Nickel and chromium levels in the saliva of patients with fixed orthodontic appliances

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Aim: The purpose of this study was to investigate the salivary concentration of nickel and chromium of patients undergoing orthodontic treatment.

Methods: In this study 32 patients who presented to the orthodontic clinic were selected. The salivary samples were taken from the patients in four stages: before appliance placement and 20 days, 3 months, and 6 months following appliance placement. The salivary samples were collected in a plastic tube and were stored in the freezer before analysis. The samples were then transferred to the laboratory, and the amounts of metals were determined by graphite furnace atomic absorption spectrometry with an autosampler. Each sample was analyzed three times, and the average was reported. Results: It was found that the average amount of nickel in the saliva 20 days after appliance placement was 0.8 μg/L more than before placement. Also, the amount of salivary nickel 20 days after the appliance placement was more than at the other stages, but the differences were not significant. The average amount of chromium in the saliva was found to be between 2.6 and 3.6 μg/L. The amount of chromium at all stages after appliance placement was more than before, but the differences between the chromium levels of saliva at all stages were not significant.

Conclusion: There was no significant difference in the average amount of salivary nickel and chromium of patients at various stages of orthodontic appliance placement. ORTHODONTICS (CHIC) 2013;14:e76–e81. doi: 10.11607/ortho.810

Key words: chromium, nickel, salivary samples, corrosion

Metallic components of fixed orthodontic appliances are bands, brackets, and wires. Bands and brackets are made of stainless steel (SS), which has 8% to 12% nickel and 17% to 22% chromium.¹,² Orthodontic wires can be made of SS, nickel titanium (NiTi), or beta-titanium. The alloys containing nickel are widely used in orthodontic appliances. Thus, they are an important part of orthodontic treatment. NiTi wires have 47% to 50% nickel and are the richest source of nickel in the oral cavity of half of orthodontic patients.¹,²
Kim and Johnson\(^3\) reported that corrosion is common among all orthodontic wires, including SS wires. Nickel and chromium release from brackets, bands, and orthodontic wires during treatment (ie, corrosion takes place in the appliance) and can lead to reduction of appliance strength and adverse biologic effects such as allergic reaction to nickel.\(^2\) These reactions include various clinical manifestations such as inflammation and redness of the gingiva or lips,\(^4\)–\(^6\) angioedema,\(^4\) eczema,\(^4\) a burning sensation,\(^5\)\(^,\)\(^6\) labial desquamation,\(^5\)\(^,\)\(^6\) erythema multiforme,\(^5\)\(^,\)\(^6\) stomatitis with mild to severe erythema,\(^5\)\(^,\)\(^6\) loss of taste or metallic taste,\(^5\)\(^,\)\(^6\) numbness, soreness of the side of the tongue,\(^5\)\(^,\)\(^6\) and angular cheilitis.\(^4\)–\(^7\) The prevalence of allergic reaction during fixed orthodontic treatment is 0.3% to 0.4%.\(^4\)\(^,\)\(^8\)

Some researchers reported that there is no significant increase in the nickel salivary concentration of patients during orthodontic treatment. Kerosuo et al\(^9\) evaluated the concentration of the nickel and chromium of the saliva and dental plaque of the patients with fixed orthodontic appliances before and 1 to 2 days, 1 week, and 1 month after appliance placement and found that the concentration of nickel and chromium did not change significantly after appliance placement. Kocaderli et al\(^10\) evaluated the concentration of nickel and chromium in stimulated saliva of 30 patients. The samples were measured before and 1 week, 1 month, and 2 months after appliance placement. They found no significant differences between nickel and chromium levels of saliva at different stages of treatment.

However, other studies found that there is a significant difference between nickel concentration of saliva before and after orthodontic treatment. Ağaogluet al\(^11\) carried out a cross-sectional study and gathered nonstimulated saliva samples before and 1 week, 1 month, 1 year, and 2 years following appliance placement. They found that the amount of nickel and chromium was at the highest level in the saliva of patients after 1 month of treatment and then showed a decrease. Petoumenou et al\(^12\) evaluated the concentration of nickel in nonstimulated saliva before and after band and bracket placement and before and after placement of the NiTi wires. The study included a control group. They found an increase in the concentration of nickel from 34 μg/L (before the treatment) to 78 μg/L (after the appliance placement), which then decreased to 56 μg/L following placement of the wires.

Fors and Persson\(^13\) studied the concentration of nickel in the nonstimulated saliva and dental plaque of 24 patients with or without orthodontic fixed appliances. They did not find any significant difference in the salivary nickel concentration, but the amount of nickel in the dental plaque of the patients with fixed appliances was more than in patients without the fixed appliance.

Regarding the limited number of clinical trials done on the corrosion of orthodontic appliances during treatment and contradictory findings of previous studies, we decided to study the amount of the salivary concentration of nickel and chromium before and during fixed orthodontic treatment up to 6 months after appliance placement.

**METHODS**

This is a cohort study; license number p/17/1/177391 was issued by the Ethics Committee of Shahid Sadoughi University of Medical Sciences. The sampling was done consecutively on 32 patients referred to the orthodontic ward, aged 11 to 24 years with an average age of 15 years, 3 months. The first molars were banded; premolars and anterior teeth were bonded using twin brackets (Gemini, 3M Unitek). The NiTi and stainless steel wires were manufactured in France (M.I.B.). The inclusion criteria of this study were:
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- Patient in the permanent dentition stage
- No amalgam fillings or metal restorations
- No palatal attachments welded to the bands
- No headgear or extraoral appliances used

The documented consent was taken after patient selection and explanation of the purpose of the study. The sample of the saliva was collected in four stages:

- T1: before appliance placement
- T2: 20 days after appliance placement
- T3: 3 months after appliance placement
- T4: 6 months after appliance placement

It should be noted that when the samples were taken at T4, the wire had to be stainless steel with at least one month in place.

The samples were taken at least 3 hours following a meal and after rinsing the mouth with distilled water. The samples were collected into the plastic tubes without stimulation and were stored at -20°C.

A 220Z Varian SpectrAA Zeeman atomic absorption spectrometer (Varian) was used for all metal measurement throughout this study. A PC computer was used to record the absorbance signal profile. The Varian SpectrAA hollow cathode lamps for chromium and nickel were used as light sources. The furnace tube was a standard plateau tube with a paralytic graphite coating. The analytical wavelength (357.9 and 232.0 nm), spectra bandwidth (0.2 and 0.2 nm), and lamp current (7 and 4 mA) were used for chromium and nickel measurement, respectively, as recommended by the manufacturer. The operating conditions and the optimum temperature program of graphite furnace atomic absorption spectrometry (GFAAS) used for determination of chromium and nickel in the salivary samples are presented in Tables 1 and 2. The method was validated by a recovery experiment. The metal content of all samples was measured three times, and the results were averaged.

### Table 1 Operating conditions of GFAAS for measurements of nickel and chromium

<table>
<thead>
<tr>
<th>Measurements</th>
<th>Nickel</th>
<th>Chromium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength (nm)</td>
<td>232.0</td>
<td>357.9</td>
</tr>
<tr>
<td>Slit width (nm)</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Lamp current (mA)</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Background correction</td>
<td>On</td>
<td>On</td>
</tr>
<tr>
<td>Sample volume (µL)</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Gas</td>
<td>Argon</td>
<td>Argon</td>
</tr>
</tbody>
</table>

### Table 2 Temperature program of GFAAS for determination of chromium and nickel

<table>
<thead>
<tr>
<th>Steps</th>
<th>Chromium</th>
<th>Nickel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Temperature (°C)</td>
<td>Time (s)</td>
</tr>
<tr>
<td>1</td>
<td>85</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>95</td>
<td>40</td>
</tr>
<tr>
<td>3</td>
<td>120</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>1,000</td>
<td>6</td>
</tr>
<tr>
<td>5</td>
<td>1,000</td>
<td>2</td>
</tr>
</tbody>
</table>

**Statistical analysis**

According to the Kolmogorov-Smirnov test, the hypothesis of normal distribution of nickel concentration at different stages was approved (P > .05); so, for comparing the averages of the amounts of nickel at different stages, a parametric test of repeated measures was performed. However, for chromium, the hypothesis of normal distribution at different stages was not approved (P < .05). Thus for comparison of the average amounts of chromium at different stages, the nonparametric test of Friedman was done. All the statistical analyses were done using SPSS 17 (IBM).
RESULTS

The results indicate differences in the amounts of nickel and chromium in the saliva of the patients with fixed orthodontic appliances at different periods of treatment time. It was found that the average amount of nickel in the saliva at 20 days after placement was 0.8 μg/L more than before it. Also, the amount of the salivary nickel at 20 days after placement was more than at any other stage (Fig 1), but the differences were not significant. The average amount of chromium in the saliva was found to be between 2.6 and 3.6 μg/L. The average increased from 2.6 μg/L in T1 to 3.6 μg/L in T2. The amount of chromium in other stages was more than before placement, but the differences in the chromium levels of saliva were not significant at any stage (Table 3).

DISCUSSION

Since most orthodontic devices used in the oral cavity can undergo some degree of corrosion, they present potential toxicity by releasing metals in the mouth. Grimsdottir et al\textsuperscript{14} in their study concluded that danger from copper releasing from some kinds of alloys is more serious than that posed by nickel. However, although the risk of nickel and chromium toxicity is minimal, there is interest regarding its release from orthodontic appliances. Previously, corrosion from individual orthodontic appliances such as wires, bands, and brackets was reported.\textsuperscript{15} In this study, the corrosion of the whole appliance is considered.

Saliva has a dynamic composition that is affected by many physiologic variables such as diet, pH, physical status, and salivary flow rate.\textsuperscript{16} Thus, in order to limit the effect of these variables the patients selected for the study were in good general health, ie, no dental caries or metallic restorations were observed.

The daily oral intake of nickel and chromium are about 300 to 600 μg/day\textsuperscript{17} and 50 to 200 μg/day,\textsuperscript{18} respectively. The main sources of nickel and chromium are vegetables, grains, and nuts.\textsuperscript{17} In this study for standardization of the saliva collection the samples were taken at least 3 hours following a meal and after rinsing the mouth with distilled water.
In a study Ağaoglu et al\textsuperscript{11} investigated different individuals’ saliva in various stages of orthodontic treatment. Since health status and food regimen play a role in saliva compounds, in the present study the saliva of 32 patients was investigated before and during treatment stages. Therefore, individual differences did not influence the results of present study.

For evaluating the status of releasing elements during orthodontic treatment, it is important to carry out the process throughout the treatment; limitation of study to one period may result in ignorance of metal release variation during different stages. Eliades et al\textsuperscript{19} studied the levels of nickel, chromium, and iron in orthodontic patients and found no significant difference compared to the levels of these metals in a control group. However, since their study was limited to the samples collected before treatment and one stage after that, they postulated that the concentration of these elements may change during different stages. Thus, based on this assumption, we evaluated the variation of salivary nickel and chromium of patients undergoing orthodontic treatment during four stages.

In a study conducted by Fors and Persson,\textsuperscript{13} 33\% and 67\% of patients had SS and NiTi archwires, respectively, during saliva sampling; since the nickel and chrome amounts of NiTi wires are significantly greater than those of SS wires, in their study all patient statuses were not identical. However, in the present study, all patients, having identical archwires, experienced the same condition at various stages, eg, in T2 stage (20 days after placement) all patients possessed titanium archwire, and in T4 stage patients had SS archwires, and the SS archwires were in place for at least 1 month.

The alteration of nickel and chrome concentration at different stages of treatment are presented in Table 3 and Fig 1. As the results demonstrate, the average amounts of salivary nickel in T2 were 0.8 μg/L more than in T1 and were more than at other stages (see Fig 1), but there is no significant difference between the concentrations of nickel in other stages. The results also revealed that the average amounts of salivary chromium were between 2.6 and 3.6 μg/L. The average increased from 2.6 μg/L in T1 to 3.6 μg/L in T2. Thus, the amount of chromium was at a minimum level before appliance placement and then slightly increased during the treatment; however, the differences are not statistically significant (see Table 3). Furthermore, the high variation of concentration of these metals may be due to the effect of diet, physical health, and salivary flow rate on the salivary composition.\textsuperscript{14} Similar variation was observed in past studies.\textsuperscript{9,20,21}

There is some inconsistency in the concentration of the nickel and chromium found in different studies. Kerosuo et al\textsuperscript{9} and Kocaderli et al\textsuperscript{10} reported that there is no difference between nickel and chromium concentration before and at three intervals after treatment. Also, Gjerdet et al\textsuperscript{21} did not find any difference between the concentrations of nickel before treatment and 3 weeks after placement of the appliances. However, Petoumenou et al\textsuperscript{12} found that the concentration of nickel increases from 34 μg/L before treatment to 78 μg/L after the appliance placement and then decreases to 56 μg/L. Thus, the results of this study are in agreement with the results of Kerosuo et al,\textsuperscript{9} Kocaderli et al,\textsuperscript{10} and Gjerdet et al\textsuperscript{21} but different from the Petoumenou et al\textsuperscript{12} and Ağaoglu et al\textsuperscript{11} outcomes. The reason for this difference may be that in the study done by Ağaoglu et al\textsuperscript{11} the research design was cross sectional, and therefore salivary samples were collected from different patients at various stages, and the results of their study were affected by individual variations in composition of saliva. Petoumenou et al\textsuperscript{12} investigated nickel concentration in the saliva of patients with NiTi appliances. Considering the higher amount of nickel and chrome in NiTi wires, observation of significant increases in nickel concentration of saliva immediately after placement of the bands, brackets, and NiTi archwires seems reasonable. They also found that no statistically significant differences existed between the nickel concentrations in the samples taken before placement of
appliances, 2 weeks after placement of the bands and brackets, and 4 and 8 weeks after placement of the archwires, and these findings are in line with the present study results, which proved no long-term alteration in salivary nickel and chrome amounts. However, interpretation of different studies’ results should be done with caution since the different methodologies used may cause the results to be different.

The average amounts of salivary nickel 20 days after appliance placement were more than at T1 and other stages, which is in agreement with the studies of Petoumenou et al\textsuperscript{12} and Ağaoğlu et al\textsuperscript{11}; however, the differences they found were statistically significant, whereas the differences between stages were not significant in our study. Also, it should be noted that in stage T4, the SS wire, which is prepared in austenite phase for orthodontic appliances and contains iron, carbon, and nickel\textsuperscript{22} was maintained for at least 1 month in place; thus, this might be the reason for the amount of nickel found in salivary samples of stage 4 of this study.

CONCLUSIONS

A study limitation was the small number of patients who do not have metal restorations in their mouth (one of the inclusion criteria of the study), which made achieving the appropriate sample size time consuming. The results of the present study demonstrated that salivary composition in terms of nickel and chrome is not significantly affected by fixed orthodontic appliances during the first 6 months of treatment commencement. It is recommended that clinical trials with a control group and randomization be done in the near future.

REFERENCES