Nickel and iron in saliva of patients with fixed orthodontic appliances

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Saliva was obtained from patients receiving treatment with fixed orthodontic appliances. One saliva sample was taken without appliances, and another at least 3 weeks after placement. In some patients samples were also taken immediately after insertion of the appliance. Nickel and iron were quantified by electrothermal atomic absorption spectroscopy. There was a large scatter in the results. No statistically significant differences were found either in the concentrations or in absolute masses of nickel or iron in samples taken without appliances and in those obtained when the appliances had been in the mouth for at least 3 weeks. For samples taken immediately after placement of the appliance, there was a significant increase in both concentrations and masses of nickel and iron. It thus seems that there is a high initial release of metals, and the effect diminishes with time. □ *Chemical analyses; corrosion; dental alloys*

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Nickel-containing alloys frequently constitute parts of fixed and removable orthodontic appliances. Austenitic stainless steels, containing 6–14% nickel and 64–75% iron (1), are widely used. Some orthodontic wires have a nickel content exceeding 50% (2).

Few data exist on intra-oral corrosion of orthodontic appliances. In a recent preliminary report increased saliva concentrations of nickel and chromium could be detected 3 days after insertion of fixed orthodontic appliances. The changes in concentrations were inconclusive at later periods of time (3). Bands, brackets, and metallic components used in removable orthodontic appliances showed signs of corrosion after 6 to 10 months of clinical use (4). Furthermore, it has been reported that corrosion products from bracket bases have stained the underlying tooth surface (5–7).

In vitro tests have shown that fixed orthodontic appliances release metals to electrolytes (8, 9). It has been demonstrated that the release of metals from stainless steel or cobalt–chromium wires increases after being heated to 400–800°C (10). Electrochemical tests have indicated that stainless steel, cobalt–chromium, and beta-titanium wires were electrochemically passive, whereas a nickel–titanium wire was less passive and showed corrosion defects in vitro (11).

Electrochemically passive alloys may release measurable amounts of metals in the mouth. The presence of cobalt–chromium partial denture alloys increased the amounts of cobalt and chromium both in saliva (12) and in tongue scrapings (13).

There has been some concern about the potential biologic hazards, particularly hypersensitivity, in using nickel-containing dental alloys (14). Nickel sensitivity is common in some populations, the prevalence being higher in women than in men (15, 16).

There are a few case reports on metal hypersensitivity reactions seen in conjunction with fixed orthodontic appliances (9, 17). Nickel-containing dental alloys may cause adverse reactions in sensitive subjects. Other types of dental alloys containing nickel have been associated with hypersensitivity reactions (18–20).

The purpose of this study was to establish whether fixed orthodontic braces released measurable amounts of nickel and iron to the saliva of patients.

Materials and methods

The patients included in this study were treated at the departments of orthodontics at the dental faculties of University of Oslo and University of Bergen, Norway. Thirty-four patients undergoing treatment with fixed orthodontic appliances participated, 18 females and 16 males. The mean age was 14.4 years (range, 9–33). The appliances consisted of an average of 13 bands or bonded brackets. Stainless steel products were used, except for nickel-based archwires, which were used in 11 patients.

Saliva sampling

Saliva was collected in the following manner: The subjects rinsed the mouth thoroughly with about 100 ml of deionized and distilled water. Immediately after the rinsing unstimulated saliva was collected for 5 min with the mouth closed. The saliva was transferred to pre-weighed plastic test tubes (Nunc no. 01880, Copenhagen, Denmark).

For each individual one saliva sample was taken after at least 3 weeks with the fixed orthodontic appliances present in the mouth. To obtain a reference level for metal content, saliva samples were taken from the same patients either before the appliances were inserted or 3–5 weeks after removal. The saliva samples were kept at −20° C until they were processed.

In six patients saliva samples were obtained 5 to 10 min after placement of the appliances. Long-term samples were not obtained in three of these patients.

Preparation of the saliva samples

The mass of saliva was determined by weighing, and 0.5 ml of saliva was transferred to acid-washed plastic tubes. To digest organic matter, 0.15 ml of concentrated HCl (Suprapur, Merck, Germany) was added. The samples were then heated at 80°C for 8 h (12). Samples with visible blood contamination were discarded.

Analytic procedure

Electrothermal atomic absorption spectrophotometry (Perkin-Elmer 372, Perkin-Elmer Corp., USA, and HGA 76B Graphite Furnace, Bodenseewerk Perkin Elmer & Co. GmbH, Germany) was used for the chemical analyses. Unspecific absorption was corrected for by a deuterium background corrector.

The analytic line used for nickel was 232.0 nm. Fifty microliters of sample were used for each analysis. The flow of argon through the graphite furnace was stopped during the atomization, to enhance the sensitivity. The lower detection limit was estimated to be 0.3 ng/ml, on the basis of the signal to noise ratio.

Iron analyses were performed at a non-optimal wavelength of 271.9 nm, to reduce sensitivity (21). Twenty microliters were used for each analysis. The settings of the graphite furnace were otherwise as described in the manual for the instrument (21).

Calibration curves were made from results obtained with standard solutions prepared with the same reagents as those used for the samples. Peak readings were used to determine the mass of nickel and iron in the samples. It has been shown previously that between 70% and 80% of the metals was retrieved in the preparation and analyses (12). Each test was analyzed twice, and the average used as the result. The samples from one individual were prepared and analyzed in the same batch so as to minimize scatter due to variation in the analytic procedure. At least two blank samples (containing all reagents except saliva) were processed together with the saliva samples, to check for possible contamination and to establish background levels. The values for the blanks were subtracted from the results obtained for the samples.

Presentation of results and statistics

Both concentrations and absolute masses (concentration × saliva mass) of nickel and iron in the saliva samples were determined. The Mann–Whitney two-sample test was used to test for statistical significance between the no-appliance samples and those obtained with the appliances present. Paired differences between values for samples obtained with appliances and the no-appliance values were calculated for each subject. The differences were tested against zero by the Wilcoxon one-sample test. *P* values equal to 0.05 or less were considered significant. Correlations between variables were evaluated by the Spearman rank correlation coefficient (r_s). For the long-term samples subgroups related to sex, clinical department (Oslo or Bergen), number of bands/brackets (10 and fewer, or more than 10), and the presence of nickel–titanium wire were statistically evaluated.

Results

The median amount of saliva obtained after 5 min of sampling was 3.81 g (range, 0.55–10.62) without orthodontic metals in the mouth and 3.30 g (range, 0.26–9.32) when fixed appliances were present. Males had median secretion rates of 4.23 to 4.52 g/5 min, whereas females had 2.74 to 2.85 g/5 min. The findings in the two groups were not statistically different ($0.05 < p < 0.07$).

The concentrations of nickel and iron showed large variations. The median concentration of iron was up to 22 times that of nickel (Table 1). The concentration of nickel was higher in the no-appliance saliva samples than in those obtained in the presence of appliances that had been in service for at least 3 weeks (Table 1). The relationship was the opposite for iron (Table 1). The values were not statistically discernible from the no-appliance samples, when tested either by two-sample or by one-sample tests (Table 1). The concentrations found immediately after placement of the appliances were about nine times higher for nickel and three times higher for iron (Table 1) compared with the no-appliance samples. The two-sample test showed statistically significant differences, whereas the paired differences did not (Table 1). There was a statistically significant correlation between absolute amounts of iron and nickel in the samples obtained with appliances ($r_s = 0.473$, $p < 0.01$).

The absolute masses of metals in the saliva found in patients with appliances present for at least 3 weeks were not statistically discernible from the no-appliance samples, either for nickel or for iron (Table 2). For samples taken immediately after placement of the fixed appliances there were statistically significant increases in masses of both nickel and iron, as demonstrated by the two-sample test (Table 2). Values for iron showed statistical significance in the paired test as well (Table 2).

There were no statistically significant differences in metal concentrations or absolute masses between the subgroups on the basis of sex ($0.59 < p < 1.00$), clinical department ($0.08 < p < 0.86$), or the number of bands/brackets ($0.76 < p < 0.91$). No difference in nickel concentrations or masses could be

Table 1. Concentrations (ng/ml) of nickel and iron in saliva without and with orthodontic appliances present. Saliva collected for 5 min; *n* denotes the number of patients

	Nickel		Iron	
	Median (*p* value*)	Min/Max	Median (*p* value*)	Min/Max
No appliances ($n = 34$)	8.2	0.0/200	148	0.0/1454
Immediately after placement ($n = 6$)	67.6 (0.05)	5.7/128	488 (0.02)	128/1441
Paired differences ($n = 6$)	29.2 (NS)	−72.8/68.9	165 (NS)	−13.0/1436
More than 3 weeks after placement ($n = 31$)	7.8 (NS)	0.0/104	172 (NS)	17.0/1123
Paired differences ($n = 31$)	−0.8 (NS)	−147/97.0	−5.0 (NS)	−1354/929

* *P* values are the result of two-sample tests referring to the no-appliance samples. *P* values related to paired differences are based on one-sample tests. NS = *p* values > 0.05.

Table 2. Absolute masses (ng) of nickel and iron in saliva without and with orthodontic appliances present. Saliva collected for 5 min; n denotes the number of patients

	Nickel		Iron	
	Median (p value*)	Min/Max	Median (p value*)	Min/Max
No appliances (n = 34)	32.0	0.0/1081	499	0.0/4661
Immediately after placement (n = 6)	295 (0.01)	41.0/590	2380 (0.00)	819/10400
Paired differences (n = 6)	104 (NS)	−491/463	1236 (0.04)	192/10400
More than 3 weeks after placement (n = 31)	21.9 (NS)	0.0/262	599 (NS)	22.0/4224
Paired differences (n = 31)	−4.0 (NS)	−693/194	22.0 (NS)	−4358/4131

* See Table 1.

detected in patients with and without nickel–titanium wire ($0.51 < p < 0.66$).

The results obtained for the blank samples were about 0.3 ng/ml for nickel, which is close to the detection limit, and about 50 ng/ml for iron.

Discussion

The considerable scatter in the results seen in the present investigation is a common feature of analyses of metals in saliva (3, 12). Whole saliva does not show a constant composition, either between different subjects or in the same subject. The physical properties, amount, and composition of saliva are influenced by factors such as diet, time of day, and psychic condition (22). These fluctuations may affect both the behavior of metals in the mouth and the analytic performance. For nickel in urine it has been demonstrated that results from different laboratories, all using atomic absorption spectrometry, sometimes differed by a factor of 3 (23). The risk of accidental contamination is to be considered in low-level metal analyses. The present analytic technique used a minimal laboratory procedure that was monitored by blanks and by duplicate analyses.

The present median value for nickel concentration in saliva without orthodontic appliances present (8.2 ng/ml) is higher than that reported for parotid saliva, 1.9 ± 1.0 ng/ml (range, 0.8–4.5) (24). In spite of different analytic procedures and the fact that the present results were obtained from whole saliva, the result may suggest that the nickel concentration is actually elevated in patients with fixed orthodontic appliances. The reason for this might be that the saliva samples are influenced by the history of metal exposure immediately before the saliva sampling procedure, such as metals released from dental instruments used during the preceding examination. Rinsing with distilled water may not remove all traces of metals.

Fluctuations in the amounts of metals in saliva due to intake of nickel and iron from food might tend to obscure the potential effect from the orthodontic appliances. The daily intake of nickel has been estimated to 300–760 μg (25, 26) and for iron 9–30.5 mg (26). The samples taken immediately after placement of the appliances are less prone to be influenced by external metal exposure than samples obtained after several weeks. Even though samples with visible blood were discarded, the possibility cannot be excluded that the presence of hemoglobin may affect the values for iron.

Metallic orthodontic appliances have a potential capability to increase the amount of metals in the saliva. Iron in particular was expected to increase, since it is the main constituent of stainless steel (1). Statistically significant changes in the amounts of nickel or iron could not be demonstrated in patients with appliances that had been in the mouth for more than 3 weeks. Increase in the amounts of the metals was, however, readily detectable just after placement of the appliances. Manipulation of bands, brackets, and wires imply abrasion of the metal surfaces (27, 28). The results obtained some weeks after banding/bonding suggest that the orthodontic appliances had reached a passive state. Metals placed in the mouth immediately change their surface state because of the formation of a biologic film (29). Biologic deposits have been observed on clinically used wires (30). This may be a factor that tends to reduce corrosion in vivo.

Our observations are in line with the few data presented in a recent report on nickel and chromium in saliva of patients receiving orthodontic appliances (3). It was indicated from the presentation that there was an increase in metal concentrations 3 days after insertion, but there was no clear pattern after 3 months.

On the basis of the in vitro data presented by Park & Shearer (8) it can be estimated that an appliance consisting of 14 bands and brackets releases about 70 ng nickel during a 5-min period. The present investigation, in which the average number of bands/brackets was 13, gave a median value of only about 22 ng. Comparison of data obtained in in vitro and in vivo corrosion tests are, however, problematic. It has been demonstrated that several dental alloys, including stainless steel, showed higher initial corrosion rates in vitro than in vivo, but the decrease in corrosion rate, expressed as corrosion currents, was less under in vivo conditions. This was attributed to the action of abrasion (31). It should be noted that there was no chewing action during the period of saliva sampling in the present investigation.

We did not find increased nickel content in the saliva of patients wearing nickel–titanium wires. This type of wire has been found to be susceptible to pitting corrosion in an in vitro electrochemical test (11) but did not demonstrate corrosion defects after 1 to 8 months of clinical use. Formation of biologic deposits may be one reason for the lower tendency for corrosion observed clinically (30).

The present results indicate that there is a statistically significant release of nickel and iron just after placement of fixed orthodontic appliances, but they do not cause prolonged increased amounts of metals in saliva. There are, however, large individual differences. The liberation of metals from orthodontic appliances appears to be small compared with the intake by food. Considering the maximum values found in subjects with appliances, the amount of nickel in saliva would be about 75 μg/day, correspondingly 1.3 mg for iron. These amounts are at most one-fourth of those after intake by food (25, 26).

From the viewpoint of nickel hypersensitivity the amounts of nickel found in the present study may be compared with the single dose of 2.5 mg nickel used as an oral challenge in nickel-sensitive persons (32). Fifty-two per cent of the subjects experienced flares of dermatitis after the challenge. The dose used corresponds to at least 30 days' exposure to the amounts of nickel found in the orthodontic patients studied here.

In conclusion, it appears that long-term, in vivo release of nickel and iron to the saliva is low from orthodontic appliances placed in the patients included in the present study. Furthermore, tests performed in nickel-sensitive individuals indicate that there are less symptoms associated with oral exposure to nickel-containing alloys than with skin exposure (33). However, owing to the traumatic potential of orthodontic appliances and inter-individual differences in sensitivity, release of metals from orthodontic alloys must be considered, particularly in nickel-sensitive subjects.

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