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ORIGINAL RESEARCH

Comparison of Metal Ion Release from Different Bracket Archwire Combinations: An *in vitro* Study

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ABSTRACT

Aim: The metal ion released from the orthodontic appliance may cause allergic reactions particularly nickel and chromium ions. Hence, this study was undertaken to determine the amount of nickel, chromium, copper, cobalt and iron ions released from simulated orthodontic appliance made of new archwires and brackets.

Materials and methods: Sixty sets of new archwire, band material, brackets and ligature wires were prepared simulating fixed orthodontic appliance. These sets were divided into four groups of fifteen samples each. *Group 1:* Stainless steel rectangular archwires. *Group 2:* Rectangular NiTi archwires. *Group 3:* Rectangular copper NiTi archwires. *Group 4:* Rectangular elgiloy archwires. These appliances were immersed in 50 ml of artificial saliva solution and stored in polypropylene bottles in the incubator to simulate oral conditions. After 90 days the solution were tested for nickel, chromium, copper, cobalt and iron ions using atomic absorption spectrophotometer.

Results: Results showed that high levels of nickel ions were released from all four groups, compared to all other ions, followed by release of iron ion levels**.** There is no significant difference in the levels of all metal ions released in the different groups.

Conclusion: The study confirms that the use of newer brackets and newer archwires confirms the negligible release of metal ions from the orthodontic appliance.

Clinical significance: The measurable amount of metals, released from orthodontic appliances in artificial saliva, was significantly below the average dietary intake and did not reach toxic concentrations.

Keywords: Metal ions, Brackets, Archwires, Nickel, Iron, Copper, Cobalt, Chromium, Titanium, Molybdenum.

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INTRODUCTION

Dental materials within the mouth interact continuously with physiological fluids. Oral tissues are exposed to a veritable bombardment of both chemical and physical stimuli, as well as the metabolism of about 30 species of bacteria. Yet, for the most part, oral tissues other than dental tissues remain healthy.[1] The pH of saliva varies from 5.2 to 7.8. Corrosion, the graded degradation of materials by electrochemical attack, is of concern particularly when orthodontic appliances are placed in the hostile electrolytic environment provided by the human mouth.[2,3]

A considerable part of an orthodontist's armamentarium consists of metal. Noble metals and their alloys were esthetically pleasing and were corrosion resistant, but they lacked flexibility and tensile strength, these alloys were inappropriate for complex machining and joining when used as traction bars at that time.[4] Stainless steel has been the mainly used material in orthodontics since its introduction in 1932, with a wide range of applications in both fixed and removable appliances.[5]

Nickel titanium wires have unique properties of shape memory and superelasticity and are excellent for initial alignment. Beta-titanium offers a high desirable combination of strength and springiness. It also has reasonably good formability, which is lacking in nitinol.[6] 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). The various components of devices, such as face bows, molar bands, and brackets are either welded together or brazed. The most common used brazing alloys consist mainly of silver and Cu, but some also contain zinc. All brazed appliances corrode to some extent in the oral environment, facilitating the release of metal ions that can cause adverse effects. Cytotoxic effects result when tissues are exposed to a sufficient concentration of a primary irritant for a sufficient period of time. Animal research has shown that a relatively high concentration of Ni is needed to produce toxic effects but even at low concentration this metal can provoke an

allergic reaction. Literature indicates that approximately 10% of population is sensitive to Ni and more commonly seen in female individuals.[7]

Nickel is the most common cause for metal induced allergic contact dermatitis in human beings; it produces more allergic reactions than all other metals combined together. Second in frequency is chromium.[8] Leakage of heavy metals from orthodontic appliances has been amply described in literature.[8-10] Human saliva is particularly ideal for the biodegradation of metals, because of its thermal, microbiologic and enzymatic properties.[11]

During the last decade there has been an increased interest amongst health professionals about the side effects of biomaterials especially the metallic materials. This concern has been raised because of the well-established hazardous nature of the metal ions.[10,12]

In this study, we compared the levels of release of nickel, chromium, copper, cobalt and iron ions in artificial saliva from different types of standard orthodontic appliance when placed in artificial saliva for 90 days period.

OBJECTIVES

1. To measure the amount of nickel, chromium, copper, cobalt and iron ions released from different groups of new brackets and archwires immersed in artificial saliva for 90 days.
2. To compare the levels of nickel, chromium, copper, cobalt and iron ions released within the groups of new brackets and archwires immersed in artificial saliva for 90 days.

MATERIALS AND METHODS

All the materials used were procured from 3M Unitek, Monrovia, California and Company. All the materials were used in as-received state.

1. Three hundred stainless steel premolar brackets of 0.022 × 0.028 inch slot preadjusted (Roth system).
2. 0.017 × 0.025 inch NiTi archwires.
3. 017 × 0.025 inch copper NiTi archwires.
4. 017 × 0.025 inch stainless steel archwires.
5. 0.017 × 0.025 inch elgiloy archwires.
6. Band material, 0.005 inch stainless steel, each 4 cm long.
7. 0.010-inch ligature wires.
8. Artificial saliva, prepared according to the formula given by Sali Lube, Sinphar Pharm, Taipei, Taiwan.
9. Polypropylene bottles.
10. Incubator.
11. Atomic absorption spectrophotometer (AAS).(GBC Scientific Equipment Pvt Ltd. Australia, Model: Avanta, Optics: Double beam with background correction, Wavelength range: 1085 to 900 nm)
12. Electronic balance.

Fig. 1: Incubator

Fig. 2: Salts for artificial saliva

Fig. 3: Artificial saliva in container with measuring cylinder and pipette

Sixty sets of archwires, band material, brackets and ligature wires were prepared simulating fixed orthodontic appliance. Each set included five premolar brackets, five ligature wires, one 3 cm long particular archwire (depending

Fig. 4: Electronic balance

Fig. 5: Atomic absorption spectrophotometer

Figs 6A and B: (A) Group I samples (New SS brackets and new SS wires), (B) group II samples (New SS brackets and new NiTi wires)

Fig. 7: Group III samples (New SS brackets and new copper NiTi wires)

Fig. 8: Group IV samples (New SS brackets and new elgiloy wires)

on particular group) and one 4 cm long stainless steel band material. These 60 sets (appliance) were divided into four groups of 15 samples each.

Group 1: Stainless steel archwires.

Group 2: NiTi archwires

Group 3: Copper NiTi archwires

Group 4: Elgiloy archwires.

The polypropylene bottles were color coded. Artificial saliva solution was prepared according to the formula given by Sali Lube Sinphar Pharm, Taipei, Taiwan.[13] According to this formula, salts were measured on an electronic balance and mixed thoroughly in distilled water. The pH of the artificial solution was neutral. The proportion of salts to prepare one liter of artificial saliva (Table 1). Fifty millimiter of the solution was put in the polypropylene bottles using measuring cylinder. Then the components of each appliance were immersed artificial saliva solution at 37°C for 90 days to simulate oral conditions. After 90 days the solutions were tested for nickel,

Table 1: Composition of artificial saliva

Compound	*Amount (mg)*
1. Sodium chloride	0.844
2. Potassium chloride	1.2
3. Calcium chloride anhydrous	0.146
4. Magnesium chloride. $6H_2O$	0.052
5. Potassium phosphate dibasic	0.34
6. Sorbitol solution 70%	60 ml
7. Hydroxyethyl cellulose	3.5

chromium, copper, cobalt and iron ions with help of atomic absorption spectrophotometer.

All samples collected were analyzed at Central Materials and Processes Laboratory, Foundry and Forge (Division), Hindustan Aeronautics Limited (HAL) Bengaluru, using Atomic Absorption Spectrophotometer GBC Scientific Equipment Pvt. Ltd., Australia. Model: Avanta. Spectrophotorneter is the analytical methodology of using radiation emission and absorbance phenomena to determine the quantity of a substance in a sample. The GBC Avanta spectrophotometer used for this experiment is set up as a conventional flame atomic absorption spectrophotometer for the determination of atomic absorption.

Before the atomic absorption was used to test the level of various ions it was calibrated for that particular element. Calibration was done with stock solution provided by the commercial laboratories. To zero the instrument, first the instrument was run on blank solution. The blank solution used was deionized water. The standard were then analyzed with the lowest concentration first and blank solution was run between standards to ensure the baseline (zero point) had not changed. After the calibration was done the samples were tested and their absorbance was recorded. A standard calibration curve was employed for each ion analyzed and each metal was quantified separately.

STATISTICAL ANALYSIS

Mean and standard deviation for the concentration of released ions of Cr, Ni, Fe, Cu and Co was calculated. One way analysis of variance (ANOVA) was used for inter and intragroup comparison. p-value < 0.05 was considered statistically significant.

RESULTS

High levels of nickel ions were released from all the groups, compared to all other ions. Iron ion levels were second highest in all the groups. There is no significant difference in the levels of all metal ions released in the different groups (Table 2). However, there is significant difference between the levels of different metal ions released within groups, in other words the release of all metal ions are not the same in each group (Table 3). The use of newer brackets and newer archwires confirms that the level of release of ions is insignificant in all the groups. Release of metal ions was influenced by composition of the orthodontic archwire, but this was not proportional to the content of metal in the wire. All the observed parameters—chemical composition of the archwire, the artificial saliva, and time of exposure to the solution influenced ion release. After a 12-week (90 days period) immersion, the total amount of ion release was less than the cumulative daily intake. Quantities of all released ions were below toxic levels and did not exceed the daily dietary intake. However, these levels are sufficient to cause an allergic reaction because of the high haptenic potential of released elements. Further research work is required on this subject to account for long-term release of ions from orthodontic appliances.

Table 2: Comparison of release of metal ions in four groups with different archwires

	Group I		*Group II*		*Group III*		*Group IV*		
Ions	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*p*
Ni	1.292	0.4375	1.864	0.6002	2.466	0.8678	2.132	1.143	0.1724
Fe	0.31	0.1231	0.45	0.2228	0.614	0.5317	0.534	0.5880	0.6961
Cr	0	0.0	0.018	0.0349	0.03	0.0519	0.02	0.04472	0.6700
Cu	0.01	0.007071	0.01	0.007071	0.002	0.00447	0.004	0.008944	0.2071
Co	0.004	0.00547	0.01	0.007071	0.012	0.00447	0.012	0.004472	0.1070

Table 3: Comparison of release of different metal ion levels in same group

Groups	*Nikel*		*Iron*		*Chromium*		*Copper*		*Cobalt*	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
I	1.292	0.4375	0.31	0.1231	0	0.00	0.01	0.007071	0.004	0.005477
II	1.864	0.6002	0.45	0.2228	0.018	0.0349	0.01	0.007071	0.01	0.007071
III	2.466	0.8678	0.614	0.5317	0.03	0.0519	0.002	0.00447	0.012	0.00447
IV	2.132	1.143	0.534	0.5880	0.02	0.04472	0.004	0.008944	0.012	0.004472

DISCUSSION

The present study results coincides with the study of Huang et al[14] which shows that after a 12 weeks immersion period, the total amount of ion release was less then cumulative daily intake which have been expressed in the units of ppm (parts per million), which is the standard unit to measure the ions.

Huang et al[14] reported that the metal ion release was more when the brackets were placed in an acidic environment. Considering this in the present study storage media with neutral pH was used so that a more accurate picture of release of metal ion could be obtained.

The release of metal ions from dental alloys is a phenomenon that cannot be avoided; it is difficult to find a material that will be fully stable within an organism and will show no signs of biodegradation.[15] There is increasing concern about the biocompatibility of dental materials. Particularly in orthodontics, there is interest in investigating reactions secondary to the use of metals that are known allergens.

Studies done by Barret et al[16] have demonstrated that the maximum ions released are at the 7th day and that all release was completed within 4 weeks. Considering this in the present study the components of sample were stored for 90 days as was done by Hwang et al[13] and Huang et al.[14]

Park and Shearer[8] reported the average amount of nickel and chromium released per day *in vitro*, and Barrett et al[16] studied the corrosion rate of simulated orthodontic appliances and compared stainless steel and NiTi archwires. Grimsdottir et al[17] and Kerosuo et al[18] analyzed the amount and time of release in different types of appliances in 0.9% Nacl. Park and Lee[19] measured the amount of release with various archwires in simulated orthodontic appliances corresponding to half of lower arch. Kim et al[20] measured the amount of release following titanium nitride coating, and Rhu and Kim[21] compared metal release between the same and different types of orthodontic appliances. Previous studies done to estimate the amount of metal ion released from the orthodontic appliance have shown that the amount of nickel released was below the dietary intake (200 to 300 ppm for nickel and 280 ppm for chromium). Results obtained in our study are in accordance with these studies.

Here we found that chromium released was insignificant. This is in contrast with studies done by Park et al,[8] Kerosue et al[18] and Barret et al.[16] Barret et al[16] reported that the presence of calcium in saliva solution could interfere with the readings of chromium metal by an atomic absorption spectrophotometer. This could possibly explain the difference in the present study with that of previous studies.

This *in vitro* study emphasizes the importance of factors that can influence the release of metal ions from fixed orthodontic appliances, namely, the type of alloy, the artificial saliva, and time of exposure to the solution influenced ion release.

The appliance consisted of the brackets and wires and it is likely that the brackets contributed to the quantities of released ions. However, because the brackets consisted of the same material in all samples, their contribution was constant and did not influence relative comparisons of ions released from wires.

The main conclusions with our present study indicate that the measurable amount of metals, released from orthodontic appliances in artificial saliva, was significantly below the average dietary intake and did not reach toxic concentrations. Although the orthodontic appliances had no effect on the general levels of metals, it cannot be excluded that even nontoxic concentrations might be sufficient to induce important biologic effects in cells of oral mucosa.

A growing number of recent studies are investigating the problem of biocompatibility with the goals of (1) determining the upper limit of biological tolerance and (2) finding means through which the release of ions will be kept within these limits. The present study identified the effects of changes in the archwire material on the release of metal ions. However, the absorption of released metal ions and their effects on oral tissues remain to be examined in future *in vivo* studies.[15]

Recycling orthodontic wires and brackets was once common, but this practice is no longer recommended in some countries such as the United Kingdom (BOS, Advice Sheet 16). Lee and Chang[22] tested NiTi wires that had been exposed to artificial saliva for 4 weeks and a similar group that was then sterilized at 121°C at 15 to 20 psi for 20 minutes. Although there was no difference in tensile properties or bending fatigue, there were increases in surface roughness and coefficient of friction in the recycled group. Hence, it is better to use newer brackets and newer archwires to safeguard the health of the patient.

It would seem that caution and close monitoring should be exercised in patients with a definite history of hypersensitivity to nickel-containing metals but orthodontic treatment avoidance is unnecessary.

The results of these *in vitro* tests are limited and extrapolation to the clinical situation difficult because the methodologies used are unable to precisely reproduce the highly complex and dynamic oral environment. Thus, further studies are needed to simulate this additional variable in the analysis of ion release from fixed orthodontic appliance.

CONCLUSION

High levels of nickel ions were released from all the groups, compared to all other ions followed by iron. The release of all metal ions are not the same in each group. Release of metal ions was influenced by composition of the orthodontic archwire, but this was not proportional to the content of metal in the wire. After a 12-week (90 days period) immersion, the total amount of ion release was less than the cumulative daily intake. However, these levels are sufficient to cause an allergic reaction because of the high haptenic potential of released elements.

CLINICAL SIGNIFICANCE

After a 90 days period immersion, the total amount of ion release was less than the cumulative daily intake. Quantities of all released ions were below toxic levels and did not exceed the daily dietary intake. However, further research work should be conducted on the tolerance to these metals and the recurrence of metal allergies after continuous contact with oral mucosa. More studies are needed concerning the retention period of the metal ions in the body and their cytotoxic effects.

REFERENCES

1. Martinez JR, Barker S. Ion transport and water movement. Arch Oral Biol 1987;32:843-47.
2. Maijer R, Smith DC. Corrosion of orthodontic bracket bases. Am J Orthod Dentofacial Orthop 1982;81:43-48.
3. Maijer R, Smith DC. Biodegradation of orthodontic bracket system. Am J Orthod Dentofacial Orthop 1986;90:195-98.
4. Claude G Matasa. Biomaterials in orthodontics. Orthodontics current and principles and techniques. Graber, Vanarsdall, Vig (4th ed), 345-84.
5. Robert P Kusey. Orthodontic biomaterials: From the past to the present. Angle Orthod 2002;72(6):501-12.
6. Burstone, et al. New orthodontic alloy Am J Orthod Dentofacial Orthop 1980;77;121-32.
7. Seda Gursoy. Comparision of metal release from new and recycled bracket–archwire combinations. Angle Orthod 2005; 75(1):92-948.
8. Park HY, Shearer TR. In vitro release of nickel and chromium from simulated orthodontic appliances. Am J Orthod Dentofacial Orthop 1983;(84):156-59.
9. Shin JS, Oh KT, Hwang Chung-Ju. In vitro surface corrosion of stainless steel and NiTi orthodontic appliances: Aust Orthod J 2003;19:13-18.
10. Theodore Eliades, Zinelis S, Eliades G, Athanasiou AE. Nickel content of as received, retrieved and recycled stainless steel brackets. Am J Orthod Dentofacial Orthop 2002;(122):217-20.
11. Fiorenzo Faccioiii, Paola F, Marzja C, Maria E. Francasso: In vivo study on metal release from fixed orthodontic appliances and DNA damage in oral mucosa cells. Am J Orthod Dentofacial Orthop 2003(124);687-94.
12. Turpin DL. California proposition may help patients in search of better oral health (editorial). Am J Orthod Dentofacial Orthop 2001(120)1.
13. Tsui-Hsien Huang, Chen Chieh Yen, Chia-Tze Kao: Comparision of ion release from new and recycled orthodontic brackets. Am J Orthod Dentofacial Orthop 2001;120:68-75.
14. Huang TH, et al. Metal ion release from ne and recycled stainless steel brackets. European Journal of Orthodontics 2004;26:171-77.
15. Maja Kuhta, et al. Type of archwire and level of acidity; effects on the release of metal ions from orthodontic appliances. Angle Orthod 2009;79:102-10.
16. Barrett RD, Bishara SE, Quinn JK. Biodegradation of orthodontic appliances. Part l. Biodegradation of nickel and chromium in vitro. Am J Orthod Dentofacial Orthop 1993; 103(1):8-14.
17. Grimsdottir MR, Gjerdet NR, Petterson AH. Composition and in vitro corrosion of orthodontic appliances. Am J Orthod Dentofacial Orthop 1992;101:525-32.
18. Heidi Kerosuo, Grete Moe, Erik Kelven. In vitro release of nickel and chromium from different types of simulated orthodontic appliances 1995;65(2):111-16.
19. Park SB, Lee BT. Metal release from brackets and archwires. Korean Journal of Orthodontics 1989;19;75-84.
20. Kim, et al. A study on metal release of TiN ion plated stainless steel orthodontic appliances. Korean Journal of Orthodontics 1995;25;43-54.
21. Rhu, et al. A study on the release of nickel and chromium from simulated orthodontic appliances. Iksan, Chollabuk-do; Korea; Wonkwang University 1998.
22. Lee SH, Chang Y. Effects of sterilization on the mechanical properties and surface topography of NiTi alloy wires. Am J Orthod Dentofacial Orthop 2001;120:654-63.

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