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Research Report

Nickel release and the microstructure of stainless steel orthodontic archwire surfaces after immersion in detergent and non-detergent toothpaste: an in vitro study

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ABSTRACT

Background: *Stainless steel is a material that can be used in orthodontics for components of dental braces, such as brackets, archwires and molar bands. Orthodontic archwires exposed to toothpaste can release nickel ions that cause hypersensitivity. The excessive use of sodium lauryl sulphate in detergent toothpaste can cause mouth irritation, severe ulceration, decreased salivary solubility and taste sensitivity changes.* ***Purpose:*** *The aim of this study is to compare the nickel ion released by stainless steel archwires after immersion in detergent and non-detergent toothpaste.* ***Methods:*** *Forty stainless steel archwires from Ortho Organizer (0.016 x 0.022in) were divided into two groups (n=20). Group 1 comprised stainless steel archwires immersed in detergent toothpaste. Group 2 consisted of stainless steel archwires immersed in non-detergent toothpaste. These archwires were immersed in 1.5g toothpaste then kept in an incubator at 37°C for around 24 hours. After that, the archwires were removed from the toothpaste, and the toothpaste was dissolved in 25ml of Aquadest. The amount of nickel ion released was examined by using inductively coupled plasma optical emission spectrometry (ICP-OES). After that, the structure of the sample surface was examined with a scanning electron microscope (SEM). A statistical analysis was done using the Shapiro–Wilk normality test ($p>0.05$). An independent t-test was carried out to compare the two groups ($p<0.05$).* ***Results:*** *The mean of nickel ion release in group 1 was 0.214±0.319mg/l, and in group 2 it was 0.168±0.107 mg/l. There was no significance between the groups ($p=0.323$; $p>0.05$). The SEM images of the archwire surfaces showed that there were more corrosive contour changes in the archwire surface in group 1 than in group 2.* ***Conclusion:*** *There was no difference between the nickel ion released from stainless steel orthodontic archwires after immersion in detergent and non-detergent toothpaste. After immersion in detergent toothpaste, stainless steel archwire surfaces showed more corrosive contour changes than those immersed in non-detergent toothpaste.*

Keywords: *nickel ion; orthodontic archwires; sodium lauryl sulphate; stainless steel; tooth paste*

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INTRODUCTION

Fixed orthodontic appliances basically consist of brackets attached to the teeth, rings embracing molar teeth and arches connecting the individual parts of the appliance. Orthodontic archwires are elements generating forces that allow for the movement of teeth as well as providing the base along which they move.[1] Orthodontic archwires are made from a cobalt-chromium-nickel alloy (CoCrNi), containing about 40% cobalt, 20% chromium, 15% nickel, 16% iron and an addition of molybdenum and manganese.[2]

Stainless steel has been the most commonly used material in fixed and removable orthodontic treatment since 1932.[3] Stainless steel that has a composition of 8%–12% nickel, 17%–22% chromium, 71% iron and 0.2% carbon is widely used on bracket, molar band and archwire. The nickel and chromium give stainless steel its ductility and corrosion resistance.[4]

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Oral hygiene is an important factor that must be controlled during orthodontic treatment since it can affect the quality and duration of the therapy.[5] During orthodontic treatment, patients must brush their teeth daily, but the toothpaste that they use can cause the corrosion of the archwire in the oral environment. A previous study into the corrosive behaviour of dental applications with the presence of *Vicco*® toothpaste showed that corrosion resistance is highest when artificial saliva is mixed with toothpaste, followed by toothpaste alone and, lastly, artificial saliva alone.[6]

Homogenous corrosion resistance is the most important characteristic of stainless steel. However, it is not an intrinsic property, but results from the behaviour of the material surface in interaction with its environment. Indeed, corrosion resistance in stainless steel is developed by the formation of a passive surface film, which acts as a blockade between the surface and the surrounding environment.[7] The corrosion of orthodontic appliances in the oral environment has concerned clinicians for some time, and this concern is focused on two principal issues: whether corrosion products, if produced, are absorbed into the body and cause either localized or systemic effects and what the effects of corrosion are on the physical properties and the clinical performance of orthodontic appliances.[8] In general, orthodontic materials are considered biocompatible, but there are side effects that have been reported in the literature, including allergic, inflammation, cytotoxicity, and mutagenicity.[9] The estimated incidence of an allergic reaction in orthodontic patients is 1:100, with 85% of these being contact dermatitis.[10]

With a view to furthering the understanding of such problems, we are studying the amount of nickel ion released in orthodontic archwires after immersion in detergent and non-detergent toothpaste, and the change in the morphology of the orthodontic archwire surface. The release of nickel ion was analysed using inductively coupled plasma optical emission spectrometry (ICP-OES) and the change in the morphology of the archwire surfaces was analysed using scanning electron microscope (SEM).

MATERIALS AND METHODS

The research type was an experimental laboratory posttest-only control group design using a comparison group. The sample used in this research was composed of 40 pieces of stainless steel archwire (Ortho organizer, Langenhagen, Germany), with a diameter of 0.016 x 0.022in, which were divided into two groups. Group 1 were immersed in the detergent toothpaste (Pepsodent, Tangerang, Indonesia) and group 2 in the non-detergent toothpaste (Enzim fresh mint, Depok, Indonesia). Each piece was cut into 2cm strips and immersed in 1.5g of either detergent or non-detergent toothpaste with 2.5ml of Aquadest and stored in an incubator for 24 hours at 37°C. After that, the archwire pieces were removed from the toothpaste, washed with distilled water and dried.

The samples were also tested with a scanning electron microscope (SEM) (Hitachi TM3000 Tabletop Microscope, Japan) in the Physics Laboratory UNIMED to observe the structure of the archwire surface after an immersion. The toothpaste was dissolved in 25ml Aquadest and stirred until homogenous, and then a measurement was taken of the amount of nickel ion released with Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) (Varian Liberty Series II, United State) in BTKLPP Medan. The results of the examination gave a figure in mg/l.

Using the Statistical Package for Social Science (SPSS) 17.0 edition (Chicago, US) a statistical analysis was performed with a Shapiro–Wilk normality test ($p>0.05$). The data obtained was analysed statistically by using an independent t-test to compare the difference between the two groups ($p<0.05$).

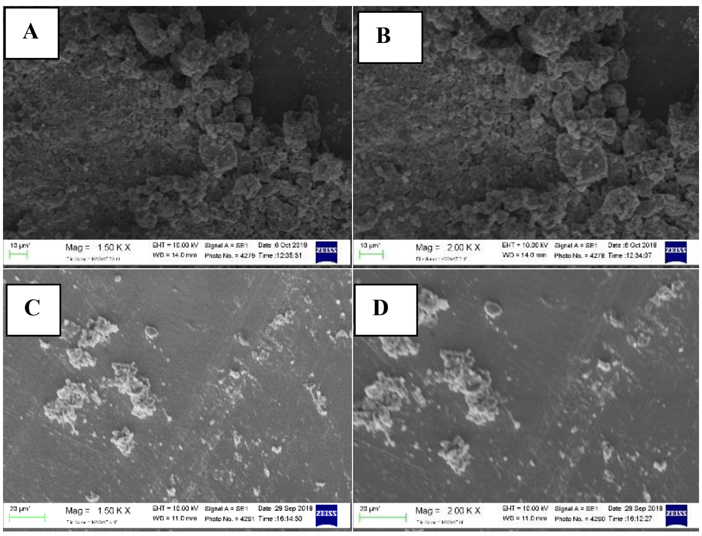

Figure 1. SS Group 1 Magnification 1500x (A); SS Group 1 Magnification 2000x (B); SS Group 2 Magnification 1500x (C); SS Group 2 Magnification 2000x (D).

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Table 1. The differences in the nickel ions released after immersion in the detergent and non-detergent toothpaste.

Groups	Mean(mg/l) ± SD	p
Detergent toothpaste	0.252 ± 0.139	0.213
Non-detergent toothpaste	0.197 ± 0.107	

RESULTS

The average amount of nickel ion released in group 1 was 0.252 mg/l, and in group 2 was 0.197 mg/l. The results of the normality test showed that the data was normally distributed in both group 1 ($p=0.884$; $p>0.05$) and group 2 ($p=0.884$; $p>0.05$). An independent t-test was carried out and the results showed no significant difference between the amount of nickel ion released after immersion in the detergent and non-detergent toothpaste ($p=0.213$; $p>0.05$) (Table 1).

The SEM images of the archwire surfaces showed that those belonging to group 1 were rougher than those from group 2. The results also revealed that the archwire surfaces in group 1 had more corrosive contour changes than those in group 2 (Figure 1).

DISCUSSION

This study measured the number of nickel ions released by stainless steel archwire after immersion in detergent and non-detergent toothpaste. The results of this study were in line with the study of Brandao *et al.*[11] which measured the release of nickel ions from a stainless steel bracket that was immersed in various toothpastes that contained detergent.

Nickel ions can be released because of the substance contained in toothpaste.[11] According to Schmalz *et al.*[12] nickel ions have soluble properties in liquids, so the length of time of the exposure of archwire to a liquid can affect the release of metal ions. Nickel ions have a high tendency to be released because the nickel atom is not strongly attached to the intermetallic compound.[12]

Several components of toothpaste can cause changes in metal. The changes of orthodontic material properties can have a negative effect on orthodontic treatment.[13] Inorganic components, such as phosphate, sodium and potassium, contained in toothpaste act as electrolyte media that can trigger electrochemical reactions. Electrochemical reactions are reactions that occur at the anode, where oxidisation takes place, and cathode, where reduction occurs. Metal ions act as anodes and H+ from electrolyte media act as cathodes.[14]

Detergent toothpaste contains sodium lauryl sulphate, which can cause the release of nickel ions, due to the presence of sodium ions that can trigger electrochemical reactions. Sodium ions will react with water to form hydroxide bonds that occur at the cathode (reduction reaction).[15,16] In addition, sodium lauryl sulphate also contains sulphate (SO_4) that can affect the release of metal ions.[15] Sulphate ions will react with water to form sulphuric acid, which occurs at the cathode (reduction reaction).[16] The presence of these ions results in the release of a protective layer (Cr_2O_3), which is the outermost layer of stainless-steel wire. The release of the protective layer can cause nickel ions to detach.

This research is in accordance with the research conducted by Minanga *et al.*[17] on the release of nickel ions and the immersion of chromium orthodontic stainless steel brackets in mouthwash containing sodium. The results of the study showed the composition of the material and the reactions of the solution where the metal was immersed. There were various types of sodium, namely sodium fluoride, sodium citrate, sodium benzoate, sodium lauryl sulphate, and sodium saccharin. The study showed that the acid contained in mouthwash, namely citric acid and benzoic acid, canresult in the release of metal ions.[17]

Another possible cause of the release of nickel ions in this study is the presence of fluoride ions found in detergent and non-detergent toothpaste. According to Alavi *et al.*[18] the release of fluoride ions will combine with hydrogen to produce hydrofluoric acid (HF), which can damage the oxide layer in orthodontic wires, resulting in the release of metal ions, such as nickel and chromium. Fatimah *et al.*[19] states that fluoride can reduce the resistance of stainless steel orthodontic wire to corrosion. This can occur because the effects of fluoride can damage the protective layer of the wire.

In this study, the non-detergent toothpaste contains citric acid ($C_6H_8O_7$), which can trigger the release of nickel ions. According to Fontana, citric acid ($C_6H_8O_7$) has high enough H+ particles to lead to faster corrosion rates.[20] Nickel ions released from archwires can be carcinogenic, mutagenic, cytotoxic and allergic. The release of nickel ions from archwires can result in gingival hyperplasia, labial desquamation, angular cheilitis, swelling, and burning in the oral mucosa.[5] The average intake of nickel per day in food is 300–500µg.[7] The concentration of nickel in drinking water is generally below 20µg / L.[7,21] A nickel content of more than 50% can cause manifestations of allergic reactions.[21] The biologic effect of the corrosion product was measured by gingival fibroblast cell viability in a released metal ion solution. The physical effect of the released metal ions was evaluated by the morphology of the appliance surface and the surface roughness of the brackets and archwires.[22] It can be concluded that both the detergent and non-detergent tooth paste can cause the release of nickel ion and surface roughness in stainless steel orthodontic archwire. Further research needs to be conducted with a variety of orthodontic wire types, and variations in the immersion and stirring times. In addition, clinical research is needed to see the effects of nickel ion release.

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