Journal of Advanced Medical and Dental Sciences Research

@Society of Scientific Research and Studies

Journal home page: www.jamdsr.com doi: 10.21276/jamdsr

(e) ISSN Online: 2321-9599; (p) ISSN Print: 2348-6805

Original Article

Release of Metallic Ions from Fixed Orthodontic Devices –An in Vivo Study

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***ABSTRACT*:**

Background: The elevated levels of metals in saliva are thought to occur by corrosion of the chemical elements in the alloys or welding materials. The aim of this study was to evaluate the concentrations of nickel and chromium ions in salivary samples from patients treated with fixed orthodontic appliance. **Materials and Methods**: This retrospective study was carried out on 23 subjects (13 females and 10 males) who had undergone fixed orthodontic therapy for a duration of 12–18 months. A same-gender brother or sister (total of 23 subjects) was selected as a control in order to limit the effects of dietary and hygiene habits on salivary metal ion concentration. Approximately 5 ml of saliva was collected from each subject, and the samples were analysed using an atomic absorption spectrophotometer. The detection limit of the method for sample solutions was 1 ng/ml. Since some variables were not normally distributed, non-parametric tests (Mann–Whitney U and Wilcoxon W) were used for statistical analysis. **Results:** The mean salivary nickel (Ni) content in subjects with and without a fixed orthodontic appliance was 17.1-12.1 and 11.7-10.6 ng/ml in the subjects and controls, respectively. A statistically significant difference ($P < 0.035$) was found between the two groups. The mean salivary chromium (Cr) ion level recorded was 2.3-1.7 in the controls and 1.6 -1.3 ng/ml in the study group. The difference, however, was statistically insignificant. **Conclusion:** Within the limits of this in vivo study, it can be concluded that the presence of fixed orthodontic appliances leads to an increased concentration of metal ions in salivary secretions.

Key words: Metallic ions, fixed appliances, saliva.

Received: 10 September 2018 Revised: 22 October 2018 Accepted: 25 October 2018

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This article may be cited as: Kharat S. Release of Metallic Ions from Fixed Orthodontic Devices –An in Vivo Study. J Adv Med Dent Scie Res 2018;6(11):16-19.

INTRODUCTION

Contemporary orthodontics (orthodontic exchange organizations and orthodontists alike), take most extreme consideration to apply materials that would be near 100% biocompatible with the tissues of the patients' oral cavity. Elements which constitute the orthodontic fixed appliances (bands, braces, wires) are manufactured from metal alloys which undergo corrosion in the environment of the oral cavity.[1,2] As a result of this process, metal ions (mostly nickel, chromium, cobalt and iron) are released into the human body.

Less information exists on corrosion of orthodontic appliances in the oral cavity during treatment. Discoloration on the underlying tooth surface during orthodontic treatment has been regarded as the consequence of crevice corrosion of the bracket bases. Since oral tissues experience long-term exposure of these fixed appliances which are not biodegradable and which show sustained release of metals over time, they are expected to produce irreversible toxic effects on the tissues. It is difficult to assess the exact level of metals that produce toxicity or cellular damage since metal toxicity is governed by various factors.[3] The corrosion of an alloy leads to discharge of free ions from the metals which may have noteworthy impact on surrounding tissues, such as toxicity, allergy, mutagenicity, and carcinogenicity. However, there is also evidence available regarding the systemic toxicity caused by the elements which are released from casting alloys due to slow release of free ions over a prolonged period of time.[4]

Biocompatibility studies (in vivo, in vitro and usage tests) aim to evaluate the effects of exposure to the metal ions released from orthodontic appliances to the human body. In order to achieve this, different biomarkers of exposure, such as saliva, blood, urine, hair, nails and oral mucosa cells, are used, with each of them having their advantages and disadvantages.[5]

Unsafe and hazardous materials, especially those that are used over a very long period of time and are in close contact with the oral mucosa, particularly in a wet environment, as in orthodontic therapy, should be avoided. Several studies have shown that orthodontic appliances release metal ions through emission of electro-galvanic currents, with saliva acting as the medium for continuous erosion over time.[6]

Both nickel and chromium can cause hypersensitivity in some people. Nickel, in particular, is the most common contact allergen in women. Ni has been systematically studied for its detrimental effects at the cell, tissue, organ, and organism levels (Costa et al., 1994; Zhou et al., 1998). It has been reported that Ni complexes, in the form of arsenides and sulphides, can be allergic, carcinogenic, and act as mutating substances.[6]

Saliva acts as an electrolyte for electron and ion conduction, and the fluctuation of pH and temperature, the enzymatic and microbial activity, and the various chemicals introduced into the oral cavity through food and drink are all corrosion conductors. The inherent heterogeneity of each metal alloy and its use with other.[7]

The aim of this study was therefore to determine the metal ion concentrations in the saliva of subjects with and without fixed orthodontic appliances. The null hypothesis tested was that the concentration of metal ions in saliva does not change due to the presence of orthodontic appliances.

MATERIALS AND METHODS

The goals of the investigation were explained to the members and patients consent was taken before commencement of the study. The study consisted of total 46 subjects (13 females and 10 males) Twenty three healthy orthodontic patients with fixed appliances in both arches for a period of 12–18 months (study group). The age range of the subjects in this group was from 16 to 19 years (mean 17.5 ± 2.5 years). Same-gender sister or brother without any orthodontic appliance formed the control group. This was done to limit the effect of food and oral hygiene habits on salivary metal ion concentration; Age of control group patient ranges from was from 14 to 22 years (mean 18.2 ± 3.9 years). The average age difference between the two groups was 1 ± 3 years.

Inclusion criteria for the study

1) Same gender sibling
2) Absence of any piercings or metal restorations;
3) good health and medication-free; and
4) absence of any systemic diseases.

None of the patients had a NiTi archwire in their set-up for at least 1 month prior to sample collection as they can temporarily cause an increase in Ni concentration.

The fixed appliance consisted of bonded 0.018 inch slot pre-adjusted Roth prescription stainless steel brackets on all teeth except the molars; an average of four to eight stainless steel orthodontic bands; NiTi alloy; and stainless steel arch wires. The sampling was performed 16 ± 2 months after the start of treatment with fixed orthodontic appliances (range 12–18 months).

Sample collection was carried out such that after rinsing with 15 ml of distilled and deionized water for 30 seconds, approximately 5 ml of saliva was collected from each subject and transferred to an assigned cold polypropylene tube. The samples were kept at −20°C until they were processed and diluted with Zolal deionized water to eliminate interference and to reduce the effects of the biological matrix (protein, salt, etc.).

A volumetric flask was used to dilute 1 ml of saliva in 10 ml of deionized water and the samples were analysed using an atomic absorption spectrophotometer (Varian SpectrAA-220; Varian Australia Pty Ltd, Mulgrave, Australia). The detection limit of the method for sample solutions was 1 ng/ml.

Statistical analysis: nonparametric Kolmogorov–Smirnov test was used for Normal distribution of data. Since some variables were not normally distributed, the non-parametric tests (Mann–Whitney U and Wilcoxon W) were used for statistical analysis. Statistical significance was set at $P < 0.05$.

RESULTS

A large variation of Ni and Cr concentration was observed in both the study and control groups. The Ni concentration varied from 1 to 46.0 ng/ml in the controls and from 1 to 50 ng/ml in the study group. The mean salivary Ni content was 17.1-12.1 and 11.7-10.6 ng/ml in the subjects and controls, respectively. Statistically significant differences were found between the groups ($P < 0.03$; Table 1). The salivary concentration of Cr varied from .2 to 5 ng/ml in the study and from 1 to 7 ng/ml in the subjects with an appliance. The mean level of Cr ion was 2.3-1.7 in the controls and 1.6 -1.3 ng/ml in the study group. However, the minimal increase in Cr concentration in the study group was not statistically significant (Table 1)

Table 1: Salivary nickel (Ni) and chromium (Cr) content [mean and standard deviation (SD), nanograms per millilitre] in subjects with and without orthodontic appliances. Min, minimum; Max, maximum.

Ions	With appliance(n=23)					Without appliance					P value
	mean	SD	min	max	variance	mean	SD	min	max	variance	
Ni	17.1	12.1	1	50	147.1	11.17	10.6	1	46	112	0.03
Cr	1.6	1.3	.2	5	1.8	2.3	1.7	1	7	3	0.2

DISCUSSION

There have been numerous in-vitro studies which show the release of nickel and chromium from stimulated fixed orthodontic appliance immersed in artificial saliva, which was found below the toxic dose to humans.[8,9] We carried out our study to validate the results of in vitro studies conducted in past.

Individual variations in newly secreted salivary nickel are expected because serum nickel is influenced in air and water by food, tobacco smoking and nickel (IPCS, 1991)[10].The release of nickel ions into the saliva through corrosion is also likely to vary over time, depending on factors that have been shown to influence ion release, such as mechanical stress in the device (Jia et al., 1999)[11] and pH levels (Huang et al., 2001)[12].

In general, this study showed an increase in salivary Ni and Cr concentration in patients with fixed orthodontic appliances compared with their same-gender control sister or brother. This finding is consistent with that of Ağaoğlu et al. (2001)[13], which reported an increase in salivary concentrations of Cr and Ni 1 year after insertion of the appliance. Fors and Persson (2006)[14] also showed that the amount of Ni in saliva debris retained on filters was significantly higher in orthodontic patients when the salivary sample was collected after an average period of 16 months.

Jamshidi et al (2017)[15] showed slightly elevated levels of Ni and Cr ions in the scalp hair of patients treated with fixed orthodontic appliances and considering the cytotoxic and allergic effects of these ions. He recommended changing the ingredients in fixed orthodontic appliances for the future.

There were many studies in contrast to our results which failed failed to show increased levels of metal ions in the saliva of orthodontic patients. Eliades et al. (2003)[16] reported no statistically significant difference between control and patient group with respect to salivary metal content, regardless of element. The range of salivary metal levels found did not exceed those of daily intake through food and air and same results were reported by Gjerdet et al. (1991)[17.] Present study was consistant with the above mentioned studies in case of chromium but differ in case of nickel. This difference may be due to diverse methods for analysing the levels of the metals or sample selection.

Other studies, however, were either carried out over a short period of time of 1 week to 3 months (Staffolani et al., 1999; Kocadereli et al., 2000; Singh et al., 2008; Petoumenou et al. 2009)[18,19,20] or were in vitro investigations. Currently, the concentration of metal ions at a specific time point cannot be applied to full-term treatment, so the results could not be directly compared.

Future research should be carried for a longer time to study the effect of corrosion process and mechanical phenomenon such as wear and fatigue on the release of Ni and Cr in the oral cavity. In addition, nickel and chromium should be observed for different combination of brackets and wire and also from recycled brackets.

CONCLUSION

Using an appropriate sample collection method, a sufficiently long study period, each patient's sibling as a control and taking into account the same criteria for both groups and within the limits of an in vivo study, it can be concluded that for an average period of 16 months, fixed orthodontic appliance therapy can lead to an increase in Ni and Cr ions in patient’s saliva. Although low levels of these metal ions may be of concern to allergy patients, they do not cause problems in most orthodontic patients because toxic levels are never achieved.

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Source of support: Nil **Conflict of interest:** None declared