

Comparison of Metal Release from New and Recycled Bracket-Archwire Combinations

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Abstract: Most orthodontic brackets and archwires made from stainless steel or nickel (Ni)–titanium (Ti) alloys can release metal ions into the saliva. This study measures the amounts of metal released from simulated fixed orthodontic appliances. Sixty simulated fixed orthodontic appliances were manufactured in different ways and divided into four equal groups as follows: new brackets and new archwires (group 1 controls), new brackets and recycled archwires (group 2), recycled brackets and new archwires (group 3), and recycled brackets and recycled archwires (group 4). The bracket bases coated with adhesives were heated at 350°C for 30 minutes. Recycled archwires were sterilized by autoclaving. Each appliance was soaked in artificial saliva of pH 7 at 37°C for 45 days. At the end of this period, a sample of the artificial saliva was collected for analysis. Concentrations of Ni, chromium (Cr), iron (Fe), manganese, copper (Cu), and Ti ions were measured by atomic absorption and recorded in micrograms per liter. Analysis of variance and the Duncan multiple-range test indicated significant differences among the groups ($P < .001$). The study revealed the following: (1) group 4 released higher amounts of Cr, Fe, and Ti than any of the other three combinations; (2) Ni release was similar in groups 1 and 2 and in groups 2, 3, and 4; (3) the amounts of Cu, Cr, and Ti ions released from groups 3 and 4 were significantly greater than the amounts released from the other two combinations. (*Angle Orthod* 2004;75:92–94.)

Key Words: Corrosion; Salivary pH

INTRODUCTION

Most orthodontic bands, brackets, and archwires are made of stainless steel containing 8% to 12% nickel (Ni), 17% to 22% chromium (Cr), and various proportions of manganese (Mn), copper (Cu), titanium (Ti), and iron (Fe).¹ The various components of devices such as face bows, molar bands, and brackets are either welded together or brazed. The most common brazing alloys consist of silver and Cu, and some also contain zinc.² All brazed appliances corrode to some extent in the oral environment, facilitating the release of metals that can cause adverse effects.³ The corrosion resistance of stainless steel products can be increased by incorporating higher proportions of Cr, Ni, molybdenum, Ti, and lower amounts of sulfur and carbon.⁴

Cytotoxic effects result when tissues are exposed to a sufficient concentration of a primary irritant for a sufficient

time. Cu and zinc are cytotoxic metals.² Ni and Ti are much less toxic than other heavy metals. Animal research has shown that a relatively high concentration of Ni is needed to produce toxic effects but that low concentrations of this metal can provoke allergic reactions.^{5,6} Reports in the literature indicate that approximately 10% of the general population is sensitized to Ni and that the prevalence is higher in female individuals.^{7,8} Average daily intake through food has been estimated at 3.52 mg/d for Mn,⁹ 200 to 300 µg/d for Ni,^{10,11} 280 µg/d for Cr,¹² and 300 to 2000 µg/d for Ti.¹³

NiTi archwires exhibit unique physical properties of increased elasticity and resilience, greater working range, and higher resistance to corrosion than stainless steel. Reuse of NiTi archwires has been advocated because of the high costs of these materials.¹⁴

Previous work has focused on corrosion of alloys containing Ni, Cr, Ti, and Fe, but no study to date has examined the levels of Ni, Cr, Mn, Cu, Ti, and Fe released from fixed appliances made of different combinations of new and recycled materials. In this investigation, we compared levels of release of several ions from different types of standard orthodontic appliances in vitro. The appliances consisted of different combinations of new and recycled bands, brackets, and NiTi archwires. The aim was to determine and compare the levels of Ni, Cr, Mn, Cu, Ti, and Fe released from four bracket-archwire combinations.

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TABLE 1. The Mean Concentration ($\mu\text{g/L}$) and Standard Deviation (SD) for Each Ion Assessed, and Comparison of Differences Among Groups by Analysis of Variance^a

Group	1		2		3		4		P
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Fe	67.7	9.6	64.3	8	115	11.9	140	9.4	.001***
Ni	10	6.3	15	3.3	20	6.5	20	3.3	.001***
Mn	2	0.7	2	0.8	2	0.6	2.5	0.3	.09
Cu	10	3.2	15	5	25	6.3	31	10.2	.001***
Cr	4.5	0.5	4	0.7	7.3	0.6	7.5	0.6	.001***
Ti	2	0.6	2	0.7	3.5	1.3	4	0.7	.001***

^a SD, standard deviation.

*** $P < .001$.

MATERIALS AND METHODS

Sixty structurally identical sets of bands, brackets, and archwires simulating fixed orthodontic appliances were constructed. Each appliance included five premolar brackets, five ligature wires, a three-cm-long NiTi archwire and a four-cm-long stainless steel band material. The 0.018-inch-slot width stainless steel bondable brackets and band materials and the 0.016-inch NiTi archwires were made by GAC International Inc (Bohemia, NY). The inner surfaces of the bands and new brackets were not coated with resins. The recycled bracket bases were coated with adhesives, and these were heat treated at 350°C for 30 minutes to burn off the adhesives. The brackets were welded at two points, simulating clinical welding, and were ligated with 0.010-inch stainless steel ligature wires. All reused archwires had been worn intraorally for 12 weeks and then sterilized in an autoclave.

The 60 appliances were divided into four groups as follows: new brackets and new archwires (group 1 controls, $n = 15$), new brackets and recycled archwires (group 2, $n = 15$), recycled brackets and new archwires (group 3, $n = 15$), and recycled brackets and recycled archwires (group 4, $n = 15$). Each appliance was immersed in 50 mL of artificial saliva at pH 7 and kept in an incubator at 37°C for 45 days. The sample solution from each specimen was then filtered through red-ribbon filter paper (Schleicher and Schüll), and inductively coupled plasma (ICP-OES) was used to analyze the Ni, Cr, Mn, Cu, Ti, and Fe ion concentrations by atomic absorption spectrophotometry. Levels were recorded in micrograms per liter.

Analysis of variance was used to analyze differences among mean ion concentrations in the four groups. The Duncan multiple-range test was used to show differences between groups.

RESULTS

Analysis of variance showed that there were statistically significant differences among the groups for all ions tested except Mn (Table 1). The Duncan multiple-range test showed that Fe ion release was similar in groups 1 and 2 (Table 2). Ni release was similar in groups 1 and 2 and in groups 2–4 (Table 2). The amounts of Cu, Cr, and Ti ions

TABLE 2. The Results of Analysis with the Duncan Multiple-Range Test, Which Assessed for Similar Levels of Ion Release Among the Groups

Group	Fe	Ni	Cu	Cr	Ti
1	▲	●	▲		
2	▲	▲●	▲		
3		▲	●	▲	▲
4		▲	●	▲	▲

▲ and ● show the similar ion concentrations.

$P < .001$.

released from the group-3 and group-4 appliances were significantly greater than the amounts of these ions released from the other two combinations (Table 2).

DISCUSSION

Factors such as temperature, quantity and quality of saliva, salivary pH, plaque, the amount of protein in saliva, physical and chemical properties of food and liquids, and general and oral health conditions may influence corrosion in the oral cavity. Huang et al⁴ analyzed metal ions released from new and recycled metal brackets after immersion in artificial saliva or buffer ions of varying pH values and observed greater release of Ni, Cr, Fe, and Mn in artificial saliva under acidic conditions compared with the amounts released in other buffers. Several studies have demonstrated that levels of metal release from fixed orthodontic appliances peak at day 7 and that all release is completed within four weeks.^{15–17} Considering this, for our study we immersed simulated fixed orthodontic appliances in artificial saliva of neutral pH at 37°C for six weeks. At the end of this period, we observed rust-colored precipitates in all the sample bottles, with the darkest in group 4. This was due to a high Fe concentration, as noted by Gjerdet and co-workers.¹⁸

Several previous reports have documented different amounts of Cr, Mn, Cu, and Fe release for appliances made of new brackets and new archwires.^{1,15,17,19} In our study, we found that the amounts of Fe, Cu, Cr, and Ti released from the appliances with recycled brackets (groups 3 and 4) were significantly higher than the levels observed in the other two groups.

In contrast, reuse of archwires is not associated with significantly greater release of these ions. Huang et al⁴ also noted increased release of Fe and Cr ions from the recycled brackets. Surface characteristics can provide information about the corrosion of used archwires compared with new archwires. Although the surfaces of recycled NiTi wires do show pitting corrosion, the physical and mechanical properties of the wires are unchanged.^{19–21} Sarkar and Schwaninger²⁰ noted pitting corrosion and corrosion products rich in Ti on the surface of used NiTi wires. Grimsdottir and Hensten-Pettersen²² evaluated and analyzed the surface of reused NiTi archwires and new NiTi archwires, both of which were worn intraorally, for evidence of corrosion and corrosion products and detected no differences in surface topography or the composition of reused and new archwires. We found that Mn release was greatest in the group with appliances made from recycled brackets and recycled archwires, but this level was not statistically different from the levels in any of the other three groups. In accord with this, Huang et al⁴ also noted increased Mn ion release with recycled brackets.

Several studies have demonstrated increased Ni release from recycled brackets and from corrosion of NiTi archwires.^{4,19–21} In our study, the control group (new brackets and new wires) showed the lowest level of Ni release. Analysis showed that the other three groups had similar Ni concentrations and that the level of Ni release in group 2 (new brackets–recycled archwires) was similar to that in the control group. These findings suggest that recycling of brackets and archwires results in increased Ni ion release into the saliva. However, Ni release was similar in the two groups with new brackets (regardless of archwire type), and only the use of recycled brackets was statistically associated with higher amounts of Ni in the samples.

According to our results, the use of recycled brackets results in significantly higher amounts of metal released into artificial saliva. In contrast, reuse of archwires is associated with very low levels of metal release. Although experimental conditions and oral conditions *in vivo* differ, the amounts of metals that were released from the new or recycled orthodontic appliances in our study are insignificant in comparison with the amounts ingested during daily food intake. Thus, the release of metal ions from these materials may have no biological effects. Still, it is important that individuals who are sensitive to such metals, particularly those with Ni sensitivity, should not be exposed to these ions.

CONCLUSIONS

This study revealed the following:

- The recycled brackets–recycled archwires appliances (group 4) released higher amounts of Cr, Fe, and Ti than any of the other three combinations.
- Ni release was similar in groups 1 and 2 and in groups 2, 3, and 4.
- The amounts of Cu, Cr, and Ti ions released from the recycled brackets–new archwires (group 3) and recycled brackets–recycled archwires (group 4) appliances were

significantly greater than the amounts released from the other two combinations.

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