodes were connected to a potentiostat (Gamry 600). Tribological tests were carried out during open circuit potential (OCP) and during anodic polarization. The anodic polarizations tests were performed from the OCP with a scan rate of 1 mV/s. The dynamic tests operational conditions are given in Table 1.

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Table 1. Tribological operational conditions.

Applied load (mN)	200
Stroke distance (mm)	1
Frequency (Hz)	1
Duration (min)	10
Contact stress (MPa)*	158

* Determined by application of Hertz equation for elastic contact.

3. RESULTS AND DISCUSSION

In order to evaluate the possibility of tribocorrosion due to the relative motion between abutment and implant, pin on plate reciprocating wear tests were performed using two possible test configurations. The chosen applied load was within the masticatory pressure. In fact, in the literature the mastication force varies between 70 to 700 N. If it is considered an occlusal contact area of 2 mm^2, the compressive stress varies between 35 and 350 MPa during mastication. In the occlusal contact the sliding distance is around 0.9 to 1.2 mm. Also the tests were performed in lubricated medium in artificial saliva to mimic the oral conditions.

The friction coefficient results in OCP conditions were different between test configurations: for the configuration where the plate was Ti6Al4V the fiction coefficient was 1.30±0.03 while for the configuration where the pin was Ti6Al4V was 0.39±0.02.

The OCP tests showed that for both studied configurations, during wear, the OCP dropped revealing increases of the corrosion activity during sliding (Figure 1, region b). The potential drop during wear is due to the partial or total disruption of the passive film during wear [3-5].When the wear tests were stopped the passive film was recovered and the OCP reached the initial value (region c and d). Note that there was one difference between the two experiments. In the experiment carried out with the Ti6Al4V ball, during part of the recovery period the ball was in touch with the zirconia plate (Figure 1, region c) which limited the oxygen diffusion to the contact area and consequently decreases the kinetics of the passive film restoration. In addition, the OCP drop during sliding was different between test configurations. When the pin was Ti6Al4V the potential drop was much higher than when a Ti6Al4V plate was used, revealing more corrosion activity for the configuration where the ball was Ti6Al4V.

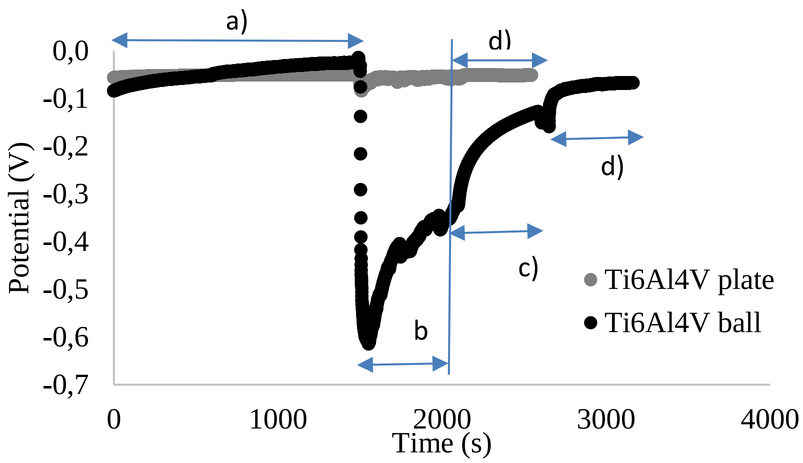

Figure 1. OCP readings for the two tested configurations. a) static conditions before wear testing; b) during wear testing; c) static conditions after wear testing with the ball in contact with the plate; d) static conditions after wear testing without contact between the ball and the plate.

The current obtained in the anodic scans during wear was higher than the one obtained during static conditions (without contact) revealing tribocorrosion (Figure 2). In addition, the anodic polarization tests during wear testing showed differences between test configurations. The anodic current density was higher for the Ti6Al4V ball indicating higher corrosion activity for this configuration.

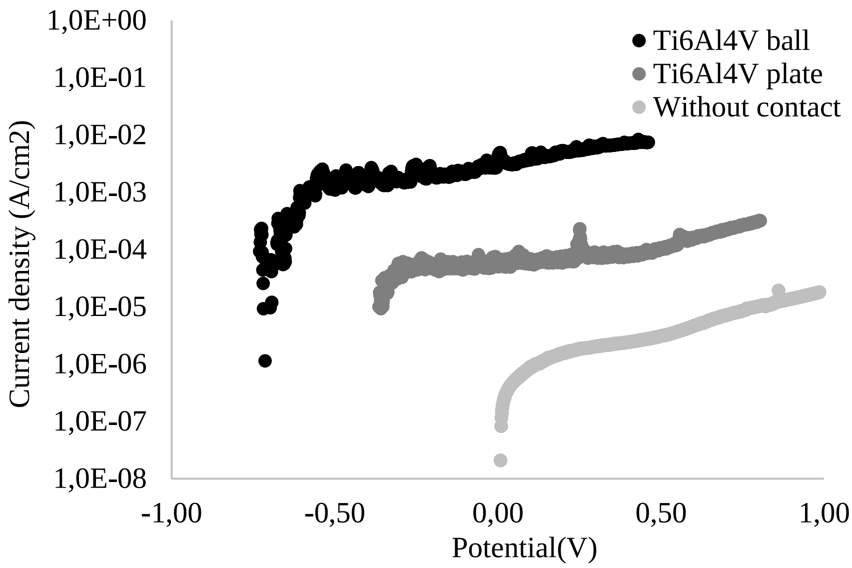

Figure 2. Anodic polarization curves in static conditions (without contact) and dynamic conditions (during sliding) with different test geometries.

The results showed dramatic differences between test configurations in terms of friction and electrochemical response. When a ceramic ball slides against a metallic plate under reciprocating movement (Figure 3 a), the passive film is disrupted on the contacting area between the ball and the plate while in the rest of the wear track the passive film is, at least in part, recovered from the damage produced during mechanical contact. The amount of passive film recovery until the next passage of the ball depends on the ball sliding velocity, passive film recovery kinetics and the previous passive film damage. In contrast, when a metallic ball slides against a ceramic plate (Figure 3 b) all the metallic damaged surface is always in contact with the ceramic counterface. For this test configuration, the recovering of the passive film in the damaged metallic surface will be very difficult due to the mechanic action of the ceramic counterface and limitations of oxygen diffusion to the contacting area. In the contacting area the electrochemical condition can be altered during sliding, for example due to accumulation of wear debris and transference of material to the ceramic surface, changing the electrochemical response during testing.

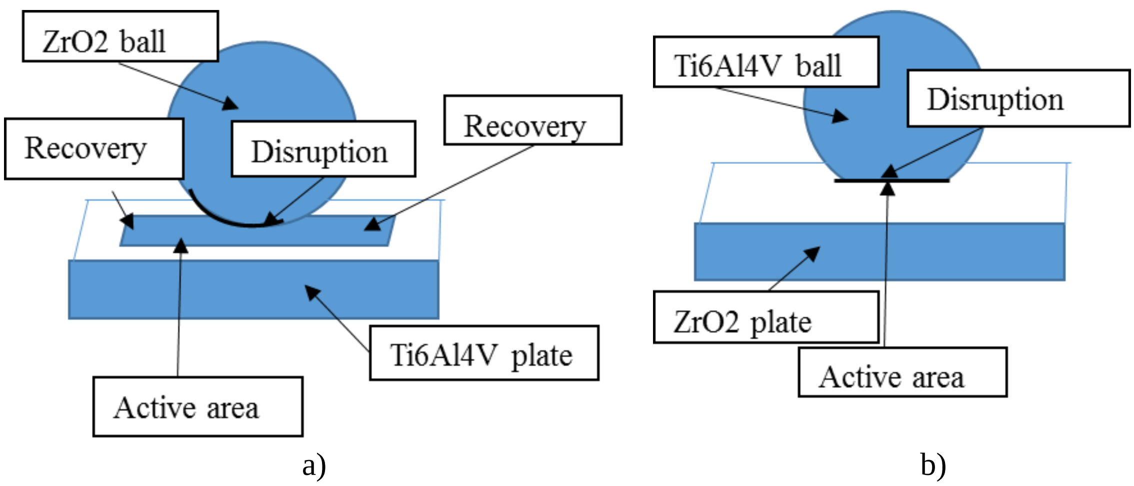

Figure 3. Tribocorrosion model for the two tested configurations a) zirconia ball on Ti6Al4V plate and b) Ti6Al4V ball on zirconia plate.

In the zirconia abutment and titanium implant contacting surfaces, the titanium metallic surface is always in contact with the zirconia pillar. Thus, in reciprocating tests, the configuration more suitable for studying this contact corresponds to the metallic ball on the ceramic plate**.**

3. CONCLUSIONS

The tests performed in artificial saliva revealed the existence of tribocorrosion phenomenon in two different experimental test conditions. In all cases, the OCP decreased and the current density increased during sliding. However, the current density and the OCP results were different between tests configuration: the OCP was the lowest and the current density was the highest for the configuration were the pin was titanium alloy, suggesting differences in tribocorrosion behavior between experimental configurations.

Overall, the present work shows that it is possible to perform nanotribocorrosion tests to study the abutment/implant interaction. In addition reveals the possibility of occurring tribocorrosion in the interface abutment/implant for the system titanium alloy/zirconia.

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