Galvanic Corrosion among Different Combination of Orthodontic Archwires and Stainless Steel Brackets

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Abstract

Introduction: The aim of this study was to assess the galvanic behavior of different bracket and archwire combinations that are commonly used in orthodontic treatments. **Methods:** Three types of orthodontic archwires with a diameter of 0.016×0.022 inch and 80 standard edgewise maxillary central incisor brackets were selected. Three groups consisted of different wire-bracket couples and one group was just brackets as a control group. Each group had five samples. Four brackets were then connected to each wire by elastic bands made from electrochemically neutral material. The samples were immersed into capped containers of Fusayama-Meyer artificial saliva. After six weeks, the released nickel ions were quantified via ion absorption technique. The mean and the standard deviation of all four groups were calculated and the data were compared together with Kruskal-Wallis non-parametric statistical test. **Results:** The highest concentration of released nickel ions was for bracket+ steel archwire and the least for the bracket without archwire. **Conclusion:** There were not significant differences among experimental groups, so it could be concluded that galvanic corrosion would not be a serious consideration through orthodontic treatment.

Key words: artificial saliva, bracket, galvanic corrosion, orthodontic archwire.

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Introduction

A variety of orthodontic archwires and bracket designs offer the orthodontists a wide choice of different combinations of orthodontic brackets and archwires. The introduction of more flexible wires such as NiTi or TMA wires has increased treatment efficiency and allowed the orthodontist to visit their patients in longer intervals. This entails remaining the wires in the mouth for a correspondingly longer time (1). So; they can be exposed to electrochemical reactions, mechanical forces of mastication, and generalized wear (1,2). All these phenomena are able to accelerate the different types of corrosion processes that can take place in the patient's mouth, and the degradation products from brackets and/or archwires are then released into the oral environment (3). Corrosion is an electrochemical process that arises from 2 concomitant reactions, an oxidation reaction at the anode and a reduction reaction at the cathode (4,5). Based on the conditions of the oral environment, different types of corrosion can occur in the mouth, for instance, crevice corrosion, microbiologically influenced corrosion, and galvanic corrosion.

Constituents of alloys utilizing as orthodontic appliances are mostly nickel, chromium, cobalt, iron, molybdenum, and titanium. Concerning biocompatibility, nickel stands out among the other elements (6). It has been stated that the ions releasing into oral cavity from orthodontic appliances can cause some oral clinical manifestations such as glositis, metal taste, gingivitis, peeling lips, erythema multiforme, and gingival hypertrophy (7-11). On the other hand, the surface alterations of orthodontic devices due to corrosion, might compromise the appliance's esthetics, increase friction during sliding, result in wire fractures, and diminish the torque expression of preadjusted appliances (5,6,12-16).

Considering these negative consequences and since an important part of orthodontic devices such as bands, brackets, and archwires are made of metallic alloys, the focus of many studies has been on corrosion in orthodontic appliances (17-20). Most research on corrosion has observed the measurement of ion release, notably nickel ion, [21-24] or the effect of certain ions, such as fluoride, on corrosion resistance of metals (25-27). Fewer studies have considered galvanic corrosion with various combinations of brackets and wires (1,28-31). Therefore, we aimed to compare the galvanic behavior of different combinations of brackets and archwires that are commonly used in most orthodontic practices.

Materials and Methods

In this study, three types of orthodontic archwires and 80 standard edgewise maxillary central incisor brackets (Equilibrium 2, Dentaurum, Ispringen, Germany) with a slot size of 0.018 inch were used. These three types of archwires were designated as follows: NITI (Dentaurum, Ispringen, Germany), TMA (Dentsply GAC, Calexico, CA, USA), and Stainless steel (Dentaurum, Ispringen, Germany), each with a diameter of 0.016×0.022 inches. The test was composed of four groups, three of which consisted of different wire-bracket couples and the forth was just brackets as a control group. Each group had five samples. All similar specimens were from the same batch number and tested in "as-received" condition from the manufacturers. The wires were cut into 40 mm long specimens. All materials were degreased by swabbing with acetone and placed in an ultrasonic container with distilled water for 10 minutes before testing. Finally they were dried with a hairdryer. Four brackets, then, were connected to each wire by elastic bands made from electrochemically neutral material (American orthodontics, Sheboygan, WI, USA). The bases of all brackets were painted with nail polish to insulate the brackets' meshes from the corrosive effect of the medium. The samples were immersed into capped containers, including 1.8 cc Fusayama-Meyer artificial saliva (Table 1) and placed inside one incubator (GCA, Precision Scientific) with a temperature of 37±1ºC.

After six weeks, the samples were removed from the incubator and sent to chemical lab for ion absorption test to evaluate the concentration of nickel ion in each medium. The mean and the standard deviation of all four groups calculated and the data were compared together with Kruskal-Wallis non-parametric statistical test, carried out by SPSS 11.0 (SPSS 11.0 Windows, SPSS Inc, Chicago).

Results

As to the obtained data, charted in the Table 2, the highest concentration of released nickel ion belonged to the third group (steel bracket+ steel archwire) and the least was for the fourth group (steel bracket without archwire). Amid these two groups, Bracket-NiTi wire and Bracket-TMA wire groups were in second and third rank, respectively.

As it could be seen, the average of nickel ion concentrations was roughly the same in the groups including NiTi wires and steel wires (Table 2).

However, Based on Kruskal-Wallis test, there were no significant differences in the amount of nickel ion concentration among the four groups ($P= 0.319$).

Table 1. Fusayama-Meyer artificial saliva solution composition

Chemical compound	Concentration (g/l)
KCl	0.4
$NaCl$	0.4
$CaCl_2 \cdot 2H_2O$	0.906
$NaH_2PO_4 \cdot 2H_2O$	0.690
$Na_2S \cdot 9H_2O$	0.005
$CO(NH_2)_2$	1.000

Table 2. The mean and standard deviation of released nickel ion in experimental groups

Group	$\bar{X} \pm SD$	Median	P-value
Bracket-NiTi wire	146.21 ± 83.97	172.42	0.319
Bracket-TMA wire	84.01 ± 27.00	84.49	
Bracket- steel wire	155.40 ± 126.04	150.80	
Bracket alone	46.27 ± 18.18	49.72	

Discussion

Nowadays, many new alloys have been introduced and were used as to their physical and mechanical properties in modern orthodontic treatments. Archwires made of nickel-titanium (NiTi), titanium-molybdenum (TMA), and also stainless steel are examples that are suitable to apply optimum and physiological forces to teeth.

It has been proved that orthodontic archwires could lead to adjacent brackets corrosion in oral cavity in the presence of saliva, and it would be intensified if two alloys were not similar. In electrochemical corrosion, a galvanic cell is created when two different metals, or different areas on the same metal, are coupled. In galvanic corrosion, some current flows between the anodic and the cathodic areas situated at different parts of a metallic surface or between different metals of the same or different materials. The driving force for corrosion is a potential difference between the different materials (32-35).

Clinically, mixed alloys having different corrosion potentials are often placed in contact in the oral environment, as with orthodontic brackets and archwires. This can cause galvanic corrosion that leads to preferential release of metal ions from the anodic alloy (galvanic corrosion) (32-35).

While it is common for orthodontists to use such archwires in their treatments, hypersensitivity to nickel ion in some cases has been reported and some studies showed an allergic as well as toxic effect for this metallic ion (13-15). On the other hand, corrosion is able to deteriorate mechanical properties of archwires.

Present research, conducted in order to compare the amount of nickel ion released from different archwire-bracket complex, the control group, which included just brackets without any orthodontic wires, illustrated the least amount of the ion while the most belonged to stainless steel brackets coupled with steel archwires (Table 2). This finding was similar to the results of Kim's study, compared the corrosion resistance of different types of orthodontic archwires in a normal saline solution (19).

However, there were not any statistical differences in the amount of nickel ion release among tested groups (P=0.319). Therefore, it could be concluded that galvanic corrosion would not be a major concern to intensify nickel release in oral cavity during orthodontic treatments.

There are, nevertheless, many factors intervening in corrosion resistance changes in vivo that ought to be taken into account. On the other hand, in-vitro studies testing corrosion resistance lack the simulation of the oral cavity with its multifactorial environment. It is difficult to produce a similar corrosive environment. Studies showed that the surface roughness of orthodontic archwires should to be taken as an important indicator of the trend toward archwires' corrosion resistance (36,37). The surface defects on orthodontic archwire produced during the manufacturing procedure can be the probable locations for corrosion occurrence (38).

Although *in vivo* studies are extremely beneficial in explaining how oral tissues and orthodontic materials react in their actual functioning environment, the interpretation of the results is usually difficult because of many factors not under experimental control. So in this study, we decided to evaluate galvanic corrosion behavior of different types of orthodontic archwires in vitro.

Conclusion

Based on the results obtained in this study, it could be concluded as follows:

- The least amount of nickel ion release was for control group (bracket alone without any combined archwire) and the most for bracket-stainless steel archwire.
- The order of nickel release in experimental group was

Bracket-stainless steel wire > bracket- NiTi wire > bracket-TMA wire> bracket only

- There were no significant differences among experimental groups, so it could be concluded that galvanic corrosion would not be a serious consideration through orthodontic treatment.

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