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ORIGINAL RESEARCH

Comparison of Nickel and Chromium Ions Released from Stainless Steel and NiTi Wires after Immersion in Oral B®, Orthokin® and Artificial Saliva

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ABSTRACT

Aim: Oral environment of the mouth is a suitable place for biodegradation of alloys used in orthodontic wires. The toxicity of these alloys namely nickel and chromium has concerned the researchers about the release of these ions from orthodontic wires and brackets. The aim of this study was to measure the levels of nickel and chromium ions released from 0.018" stainless steel (SS) and NiTi wires after immersion in three solutions.

Materials and methods: One hundred and forty-four round NiTi and 144 round SS archwires with the diameters of 0.018" were immersed in Oral B®, Orthokin® and artificial saliva. The amounts of nickel and chromium ions released were measured after 1, 6, 24 hours and 7 days.

Results: Two way repeated ANOVA showed that the amount of chromium and nickel significantly increased in all solutions during all time intervals ($p < 0.002$).

Conclusion: Chromium and nickel ions were released more in NiTi wire in all solutions compared with SS wire. The lowest increase rate was also seen in artificial saliva.

Clinical significance: There is general consensus in literature that even very little amounts of nickel and chromium are dangerous for human body specially when absorbed orally; therefore, knowing the precise amount of these ions released from different wires when immersed in different mouthwashes is of high priority.

Keywords: Laboratory research, Nickel ion, Chromium ion, Orthodontic wire, Mouthwash.

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INTRODUCTION

Orthodontic appliances are made of alloys containing nickel, cobalt, and chromium in different percentages. Thermal, microbiologic and enzymatic properties of oral environment make the mouth an ideal place for the biodegradation of these alloys. Metals used as components of these alloys, i.e. nickel and chromium, have been identified as cytotoxic, mutagenic and allergenic.[1] In addition, nickel is the most common cause of metal-induced allergic contact dermatitis and produces more allergic reactions than all other metals combined, followed by chromium.[2] Brackets, bands, and archwires in oral environment are permanently exposed to conditions, such as variable (acidic) pH, which can be related with dietary intake, temperature, mechanical fatigue, and susceptibility of alloys to corrosion.[3] It has been shown that the level of nickel in saliva and serum increases significantly after the insertion of fixed orthodontic appliances.[4] Nickel titanium (NiTi) and stainless steel (SS) wires are two of the most common orthodontic wires applied clinically due to their mechanical properties; however, nickel-titanium wires may contain more than 50% nickel; whilst, SS wires contain only 8% nickel.[5] During orthodontic treatment, practitioners recommend that their patients use mouthwashes for better oral hygiene. Schiff et al studied the influence of fluoridated mouthwashes on corrosion resistance of orthodontics wires and found that the practitioner should pay attention to the type of mouthwash depending on the orthodontic treatment phase and the alloy used.[6] Huang et al studied the ion release from NiTi orthodontic wires in artificial saliva with various acidities and found that the amount of released ions increased by increase of the pH.[7]

To our knowledge, no studies have yet been carried out to assess the influence of different mouthwashes and artificial saliva on ion release from two different types of orthodontic wires. Therefore, the aim of this study was to measure the levels of nickel and chromium ions released from 0.018" SS and NiTi wires after immersion in Oral B®, Orthokin®, and artificial saliva.

MATERIALS AND METHODS

One hundred and forty-four round NiTi and 144 round SS archwires with the diameters of 0.018" were used in this study. The wires were obtained from American Orthodontics (AO, Sheboygan, Wis.). Each type of wire was divided into three equal groups (48 wires) and immersed in Oral B®, Orthokin® and artificial saliva (SaliLube®, Sinphar Pharmaceutical Co., Ltd, Taipei, Taiwan)[8] (Table 1).

The as-received wires were separately dipped into polypropylene tubes containing 50 ml of solution and were incubated and maintained at 37°C. In order to simulate the actual oral environment, having an upper and lower wire, 2 wires of each kind were placed in each tube. The amounts of nickel and chromium ions released were measured after 1, 6 and 24 hours and 7 days.

At the end of each immersion period 5 ml were removed from each solution using a syringe with a plastic tip. An atomic absorption spectrophotometer (ICP-AES; Perkin Elmer, 2100DV Shelton, CT 06484 USA) was used to determine the amount of nickel and chromium ions released after each immersion period.

Statistical Analysis

Normal distribution of data was assessed by the nonparametric Kolmogorov-Smirnov test. Since, some variables presented abnormal distribution, nonparametric tests were employed (Two-way repeated measures ANOVA, Mann-Whitney, Tukey, and Kruskal-Wallis). All results were analyzed at a significance level of 5%.

RESULTS

The results of the Kolmogorov-Smirnov test showed that none of the data had normal distribution. Thus, nonparametric tests were used for assessment of the data.

Two way repeated ANOVA showed that the amount of chromium and nickel significantly increased in all solutions during all time intervals. However, Tukey test showed that the amount of release was significantly different between the two wires at all the time intervals (Tables 2 and 3).

Kruskal-Wallis test showed that at each time interval the amounts of chromium and nickel released from the wires were significantly different between the two wires; however, when the solutions are compared two by two Mann-Whitney test shows that at 1 hour there is no significant difference between the amount of chromium and nickel released from Oral B and Orthokin (Tables 4 to 7).

DISCUSSION

This study showed that placing wires in Oral B® or Orthokin® increase the release of ions compared with artificial saliva. However, these ions are released much less in SS wire in comparison with NiTi wire.

Stainless steel and NiTi wires have been used routinely until now. In the oral cavity, these metallic materials undergo electrochemical corrosion phenomenon, which may result in release of free metal ions like nickel and chromium. Carcinogenicity, allergenicity, mutations, contact dermatitis and cytotoxicity of these ions have compelled many orthodontists to search the amount of release of these ions

Table 1: Contents of the artificial saliva, Orthokin® and Oral B®

Solution	*Main ingredients*
Artificial saliva	Sodium chloride 0.844 mg, potassium chloride 1.2 mg, calcium chloride anhydrous 0.146 mg, magnesium chloride $6H_2O$ 0.052 mg, potassium phosphate dibasic 0.34 mg, sorbitol solution (70%) 60 mg, methylparaben 2 mg, hydroxyethyl cellulose 3.5 mg
Orthokin®	Aqua, sorbitol, glycerin, propylene glycol, Peg 40, hydrogenated castor oil, zinc acetate, aroma, chlorhexidine digcluconate, sodium saccharin, sodium fluoride, menthol, citric acid, cinnamal, limonene
Oral B®	Aqua, glycerin, polysorbate 20, aroma, methylparaben, cetylpyridinium chloride, sodium fluoride, sodium saccharin, sodium benzoate, propylparaben, CI 42051, CI 47005

Table 2: Release of chromium ions from SS and NiTi wires at different time intervals

Solution	*Intervals wire*	*1 hour*	*6 hours*	*24 hours*	*7 days*	*p-value*
		Mean ± SD	*Mean ± SD*	*Mean ± SD*	*Mean ± SD*	
Saliva	SS	3.2 ± 2.9	2.9 ± 0.2	4.7 ± 1.2	4.4 ± 1.9	0.001
	NiTi	3.0 ± 0.6	4.3 ± 0.9	5.8 ± 2.0	8.1 ± 1.7	0.001
	p-value (Tukey)	0.001	0.001	0.001	0.001	—
Oral B	SS	3.5 ± 0.5	4.9 ± 0.7	18.1 ± 0.1	22.9 ± 9.2	0.001
	NiTi	13.0 ± 2.9	21.7 ± 6.1	31.6 ± 5.3	46.3 ± 4.0	0.001
	p-value (Tukey)	0.001	0.001	0.001	0.001	—
Orthokin	SS	5.6 ± 2.5	13.9 ± 1.7	39.4 ± 0.1	53.6 ± 0.2	0.001
	NiTi	13.7 ± 2.6	16.6 ± 2.3	18.0 ± 2.9	29.9 ± 4.9	0.001
	p-value (Tukey)	0.001	0.001	0.001	0.001	—

Table 3: Release of nickel ions from SS and NiTi wires at different time intervals

Solution	*Intervals wire*	*1 hour*	*6 hours*	*24 hours*	*7 days*	*p-value (ANOVA)*
		Mean ± SD	*Mean ± SD*	*Mean ± SD*	*Mean ± SD*	
Saliva	SS	1.7 ± 0.8	3.0 ± 1.4	6.5 ± 3.2	4.5 ± 1.9	0.001
	NiTi	5.8 ± 2.1	8.2 ± 1.0	11.6 ± 1.4	24.2 ± 2.4	0.001
	p-value (Tukey)	0.001	0.001	0.001	0.001	—
Oral B	SS	15.0 ± 3.1	20.1 ± 4.2	38.5 ± 0.4	47.4 ± 0.1	0.001
	NiTi	37.8 ± 3.6	42.4 ± 8.4	66.4 ± 0.2	92.2 ± 5.1	0.001
	p-value (Tukey)	0.001	0.001	0.001	0.001	—
Orthokin	SS	15.3 ± 1.9	16.1 ± 2.5	35.9 ± 6.8	51 ± 5.6	0.001
	NiTi	32.3 ± 5.8	38.3 ± 0.1	55.7 ± 4.3	67 ± 3.8	0.001
	p-value (Tukey)	0.001	0.001	0.001	0.001	—

Table 4: Difference between chromium ions released from SS wire at each time interval

Time	*Saliva Mean ± SD*	*Oral B Mean ± SD*	*Orthokin Mean ± SD*	*p-value (Kruskal-Wallis)*	*Saliva and Oral B (Mann-Whitney)*	*Saliva and Orthokin (Mann-Whitney)*	*Oral B and Orthokin (Mann-Whitney)*
1 hour	3.2 ± 2.9	3.5 ± 0.5	5.6 ± 2.5	0.03	0.06	0.04	0.09
6 hours	2.9 ± 0.2	4.9 ± 0.7	13.9 ± 1.7	0.001	0.002	0.002	0.002
24 hours	4.7 ± 1.2	18.1 ± 0.1	39.4 ± 0.1	0.001	0.002	0.002	0.04
1 week	4.4 ± 1.9	22.9 ± 9.2	53.6 ± 0.2	0.001	0.002	0.002	0.03

Table 5: Difference of nickel released from SS wire at each time interval

Time	*Saliva Mean ± SD*	*Oral B Mean ± SD*	*Orthokin Mean ± SD*	*p-value (Kruskal-Wallis)*	*Saliva and Oral B (Mann-Whitney)*	*Saliva and Orthokin (Mann-Whitney)*	*Oral B and Orthokin (Mann-Whitney)*
1 hour	1.7 ± 0.8	15.0 ± 3.1	15.3 ± 1.9	0.002	0.002	0.002	0.4
6 hours	3.0 ± 1.4	20.1 ± 4.2	16.1 ± 2.5	0.002	0.002	0.002	0.07
24 hours	6.5 ± 3.2	27.0 ± 6.3	35.9 ± 6.8	0.002	0.002	0.002	0.04
1 week	4.5 ± 1.9	47.4 ± 0.1	51 ± 5.6	0.002	0.002	0.002	0.1

Table 6: Difference between chromium ions released from NiTi wire at each time interval

Time	*Saliva Mean ± SD*	*Oral B Mean ± SD*	*Orthokin Mean ± SD*	*p-value (Kruskal-Wallis)*	*Saliva and Oral B (Mann-Whitney)*	*Saliva and Orthokin (Mann-Whitney)*	*Oral B and Orthokin (Mann-Whitney)*
1 hour	3.0 ± 0.6	13.0 ± 2.9	13.7 ± 2.6	0.003	0.002	0.002	1
6 hours	4.3 ± 0.9	21.7 ± 6.1	16.6 ± 2.3	0.002	0.002	0.002	0.09
24 hours	5.8 ± 2.0	31.6 ± 5.3	18.0 ± 2.9	0.001	0.002	0.002	0.002
1 week	8.1 ± 1.7	46.3 ± 4.0	29.9 ± 4.9	0.001	0.002	0.002	0.002

Table 7: Difference of nickel released from NiTi wire at each time interval

Time	*Saliva Mean ± SD*	*Oral B Mean ± SD*	*Orthokin Mean ± SD*	*p-value (Kruskal-Wallis)*	*Saliva and Oral B (Mann-Whitney)*	*Saliva and Orthokin (Mann-Whitney)*	*Oral B and Orthokin (Mann-Whitney)*
1 hour	5.8 ± 2.1	37.8 ± 3.6	32.3 ± 5.8	0.002	0.002	0.002	0.09
6 hours	8.2 ± 1.0	42.4 ± 8.4	38.3 ± 0.1	0.003	0.002	0.002	0.8
24 hours	11.6 ± 1.4	66.4 ± 0.2	55.7 ± 4.3	0.001	0.002	0.002	0.07
1 week	24.2 ± 2.4	92.2 ± 5.1	67 ± 3.8	0.001	0.002	0.002	0.002

in various conditions. Kerosuo et al[9] conducted a study on different types of simulated orthodontic appliances and they found that clearly detectable releases of nickel and chromium occur with different SS orthodontic appliances *in vitro*. They also mentioned that the quantities released were negligible from a toxicological standpoint. Matos de Souza et al[10] assessed the *in vivo* release of nickel, chromium, and iron ions into saliva by three commercially different metallic brackets. They found that nickel and chromium ion concentrations increased immediately after placement of the appliance in the mouth for all study groups. There were no significant differences in the nickel, chromium, and iron levels released by the three different brands of brackets at all study periods. Schiff et al[11] studied the corrosion resistance of cobalt-chromium, iron-chromium-nickel and titanium based brackets in 3 different fluoride mouthwashes. Their corrosion resistance was compared with that of platinum. The results showed that in all three mouthwashes, the electrochemical properties of cobalt-chromium were satisfactory and similar to those of platinum. Barret et al[12] compared the *in vitro* corrosion rate of SS or nickel titanium archwires at various time intervals. They found that the nickel release reached a maximum after approximately 1 week, then the release diminished; while, chromium release increased during the first 2 weeks and levels off during the subsequent 2 weeks. They also founded that for both archwire types the release for nickel was an average 37 times greater than that of chromium. In a recent study, Danaei et al[13] measured the amount of metal ion release from orthodontic brackets when kept in different mouthwashes. They found that if ion release is a concern, Oral B® and Persica® mouthwashes might be better options than chlorhexidine for orthodontic patients with SS brackets.

Physiological conditions in the oral cavity[14,15] differ from *in vitro* arrangements, thus it is recommended to carry out a research in the mouth to achieve more accurate results.

CONCLUSION

The amount of chromium and nickel increased significantly in both wires in all three solutions with the progress of time; however, the rate of release was minimal in artificial saliva. Moreover, chromium and nickel increased at a slower rate in SS wire.

CLINICAL SIGNIFICANCE

There is general consensus in literature that even very little amounts of nickel and chromium are dangerous for human body specially when absorbed orally; therefore, knowing the precise amount of these ions released from different wires when immersed in different mouthwashes is of high priority.

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