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RESEARCH ARTICLE

Differences in nickel ions released from nickel-titanium arch wire after immersion in detergent and non-detergent toothpaste

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ABSTRACT

Nickel-titanium (NiTi) arch wire has properties that favor its use during the leveling and aligning phase of orthodontic treatment. This NiTi orthodontic arch wire has the potential to experience nickel ion release. One factor that can cause the release of nickel ions is toothpaste. Nickel ions released can enter the body and cause carcinogenic, mutagenic, cytotoxic, and allergic effects. The purpose of this study was to see the differences of nickel ions released from NiTi orthodontic arch wire after immersion in detergent and non-detergent toothpaste. This was a laboratory experimental research to draft a comparative design. The sample size was 40 pieces of NiTi orthodontic arch wire which were divided into 2 groups, immersion in detergent toothpaste and immersion in non-detergent toothpaste. The sample used was NiTi arch wire solution immersed in toothpaste and distilled water for 24 hours in an incubator at 37 °C then measured using inductively coupled plasma (ICP) mass spectrometer to determine the released nickel ions. Data were analyzed using Mann-Whitney test. The Mann-Whitney test resulted in a value of 0.872 ($p \geq 0.05$) which indicates no significant difference between the two groups. The study concluded that there is no difference in the nickel ions released from NiTi orthodontic archwire after immersion in detergent and non-detergent toothpaste.

Keywords: nickel ion; corrosion; nickel-titanium (NiTi); toothpaste

INTRODUCTION

The number of adult patients seeking orthodontic treatment is increasing. Orthodontic treatment in adult is growing steadily in the last 3 decades.[1] In the United States, orthodontic treatment in adult was reported to increase from 15.4% to 21.0% between 1981 and 2017.[1] In 2018, a survey done by the British Orthodontic Society showed that members treated 5% more adult patients in the private clinic than in 2016.[1,2] Approximately 83% of the patients looked for orthodontic treatment for aesthetic tooth alignment and 85.7% of the patients felt that orthodontic treatment was necessary in their daily lives.[3] Based on an investigation done by the Health Research and Development Department, the Ministry of Health of the Republic of Indonesia, the highest malocclusion prevalence in children aged 12-15 years was 15.6%.[4]

Orthodontic treatment is important to improve and maintain good oral hygiene. The mechanical basic of orthodontic treatment is based on the principles that stored elastic energy can be changed into mechanical force by tooth movement, and that the ideal control of tooth movement needs the application of a proper distinctive force system supported by accessories such as orthodontic arch wires.[5] One of the orthodontic arch wires used in the initial stages of orthodontic treatment is NiTi.[6-8] Nickel-titanium contains 55% nickel and 45% titanium which have been widely used in orthodontics because of their favorable mechanical properties, a remarkable feature of excellent biocompatibility, super elasticity, low density, low thermal conductibility, mechanical behavior, and corrosion-resistance.[9] The excellent corrosion resistance of titanium is the result of the existence

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of a protective and self-adherent oxide film with 2-6 nm thickness formed on the titanium surface, which mostly contains titanium dioxide (TiO2).[10]

There is a possibility of harmful effect when using NiTi arch wire for orthodontic treatment, that is nickel ion release.[11] The latest evidence has associated cytotoxic, carcinogenic, mutagenic, and allergic effects to nickel in various forms and compounds.[12,13] Although there are no reports on the cytotoxic effect caused by NiTi alloys, information about the biological side effects of nickel is available in the literature. Nickel is capable of causing a toxic and more allergic reaction than all other metal elements.[14] In vivo study, NiTi alloys show cytotoxic reactions. Cases also show the alteration of Ni-nonsensitive subjects into Ni-sensitive subject after using NiTi arch wires.[12]

Corrosion is an electrochemical reaction during which the surface of metal deteriorates through the release of ion. The oral environment is conducive for biodegradation and corrosion of dental material caused by constant changes of chemical, mechanical, thermal, and microbiological conditions, as well as enzyme.[15] The fact that NiTi is at a low pH and reactive ions such as halide groups are present will interfere with the thin layer of oxide on the metal surface.[16] An increase in temperature will also increase corrosion rate.[17]

Besides, any products such as toothpaste, mouthwash, food, or drink that enter the oral cavity also have the potential to corrode orthodontic arch wires, causing the release of metal constituent elements of the arch wire.[18] Toothpaste is composed of active ingredients or additives that have specific functions. These additives are abrasive agents, fluorides, desensitizing agents, antiplaque agents, and anti-tartar ingredients. Toothpaste is also composed of detergents, humectants, thickeners, preservatives, flavoring agents, sweeteners, and coloring agents. Detergents are responsible for toothpastes' actions. The most widely used detergent in toothpaste is sodium lauryl sulfate (SLS).[19]

Fluoride ions contained in toothpaste can cause nickel ions to be released from NiTi arch wires. The occurrence of reactions on the metal surface that is used in the oral environment can damage the protective coating on metals.[16] Some types of sodium contained in mouthwashes or toothpaste support the release of ions contained in orthodontic arch wires. The acid contents found in mouthwashes such as citric acid, benzoic acid, and some types of sodium, namely sodium fluoride, sodium citrate, sodium benzoate, sodium lauryl sulfate, and sodium saccharin, can cause nickel ion release but the amount of the released ions varies due to the fact that each brand of mouthwash contains different compositions.[10]

Based on the explanation above, the authors were interested in examining whether there is a difference in the amount of nickel ions released from NiTi arch wire after being immersed in toothpaste. We used detergent toothpaste and non-detergent toothpaste based on contents contained in toothpaste are different from one another due to many types of toothpaste nowadays.

MATERIALS AND METHODS

This was a laboratory experimental research using a comparative design. The samples used were orthodontic NiTi archwires with a diameter of 0.016 inches and a length of 2 cm. The samples were divided into 2 groups and each group consisted of 20 samples. The first group of the samples was immersed in detergent toothpaste and the second group was immersed in non-detergent toothpaste. The samples were immersed in 1.5 g of detergent and non-detergent toothpaste which had been mixed with 29 ml of distilled water and then stored in a 37 °C incubator for 24 hours. The samples were removed from the toothpaste solution and the solution was tested using an inductively coupled plasma (ICP) mass spectrometer to see the amount of released nickel ions.

The results of the research were processed statistically using the SPSS version 17. The normality of the data obtained were first analyzed using the Shapiro-Wilk test with a p-value ≥0.05. If the results of the test showed that the data were distributed normally (p≥0.05), the data were then tested using the unpaired parametric t-test. On the other hand, if the results of the testing showed that

the data were not normally distributed, the data were then tested using a non-parametric Mann-Whitney statistical test (p≤0.05).

Detergent and non-detergent toothpaste with a weight of 1.5 grams each were dissolved with 29 ml distilled water in each soaking container. The samples of NiTi arch wires with a length of 2 cm and a diameter of 0.016 inches were immersed in a toothpaste solution, according to the treatment groups. Treatment group 1 was soaked in detergent toothpaste and treatment group 2 was soaked in non-detergent toothpaste. Each treatment group consisted of 20 samples. The container containing the sample was put into an incubator at 37 °C for 24 hours. After 24 hours, the container was removed from the incubator.

The toothpaste solution was transferred to the test tube and 10 drops of concentrated nitric acid were added to reach pH 2. The toothpaste solution was vibrated with a vortex for 15 seconds to mix evenly. The hose in ICP device was inserted into the test tube containing the toothpaste solution. The amount of nickel ions released was measured using waves of 231.604 nm.

RESULTS

After the nickel ion release testing, there was one sample from each group that was excluded, so each group consisted of only 19 samples. The samples were excluded because there were significant differences in values compared to the other samples. The results of the research on nickel ions released from NiTi arch wires after immersion in detergent and non-detergent toothpaste showed on Table 1.

The results of the mean of released nickel ions obtained in each group can be seen in Table 1. The mean of nickel ions released in group 1 was 0.203 ± 0.083 mg / l while that in group 2 was 0.231 ± 0.140 mg/l. Thus, it can be seen that the highest mean of released nickel ions was found in group 2, namely those immersed in non-detergent toothpaste.

The results of the normality test using the Shapiro-Wilk statistical test showed that the data in group 1 were normally distributed, while the data in group 2 were not normally distributed, which means that the data in this study were not normally distributed. In the Mann-Whitney test results, there was no significant difference in the amount of nickel ions released from the NiTi arch wires after immersion in detergent and non-detergent toothpaste with a different value of 0.872 (p≥0.05).

Based on the Mann-Whitney test results in Table 1, there was no significant difference in the amount of nickel ions released from the NiTi arch wires after immersion in detergent and non-detergent toothpaste with a significance value of p = 0.872 (p≥0.05).

Table 1. Difference in the amount of nickel ions released from NiTi arch wires after being immersed in detergent and non-detergent toothpaste

Group	N	Mean of Released Nickel Ions (mg/l)		p-value
		Mean	SD	
1	19	0.203	0.083	0.872
2	19	0.231	0.140	

DISCUSSION

Table 1 shows the mean of nickel ions released from the NiTi arch wire after immersed in detergent toothpaste with a pH of 8.4 was 0.203 ± 0.083 mg /l, while that in non-detergent toothpaste with a pH of 5.6 was 0.231 ± 0.140 mg / l. This study showed that the highest mean of released nickel ions was found in group 2, i.e. after immersion in non-detergent toothpaste. The results of this study are in line with a research by Jakfar et al. 2010, that the release of nickel ions from nickel-chromium (NiCr) alloy metals soaked in 3 groups of toothpaste solutions with different pH showed a significant different. The nickel ions released in the group I toothpaste solution (pH 9) were lower than those in the group II and III toothpaste solution (pH 7 and 6).[16] In this study the highest amount of released nickel ions was found in non-detergent toothpaste. This might be caused the pH of non-detergent toothpaste is lower than the pH of detergent toothpaste. In this study, detergent toothpaste containing SLS had a pH of 8.4. According to Raymond et al., SLS has an alkaline pH of 7-9.5.[20] The alkaline condition of SLS contained in detergent toothpaste causes detergent toothpaste to have a higher pH compared to non-

detergent toothpaste. This statement is supported by a research conducted by Achmad H et al., that samples using toothpaste containing detergent have a higher pH which can accelerate the growth of plaque.[21]

The Mann-Whitney test results showed that there was no significant difference in the amount of nickel ions released from the NiTi arch wires after immersion in detergent and non-detergent toothpaste with a significance of p = 0.872 (p≥0.05). This study is in line with a research by Huang et al. According to the research by Huang et al. pH and immersion time can significantly influence the amount of nickel and titanium ions released from NiTi arch wires soaked in artificial saliva with a pH of 2.5-6.25 for 1, 3, 7, 14, 21 and 28 days. The amount of nickel and titanium ions released in artificial saliva with a pH of ≥3.75 was less than pH 2.5.[14]

The absence of significant differences in the released nickel ions after immersion in detergent and non-detergent toothpaste in this study may be due to the possibility that the toothpaste and distilled water solution was not stirred until homogeneous so there was a possibility that nickel ions could not be separated from the NiTi wires. In this study, detergent toothpaste had a pH of 8.4 and non-detergent toothpaste had a pH of 5.6. The non-detergent toothpaste was not categorized as having a strong acid pH because, based on the universal indicators, strong acids are ones with a pH of 0-3. In addition, the immersion time in this study was shorter than that of Huang et al.

In this study, the release of nickel ions from the NiTi arch wires after immersion in toothpaste occurred due to corrosion process. When NiTi arch wire is in an acidic environment (low pH) there will be a corrosion process due to a reduction and oxidation reaction. The acidic environment will form hydrogen ions (H^+). A higher concentration of acid leads to more H^+ ions from the acid that react and experience reduction. As a result, more metal ions undergo oxidation which speeds up the corrosion process, resulting in the release of nickel ions.[1,4,22-24] NiTi arch wire has a titanium element which will form a thin passive layer in the form of a layer of TiO2 on the wire surface. This passive layer serves to protect NiTi arch wire from corrosion process, but if there is a damage to the passive layer it will cause the release of nickel ions on the surface (especially TiO2) of NiTi arch wire. One factor that can damage TiO2 layer in NiTi arch wire is acidic pH.[14,18,24] According to Huang et al., acidic pH can damage TiO2 passive layer in the NiTi arch wire through a corrosion process which causes nickel ion release.[14]

In addition to being caused by pH, there were also several factors that can cause the release of nickel ions in this study such as the composition and concentration of the ingredients contained in toothpaste and the distilled water used in this study to dissolve the toothpaste. Water can also cause corrosion in metals which ultimately causes the release of nickel ions from NiTi arch wire. This statement is also supported by a research conducted by Mirhashemi A et al, showing that when titanium wire reacts with water it will also influence the release of metal elements.[24] However, small amounts of nickel ions released can also cause allergic reactions in the form of contact stomatitis. A research conducted by Faccioni et al. showed that there was a correlation between significant release of nickel ions from fixed orthodontic appliances that can cause DNA damage to oral mucous cells or can trigger hypersensitivity reactions in patients with fixed orthodontic treatment.[13]

CONCLUSION

There was no significant difference in the amount of nickel ions released from NiTi arch wires after immersion in detergent and non-detergent toothpaste.

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