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Evaluation of Nickel and Chromium Ion Release from Stainless Steel, HANT and NiTi Arch Wires in Two 28-day Time Spans

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Abstract

Background: Stainless steel and Nickel Chromium alloys show special mechanical features, which has made them the most common materials for fabrication of orthodontic arch wires.

Objectives: The aim of this study was to evaluate the effect of length of immersion and type of arch wire on release of nickel and chromium ions from fixed orthodontic appliances.

Materials and Methods: 15 simulated half-arch maxillary fixed orthodontic appliances were divided into 3 groups according to the types of arch wires. Each sample was individually immersed in 50 ml of distilled water and incubated at 37°C for 28 days. Afterwards, solutions were sent to laboratory for investigation of the released ions and the samples were incubated for another 28 days in new distilled water. After each 28-day time span, the concentrations of nickel and chromium were measured using an atomic absorption spectrophotometer. T-test was used for statistical analysis and $P < 0.05$ were considered statistically significant.

Results: Stainless steel arch wires released the greatest amount of nickel and chromium ions at both 28 days periods. The lowest amount of nickel and chromium in both time spans was released from NiTi and HANT arch wires, respectively Nickel ion release decreased overtime while the chromium release increased.

Conclusions: The amounts of released nickel and chromium ions from fixed orthodontic appliances from all three types of evaluated arch wires were below the daily dietary intake of these ions and do not bring about biological concerns.

Keywords: Metal Ion, Nickel, Chromium, NiTi, Stainless Steel

1. Background

Stainless steel and Nickel Chromium alloys show special mechanical features, which has made them the most common materials for fabrication of orthodontic arch wires. However, several investigations have revealed cytotoxic or allergenic characteristics for some of their major components i.e. nickel and chromium (1-3). Oral cavity's moisture, temperature, and microbial content make it a potentially destructive environment for orthodontic arch wires (4). Considering their prolonged existence in the oral cavity, fixed orthodontic appliances in the presence of saliva as an electrolyte, could form an electric cell. Hence, these appliances are capable of releasing metal ions by induction of electric currency and corrosion (5). Nowadays, some concerns have risen up about the biological adverse effects of metal ions regarding the possibility of foreign body reactions or pathologic phenomena. Furthermore, the by-products of corrosion in oral cavity might lead to local hypersensitivity, which is hard to be distinguished from bacterial gingivitis (6). It has been more than a century that eventual dangers of nickel and chromium for health are a great concern. It has been reported that nickel shows carcinogenic and cytotoxic traits and is related with hypersensitivity and asthma (7-9). Considering the fact that high amounts of nickel and chromium release could establish detrimental local and systemic effects, the aim of this study was to investigate the amount of ion release from fixed orthodontic appliances.

2. Objectives

The aim of this study was to evaluate the effect of length of immersion and type of arch wire on release of nickel and chromium ions from fixed orthodontic appliances.

3. Materials and Methods

This in vitro study included 15 half-arch maxillary fixed orthodontic appliances (Figure 1) which were divided into 3 groups based on the type of arch wire:

Group 1: Stainless steel, 0.017 × 0.025 inch half-arch wire (American orthodontics-Sheboygan-WI-USA)

Group 2: NiTi, 0.017 × 0.025 inch half-arch wire (American orthodontics-Sheboygan-WI-USA)

Group 3: HANT, 0.017 × 0.025 inch half-arch wire (American orthodontics-Sheboygan-WI-USA).

The other components of the appliances were equal in all groups and contained one 0.022 inch slot MBT molar band (American orthodontics-Sheboygan-WI-USA), one sequence of 0.022 inch slot MBT brackets from second premolar to central incisor (American orthodontics-Sheboygan-WI-USA) and ligature wire for fixation of the wires. (Figure 1) In order to prevent ion release from the containers, we used propylene bottles containing 50 ml distilled water. The lids were tightened and the samples were stored in 37° C incubator for 28 days. After the first 28 days span, the appliances were taken out and immersed in new bottles filled with fresh distilled water; while the former bottles were sent to the central laboratory of Tehran University of Medical Sciences for analysis of the solutions and determination of the ion contents. The same approach was performed for new bottles after 28 days. The ion content was determined via ContrAA 700 atomic absorption spectrophotometer (Analytik Jena, Germany) using graphite furnace method. In order to determine the nickel content of each sample, the spectrophotometer was first calibrated using a standard solution. Afterwards, a couple of drops from each sample were injected into the graphite furnace, and the 3000 °C temperature produced by the electrodes, decomposed the samples into atoms and the nickel content was determined. The same method was applied for the chromium content determination. The data from spectrophotometer showed the ion concentrations in microgram per liter. Independent T Test and Paired T Test were used for statistical analysis. $P < 0.05$ were considered as statistically significant.

4. Results

4.1. Nickel ion Release

In both 28 day periods, stainless steel arch wires showed the highest amount of nickel release while NiTi arch wires had the lowest nickel release. Table 1 shows the average nickel release in first and second 28 day periods. The results of independent T Tests comparing the three groups are shown in Table 2. Paired T Test revealed that Nickel release from all groups in the second 28 days period was significantly less than the first time span (Table 3).

4.2. Chromium Ion Release

Data in Table 1 show that similar to the nickel ion, the highest amount of chromium ion in both time spans was released from stainless steel wires. However, the minimum chromium release was from HANT arch wires. Independent T Test showed significant differences between all groups in both time spans except HANT and NiTi in second 28 days period (Table 2). Chromium release from all groups in the second 28 days period was significantly more than the first time span (Table 3). The findings of the present research are illustrated in Tables 1 and 2.

Figure 1. The Half Arch Maxillary Fixed Orthodontic Appliance

Table 1. Amount of Ion Release After Each 28 Day Time Spans[a]

	Ion content (μg/L)	
	Chromium	**Nickel**
Stainless Steel		
First 28 day spans	0.23 (2.57)	1032.001 (1999.80)
Second 28 day spans	0.31 (3.40)	363.31 (908.50)
NiTi		
First 28 day spans	0.24 (1.88)	192.87 (1663.80)
Second 28 day spans	0.21 (3.00)	75.36 (386.60)
HANT		
First 28 day spans	0.02 (1.60)	105.74 (1718.60)
Second 28 day spans	0.02 (2.93)	134.00 (619.60)

[a]Values are expressed as mean (SD).

Table 2. Results of Independent t Test Comparing Ion Release from Different Arch Wires

	P Value	
	Chromium	Nickel
Stainless steel and NiTi		
First 28 day span	0.00	0.495
Second 28 day span	0.046	0.014
Stainless steel and HANT	0.00	0.561
First 28 day span	0.010	0.134
Second 28 day span		
NiTi and HANT	0.00	0.0593
First 28 day span	0.521	0.010
Second 28 day span		

Table 3. Results of Paired t Test Comparing Ion Release From Each Arch Wire in Two Time Spans

	P Value	
	Chromium	Chromium
Stainless steel	0.022	0.00
NiTi	0.00	0.00
HANT	0.00	0.00

5. Discussion

Results of the present study revealed that in spite of higher amount of nickel incorporated in NiTi alloys, the highest amount of nickel as well as chromium release was from stainless steel arch wires. In other words, it seems that the amount of the released ion is not relevant with the ion content of the alloy. These findings were concordant with the results of the studies of Suarez et al. Karnam et al., and Kuhta et al. (3, 10, 11). NiTi alloys usually contain 48% - 54% nickel. However, resistance to corrosion in before mentioned alloys is acquired from different types of Titanium oxides i.e. TiO, Ti2O5 and TiO2 which the latter is the most common and the most stable form. In stainless steel alloys, chromium constitutes a superficial layer of chromium oxide that leads to resistance against corrosion. It seems that higher resistance of titanium oxide in comparison to chromium oxide can explain the higher amount of ion release -especially nickel release- from stainless steel arch wires (12). Results of the present study revealed that nickel release diminished over time and the amount of nickel release was significantly higher than chromium. These finding coincides with results of Kerosuo et al. and Mikulewicz et al. (13-15). The daily body intake of nickel and chromium via food is approximately 300 - 500 and 5 - 100 microgram, respectively. In addition, the average concentration of nickel in drinkable water is less than 20 microgram per liter. The aforementioned quantity for chromium is much less and equals to about .43 microgram per liter. According to the present study, the maximum amount of average daily chromium release from full arches fixed orthodontic appliance is 0.018 microgram in the first time span and 0.024 microgram for the second one, which is immensely less than daily intake and is not capable of inducing systemic toxicity. Considering the mean daily nickel release from fixed appliance in the first and second time span which is 14.28 microgram and 6.48 microgram respectively. Adverse systemic effects from nickel and chromium release from orthodontic appliances is not contingent. However, this amount of nickel release in two years is capable of eliciting hypersensitivity. A unique characteristic of super elastic A-NiTi arch wires is the fact that their loading and unloading curves are completely different. This feature helps us to change the exerted force by only releasing and retying the wire. Therefore, using this characteristic often leads to keeping the wire in the appliance 28 days more than the usual 28 days span. Since the results of the present study revealed that the nickel ion release decreases in the second 28 days, it is possible to use the biomechanical advantages of these arch wires without biological concerns.

5.1. Conclusion

Release of chromium from fixed orthodontic appliances is less than nickel; Nevertheless, it increases over time. However, release of these ions is below the daily dietary intake and does not bring about biological concerns.

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