Original Article

Evaluation of nickel ion release from various orthodontic arch wires: An *in vitro* study

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Abstract

Aim: The high incidence of nickel (Ni) allergy and the increasing use of Ni-containing dental biomaterials have been of growing concern. The purpose of this investigation was to analyze and evaluate the rate of Ni ion release from different types arch wires used in orthodontics. **Materials and Methods:** Four groups of arch wires (nickel titanium [NiTi], SS, Cu NiTi and ion implanted NiTi) with twelve samples were stored in artificial saliva with a pH 5.6-7.0 thermostated at (36.5°C) and tested at different intervals i.e., 7^{th} day, 14^{th} day, and 21^{st} day. The amount of Ni and Ti ions released from the sample were evaluated using an atomic adsorption spectrophotometer. The solution was replaced with a fresh bottle to avoid sediments. **Results:** Statistical analysis was performed by nonparametric tests (Student's paired *t*-test, one-way analysis of variance and multiple comparison test by Tukey "Honestly significant difference"). The statistical package SPSS PC plus (version 4.0.1) was used for data processing and statistical analysis. Results showed significantly statistical influence on the release amount of Ni and Ti ions. Large variation in concentration of Ni released from brackets and bands combined. However, the amount of Ni ions released in all test solutions diminished with time and was below the critical value necessary to induce allergy and below daily dietary intake level. **Conclusions:** The daily release of NiTi, SS, Cu NiTi and ion implanted NiTi by an orthodontic appliance in acid pH, particularly favorable to corrosion, was well below that ingested with a normal daily diet. It is therefore concluded that the quantities of metal ions released in our experimental conditions should not be cause for concern in utilizing the appliance.

Key words: *Alloys, artificial saliva, nickel release, spectrophotometry*

INTRODUCTION

Nickel (Ni)-containing alloys has become an integral part of almost every routine orthodontic intervention.[1] As contemporary orthodontics relies on various bonded attachments, arch wires, and other devices to achieve tooth movement. The demands made on them are complex because they are placed under many stresses in the oral environment, which include immersion in saliva, ingested fluids, temperature fluctuations, and masticatory force.

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The orthodontic appliances, i.e., orthodontic bands, brackets, and arch wires were introduced in 1930s. Since then the alloys have become an invaluable material in orthodontics, which are made of stainless steel containing 8-12% Ni, 17-22% chromium, and various proportions of manganese, copper, titanium, and iron.[2] These are extremely durable and relatively inexpensive. The combination of the alloys materials are in close proximity and in hostile conditions leading to corrosion and adverse reaction biologically and increase the friction mechanically.

When using nickel titanium (NiTi) arch wire for dental orthodontic treatment, the possible danger associated with arch wire corrosion derives from the biologically harmful effects due to the released Ni ion.[3-6] Therefore, NiTi arch wire with a good corrosion resistance is crucial to its biocompatibility. On the other hand, the surface corrosion of NiTi arch wires may increase the friction that appears at the interface between the arch wire and bracket, reducing the free sliding action during orthodontic treatment.

The purpose of this study is to evaluate the rate of Ni ion release from different types arch wires used in orthodontics. The study was performed using a classic batch procedure by immersion of the samples in artificial saliva at various acidities over an extended time interval and Ni release was quantified with the use of a flameless atomic absorption spectrophotometer.

MATERIALS AND METHODS

Four groups of arch wires (NiTi, SS Cu NiTi and ion implanted NiTi) were used in the "as received" condition from the dealers [Table 1]. The Ni release was tested by placing each sample in separate polyethylene screw top bottles containing 100 ml of artificial saliva. The stimulated saliva medium consisted of: Sodium chloride - 0.4 G, potassium chloride - 1.21 G, sodium hypo phosphate - 0.78 G, sodium sulfide - 0.005 G, urea - 1G, distilled water and deionized water - 1000 ml. The pH of artificial saliva was adjusted to 6.75 ± 0.15 by adding in increments of 50 ml of 10 N sodium hydroxide and it was measured by using E. Merch (D-6100 Darmstadt F.R. Germany) pH indicator papers with a high degree of sensitivity (0.2 units sensitivity).

The analysis was performed with an atomic absorption spectrophotometer (GBC Avanta, Australia) model which is based on the unique spectrum of each element. Atomic absorption spectrometer measures the quantities of chemical elements present in environmental samples by measuring the absorbed radiation. This is done by reading the spectra produced when the sample excited by radiation. Atomic absorption methods measure the amount of energy in the form of photons of light that are absorbed by the sample For every element analyzed, characteristic wavelengths are generated in a discharge lamp (hollow cathode lamp), and in turn are absorbed by a cloud or vapor of that element. Since the sensitiveness of the equipment was restricted up to 1 ppm a "standard addition method" was used.

The prepared samples were immersed in artificial saliva (36.5°C) at pH 5.6-7 and tested at different intervals i.e., 7th day, 14th day, and 21st day. A volume of 20 ml of known concentration was taken and the amount of Ni and Ti ions released from NiTi wires was determined using an atomic adsorption spectrophotometer. A standard graph is plotted. 10 ml of known concentration of Ni is added to 10 ml of saliva test sample. The values were recorded for the released metal as and when the valued dropped it indicated that the standard solution was diluted because of deionized water showing a lesser ppm level. Hence for each sample analysis was done 3 times and an average was taken to obtain the accurate results and the results were statistically analyzed.

RESULTS

The results of the absorption analysis of the solution were compared using one way analysis of variance (ANOVA). The results of one-way ANOVA to compare the average per day Ni release between different groups are shown in Table 2. Difference in the mean was analyzed with the multiple comparison

Table 1: Materials used in the study

Material (arch wires)	Alloy	Size (in inches)	Sample size	Manufacturer
Group I	NiTi	0.016×0.022	12 wires	American orthodontics
Group II	Stainless steel	0.016×0.022	12 wires	American orthodontics
Group III	Ion implanted NiTi	0.016×0.022	12 wires	GAC international
Group IV	Copper NiTi	0.016×0.022	12 wires	Ormco
Total samples			48	

NiTi=Nickel titanium

Table 2: The results of one-way ANOVA to compare the average per day nickel release between different groups

Result of one-way ANOVA to compare the "average/day" between groups

Source of variation	df	Sum of squares	Mean squares	*F* ratio	*P* value
Between groups	3	0.564	0.188	155.88	<0.0001 (significant)
Within groups	45	0.053	0.001		
Total	48	0.617			

ANOVA=Analysys of variance, df=Degrees of freedom test by Turkey's honestly significant difference (HSD) and were considered to be significant at $P > 0.05$. The statistical package SPSS for Windows, Version 16.0. Chicago, SPSS Inc-United states of America was used for data processing and statistical analysis.

Release of Ni ions

In all cases the release of Ni reached the maximum on 7th day thereafter, it diminished with time.

The mean and standard deviation of Ni release in micrograms for different study group at a different point i.e., 7th, 14th and 21st days when analyzed, It was found to be (7.34 ± 0.38 µg, 6.78 ± 0.35 µg and 5.37 ± 0.46 µg) respectively for Group I. Similarly for Group II (stainless steel wire) it was 6.53 ± 0.41 µg, 5.18 ± 0.38 µg and 2.04 ± 0.22 µg. For Groups III (ion implanted NiTi wire) it was 6.11 ± 0.41 µg, 4.87 ± 0.21 µg and 3.16 ± 0.27 µg and for Group IV (copper NiTi wire) it was 7.03 ± 0.48 µg, 5.17 ± 0.36 µg and 4.03 ± 0.22 µg respectively. The average Ni release per day for Group I, II, III and IV was 0.93 ± 0.04 µg, 0.66 ± 0.02 µg, 0.67 ± 0.02 µg and 0.77 ± 0.05 µg, respectively. The result infers that maximum Ni release was from untreated NiTi wire followed by copper NiTI, ion Implanted NiTi and Stainless steel wires.

Table 3 illustrates the results of Student's paired *t*-test for the mean changes of Ni content between different time point viz. 7th day versus 14th day, 7th day versus 21st day and 14th day versus 21st day for different study groups. It was found that the mean change for the entire four group and between the different time points were significantly different from zero.

Table 3: Student's pair *t* test

Groups	Time point compared	Change mean±SD (µg)	*P* value (significant)
	Mean change and test of significance for wires (Student's pair *t* test)		
I	Day 7 versus day 14	0.56±0.19	<0.0001
	Day 7 versus day 21	1.98±0.51	<0.0001
	Day 14 versus day 21	1.42±0.55	<0.0001
II	Day 7 versus day 14	1.35±0.69	<0.0001
	Day 7 versus day 21	4.49±0.46	<0.0001
	Day 14 versus day 21	3.14±0.49	<0.0001
III	Day 7 versus day 14	1.24±0.48	<0.0001
	Day 7 versus day 21	2.95±0.55	<0.0001
	Day 14 versus day 21	1.71±0.29	<0.0001
IV	Day 7 versus day 14	1.86±0.38	<0.0001
	Day 7 versus day 21	2.99±0.34	<0.0001
	Day 14 versus day 21	1.33±0.24	<0.0001

SD=Standard deviation

Multiple comparison test by Turkey – HSD procedure showed that the mean value in Group I (0.93 ± 0.04 µg) was significantly higher ($P < 0.05$) than the mean Group II (0.66 ± 0.02 µg), Group III (0.67 ± 0.02 µg) and Group IV (0.77 ± 0.05 µg). Furthermore, the mean value in Group IV was significantly higher (<0.05) than Group II and III. However, there was no significant difference between Group II and III ($P > 0.05$). The result shows that there is no significant difference in Ni release between ions implanted NiTi wire and stainless steel wire. Moreover, these two wires leached less Ni when compared to untreated NiTi and Copper wire. Graph 1 illustrates the release of Ni in groups.

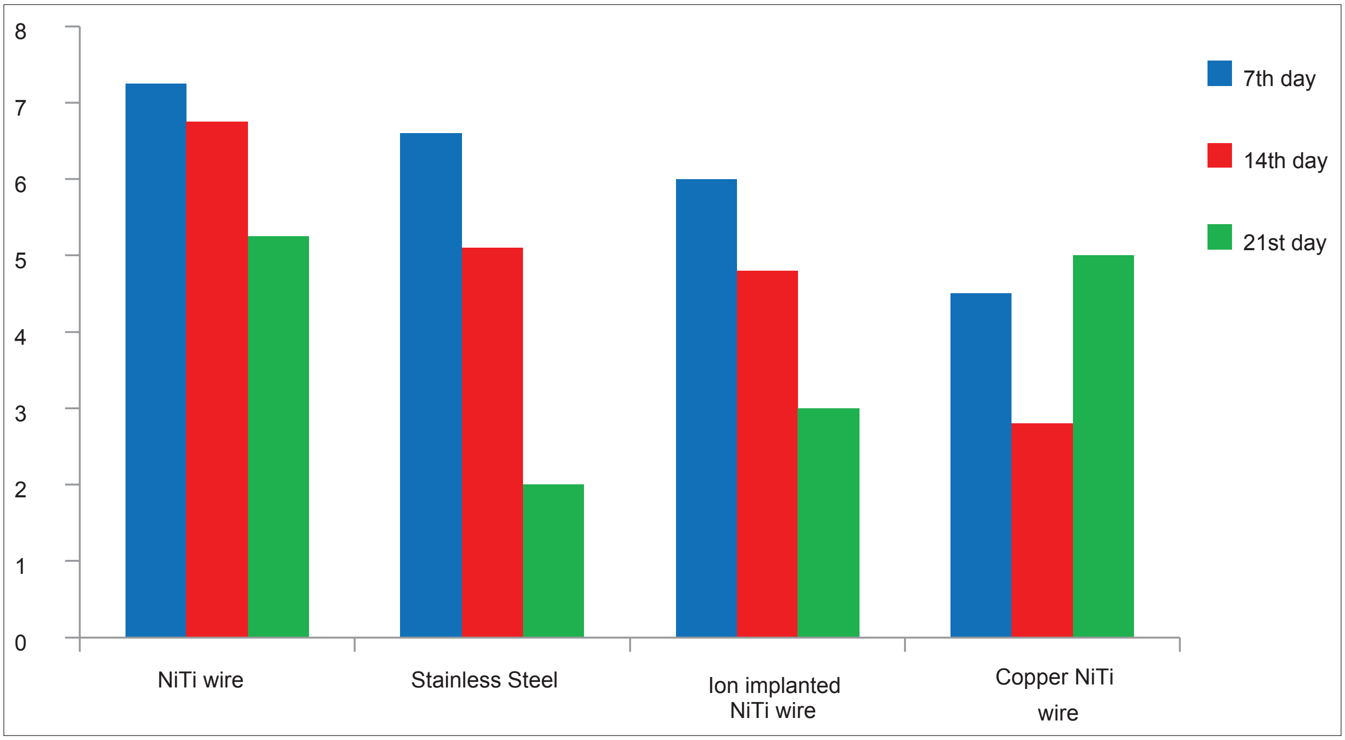
DISCUSSION

NiTi orthodontic wire products from different manufacturers would have different corrosion resistance.[7] We assayed the corrosion resistance, in terms of ion release, of different NiTi orthodontic wires in artificial saliva at different interval.

It is known that corrosion of orthodontic alloys occurs in the intraoral environment, regardless of the alloys' metallurgic structure, and it is also known that the extent of manufacturing defects may accelerate the process.[8] Concomitant increases in the prevalence of Ni hypersensitivity and demand and availability of orthodontic treatment have created growing interest in the composition of alloys and the release of metals during treatment.

In orthodontics, the tolerance concept has been introduced to explain observations associated with Ni reactions for, e.g., ear piercing, which is very common among adolescent girls, may enhance the prevalence of these sequelae.[9] However, there are indications that orthodontic treatment with Ni-containing metallic appliances before sensitization to Ni (i.e., ear piercing) may lower the incidence of Ni hypersensitivity.[10-12] Observations indicate that early contact with potential allergens may actually lead to a diminished probability for allergic reactions later in life.[13,14]

All the orthodontic appliances used in this study contained, Ni as one of their components. The Ni release was measured at 3 different time intervals to find out whether the Ni release increases constantly or it decreases after an initial increase. The findings of the current study are in accordance with the study by Kerosuo *et al.*[15] and Gjerdet *et al.*,[16] did not find any significant increase in Ni and chromium concentration in saliva of orthodontic patients after insertion of



Graph 1: Total release of nickel in Group I, II, III and IV

different fixed appliances. The Ni can be both a solubilized solution and insoluble precipitate. The results of the present study were in relevance with the study done by Park and Shearer.[17]

Several authors have reported corrosion of orthodontic appliances *in vitro*, but variation in study designs and different electrochemical factors make comparisons between the studies differs. The preparation and analytical procedures are technique sensitive and may be a source of variation also; some of the corrosion products might adhere to the metal surface and would not be available for the instrumental analysis of the solutes and thus remain undetected.

Of the orthodontic wires tested in this study, the largest amount of Ni release per day was from Group I (NiTi wire) 0.93 ± 0.04 µg followed by (copper NiTi wire) 0.77 ± 0.05 µg, Group III (ion implanted NiTi wire) 0.67 ± 0.02 µg and Group II (Stainless steel wire) 0.66 ± 0.02 µg. The result clearly showed that less Ni was released from ion implanted NiTi and stainless steel arch wires. Compare with uncoated NiTi (0.67 ± 0.02 µg/day). Gjerdet and Hero[18] reported Ni release of 0.26 µg/day from stainless steel arch wires, their value is lower than that of the value obtained in this present study (0.66 ± 0.02 µg/day). The release rates of Ni at various time intervals were found to be common in all the arch wires. When the concentrations of Ni were measured at various time intervals, a maximum level was found on day 7, which steadily decreased during the subsequent 2 weeks.

Various study reported a release of 20 µg of Ni per day from a simulated full mouth orthodontic appliance. In this study, the total release of Ni values was well below the normal daily intake of Ni 200-300 µg/day. However, the amounts are not directly comparable because the amount of Ni required to create contact hyper sensitivity reactions depends on the individual. Dunlap *et al*.[19] in their study have reported a case of severe allergic reactions after insertion of NiTi arch wire in a Ni sensitive patient.

Hence, orthodontic treatment for Ni sensitive patients may prove challenging. Further studies are required to examine the cytotoxic effects of released Ni *in vitro* cell cultures and how much of the corrosive products are actually absorbed by the patients. Recently, Ni free brackets like titanium brackets and ceramic brackets can be used effectively for Ni sensitive patients.[20] Among the arch wires ion implanted NiTi can be used instead of untreated NiTi wires.

CONCLUSION

Ni is found in many alloys used in the practice of dentistry. These alloys have a long-standing history of successful use in dentistry, with no significant reports of biological effects. Nevertheless, when clinical signs or symptoms presumed to be due to Ni hypersensitivity are distressing to patients there are many choices of materials available to the dentist as alternatives.[21]

In this present study the release of Ni was very much below with the average dietary intake of Ni which was not capable of causing any toxic effects. Researchers have observed a significant variation in the concentrations of Ni in saliva, but when Orthodontic appliances are placed in an artificial saliva medium there release measurable amounts of elements. In this present study, the Ni release reaches a maximum after approximately 1 week, and then the rate of release diminishes with time. The estimated release rates from full-mouth orthodontic appliances are less than 10% of the reported average daily dietary intake for Ni and how much of these corrosive products are actually absorbed by patients undergoing orthodontic treatment still needs to be determined. The ingested amount of Ni released from orthodontic appliances cannot be quantified using the currently available release data, but it is well below the daily dietary intake levels.

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