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Research Report

Nickel ion release from stainless steel brackets in chlorhexidine and *Piper betle Linn* mouthwash

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ABSTRACT

Background: *Orthodontist prescribe mouthwash for their patients especially since most of patients do not have a satisfactory oral hygiene and have high risk of dental caries. Stainless steel brackets that exposed by mouthwash may have nickel ion release. Corrosion and nickel ion release can induced allergic reaction and make more friction during orthodontic treatment.* ***Purpose:*** *This study aimed to measure nickel ion release of stainless steel bracket that immersed in chlorhexidine and Piper betle Linn mouthwash.* ***Methods:*** *Thirty-six stainless steel bracket immersed in artificial saliva, chlorhexidine, and Piper betle Linn mouthwash. All brackets stored in incubator for 1, 3, 5, and 7 weeks. Nickel ion release was measured by Atomic Absorption Spectrophotometry (AAS).* ***Results:*** *The results showed a significant differences of nickel ion release in all groups ($p<0.05$).* ***Conclusion:*** *In conclusion, among the mouthwash, chlorohexidine has the highest nickel ion release from stainless steel brackets, followed with Piper betle Linn mouthwash.*

Keywords: *nickel ion release; stainless steel bracket; chlorhexidine mouthwash; Piper betle Linn. mouthwash*

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INTRODUCTION

Orthodontic brackets are an important component in orthodontic appliances. Brackets should have the correct hardness and strength to deliver the exact force from the wire to the teeth. They also should have a smooth archwire slot to reduce frictional resistance and plaque deposition. Orthodontic brackets should be accurately manufactured to reflect the prescription type of each bracket. They should also have a good biocompatibility and high corrosion resistance.[1–3]

Brackets are usually placed in oral cavity between two and three years. During this time, brackets are contaminated by substances from the inside and outside mouth. This situation can destroy brackets physically and chemically then leading to corrosion and ion release. Thus, high corrosion resistance metals or alloys are the best choice to prevent orthodontic brackets corrosiveness.[1,2]

Stainless steel bracket is one of metal orthodontic bracket. This brackets have some primary advantages such as greater strength, lower cost, good modulus of elasticity and formability than any other brackets, and have high corrosion resistance in the oral cavity.[1–4]

There are some types of stainless steel brackets, such as AISI type 304 L SS, 316 L SS, and 17-4 PH SS. Stainless steeel 304 L consist of 18–20% chromium, 8–10% nickel, and less than 0.03% manganese, silicon, and carbon. Stainless steel 316 L has a higher nickel content than 304 L, 2–3% molybdenum, and consist of lower carbon to improved intergranular corrosion resistance and for better welding results. Stainless steel 17-4 PH has similar corrosion resistance and higher mechanical property than 304 type.[1–4]

Orthodontic corrosion and ion release in oral environment have two important concerns. First, when corrosion products absorb by body and caused local and systemic toxic effect. Nickel ion release was known as the most common allergic substance that caused contact dermatitis in women and others hypersensitive reaction in 10% of general population. Nickel is a strong medium immune reaction that can cause

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hypersensitivity reaction, contact dermatitis, gingival enlargement, asthma, hypercytotoxicity, and mutagenic. Cultured human cells study reported that nickel ion release was moderately cytotoxic in cells. Nowadays, there are alternative low-nickel and nickel-free alloys to replace stainless steel. However, the biocompatibility of low-nickel alloys have not been accurately evaluated. Second, metal corrosion could affect stainless steel physical and clinical properties. Metal surface corrosion could increase friction of two different type of metal that cause prolonged treatment time and uncomfortable tooth movement.[5–12]

Good oral hygiene is an essential part of a successful orthodontic treatment. Orthodontist prescribes mouthwash due to most of patients have lack oral hygiene and high risk of dental caries. Mouthwashes are effective to prevent formability of microbial plaques. Among mouthwashes, chlorhexidine has known to be highly effective in prevention of dental plaques and reduction *Streptococcus mutans*. However, some studies report that chlorhexidine mouthwash could make high ion release due to irrigation effect it self.[13,14]

Recently, the use of herbal mouthwash is increasing. Natural products that extract from herbal plants are found to be highly efficient to prevent the dental caries/plaque found in fixed orthodontic appliances patients undergoing orthodontic treatment. One of most common herbal plant in Indonesia is *Piper betle Linn*. This plant has known as traditional medication including to prevent bad breath and dental caries. Piper betle leaves contains several active compounds such as eugenol and its isomers, chavibetol, hydroxychavicol, pentatriacontanol, piperol, piperbetol, carotenes, and ascorbic acid. Hydroxychavicol has been examined as an antimicrobial ingredient, and it shows promising results for several applications as an oral care agent. Antimicrobial profiles of hydroxychavicol are well suited for an active ingredient for oral care products. Corrosion behaviour of this plant is still unknown.[14–16]

This study report measured the levels of nickel ion release from stainless steel brackets immersed in chlorhexidine and *Piper betle Linn* mouthwash. These results should help orthodontist to prescribe the best choice of mouthwash for their patient needs.

MATERIALS AND METHODS

Thirty six brackets (first premolar bracket, stainless steel, 0.018-in, Roth prescription, Mini-Gamma SD Orthodontic, USA) were used for this study. The brackets divided into 12 groups. Each group immersed for 1, 3, 5, and 7 weeks in different solutions. Group 1-4 is a control group that immersed in artificial saliva. Group 5-8 immersed in chlorhexidine mouthwash 0.2%. Group 9-12 immersed in *Piper betle Linn* mouthwash 3%.

Direction of use mouthwash is usually rinse for about one minute twice a week, and after having mouthwash, patient should not be eating food, drinking, and rinsing their mouth to ensure that its components remain present for period of time. To calculate the presence of mouthwash active ingredient on mouth especially on brackets, we estimated that, if an individual followed this regime, the mouthwash components would be present in a patient's mouth for 6 hours (twice a week for 24 months is equal 69.000 minutes). Therefore, on this study the immersion and incubation time of brackets was 49 days (49 days being almost equivalen to 69.700 minutes).[16] Each bracket was placed in individual glass tube containing 10 mL of immersion solution and incubated at 37° C for 1, 3, 5, and 7 weeks. After incubation, the immersion solution was measured with atomic absorption spectrophotometer (AAS) (Shimadzu AA-7000).

AAS is spectroanalytical procedure to measuring the ion concentration in immersion solution using energy absorption from certain wavelength of light (commonly 190-900 nm). AAS typically include a flame burner to atomize the sample (in this research we used a hollow cathode lamp as a flame burner), a monochromator and a photon detector. Wavelength to measured nickel ion is 232.10 nm. First, we have to make standard solutions of three different concentrations, determine the absorbance then make a calibration curve from the values. Fitting nickel light source lamp to the lamp housing to measure the absorbance then switch on the instrument. Switch on the source lamp and set at nickel's wavelength (232.10 nm). Ignite the mixture of these gases. Adjust the gas flow rate and pressure, and make the zero adjustment after nebulizing the solvent into the flame. The absorbance for the sample was measured then determined concentration from the previous curve of calibration.[17]

RESULTS

Results on Table 1 showed nickel ion release mean levels in the groups. Therefore, to look the presence of different nickel ion release we need to tested data with Kruskal-Wallis test in Table 2.

A non-parametric test (Kruskal-Wallis) in Table 1 showed nickel ion release statistically significant differences in artificial saliva among 1, 3, 5 and 7 weeks groups $p = 0.030$ ($p < 0.05$); in chlorhexidine was significantly different $p = 0.015$ ($p < 0.05$); in *Piper betle Linn* was significantly different $p = 0.015$ ($p < 0.05$).

This research not only report based on type solution but also based on immersion time (Table 3). Kruskal-Wallis test reported nickel ion release statistically significant differences in artificial saliva, chlorhexidine, and *Piper betle Linn* for 1 week $p = 0.023$ ($p < 0.05$), 3 weeks $p = 0.020$ ($p < 0.05$), 5 weeks $p = 0.017$ ($p < 0.05$); and 7 weeks $p = 0.015$ ($p < 0.05$).

DISCUSSION

Metal corrosion could be happen in the mouth environment and released metal ion into saliva. Orthodontist

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Table 1. Mean levels of the ions released in all groups

Groups (solution)	Immersion time (weeks)	n	p
Artificial saliva	1	3	0.030*
	3	3	
	5	3	
	7	3	
Chlorhexidine	1	3	0.015*
	3	3	
	5	3	
	7	3	
Piper betle Linn	1	3	0.015*
	3	3	
	5	3	
	7	3	

* $p<0.05$

Table 3. Kruskal-Wallis test in immersion time groups

Groups Immersion time (weeks)	Solution	n	p
1	Artificial saliva	3	0.023*
	Chlorhexidine	3	
	Piper betle Linn	3	
3	Artificial saliva	3	0.020*
	Chlorhexidine	3	
	Piper betle Linn	3	
5	Artificial saliva	3	0.017*
	Chlorhexidine	3	
	Piper betle Linn	3	
7	Artificial saliva	3	0.015*
	Chlorhexidine	3	
	Piper betle Linn	3	

* $p<0.05$

Table 2. Kruskal-Wallis test of nickel ion released in the artificial saliva, chlorhexidine, and *Piper betle Linn.* mouthwash in 1, 3, 5, 7 weeks

Groups / Immersion time (weeks)	Artificial saliva (control) (n=3) χ ± SD (ppm)	Chlorhexidine (n=3) χ ± SD (ppm)	*Piper betle Linn.* (n=3) χ ± SD (ppm)
1	0.0073 ± 0.00577	0.185 ± 0.05	0.033 ± 0.00667
3	0.0103 ± 0.00577	0.5463 ± 0.00667	0.099 ± 0.01000
5	0.0113 ± 0.00577	0.9313 ± 0.00667	0.154 ± 0.02000
7	0.0133 ± 0.00577	1.333 ± 0.00667	0.203 ± 0.00667

* $p<0.05$

commonly recommended mouthwash for their patients to decrease the risk of plaque and caries formability. However, lack of study reported the effects of various mouthwashes on ion release of orthodontic brackets.[18]

This study reported nickel ion release from stainless steel brackets that immersed in artificial saliva, chlorhexidine, and *Piper betle Linn.* mouthwash increased over time. This result relevant with Amini's study that measured chromium and nickel concentration in gingival crevicular fluid before treatment, 1 month, and 6 months after using orthodontic appliance from 24 patients using AAS. The nickel levels were increased over time same with this study.[19]

Among various mouthwash solutions, chlorhexidine showed the maximum level of nickel ion released, the next highest being in *Piper betle Linn* mouthwash, and the lowest in artificial saliva. This result relevant with Danaei *et al.* study that immersed 160 stainless steel brackets divided randomly in four solution groups (chlorhexidine, oral-B fluoride, persica mouthwash, and distillated deionized water) and incubation time for 45 days at 37° C. Nickel, chromium, iron, copper, and manganese ion release were measured by inductively coupled plasma spectrometer. The highest nickel ion release showed in chlorhexidine solution compared with the other mouthwash.[20]

It reported on a fixed appliance simulator that described full upper arch. The samples were measured at 1, 7, 14, 21, and 28 days by flame atomic absorption spectrophotometer. The highest levels of metal ion release at day 7, and all releasing ion is finished within 28 days. This results is not relevant with our study.[21]

Corrosion occurs from either dissolve of metal ions into solution or progressive release of a protective layer, usually an oxide or a sulphide. The corrosion and metal ion release mechanism from stainless steel alloy started from dissolved the protective film that consist of chromium oxide and chromium hydroxide, and then forms on contact with oxygen on the stainless steel's surface.[20]

Corrosion made from two simultaneous reactions: oxidation and reduction (redox). For example we were using iron in a weak acid. Oxidation (anodic) reaction results

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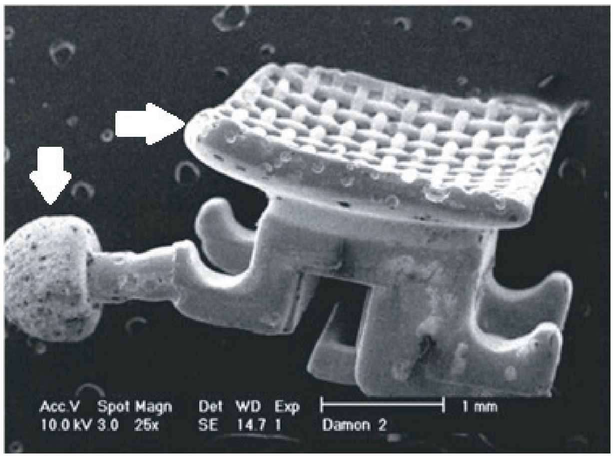

Figure 1. Corrosion on orthodontic bracket.[26]

in dissolution of the iron as ferrous ions are produced (Fe → Fe^{2+}+ $2e^-$). Reduction occurs at the cathode, with hydrogen ions reduced to hydrogen gas ($2H^+$+ $2e^-$ → H_2). This reaction will continue until all of the metal consumed, unless the metal can form a protective surface layer (passivation), or until the cathodic reactant is consumed (exhaustion of dissolved oxygen in solution).[22,23]

Corrosion levels of any metal depends on chemical reaction of the immersion solution (Figure 1). The formation of passive oxide film can delay the corrosion process on the orthodontic appliances. However, this protective layer can dissolve mechanically and chemically. This passive oxide films can slowly dissolve (passivation) without chemical or mechanical abrasion only to reform (repassivation) as the metal surface is exposed to oxygen from the air or the surrounding medium. The passivation reaction could accelerated by chloride ions and acidic environment that happen because of sodium chloride, acidic carbonated drinks intake, and fluoride-containing products, such as toothpaste and mouthwash. Some studies reported, the corrosion resistance of some metals, especially titanium, are decreased in a fluoridated, acidic environment,.[22–25]

The orthodontic metal alloy risk of corrosion depends on the oral environment, which is determined by mechanical and chemical factors. Mechanical factors including foods, liquids, and tooth brushes abrasion. Chemical factors including quantity and quality of saliva, and pH of food and beverages. Corrosion will occur continuously in the mouth over time.[27]

Some factor that effect different results betwen studies are study design, measuring system, immersion time, and immersion solution. Moreover, same products on different manufacturers have been shown different results. Surface area of the bracket is one of an important factor to determine the amount of corrosion and ion release, but calculating orthodontic bracket's comprehensive surface area was on our exclusion criteria in this study because of their complex shape and geometry.

The corrosion of brackets could influence the process of orthodontic treatment. Nickel ion release can result allergic reactions and cytotoxicity. Since the nickel allergic reaction is one of our concern, orthodontist should be aware that nickel ion release might cause some allergic reaction including contact allergy and gingivitis. Contact allergy clinically seems at oral soft tissue that contact with brackets. In orthodontic patient, severe gingivitis not only related to lack of oral hygiene but also to nickel allergic reaction from stainless steel brackets. We also need to determine patient history of hypersensitivity by anamneses the patient.[20]

Parameters that affect the corrosion and ion release of metals in saliva including immersion time, presence of oxygen, pH, and temperature. Metal ion released into the oral environment with saliva as the medium. High level of chloride contain in saliva, various intake of foods and drinks with a low pH could lead to acidic condition that increase the amount of corrosion and ion release. Furthermore, the characteristics of saliva change according to the patient's health and the time of day can affect the ion release.[22–24]

In this study, mouthwash was used in a static environment. However, in real life, mouthwash were used in dynamic environment. Increasing metal ion release could happen in dynamic condition not only because of the saliva fluidity and pH but also abrasion by tooth brushing and mastication mechanism. A large number of metal ion release after using an oral functioning simulator apparatus to describe the dynamic condition of oral environment.[28] In this study, we did not use adhesive resin to coverage base of brackets so the involved bracket surface was larger than clinical conditions.[29,30]

Average nickel intake a day from foods are 5–100 mg and 300–500 mg, respectively. Nickel ion intake in beverages is commonly under 20 mg per liter. The amount of nickel ion released from in this study is lower than daily food and water nickel intake. However, patient with nickel intolerant reacted even with a small amount of nickel ion release.[20]

This study clearly identifies the risk of corrosion and nickel ion release when mouthwashes are used. Corrosion could make some clinical problems when orthodontic treatment occurs including allergic reaction and uncomfortable sliding movements. It also could negatively impact the aesthetic result of orthodontic treatment. Patients who have metal ion hipersensitivity especially nickel is recommended not having mouthwash for a long period of time. It seems to be a need for a new type of mouthwash containing both anti-caries and corrosion inhibitors which could be used without restriction by patients undergoing orthodontic therapy. In conclusion, among the mouthwash, chlorohexidine has the highest nickel ion release from stainless steel brackets, followed with *Piper betle Linn* mouthwash.

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REFERENCES

1. Amini F, Jafari A, Amini P, Sepasi S. Metal ion release from fixed orthodontic appliances—an in vivo study. Eur J Orthod. 2012; 34: 126–30.
2. Tanabe M, Takahashi T, Shimoyama K, Toyoshima Y, Ueno T. Effects of rehydration and food consumption on salivary flow, pH and buffering capacity in young adult volunteers during ergometer exercise. J Int Soc Sports Nutr. 2013; 10: 49.
3. Kolokitha OEG, Chatzistavrou E. Allergic reactions to nickel-containing orthodontic appliances: clinical signs and treatment alternatives. World J Orthod. 2008; 9(4): 399–406.
4. English JD, Peltomaki T, Pham-Litschel K. Mosby's Orthodontic Review. St. Louis: Elsevier Health Sciences; 2008. p. 239-43.
5. Gautam P, Valiathan A. Ceramic brackets: in search of an ideal! Trends Biomater Artif Organs. 2007; 20(2): 117–22.
6. Matos de Souza R, Macedo de Menezes L. Nickel, chromium and iron levels in the saliva of patients with simulated fixed orthodontic appliances. Angle Orthod. 2008; 78(2): 345–50.
7. Bakhtari A, Bradley TG, Lobb WK, Berzins DW. Galvanic corrosion between various combinations of orthodontic brackets and archwires. Am J Orthod Dentofac Orthop. 2011; 140: 25–31.
8. Arezou J, Shahabi M, Mokhber N, Ardakani T. Comparison of nickel ion release and corrosion sites among commonly used stainless steel brackets in Iran. J Mashhad Dent Sch. 2009; 33: 17–24.
9. Amini F, Khazali M, Mahmodei F, Hematpour S. Salivary content of nickel, chromium and cobalt ions in subjects with fixed orthodontic appliances. Iran J Orthod. 2010; 5: 63–6.
10. Costa MT, Lenza MA, Gosch CS, Costa I, Ribeiro-Dias F. In vitro evaluation of corrosion and cytotoxicity of orthodontic brackets. J Dent Res. 2007; 86(5): 441–5.
11. Newman MG, Takei HH, Klokkevold PR, Carranza FA. Carranza's clinical periodontology. 11th ed. Philadelphia: Saunders Elsevier; 2011. p. 235–7.
12. Hafez HS, Selim EMN, Kamel Eid FH, Tawfik WA, Al-Ashkar EA, Mostafa YA. Cytotoxicity, genotoxicity, and metal release in patients with fixed orthodontic appliances: a longitudinal in-vivo study. Am J Orthod Dentofac Orthop. 2011; 140(3): 298–308.
13. Omidkhoda M, Sahebnasagh Z, Poosti M, Yaghoobi M, Izadpanahi A. Evaluation of mechanical properties of NiTi orthodontic wire after immersion in three different mouthwashes. Iran J Orthod. 2011; 6: 32–8.
14. Farah CS, McCullough MJ, McIntosh L. Mouthwashes. Aust Prescr. 2009; 32(6): 162–4.
15. Singgih M, Damayanti S, Pandjaitan N. Antimicrobial activity of standardized piper betel extract and its mouthwash preparation. Int J Pharm Pharm Sci. 2014; 6(7): 243–6.
16. Sandhya R. Herbal product as mouthwash - a review. Int J Sci Res. 2017; 6(7): 1334–7.
17. Dubey RC. A textbook of biotechnology. New Delhi: S. Chand Publishing; 2007. p. 190–4.
18. Rafeeq RA, Saleem AI, Nissan LMK. Ions release from fixed orthodontic appliance in two different mouthwashes. J baghdad Coll Dent. 2014; 26(4): 152–5.
19. Amini F, Shariati M, Sobouti F, Rakhshan V. Effects of fixed orthodontic treatment on nickel and chromium levels in gingival crevicular fluid as a novel systemic biomarker of trace elements: a longitudinal study. Am J Orthod Dentofac Orthop. 2016; 149(5): 666–72.
20. Danaei SM, Safavi A, Roeinpeikar SMM, Oshagh M, Iranpour S, Omidekhoda M, Omidekhoda M. Ion release from orthodontic brackets in 3 mouthwashes: an in-vitro study. Am J Orthod Dentofac Orthop. 2011; 139(6): 730–4.
21. Mikulewicz M, Chojnacka K, Wołowiec P. Release of metal ions from fixed orthodontic appliance: an in vitro study in continuous flow system. Angle Orthod. 2014; 84(1): 140–8.
22. Patel R, Bhanat S, Patel D, Shah B. Corrosion inhibitory ability of ocimum sanctum linn (tulsi) rinse on ion release from orthodontic brackets in some mouthwashes: an invitro study. Natl J Community Med. 2014; 5: 135–9.
23. Kuhta M, Pavlin D, Slaj M, Varga S, Lapter-Varga M, Slaj M. Type of archwire and level of acidity: effects on the release of metal ions from orthodontic appliances. Angle Orthod. 2009; 79: 102–10.
24. House K, Sernetz F, Dymock D, Sandy JR, Ireland AJ. Corrosion of orthodontic appliances—should we care? Am J Orthod Dentofac Orthop. 2008; 133(4): 584–92.
25. Gajapurada J, Ashtekar S, Shetty P, Biradar A, Chougule A, Bhalkeshwar, Bansal A, Zubair W. Ion release from orthodontic brackets in three different mouthwashes and artificial saliva: an in-vitro study. IOSR J Dent Med Sci. 2016; 15(4): 76–85.
26. Luft S, Keilig L, Jäger A, Bourauel C. In-vitro evaluation of the corrosion behavior of orthodontic brackets. Orthod Craniofac Res. 2009; 12: 43–51.
27. Kao CT, Huang TH. Variations in surface characteristics and corrosion behaviour of metal brackets and wires in different electrolyte solutions. Eur J Orthod. 2010; 32(5): 555–60.
28. Chaturvedi TP, Upadhayay SN. An overview of solutions. Dent Mater J. 2010; 29: 53–8.
29. Fábián TK, Fejérdy P, Csermely P. Saliva in health and disease, chemical biology of. In: Wiley Encyclopedia of Chemical Biology. Hoboken, USA: John Wiley & Sons, Inc.; 2008. p. 1–9.
30. Iijima M, Yuasa T, Endo K, Muguruma T, Ohno H, Mizoguchi I. Corrosion behavior of ion implanted nickel-titanium orthodontic wire in fluoride mouth rinse solutions. Dent Mater J. 2010; 29: 53–8.

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