Ion release from orthodontic brackets in 3 mouthwashes: An in-vitro study

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Introduction: Stainless steel orthodontic brackets can release metal ions into the saliva. Fluoridated mouthwashes are often recommended to orthodontic patients to reduce the risk of white-spot lesions around their brackets. However, little information is available regarding the effect of different mouthwashes in ion release of orthodontic brackets. The purpose of this study was to measure the amount of metal ion release from orthodontic brackets when kept in different mouthwashes.

Methods: One hundred sixty stainless steel brackets (0.022-in, 3M Unitek, Monrovia, Calif) were divided randomly into 4 equal groups and immersed in Oral B (Procter & Gamble, Weybridge, United Kingdom), chlorhexidine (Shahdaru Laboratories, Tehran, Iran), and Persica (Poursina Pharmaceutical Laboratories, Tehran, Iran) mouthwashes and distilled deionized water and incubated at 37°C for 45 days. Nickel, chromium, iron, copper, and manganese released from the orthodontic brackets were measured with an inductively coupled plasma spectrometer. For statistical analysis, 1-way analysis of variance (ANOVA) and the Duncan multiple-range tests were used.

Results: The results showed that ion release in deionized water was significantly \( P < 0.05 \) higher than in the 3 mouthwashes. Higher ion release was found with chlorhexidine compared with the other 2 mouthwashes. There was no significant difference \( P > 0.05 \) in nickel, chromium, iron, and copper ion release in the Oral B and Persica mouthwashes. The level of manganese release was significantly different in all 4 groups.

Conclusions: If ion release is a concern, Oral B and Persica mouthwashes might be better options than chlorhexidine for orthodontic patients with stainless steel brackets. (Am J Orthod Dentofacial Orthop 2011;139:730-4)

During the last decade, there has been increased interest among dental and biomedical professionals in the side effects associated with the use of biomaterials, especially the metallic materials. Fixed appliances in orthodontics involve brackets and archwires that are metallic. These brackets are exposed to the oral cavity, which is a potentially hostile environment where electrochemical corrosion phenomena can occur. Thus, orthodontic brackets and other auxiliary components should be made of highly corrosion-resistant metals and metal alloys. In recent years, it has been reported that bracket corrosion can occur in the oral environment. In an acidic environment and in the presence of fluoride ions, the corrosion resistance of certain materials, particularly titanium and titanium alloys, can deteriorate. Practitioners can choose from a wide range of wires and brackets made from various alloys such as stainless steel (iron, chromium, and nickel), titanium, and cobalt-chromium alloy. Generally, stainless steel alloys that contain 8% to 12% nickel and 17% to 22% chromium are used for the metallic parts of orthodontic appliances.

The harmful effects of nickel—its carcinogenicity, allergenicity, and mutating substances—have been systematically investigated at the cell, tissue, organ, and organism levels. Approximately 10% of the general population has a hypersensitive reaction to nickel. Peltoten reported that women are 10 times more sensitive to nickel than men. Nickel can cause...
hypoallergenic, contact dermatitis, asthma, and cytotoxicity. In a study in which cultured human cells were used, nickel was recently reported to be moderately cytotoxic, whereas chromium was considered to have little cytotoxicity. Park and Shearer measured the in-vitro average amounts of nickel and chromium released per day, and Barrett et al studied the corrosion rate of simulated orthodontic appliances. However, the ion release in only a short time was not enough to evaluate the biocompatibility of orthodontic appliances that are in the mouth for 2 to 3 years.

During orthodontic treatment, practitioners recommend that their patients use mouthwashes, especially since most are adolescents who do not always follow a satisfactory oral-hygiene regimen and have a high risk of dental caries. Nowadays, the regular use of fluoride-containing products such as toothpastes and mouthwashes during orthodontic treatment is recommended to reduce the risk of the development of white spots around orthodontic brackets. Although fluoride ions in the prophylactic agents have been reported to cause corrosion and discoloration, little information is available regarding the effect of different mouthwashes in ion release of orthodontic brackets. The purpose of this study was to measure the levels of metal ions released from orthodontic brackets after immersion in several mouthwashes. These results should help practitioners to decide which mouthwash to prescribe for their patients.

MATERIAL AND METHODS

One hundred sixty premolar stainless steel brackets (0.022-in, 3M Unitek, Monrovia, Calif) were used for this study. All brackets were used in as-received condition. The brackets were divided randomly into 4 equal groups and immersed in Oral B (Procter & Gamble, Weybridge, United Kingdom), chlorhexidine (Shahdaru Laboratories, Tehran, Iran), and Persica (Poursina Pharmaceutical Laboratories, Tehran, Iran) mouthwashes, and distilled deionized water.

These mouthwashes were chosen because of their commercial availability and identical methods of application. Group 1 used Oral B mouthwash containing water, glycerin, alcohol, aroma, methyl paraben, poloxamer 407, cetyl pyridium chloride, sodium fluoride, sodium saccharin, and propylparaben. Group 2 used chlorhexidine mouthwash with 0.2% chlorhexidine digluconate and 13.65% ethanol. Group 3 used Persica herbal mouthwash containing extracts of Salvadora persica, mint, and yarrow with the main ingredients of tanin, flavonoid, calcium, fluoride, chloride, and essence. Persica mouthwash was prepared by diluting 15 drops of the original solution into 15 mL of distilled deionized water. In addition to these 3 mouthwashes, distilled deionized water was used in group 4 (control).

Each bracket was incubated in an oven set at a constant temperature of 37°C in individual 20-mL plastic-capped vials containing 15 mL of 1 mouthwash solution or distilled deionized water for 45 days.

After incubation for 45 days, the immersion solution was tested with an inductively coupled plasma (ICP) spectrometer (ICP-OES, Varian, Vista-Pro model, Mulgrave, Victoria, Australia; 1400W applied power). Unlike other methods such as atomic emission spectrometry, ICP has the advantage of extracting each ion simultaneously and detecting the metals without the interference of other ions.

Standard stock solutions (100 mg mL$^{-1}$) of chromium, copper, iron, manganese, and nickel were prepared by dissolving their appropriate salts in distilled deionized water. More dilute solutions (0.1–10 mg mL$^{-1}$) of each ion were freshly prepared daily by appropriate dilutions of their stock solutions. To minimize the matrix effect in ICP measurements, the stock solution of each ion was diluted with the appropriate mouthwash. Each solution was analyzed for chromium, copper, iron, manganese, and nickel ions. Measurements of pH for each mouthwash and the distilled deionized water were made with a pH meter (model 781, Metrohm AG, Herisau, Switzerland) by using a combined glass electrode.

Statistical analysis

One-way analysis of variance (ANOVA) was used to analyze the differences among mean ion concentrations in the 4 groups. The Duncan multiple range test was applied to show the differences between groups.

RESULTS

Mean levels of the ions released in the groups are shown in the Table. The results of the Kolmogorov-Smirnov test showed that, except for copper and iron ions, all other ions had normal distributions. Therefore, a nonparametric test (Kruskal-Wallis) showed that the release of copper and iron in the 4 mouthwashes was significantly different. ($P = 0.00$) Also, the Mann-Whitney test with a significance level of less than 0.008 showed no significant difference in iron release between Oral B and Persica ($P = 0.031$) and was significantly lower than what was observed for water. Copper release between chlorhexidine and Persica and also between chlorhexidine and distilled water was not significantly different ($P = 0.384$ and $P = 0.009$, respectively).

The test of homogeneity (Levene statistic) showed that chromium, manganese, and nickel releases were
not homogenous; a post-hoc test (Tamhane) was used to compare the groups. Only nickel release between Oral B and Persica was not significantly different ($P = 0.239$). Nickel release was similar in oral B and Persica ($P >0.05$) (Table), and this was significantly lower than in chlorhexidine and water.

Nickel release in other mouthwashes (chlorhexidine and distilled deionized water) and chromium and manganese release in all the mouthwashes were significantly different ($P = 0.00$).

Also, the level of chromium in chlorhexidine was significantly lower than in water. The level of manganese release was in the following order: chlorhexidine < Persica < Oral B < water. Except for copper release, which was similar in chlorhexidine and distilled water, the amounts of all ions released in deionized water were significantly higher than the amounts released in the 3 mouthwashes. Compared with the other ions, the level of copper release was the least among all the groups studied.

For further elucidation of the reasons for ion release in the different solutions, the pH values of the 3 mouthwashes and distilled deionized water were measured. The values were 7.5 for distilled deionized water, and 5.5, 5.2, and 5.4 for Oral B, chlorhexidine, and Persica, respectively.

**DISCUSSION**

Usually, mouthwash must be used twice a week for about 1 minute. But it is recommended that after mouthwash the patient must not eat, drink, and rinse, so the components of mouthwash are present for a long time, and it is difficult to determine the exact duration of contact between brackets and mouthwashes. We assumed that each time the mouthwash was present for 6 hours in a patient’s mouth (24 months, twice a week = about 69,000 minutes), so for this study the brackets were immersed in mouthwashes and incubated at 37°C for 45 days (45 days = about 64,000 minutes). Also, several studies have demonstrated that the levels of metal release from fixed orthodontic appliances peak at day 7, and that all release is completed within 4 weeks.$^{16-18}$

In our study, the distinct increase in the level of the release of all ions in deionized water might be attributed to its corrosive nature. The corrosion of different metals and alloys as a result of immersion in deionized water has been studied.$^{26}$ Many parameters affect the corrosion of metals in a water environment, including pH level, oxygen content, water temperature, and duration of immersion. It has also been reported that the corrosion rates of steel increase with aeration of pure water, and dissolved oxygen in pure water is 5 to 10 times more aggressive than carbonic acid. The deionized distilled water used in this study had a pH of 7.5; therefore, the deionized water was not acidic and was not responsible for its corrosiveness. The reason might be because deionized water has an extremely low concentration of ions, and the lack of ions makes this solvent one of the most aggressive solvents known.

A comparison of nickel release from the brackets in the various solutions showed that the maximum release was in deionized water and the next highest was in chlorhexidine mouthwash. Chlorhexidine mouthwash released greater amounts of metal ions (except manganese) than did the Oral B and Persica mouthwashes. Chlorhexidine not only caused the release of significantly higher amounts of nickel and chromium ions among the 3 mouthwashes studied, but it also caused not significantly higher release of copper than did Persica (Table). Since the pH values for mouthwashes had no significant difference in the acidity of the 3 mouthwashes, this could be attributed to the corrosiveness of chlorhexidine compared with the other 2 mouthwashes; this agrees with previous reports about the irrigating effects of chlorhexidine.$^{27,28}$ But the corrosiveness of chlorhexidine is not the sole parameter in the release of all metallic ions from the brackets, because high releases of manganese in Oral B and Persica solutions were observed. The level of manganese release was significantly different in all 4 groups and, interestingly, was lowest in chlorhexidine.

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**Table.** Metal ion concentrations ($\mu$g/L) in the solutions at 37°C after 45 days: mean concentration levels, standard deviations, and ranges

<table>
<thead>
<tr>
<th>Solution</th>
<th>Chromium</th>
<th>Copper</th>
<th>Iron</th>
<th>Manganese</th>
<th>Nickel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oral B (group 1) (n = 40)</td>
<td>90.7 ± 8.9</td>
<td>0.0 ± 0.0</td>
<td>53.5 ± 6.3</td>
<td>1064.8 ± 17.4</td>
<td>171.5 ± 18.4</td>
</tr>
<tr>
<td>(0.0-300.0)</td>
<td>(0.0-0.0)</td>
<td>(0.0-220.0)</td>
<td>(700.0-1510.0)</td>
<td>(0.0-540.0)</td>
<td></td>
</tr>
<tr>
<td>Chlorhexidine (group 2) (n = 40)</td>
<td>484.8 ± 39.5</td>
<td>19.0 ± 5.8</td>
<td>61.1 ± 28.1</td>
<td>206.9 ± 8.2</td>
<td>1198.3 ± 36.4</td>
</tr>
<tr>
<td>(0.0-1380.0)</td>
<td>(0.0-310.0)</td>
<td>(0.0-175.0)</td>
<td>(0.0-320.0)</td>
<td>(540.0-1950.0)</td>
<td></td>
</tr>
<tr>
<td>Persica (group 3) (n = 40)</td>
<td>25.1 ± 2.3</td>
<td>4.1 ± 1.0</td>
<td>73.1 ± 4.5</td>
<td>748.2 ± 35.3</td>
<td>109.7 ± 4.4</td>
</tr>
<tr>
<td>(0.0-80.0)</td>
<td>(0.0-50.0)</td>
<td>(0.0-170.0)</td>
<td>(0.0-137.0)</td>
<td>(4.0-180.0)</td>
<td></td>
</tr>
<tr>
<td>Deionized water (group 4) (n = 40)</td>
<td>838.1 ± 32.9</td>
<td>80.4 ± 11.8</td>
<td>882.4 ± 114.7</td>
<td>1861.1 ± 62.7</td>
<td>2627.4 ± 151.0</td>
</tr>
<tr>
<td>(0.0-1620.0)</td>
<td>(0.0-390.0)</td>
<td>(4.0-230.0)</td>
<td>(550.0-4160.0)</td>
<td>(0.0-7040.0)</td>
<td></td>
</tr>
</tbody>
</table>
mouthwash. This might be the result of the fluoride anion in the other 2 mouthwashes (Oral B and Persica); under acidic conditions, the fluoride anion increases the dissolution of manganese. In an acidic environment, corrosion could easily occur even with low fluoride concentrations. There was no significant difference between the nickel and iron ion release abilities of Oral B and Persica.

From a clinical viewpoint, the corrosion of brackets might affect how they slide on the archwire, and the final result of orthodontic treatment could be compromised.

Certain ions such as nickel and chromium can result in symptoms of toxicity and allergic reactions. These symptoms can be short-lived and intense or longer lasting and moderate, and some might be resolved, whereas others can become a chronic problem. Since the toxicity of nickel is a concern, and the natural capacity to eliminate nickel exceeds the accumulation capacity, the risks are minimal. However, clinicians should be aware that the release of metal ions might cause a local hypersensitivity reaction at oral soft-tissue sites, such as mild erythema or redness with or without edema. Also, severe gingivitis can be related not only to poor oral hygiene but also to a hypersensitivity reaction to nickel or chromium ions released from stainless steel. We also need to determine whether these ion releases have clinical significance in sensitizing patients with a history of hypersensitivity.

Metal is released into the oral cavity with saliva as the medium, and this could be influenced by a high chloride mixture in the saliva or the intake of various foods and drinks with a low PH. Also, the characteristics of saliva change according to the patient’s health and the time of day. We used mouthwashes in a static condition, but more metal release could occur in real life because of the fluidity of saliva in the mouth and also because oxide layers are removed by tooth brushing. found a great amount of release after using an oral functioning simulator apparatus to simulate the dynamic conditions of the mouth.

Adhesive resins were not used on the base of brackets in this study to prevent other sources of ion release. Therefore, the exposed surface for ion release was approximately twice that of clinical conditions because the bracket bases would be covered with a bonding material in clinical use.

Daily amounts of chromium and nickel intake from foods are 5 to 100 μg and 300 to 500 μg, respectively. Nickel concentrations in drinking water generally measure below 20 μg per liter, and average chromium levels in drinking water are 0.43 μg per liter. The ions released from orthodontic appliances in this study were insignificant when compared with the amount from daily food and water intake. Although there are different study designs, this result was also reported in other studies.

However, even such a small amount of release might produce sensitivity when the orthodontic appliances are in place for 2 to 3 years. But, for an allergic reaction in the oral mucosa, an antigen must be 5 to 12 times greater than that needed for a skin allergy.

The general mechanism for the corrosion and subsequent release of metal ions from stainless steel involves the loss of the passive layer consisting of chromium oxide and chromium hydroxide that forms on contact with oxygen on the surface of stainless steel. Crevice corrosion, which is an intense local attack in shielded areas on a metallic surface, is the mechanism involved in the corrosion of orthodontic brackets.

Since for comparison of ion release in different mouthwashes, we needed a basic solution without influencing ions, we used deionized water to prevent the effects of saliva composition on the basic results. We measured the means of ions released from every bracket in separate vials, but, on the basis of about 20 brackets in a patient’s mouth in clinical use, the results might become clinically significant.

In our study, the total amounts of nickel and chromium released during 45 days in deionized water were greater than the results of Barrett et al. They evaluated ion releases from bands and brackets in artificial saliva during a 4-week period by atomic absorption spectroscopy. This might be attributed to differences in study design, measuring methods, solutions, and timing. Also, differences have been found in the metal release between corresponding products of different manufacturers. Surface area is a relevant factor in the corrosion of metals, but determining the surface area of orthodontic bands and brackets with their complex geometry was beyond the scope of this study.

Variations in study designs and different electrochemical factors make comparisons between the studies difficult. The amounts of chromium and nickel released in chlorhexidine and deionized water during 45 days were more than those found by Kerosuo et al, although they studied ion releases of different appliances in sodium chloride under the dynamic conditions of an oral simulator. Since they used different appliances (headgear, quadhelix, and fixed appliances), comparisons between studies must be done with due consideration of the problem in measuring surface areas with complex geometry.

However, from our results, it can be concluded that the corrosiveness of the mouthwash, which in turn depends on its chemical structure, is the main factor responsible for the release of metal ions from dental brackets.
CONCLUSIONS

The orthodontic brackets released the most ions in the presence of chlorhexidine mouthwash. It might be recommended to avoid prolonged application of chlorhexidine in patients who have allergies.

REFERENCES