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Release of Nickel and Chromium ion in serum from fixed orthodontic appliance- An in-vivo study

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ABSTRACT

Introduction: Stainless steel used for fabrication of various components of fixed orthodontic appliances interact to oral environment and releases metal ions including nickel and chromium, absorbed systemically can cause side effects to the body if their concentration exceeds above toxic dose.

Aim: To determine and compare the level of nickel and chromium in serum of patients undergoing fixed orthodontic treatment at different time period.

Materials and methods: Serum sample of 13 patients was taken before (Group I) and after one week (Group II), one month (Group III) and three month (Group IV) of appliance placement. Level of nickel and chromium ion was determined using Graphite Furnace Atomic Absorption Spectro-photometry. Data was statistically analyzed using SPSS Statistical Analysis Software (Version15.0).

Results: Serum level of nickel and chromium was highest in Group II and lowest in Groups I. On comparison among different groups, statistically significant difference was found between Groups I vs II, III and IV ($p<0.05$) for nickel and between all groups except Group III vs IV (<0.001) for chromium.

Conclusion: The serum nickel and chromium level was maximum after one week of appliance placement then gradually declined. This level was well below the toxic dose of these ions.

KEY WORDS: Nickel and Chromium serum level; Graphite furnace atomic absorption spectrometry; Transpalatal arch; Fixed orthodontic appliance.

INTRODUCTION

The stainless steel used for fabrication of various components of fixed orthodontic appliances contains approximately 18% chromium (Cr) and 8% nickel (Ni).

Although it has properties to resist tarnish and corrosion but cannot withstand the ionic, thermal, microbiologic and enzymatic activity of the oral environment. The oral cavity act as a complete corrosion cell including many factors that enhances the biodegradation of orthodontic appliances.1 Saliva is hypotonic solution containing bioactonate, chloride, potassium, sodium, nitrogenous compounds, proteins and about 30 species of bacteria acts as an electrolyte for electron and ion conduction.2

The fluctuation of pH, the enzymatic and microbial activity and various chemicals introduced into oral cavity from consumption of different drink and food items at varying temperature are all corrosion conductors.3 The degradation products produced are in close contact with oral mucosa, hence can have a toxic effect on the adjacent oral tissues and when absorbed systemically and can produce varying effects in the whole body.4 Nickel and chromium are trace elements and plays an important role in the overall health of the human body. The normal serum level of nickel and chromium is 0.11 µg/ml and 0.05-0.5 µg/ml respectively.5-6 The most significant human exposure to nickel and chromium occurs through the diet.

The average dietary intake for nickel5 is 200–300 µg/day and for chromium7 is 50–200 µg/day. In higher doses both nickel and chromium are capable of inducing adverse side effects such as dermatological, toxicological, cytotoxicity and possibly mutagenic effects.8 Nickel is the most common cause of metal-induced allergic contact dermatitis and has detrimental effects at cell, tissue, organ, and organism levels.5,9-13 The most important side effect of chromium is its ability to interfere with the normal sleep pattern of the individual, headaches and vomiting.

In some people, it may be a reason of diarrhoea or irritability.4-5,14 Therefore, there is the possibility that nickel and chromium ions released from stainless steel orthodontic bands, brackets and wires may cause an allergic reaction. Various in-vitro4,15-25 and in-vivo8,26-34 studies have shown the release of nickel and chromium from orthodontic appliance in serum and saliva but none of them considered auxiliaries like the transpalatal arch, which is widely used to reinforce anchorage and can be the major source of nickel and chromium release.

Hence, the present study was conducted to determine the level of nickel and chromium ion released in the serum of the patients with fixed orthodontic appliances incorporating transpalatal arch.

MATERIALS AND METHODS

The present in-vivo study was conducted in the Department of Orthodontics and Dentofacial Orthopedics, Babu Banarasi Das College of Dental Sciences, Babu Banarasi Das University Lucknow. Approval was taken from ethical committee and written consent was obtained from each patient prier to study.

The sample comprised of 13 orthodontic patients including 6 males and 7 females in the age range of 15- 33 years. After diagnosis and treatment planning fixed orthodontic appliance was placed and bloods samples were collected at different time interval that is before placement of appliance, after 1 week, 1 month, and three months of placement of appliance.

Thus a total of 52 blood samples were obtained from 13 patients and were divided into four groups i.e. Group I: (sample taken before appliance placement), Group II (sample taken one week after appliance placement), Group III (sample taken one month after appliance placement and Group IV (sample taken 3 months after appliance placement).

Sample selection criteria: Healthy patients with no previous history of allergy to nickel and chromium. Patients were in the permanent dentition period. Patients did not have any amalgam and metal restorations, which could may cause any galvanic corrosion in the mouth. Appliance placement: After cleaning and etching of the tooth surface, pre-adjusted MBT 0.22 slot brackets (3M Unitek Orthodontic Products Monrovia, California) were bonded on incisors canine and 2nd premolars in both maxillary and mandibular dental arches using transbond XT light cure adhesive paste.

Pre-formed bands on first molars with triple buccal tube in maxillary arch and double buccal tube on mandibular molar were cemented using glass ionomer cement. A transpalatal arch made of 0.8 mm stainless steel wire was placed in the lingual sheath, welded on the palatal surface of maxillary molar band. 0.014” NiTi arch wire was placed after banding and bonding. 0.016” Ni-Ti and 0.016” × 0.022” stainless steel wire arch were ligated with elastic ligature tie after 1st and 2nd month respectively.

SAMPLE COLLECTION

Blood samples were collected from anticubital fossa of the arm. Serum was prepared from centrifugation of blood at 3000 rpm for 10 minutes on the centrifuging machine. The serum obtained was then transferred to an acid washed plastic container and were stored in the refrigerator at 0oC until they were transferred to Indian Institute of Toxicology and Research Center, Lucknow for determination of level of nickel and chromium ion in serum where the samples were kept at – 20oC till the time of processing.

Determination of level of nickel and chromium in serum: Graphite furnace atomic absorption spectrometry (GFAAS) was used for determination of nickel and chromium ions in serum by machine Zeenit 700 P, Analytik Jena AG, Konrad-Zuse-Str.1Jena/Germany. This analytical technique is designed to perform the quantitative analysis of metals in a wide variety of samples due to its enhanced sensitivity that allows measurements in pictogram. STATISTICAL ANALYSIS: The statistical analysis was done using SPSS (Statistical Package for Social Sciences) Version 15.0 statistical Analysis Software.

Mean+SD were determined for nickel and chromium level in serum. Tukey - honestly significant difference test was used to compare the level of nickel and chromium among different groups. $P < 0.05$ was considered as significant. RESULTS: The level of nickel and chromium in serum of different groups are shown in table 1, where it was found highest in Group II and lowest in Groups I for both nickel and chromium ions.

When comparison of nickel level in serum among different group was done [Table 2], statistically significant difference was found between Groups I vs II, III and IV. On comparison of chromium level in serum among different Groups [Table 3], statistically significant difference was found for all the groups except between Group III and Group IV.

DISCUSSION

Components of fixed orthodontics appliances are fabricated by the use of various materials which have different composition with their own physical and mechanical properties. Stainless steel is most commonly used for construction of wires, brackets, bands, buccal tubes, lingual sheath and other auxiliaries like transpalatal arch, head gears etc. due to its low cost, high strength, resistance to corrosion and biocompatibility.

Various factors such as variations in temperature and pH, salivary conditions, physical and chemical properties of food, mechanical loads, microbiological and enzymatic activity and oral health conditions provide an environment for the corrosion of orthodontic appliance 3,35 This results in weakening of the appliance and the release of ion including nickel, chromium and iron which come in close contact with oral mucosa and absorbed systemically causing toxic effects on the surrounding tissues and in the body.[4]

Various in-vivo studies8,26-34 have been done in the past to determine the level of nickel and chromium in saliva and serum of patients undergoing fixed orthodontic treatment considering orthodontic wires, brackets, bands or appliances separately. Nickel and Chromium were taken into consideration in the present study as they can induce toxic effect at very low concentration such as for nickel >2 µg/kg body weight and for Chromium >50 µg/kg body weight.

Although iron being the main component of stainless steel but it was not included in the present study as toxic effect of iron is seen at very high level (>60 ppm). Agaoglu et al.27 and Satija et al.28 noted a significant increase in Ni and Cr level in serum approximately after one month. Faccioni et al36 and Hafez et al8 found decreased cellular viability, DNA damage in buccal mucosal cells at three month of appliance placement.

Thus in the present study level of nickel and chromium was measured before the placement of appliance and one week, one month and three month after the placement of appliance. In present study, sample was taken from venous blood because it is the specimen of choice for most of the routine laboratory tests. It was collected from cephalic vein in anticubital fossa of the arm, as it receives venous blood from tiny capillary vessels forming a large cannula, thus it is a good site for blood collection.

The results of the present study demonstrated that the nickel and chromium released in serum of the patients undergoing orthodontic treatment was maximum after one week of the appliance placement (Group II) followed by Group III and Group IV. On comparing mean serum level of Ni and Cr between various groups it was found to be significantly higher in Group II, Group III and Group IV in comparison to Group I.

On comparing mean level of Ni in serum, Group II did not show statistically significant difference with Group III and Group IV whereas mean levels of Cr for Group II showed significantly higher values in comparison to Group III and Group IV. The mean level of Ni and Cr for Group III and Group IV did not show statistically significant difference. Our study reported an increase of 1.679 (g/L for Ni and 71.65 (g/L for Cr in serum from Group I to Group II. Mean levels of Ni in serum at one month after appliance placement (Group III) was 2.813 (g/L was significantly higher than Group I whereas it did not show significant difference with Group II or Group IV. Chromium level in serum for group III was 41.9(g/L and was significantly higher than Group I and IV and significantly lower than Group II.

The levels of Nickel and Chromium in serum did not show significant difference between Group III and Group IV. Amongst the studies evaluating serum Ni and Cr levels, the study by Agaoglu et al.27 measured Ni and Cr levels at 1 week and 1 month but did not demonstrate significant increase from pretreatment values.

They reported significant increase of Ni and Cr after longer period of time i.e. 2 years in comparison to Ni and Cr levels obtained before appliance placement, 1 week or 1 month after appliance placement. Similar to our findings serum concentration of Ni and Cr was significantly higher after 1 month of appliance placement in comparison to pretreatment values in a study by Satija et al.28 Bishara et al.33 found no difference in serum Ni levels and increased Cr levels throughout the study.

They suggested that Ni released in saliva was not absorbed in serum. The reason for higher Ni levels in serum in our study could be that salivary concentrations of Ni were above the threshold level required for absorption in serum. For the increased levels in Group II and decreased thereafter for Group III and IV, Barret et al.37 suggested that Ni on the surface of the stainless steel corroded quickly during the first 7 days and then the rate of release decreased as the surface Ni is depleted.

Secondly, the corrosion products could have formed on the surface after 7 days slowing the corrosion of the Ni. Though, the most of the orthodontic components are made of highly corrosion resistant metals and metal alloys but their electrochemical breakdown is observed in oral environment, due to potentially damaging physical and chemical agents which contribute to corrosion of orthodontic appliances.

The psychological stress can also change the oral environment by decreasing the salivary flow and pH value; and increasing the protein content of saliva. Nickel ion binds to these salivary proteins, thereby influencing its concentration. The maximum release of Ni and Cr ions in serum was less than the average daily intake of nickel from food (200-300 (g) and beverages (20 (g/l) and of chromium from food (5-100 (g) and beverages (0.43 (g/l). Thus the leaching amount of nickel and chromium ions will not cause adverse reactions at cell, tissue and organ level.

Patients with established hypersensitivity for nickel can be treated with alternative materials such as ceramic, poly carbonates coated with epoxy resins or components fabricated with other metals like T19, vanadium, cobalt-chromium and aluminium.

CONCLUSION

Serum level of nickel and chromium was significantly increased after the placement of orthodontic appliance but were below the toxic levels as recommended by WHO. The serum nickel and chromium level was maximum after one week of appliance placement then gradually declined.

In orthodontic patients with mild signs and symptoms of nickel allergy appliance should be removed immediately and treat with alternative nickel free materials.

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