Analysis of biodegradation of orthodontic brackets using scanning electron microscopy

Luciane Macedo de Menezes**, Rodrigo Matos de Souza***, Gabriel Schmidt Dolci***, Berenice Anina Dedavid****

Abstract

Objectives: The purpose of this study was to analyze, with the aid of scanning electron microscopy (SEM), the chemical and structural changes in metal brackets subjected to an in vitro biodegradation process. **Methods:** The sample was divided into three groups according to brackets commercial brand names, i.e., Group A = Dyna-Lock, 3M/Unitek (AISI 303) and Group B = LG standard edgewise, American Orthodontics (AISI 316L). The specimens were simulated orthodontic appliances, which remained immersed in saline solution (0.05%) for a period of 60 days at 37°C under agitation. The changes resulting from exposure of the brackets to the saline solution were investigated by microscopic observation (SEM) and chemical composition analysis (EDX), performed before and after the immersion period (T0 and T5, respectively). **Results:** The results showed, at T5, the formation of products of corrosion on the surface of the brackets, especially in Group A. In addition, there were changes in the composition of the bracket alloy in both groups, whereas in group A there was a reduction in iron and chromium ions, and in Group B a reduction in chromium ions. **Conclusions:** The brackets in Group A were less resistant to in vitro biodegradation, which might be associated with the type of steel used by the manufacturer (AISI 303).

Keywords: Corrosion. Biocompatibility. Orthodontic brackets. Nickel.

Editor's summary

The occurrence of hypersensitivity caused by the nickel present in stainless steel alloys—widely used in orthodontic treatment—has become increasingly common. Orthodontic brackets, bands and archwires are universally made from this alloy, which contains about 6% to 12% nickel and 15% to 22% chromium. Besides allergenicity, carcinogenic, mutagenic and cytotoxic effects have been attributed to nickel and, to a lesser extent, chromium. One of the factors that determine the biocompatibility of alloys used in dentistry is their resistance to corrosion. However, despite the high resistance of austenitic stainless steel—the major alloy employed in the manufacture of orthodontic brackets—several studies have revealed the corrosion of these brackets. In view of the wide array of factors associated with

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** PhD in Orthodontics, Federal University of Rio de Janeiro (UFRJ). Professor, Master's Program in Orthodontics, School of Dentistry, Rio Grande do Sul Catholic University (PUCRS).
*** MSc in Orthodontics and Facial Orthopedics, PUCRS.
**** PhD in Engineering, Head of the Centre for Microscopy and Microanalysis, PUCRS.

corrosion and the susceptibility of orthodontic brackets to this process, the purpose of this study was to analyze, using scanning electron microscopy (SEM), the chemical and structural changes in two brands of metal brackets subjected to a process of biodegradation in vitro.

Two different brackets were analyzed: Dyna-Lock Standard Edgewise (3M Unitek, Monrovia, CA, USA) and LG Edgewise (American Orthodontics, Sheboygan, Wisconsin, USA), which were divided into 2 experimental groups, according to their commercial brand names. For evaluation by SEM (Philips XL30, Eindhoven, Netherlands) 70 brackets were randomly selected and analyzed in two stages: T0 - analyzed "as received" and T5 - after 60 days immersion in saline. The specimens were immersed in test tubes containing 10 ml of saline solution (NaCl 0.05%, Biochemistry Department, PUCRS) and subjected to a process of chemical-mechanical aging. They remained under agitation for 8 hours a day at a constant temperature of 36±1°C (Dubnoff Bath, Nova Técnica™) for a period of up to 60 days.

The microscopic analysis (SEM) at T0 indicated that the brackets in Group A had a better surface finish than those of Group B. Alterations were found on the surfaces of the brackets after a 60-day immersion in saline solution (T5). These changes were more evident in Group A. As shown in Figures 2 and 3, differences were found in the composition of the metal alloy used in the brackets before (T0) and after having remained 60 days immersed in saline solution (T5). The brackets in Group A showed a reduction in the amount of iron and chromium ($p < 0.05$) and the brackets in Group B showed a decrease in chromium ions ($p < 0.05$).

It should be underscored that the use of alloys with a lower biodegradation rate would reduce the risk of harm to patient health.

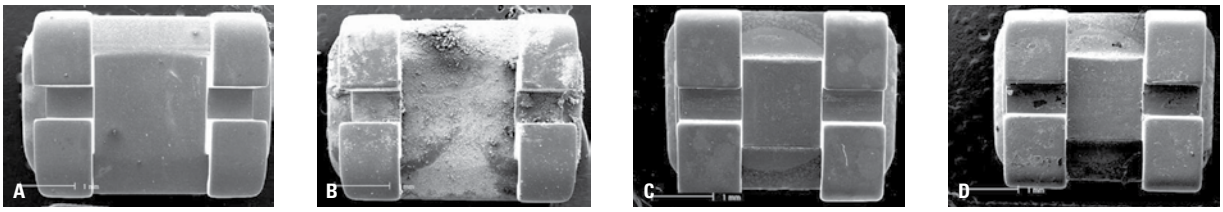

FIGURE 1 - General view (50x) of the brackets in Group A at T0 (**A**) and T5 (**B**) and general view (50x) of the brackets in group B at T0 (**C**) and T5 (**D**). Products of corrosion can be seen at T5, notably in Group A brackets.

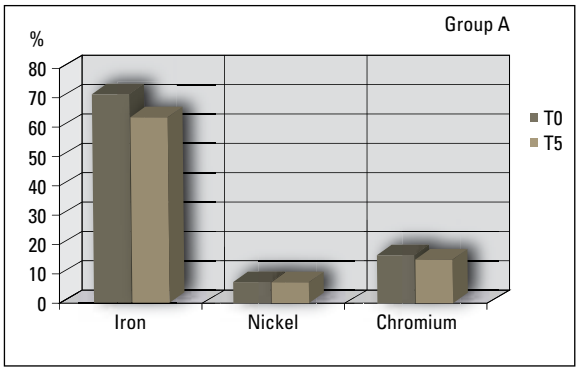

FIGURE 2 - Chemical composition (EDX) of Group A bracket alloy at T0 and T5. There was a reduction in the amount of iron ($p < 0.05$) and chromium ($p < 0.05$) ions.

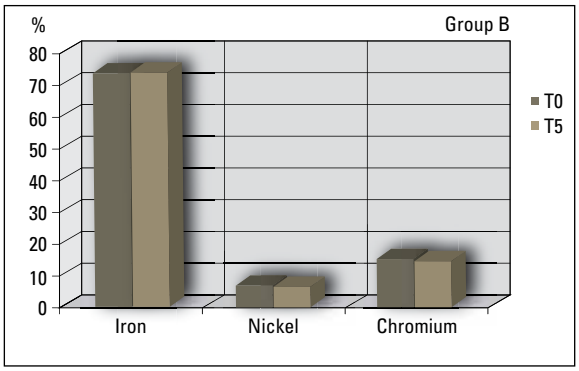

FIGURE 3 - Chemical composition (EDX) of Group B bracket alloy at T0 and T5. There was a reduction in the amount of chromium ($p < 0.05$) ions.

Questions to the authors

1) How did you develop an interest in this subject matter?

Biocompatibility began to arouse our interest because of a patient who showed an allergic reaction to the metal in his cervical headgear. At the time, the patient came to the office reporting urticaria and rash in the neck area. A clinical examination revealed an erythematous area with vesicles in the neck and with injuries on both sides, in the same size and location of the headgear metal parts. The patient's medical history disclosed allergy to non-gold earrings, which caused local inflammation and skin peeling. Thus, contact dermatitis was diagnosed. The treatment consisted in removing the stimulus (replacement of the cervical headgear by a new one with no metal contact with the skin). Fifteen days later, the patient returned with no signs of allergic reaction.[1] Since then we began to study, by means of in vitro[2] and in vivo[3-8] studies, the causes and consequences of the organic reactions which can manifest themselves in local or distant regions of the human body. One of the determinants of biocompatibility of metallic alloys in dentistry is the resistance to corrosion.[6] Corrosion is defined as metal loss or oxidation. In the humid environment of the oral cavity all alloys undergo corrosion, at least to a certain extent.[9] A number of factors can affect the process of ion release by an alloy: Manufacturing method; bracket surface characteristics; features of the environment in which brackets are inserted, such as composition, temperature, pH, bacterial flora, enzyme activity and the presence of proteins;[10] in addition to factors such as alloy usage (aging), which may be subject to adverse conditions such as stress, heat treatment, recycling or reuse of components, among others.[11]

2) What can be done to reduce the biodegradation of metal brackets?

First, we should use good quality materials to minimize corrosion effects. The use of recycled brackets should be avoided. This issue was investigated by assessing the patterns of ion release by new brackets and recycled stainless steel brackets. To this end, the brackets were immersed in solutions with different pH values over a period of 48 weeks. The release of nickel, chromium, iron, copper, cobalt and manganese ions was analyzed by atomic absorption spectrophotometry. The results showed that recycled brackets release more ions than new brackets. This study demonstrates that although both new and recycled brackets will suffer corrosion in the oral environment,[12] the cleaning and sterilization procedures involved in the recycling process result in microstructural changes that increase corrosion. We must also consider the possibility of using alternative products, such as nickel-free brackets, ceramic, titanium, polycarbonate or gold plated brackets.

3) Would it be important to evaluate the cytotoxicity of chemical agents released in the corrosion of steel brackets?

Material biocompatibility entails an appropriate response by the host (organism), which, in dentistry, means the non-occurrence of adverse reactions, or the occurrence of tolerable adverse reactions of the organism to the presence of a given material.[14] The occurrence of any adverse reaction is what we call toxicity. On the other hand, cytotoxicity, or assessment of toxicity in cell culture, is a complex in vivo phenomenon, which can manifest a wide range of effects, from simple cell death to metabolic aberrations, whereby cell death does not occur, but rather changes in cell function.[15]

The literature contains a wealth of studies focusing on metal ion release by orthodontic brackets—especially iron, chromium and nickel, the main stainless steel corrosion products. However, other metal ions present in the silver solder used in orthodontic appliances—such as cadmium, copper and zinc—may be released

into the oral cavity. These are considered potentially hazardous chemicals, included in the list of substances and processes considered of high risk to human life. In a study on ion release and silver solder cytotoxicity, Freitas[7] observed high toxicity of this material in fibroblasts, reflecting changes in cell adhesion, proliferation and growth. Additionally, it was found a significant release of silver solder ions, with high concentrations occurring immediately after appliance installation. These ions were, in descending order, copper, silver, zinc and cadmium, involving a risk of absorption and retention of these ions by the human body.

An in vitro study by Kerosuo, Moe and Kleven[16] found that there seems to occur detectable release of nickel and chromium from orthodontic appliances, with the largest amounts being released under dynamic conditions. Even so, the estimated amount of nickel release of a complete orthodontic appliance is less than 10% of the amount consumed in our daily diet[17] and can be considered negligible from a toxicological standpoint.[16] Barrett, Bishara and Quinn[17] emphasize the need to determine the quantity of these corrosion products that is actually absorbed by the patient. Bergman et al[18] pointed out that they had no information on when the dissolution of nickel alloy begins, nor when the maximum concentration of nickel occurs in various tissues. They also have no knowledge of the pattern or dynamics of nickel release, and the uptake and excretion of nickel by the organism.[3] The real effects of nickel on the functioning of organs and tissues exposed to it is still unknown. Despite several studies, many questions still remain unanswered, pointing to the need for further research on this issue.

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Contact address
Luciane Macedo de Menezes
Av. Ipiranga, 6681, prédio 6, sala 209
CEP: 90.619-900 – Porto Alegre / RS
E-mail: luciane@portoweb.com.br