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The role of fluoride on the process of titanium corrosion in oral cavity

Juliana Noguti · Flavia de Oliveira · Rogério Correa Peres · Ana Claudia Muniz Renno · Daniel Araki Ribeiro

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Abstract Titanium is known to possess excellent biocompatibility as a result of corrosion resistance, lack of allergenicity when compared with many other metals. Fluoride is well known as a specific and effective caries prophylactic agent and its systemic application has been recommended widely over recent decades. Nevertheless, high fluoride concentrations impair the corrosion resistance of titanium. The purpose of this article is to summarize the current data regarding the influence of fluoride on titanium corrosion process in the last 5 years. These data demonstrate noxious effects induced by high fluoride concentration as well as low pH in the oral cavity. Therefore, such conditions should be considered when prophylactic actions are administrated in patients containing titanium implants or other dental devices.

J. Noguti · D. A. Ribeiro
Department of Pathology, Paulista Medical School, Federal University of São Paulo, UNIFESP, Santos, SP, Brazil

F. de Oliveira · A. C. M. Renno · D. A. Ribeiro (✉)
Department of Biosciences, Federal University of São Paulo, UNIFESP, Av. Ana Costa, 95, Vila Mathias, Santos, SP 11060-001, Brazil
e-mail: daribeiro@unifesp.br; daribeiro@pesquisador.cnpq.br

R. C. Peres
University of Monte Serrat and Santos Catholic University, Santos, SP, Brazil

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Introduction

Titanium alloys exhibit excellent corrosion resistance in most aqueous media due to the formation of a stable oxide film, and some of these alloys have been chosen for surgical and odontological implants for their resistance and biocompatibility (Fovet et al. 2011; Rosalbino et al. 2012).

Treatment with fluorides (F(−)) is known to be the main method for preventing plaque formation and dental caries. Toothpastes, mouthwashes, and prophylactic gels can contain from 200 to 20,000 ppm F(−) and can affect the corrosion behavior of titanium alloy devices present in the oral cavity (Rosalbino et al. 2012).

In this regard, the goal of this article is to present an overview on the role of fluoride on the titanium corrosion in oral cavity. To the best of our knowledge, there are no reports so far.

Methodology

A comprehensive literature search for studies on “titanium corrosion; fluoride and oral cavity” was performed. In brief, a search of PubMed, MEDLINE, Embase, and Google Scholar for a variety of articles (all publications ranging from 2007 until May 2012) was carried out. Case reports were excluded from the review. Abstracts were reviewed and relevant papers were identified.

Results

Rosalbino et al. (2012) have postulated the presence of significant concentrations of fluoride species that dissolve the spontaneous air-formed oxide film giving rise to surface activation. However, an increase in stability of the passive oxide layer and consequently a decrease in surface activation is observed for the titanium alloys (Rosalbino et al. 2012). In the same way, some authors have investigated the changes in surface morphology of cobalt-chromium alloy, pure titanium and high-cobalt chromium molybdenum alloy immersed in artificial saliva with different concentrations of fluoride, in turn to analyze the corrosion resistance of these metals (Cheng et al. 2012). Metal surface roughness was increased with the concentration of fluoride. The surface roughness of the Co–Cr group and Ti group had a statistically significant difference between before and after immersion at the fluoride concentration of 0.05 % ($P < 0.01$), and the difference between Co–Cr group and Vitallium 2000 group, Ti group and Vitallium 2000 group were statistically significant difference ($P < 0.01$) (Cheng et al. 2012). The differences of three groups before and after immersion were statistically significant at the fluoride concentration of 0.2 % ($P < 0.01$), and the difference among three groups was statistically significant ($P < 0.01$) (Cheng et al. 2012). Such findings are fully in agreement with Liang et al. (2010) who demonstrated the positive correlation between lower pH value and the corrosion resistance of pure titanium and Ti–Ni–Cr alloy and the artificial saliva containing fluoride ions, which decreases the corrosion resistance of pure titanium. In fact, fluoride ions seem to exert a negative influence on the corrosion resistance of Ti–12Zr alloy and Ti–6Al–4V alloy, especially in the acidic artificial saliva which contained over 0.1 % NaF (Cao and Chen 2010).

To further elucidate the role of fluoride ion concentration on the corrosion behavior of Ti and Ti6Al4V implant alloys, when coupled with either metal/ceramic or all-ceramic superstructure, Anwar et al. (2011) examined this scenario by different electrochemical methods in artificial saliva solutions. It was concluded that increased fluoride concentration leads to a decrease in the corrosion resistance of all tested couples. The type of the superstructure also showed a significant effect on the corrosion resistance of the couple (Anwar et al. 2011). It is important to stress that the described evidence of fluoride on titanium alloys derives mostly from in vitro research, which includes oversimplifications in simulating the oral environment. The reactivity in laboratory experiments is dramatically increased relative to the actual clinical conditions, which exaggerates the effects noted. The effects shown have not been validated in vivo, since the only available evidence on intraorally fractured nickel-titanium archwires did not support the implication of hydrogen embrittlement as a failure mechanism. Rather, fractures were found to be related to: (1) mechanical factors associated with loading of the wire in specific arch sites; and (2) the masticatory forces. Clinically, the use of fluoride varnishes at specific, caries-risk sites may provide protection while minimizing the potential risk of adverse effects (Fragou and Eliades 2010).

A study was performed to investigate the putative interactive effects of acetic NaF solutions on titanium and Ti alloy brackets. To this end, two different brackets were immersed in various NaF-containing solutions for 3 days. The equilibrium Ti (EQ) bracket was composed of Ti only, whereas the ortho 2 (OR) bracket was composed of Ti (base) and Ti–6A1–4V (wings). In conclusion, an acetic NaF solution of low pH could damage Ti-based orthodontic brackets (Kang et al. 2008).

To determine the effects of a fluoride prophylactic agent on the mechanical properties and surface quality of a preformed round translucent composite archwire while comparing it with nickel-titanium (Ni–Ti) and multistranded stainless steel wires, Hammad et al. (2012) concluded that using a topical fluoride agent with translucent composite wire could decrease the mechanical properties and might damage the surface of the wire, potentially contributing to prolonged orthodontic treatment. The impact of fluoride and pH acid on the corrosion resistance of orthodontic NiTi was studied using classic electrochemical measurement techniques including follow-up over time of the corrosion potential, polarization measurements, and impedance spectroscopy (Benyahia et al. 2009). The results demonstrated the particularly low corrosion resistance of NiTi alloy in the presence of fluorides. In an acidic environment, the alloy showed greater resistance thanks to the passivation phenomenon. The synergistic action of fluoride and pH acid on NiTi corrosion was not clearly demonstrated (Benyahia et al. 2009). In fact, some authors have assumed that different NiTi archwires had dissimilar corrosion resistance in acidic fluoride-containing artificial saliva, which did not correspond to the variation in the surface topography of the archwires. The presence of fluoride in artificial saliva was detrimental to the corrosion resistance of the test NiTi archwires, especially at a 0.5 % NaF concentration (Lee et al. 2010).

The effect of topical fluoride agents on the mechanical properties of NiTi and copper NiTi archwires was investigated. The results during unloading the modulus of elasticity of the NiTi archwire fell significantly in the gel group. The moduli of elasticity and yield strengths of the NiTi archwires during loading, and the copper NiTi archwires during loading and unloading, were not affected by either the gel or the rinse. Scanning electron microscopic analysis revealed that the copper NiTi archwires in the gel group had the most pitting. Topical fluoride agents alter the mechanical properties of NiTi wires and, hence, may prolong orthodontic treatment. (Ramalingam et al. 2008). Furthermore, some authors aimed to investigate the effect of fluoride released from dental restoratives on orthodontic NiTi wires. Five different restoratives (four fluoride-containing and one non-fluoride-containing) and four different NiTi wires were examined in this study. Therefore, despite the released fluoride, wires in contact with the fluoride-containing restoratives were not damaged regardless of the pH value of test solution (Kwon et al. 2008).

When minicrew implant was investigated, pits and cracks formed on the implant surfaces after immersion in both NaF mouth rinse solutions. Corrosion products, probably sodium aluminum fluoride (Na(3)AlF(6)), were observed on the implants after immersion in both NaF solutions for both time periods. There were no significant differences for mean torque ($P = 0.063$) and twist angle ($P = 0.696$) at fracture compared with control implants (Muguruma et al. 2011). Taken as a whole, although titanium alloy miniscrew implants corroded slightly from immersion in 0.1 or 0.2 % NaF solutions, mouth rinsing by patients with the same fluoride solution concentrations should not cause deterioration of their torsional performance.

Addition of Ag was found to be effective in reducing the corrosion current density and increasing the open circuit potential of titanium in artificial saliva environment. Addition of fluoride ions in the solution severely reduced the corrosion resistance of Ti–Ag alloys (Zhang et al. 2009). To clarify the influence of chromium content on surface reaction of Ti–Cr alloys in an acidic fluoride-containing saline solution, Takemoto et al. (2009), found concentration of chromic species in all alloys, such as oxide and hydroxide in the surface oxide film. This was associated with chromium content, and chromic species improved corrosion resistance to fluoride.

The corrosion behavior of Ti–15Mo alloy in 0.15 M NaCl solution containing varying concentrations of fluoride ions (190, 570, 1,140, and 9,500 ppm) is evaluated using potentiodynamic polarization, electrochemical impedance spectroscopy (EIS), and chronoamperometric/current–time transient (CTT) studies to ascertain its suitability for dental implant applications. The results of the study suggest that Ti–15Mo alloy can be a suitable alternative for dental implant applications (Kumar and Narayanan 2008). In vitro studies using epithelial cells have demonstrated that this study indicates that epithelial cell culturing results can depend on the method used, and the adverse effects of a high F(−) concentration and low pH should be considered when prophylactic gels are applied by patients with Ti implants or other dental devices (Stájer et al. 2008).

Conclusion

In this review, we have highlighted recent advances in the study of titanium corrosion process induced by fluoride in the oral cavity. Therefore, this is an area that warrants investigation, since the estimation of the real risks regarding the issue will be added to those already established in the literature as a way to a better understanding of the corrosion process in the oral cavity.

Conflict of interest None.

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