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ORIGINAL ARTICLE

Nickel and chromium levels in the saliva of a Saudi sample treated with fixed orthodontic appliances

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KEYWORDS

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Abstract *Aim:* The aim of this study was to measure the amount of nickel (Ni) and chromium (Cr) released into the saliva of Saudi patients treated with fixed orthodontic appliances.

Materials and methods: Ninety salivary samples were collected in a cross-sectional manner. Forty samples were collected from patients (17 males, 23 females) with fixed orthodontic appliances after different periods of orthodontic treatment ranging from the first month and up to 32 months into treatment. The fixed orthodontic appliance consisted of 4 bands, 20 stainless steel brackets, and upper and lower nickel titanium or stainless-steel arch wires. The other 50 samples were collected from people without appliances (24 males, 26 females). Samples were analyzed using Inductive Coupled Plasma/Mass Spectrometry and Inductively Coupled Plasma Optical Emission Spectroscopy to measure Ni and Cr levels, respectively. Student's *t*-test was used to compare Ni and Cr levels in the treated and untreated control groups.

Results: The mean Ni level was 4.197 μg/L in the experimental group and 2.3 μg/L in the control group ($p < 0.05$). The mean Cr level was 2.9 μg/L in the experimental group and 3.3 μg/L in the control group ($p < 0.05$).

Conclusion: Fixed orthodontic appliances resulted in a non-toxic increase in salivary levels of Ni, but no change in Cr levels. Duration of orthodontic treatment did not affect Ni and Cr levels in the saliva.

1. Introduction

Fixed orthodontic appliances contain variable amounts of nickel (Ni) and chromium (Cr). The stainless-steel metal used for orthodontic appliances contains 18% Cr and 8% Ni. Orthodontic arch wires made from nickel titanium (NiTi) contain 50% Ni (Ağaoğlu et al., 2001; Rahilly and Price, 2003; Setcos et al., 2006; Platt et al., 1997). Fixed orthodontic

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appliances release Ni and Cr into the saliva as a result of electrochemical breakdown, which may lead to a "hypersensitivity" response.

Previous studies have evaluated the concentration of Ni and Cr in saliva, serum, and urine after different periods of treatment with fixed orthodontic appliances. Ni and Cr reached their highest levels within the first few months of appliance placement, thereafter decreasing to their initial levels. Although appliances released measurable amounts of Ni and Cr when placed in the mouth, the metals did not reach toxic levels in the saliva, serum, or urine (Stenman and Bergman, 1989; Singh et al., 2008). Diet is considered to be the most significant source of Ni and Cr to humans (Anderson, 1986). *In vitro* Ni release from orthodontic appliances has been reported to range 22–40 μg/d, which is low compared to the estimated dietary intake of 100–800 μg/d (Park and Shearer, 1983; Grimsdottir et al., 1992; Kerosuo et al., 1995; Jia et al., 1999; IPCS, 1991). The average dietary intake of Cr is estimated to be 50–200 μg/d.

The aim of this study was to measure the amount of leached Ni and Cr in the saliva of Saudi patients treated with fixed orthodontic appliances using Inductive Coupled Plasma (ICP)/Mass Spectrometry (ICP/MS) and ICP-Optical Emission Spectroscopy (ICP-OES), which are highly sensitive tools. In addition, we sought to use the levels of Ni and Cr in saliva as an indicator of possible toxicity from these elements.

2. Materials and methods

This study and the informed consent form were approved by the ethics committee of the College of Dentistry Research Center. Written informed consent was obtained from all participants. There were no conflicts of interest related to this research.

Salivary levels of Ni and Cr were examined randomly in 40 patients (17 males and 23 females) with fixed orthodontic appliances who were being treated at the College of Dentistry of King Saud University. The mean age of male patients was 20.1 ± 5.6 years, and the mean age of female patients was 16.8 ± 3.4 years. Orthodontic appliances consisted primarily of 4 bands, 20 stainless-steel brackets (Victory® series, 3 M Unitek, Manrovia, CA, USA), and upper and lower NiTi arch wires and stainless-steel arch wires (3 M Unitek). The control group consisted of 50 subjects (24 males and 26 females), with mean ages of 23.1 ± 4.2 years for males and 21 ± 8.2 years for females. A short questionnaire about past medical and dental history was obtained from all participants.

The inclusion criteria for this study are as follows:

1. Healthy patient with no history of significant medical problems;
2. Patient in the permanent dentition stage;
3. Patient has no metallic crowns, bridges, or any other Ni- or Cr-containing restorations; and
4. Patient had not received previous orthodontic treatment.

2.1. Sample collection

Ninety salivary samples were collected in a cross-sectional manner. Forty samples were collected from patients with fixed orthodontic appliances after different periods of orthodontic treatment ranging from the first month and up to 32 months into treatment. All participants were asked to rinse their mouth thoroughly with distilled deionized water and to deliver at least 5 ml of unstimulated saliva once into a trace element-free glass test tube. Each subject gave a single sample. The sample was divided into two parts, which were used to measure salivary levels of Ni and Cr, respectively. Samples were kept at −20 °C until they were processed.

Table 1 Mean and Standard Deviations of Nickel (Ni) and Chromium (Cr) levels in different groups.

Group/element	Sample size	Mean (SD) (μg/L)
Experimental/Ni	39	4.19 ± 3.05
Control/Ni	50	2.29 ± 2.51
Experimental Cr	39	2.83 ± 1.11
Control Cr	50	3.23 ± 1.33
Male Experimental/Ni	16	4.31 ± 3.14
Male Control/Ni	24	2.69 ± 2.75
Male Exp/Cr	17	3.14 ± 1.08
Male Control/Cr	24	3.10 ± 1.43
Female Experimental/Cr	23	2.62 ± 1.10
Female Control/Cr	26	3.36 ± 1.26
Female Experimental/Ni	23	4.11 ± 3.06
Female Control/Ni	26	1.93 ± 2.26

Samples were analyzed by ICP/MS and ICP-OES to measure Ni and Cr levels, respectively. Before analysis, samples were warmed to room temperature (20 °C) and diluted 10-fold. A calibration curve was generated from a standard solution prepared with the same reagents as those present in the samples. The average of 3 measurements for each sample was used.

2.2. Statistical analysis

Independent Student's *t*-tests were used to compare Ni and Cr levels in the treated and untreated groups for significant differences. The significance level was set at $p < 0.05$.

3. Results

The mean Ni level was 4.197 μg/L (range: 0–12.1 μg/L) in the experimental group and 2.3 μg/L (range: 0–8.2 μg/L) in the control group ($p < 0.05$). The mean Cr level was 2.9 μg/L (range: 0.8–5.4 μg/L) in

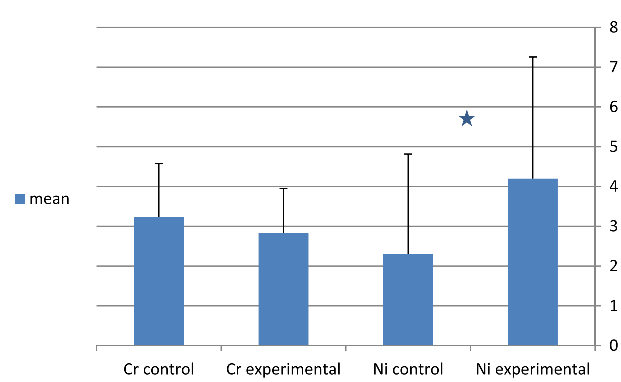

Fig. 1 Mean and standard deviation of Ni and Cr levels among experimental and control groups.

Table 2 Table showing a statistical comparison between different groups. Ni: Nickel, Cr: Chromium.

Group	n	t-Test	P value
Ni experimental group to control group	39/50	3.213	.002*
Cr experimental group to control group	39/50	−1.546	.126
Ni experimental group to control male group	16/24	1.724	.093
Cr experimental group to control male group	16/24	0.099	.921
Cr experimental group to control female group	23/26	−2.186	.034*
Ni experimental group to control female group	23/26	2.80	.008*

* $P < 0.05$

the experimental group and 3.3 μg/L (range: 0.6–6.7 μg/L) in the control group (Table 1, Fig. 1). Student's t-test revealed statistically significant differences in Ni and Cr levels between females of the experimental and control groups (Table 2, Figs. 1–4). The highest level of Ni occurred after 20 months of treatment, whereas the highest level of Cr occurred after 4 months of treatment (Fig. 4).

4. Discussion

Fixed orthodontic appliances, which contain variable amounts of Ni and Cr, can leach these metals into the saliva, which may lead to an immune response. However, previous studies have not explored the amount of Ni and Cr leached into saliva over an extended period of time. In this study, we attempted to evaluate the amounts of percolated metallic ions in patients with fixed orthodontic appliances compared to those without such appliances (Ağaoğlu et al., 2001; Rahilly and Price, 2003; Setcos et al., 2006; Platt et al., 1997; Stenman and Bergman, 1989; Singh et al., 2008; Kerousuo et al., 1996). The amounts of Ni and Cr in saliva varied considerably in our sample. The mean level of Ni in the experimental group was almost twice the level in the control group. The mean Cr level in the experimental group was lower than the level in the control group. Thus, it appears that fixed orthodontic appliances do not leach significant amounts of these metals into the saliva over prolonged treatment times.

Ni is the most common cause of metal-induced allergic stomatitis. In some cases, it can have a mutagenic effect (Kerousuo et al., 1996; Barceloux, 1999; Norseth, 1981). Previous studies using patch testing found that the prevalence of Ni hypersensitivity was 6.7% in Saudi males and 11.6% in Saudi females (Talic et al., 2007). Fors et al. (2012) performed a patch test study on 4376 subjects, evaluating Ni allergy in relation to piercing and orthodontic appliances. Use of high Ni-containing orthodontic appliances before piercing reduced the risk of Ni sensitization by a factor of 1.5–2. Blanco-Dalmau et al. (1984) conducted a patch test using 5% nickel sulfate on 121 males and 282 females (n = 403). They found a positive reaction in 28.5% of subjects (31.9% of females, 20.7% of males). Jones et al. (1986) performed a patch test on 100 patients (50 men) and found that only 2% of men developed Ni hypersensitivity, compared to 20% of women. Stenman and Bergman (1989) studied Ni hypersensitivity in 151 patients using a patch test and reported Ni hypersensitivity in 14% of their sample. Cr allergy is estimated to occur in 10% of male subjects and 3% of female subjects (Stenman and Bergman, 1989).

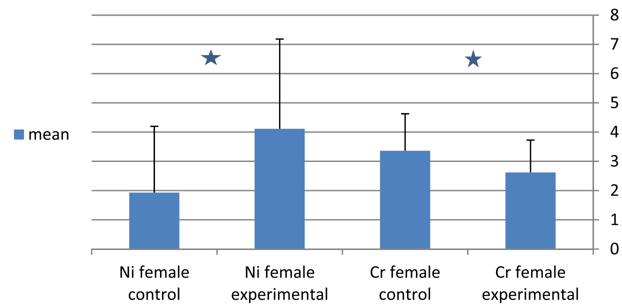

Fig. 3 Mean and standard deviation of Ni and Cr among female groups.

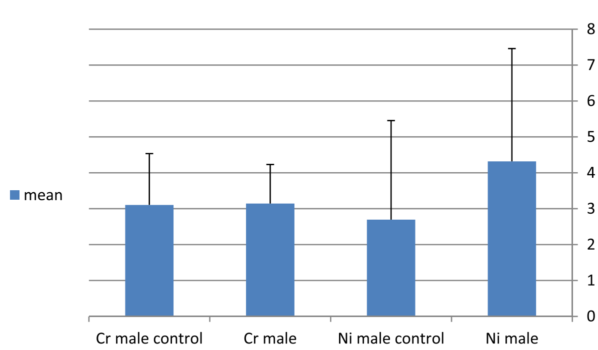

Fig. 2 Mean and standard deviation of Ni and Cr among male groups.

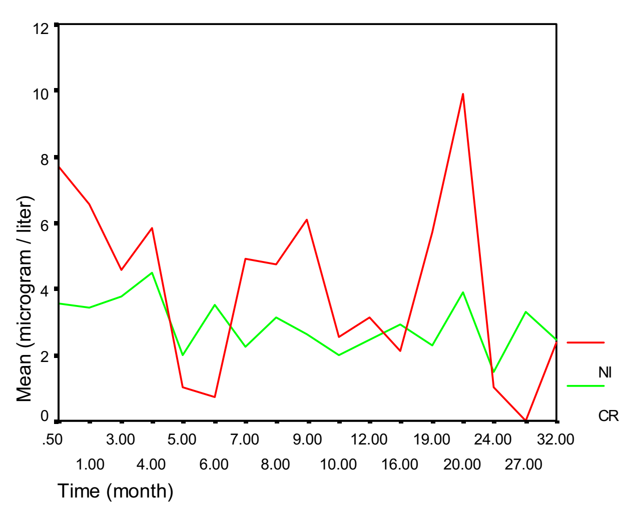

Fig. 4 Mean Ni and Cr levels after different periods of treatment.

Singh et al. (2008) studied the level of Ni and Cr in the saliva of 10 patients with fixed orthodontic appliances from the beginning of their treatment. The highest level was found 1 week after appliance placement. Kerousou et al. (1996) found that during the first month of treatment, fixed orthodontic appliances did not significantly affect Ni and Cr concentrations in saliva. Barrett et al. (1993) concluded that the release rates of Ni and Cr from stainless-steel and NiTi arch wires were not significantly different. Previous studies have examined Ni release from different arch wires and have concluded that the maximum amount of Ni released from all tested arch wires was 700 times lower than the concentrations necessary to elicit cytotoxic reactions in humans (Jia et al., 1999). The release of Ni from fixed orthodontic appliances was reported to be related to the composition and manufacturing method of the orthodontic appliance, but not to the Ni content (Toms, 1988; Kim and Johnson, 1999; Grimsdottir et al., 1992). Urinary excretion levels of Ni in orthodontic patients were studied by Menezes et al. (2007), who found that Ni levels were significantly increased 2 months after appliance placement.

In our study, 13 control salivary samples (7 females, 6 males) contained 0 μg/L of Ni. Only one experimental salivary sample, from a female with a treatment duration of 27 months, showed 0 μg/L of Ni. These null values can be attributed to either the absence or subdetectable levels (<0.5 μg/L) of Ni in saliva. One outlier in the sample was a 14-year-old male patient with 9 months of treatment, who had extreme values of 57.1 and 13.1 μg/L of Ni and Cr, respectively. These results were possibly due to sample contamination and were excluded from the results. The correlation between treatment duration and Ni and Cr levels was ambiguous and inconsistent with previous studies. This result could be due to the inherent shortcomings of cross-sectional studies. Because individual variations in Ni and Cr levels do exist, a longitudinal study would eliminate such variations and allow for a better correlation between treatment duration and metal levels.

Statistically significant differences in the amount of Ni released into saliva were observed between the experimental and control groups and between females in the experimental and control groups. These findings agree with the previous findings of Ağaoğlu et al. (2001) and Singh et al. (2008), but disagree with the findings of Barrett et al. (1993) and Kerousou et al. (1996). A statistically significant difference was also found for Cr levels between the female experimental and female control groups. However, the mean Cr level was higher in the control group than in the experimental group. The inconsistency and variations in results between previous studies and this study could be justified by the following explanations: (1) the studies were conducted on different races; (2) there may have been differences in the sampling methods, processing of salivary samples, and analysis of collected data; (3) there may have been differences in the accuracy of measuring devices utilized; and (4) there may have been differences in the fixed appliance types and number of brackets included in the study.

The reported Ni and Cr levels in the saliva of Saudi patients with orthodontic appliances were much lower than the levels that would be considered toxic, and did not even reach the levels achieved by the dietary intake of these metals. Future studies with a larger sample size are needed to confirm the findings of this study.

5. Conclusions

Fixed orthodontic appliances release trace amounts of Ni, which may lead to elevations in salivary and serum Ni levels. However, the amount of Ni released did not reach a toxic level at any period during treatment. We did not observe any elevation in Cr levels after treatment with fixed orthodontic appliances over a prolonged treatment duration. Orthodontic treatment time did not affect salivary Ni and Cr levels.

Conflict of Interest

None.

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