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Evaluation of Nickel Ion Release and Surface Characteristics of Stainless Steel Orthodontic Archwires after Using Magnetically Treated Water as a Mouthrinse

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ABSTRACT

Aims: The current study aimed to explore if the use of magnetically treated water (MTW) as a mouthrinse will affect the release of nickel (Ni) ion from stainless steel (SS) orthodontic archwires. In addition to study the surface characteristic of SS archwire after using MTW by scanning electron microscope (SEM).

Materials and Methods: forty-five (0.016" x 0.022") as received new orthodontic SS archwires from the company (Dentarum, Germany). The archwires divided into three main groups depending on the mouthrinse used as follows: magnetically treated water group (MTW), distilled water group (control negative) (DW) and Ortho Kin group (control positive) (OK). Each group contains three times point intervals (24hours, 2 weeks, and 4 weeks). Five archwires were used in each interval. The Ni ion release was measured at different time intervals (24hours, 2 weeks and 4 weeks) by using atomic absorption spectrometer (BUCK Scientific, USA). And surface characteristics were determined by using scanning electron microscope (SEM) (TESCAN MIRA3, French). Statistical analysis was done using SPSS Statistics, V26. Data were analyzed with one-way ANOVA and Duncan's multiple range tests.

Results: MTW group caused significantly less amounts of Ni ions release from SS orthodontic archwires when compared with OK mouthrinse group.

Conclusions: MTW can be used as a safer adjunct or alternative to other commercially available chemical mouthrinses (as OK) during orthodontic treatment course.

Key words: Archwire, Corrosion, Magnetically treated water, Nickel ion, Stainless steel

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INTRODUCTION

Resistance to corrosion was the most essential characteristic for biomaterials in orthodontics [1]. Metallic corrosion defined as an electrochemical process that causes material loss because of metal's reaction in the presence of aqueous solution, and the chemical composition of the aqueous medium determines the amount of the corrosion process [2]. Corrosion defects on the surface of the orthodontic appliance increases the friction between slot interface and archwires and releases ions from the metal alloy into the oral cavity [3].

Because of the existence of fixed appliance parts used during orthodontic treatment, the removal of plaque and maintenance of oral hygiene becomes problematic [4]. Most people are unable to perform adequate mechanical elimination of the plaque or if it is done, it is not sufficient to avoid plaque buildup and periodontal disease [5]. Hence, oral washing with antimicrobial agents regularly can act as an effective means for eliminating and controlling bacterial plaques to improves oral health and limit gingivitis and periodontitis [6].

There is more than one study on the effect of different mouthrinses on corrosion and metal ions release from orthodontic appliance [7-9]. And most of these studies showed that the metal ions release was increased after using the chemical mouthrinses. So a natural alternative mouthrinse that can be used for long period without undesirable side effect is needed, recently magnetically treated water (MTW) can be used as effective as a mouthrinse against S. mutans and has better action in plaque when compared with saliva. So it can be used as a natural substitute to other mouthrinses that are available commercially [10]. But its effect on corrosion and metal ions release from orthodontic archwires has not been studied yet. So the present study was conducted to explore whether the use of MTW as a mouthrinse will affect the release of Ni ions from SS orthodontic archwires and to study the effect of MTW on the surface characteristics of SS orthodontic archwires by SEM at different powers of magnification.

MATERIALS AND METHODS

Materials

The sample comprises of forty-five (0.016″ x 0.022″) new as received orthodontic SS archwires from the company (Dentarum, Germany). The archwires were divided to three groups according to the mouthrinse used as follows: MTW group prepared at 1000 gauss magnetic field, OK group (control positive), DW group (control negative). Each main group contains three times point intervals (24hours, 2 weeks and 4 weeks). Five archwires were used for each time interval so each main group has 15 archwires.

Preparation of magnetically treated water

The DW was magnetized by using 1000 gauss magnetic power neodymium type magnets. The magnetic strength and the magnetic poles were determined by Gauss meter. The magnets were placed around the glass container in north pole repulsion manner and water stayed in the container for 72 hours. And then, the electrical conductivity (EC) and pH value for the DW and MTW were measured by EC Meter and pH Meter to make sure that DW was magnetized, the obtained values presented in (Table 1). MTW was used for one minutes twice daily for a period of 4 weeks.

Preparation of artificial saliva

Components of artificial saliva (its pH was 7) are 0.40g of NaCl, 0.40g of KCl, 0.79g of $CaCL_2 .2H_2O$, 0.78g of $NaH_2 PO_4 .2H_2O$, 0.005g of $Na_2S.9H_2O$ and 0.1g of $CO(NH_2)_2$ Urea, dissolved in one liter of DW (concentration g \ l) [11].

Methods

Firstly, SS archwires were cleaned by using acetone then washed with DW and then dried with disposable absorbable towel. After that, each archwire was cut into 4 equal pieces. The pieces of the archwires putted in a 30 ml volume glass container, then 25 ml of the artificial saliva solutions were poured in each container. Later, the glass container samples were incubated at 37°C for 24 hours, 2 weeks and 4 weeks. At 12 hours' time intervals according to the usage of mouthrinse (twice daily), the containers were removed from the incubator, then the wires were removed from the containers by a plastic tweezer and washed with DW, after that the wires were immersed in another 30 ml glass containers containing 25 ml of mouthrinses samples (MTW, OK and DW). The immersion period inside mouthrinse solution was one minute twice daily. When the immersion period finished, the wires rinsed with DW and retrieved to their artificial saliva container and placed again in an incubator (nüve EN 400, Turkey) at 37°C till the following immersion period in the mouthrinse. This procedure was repeated regularity till the completion of 4 weeks. At the end of each three time-points interval, the wires were removed from the artificial saliva solution, and then, a drop of nitric acid (65% concentration) was added for stabilization of the released ions [8].

Table 1: EC and pH values for DW and MW.

	EC	pH
DW	13.8	6.9
MTW	470	7
DW: Distilled Water		
MTW: Magnetically Treated Water		
EC: Electrical Conductivity		

The effect of MTW, OK and DW on SS archwires at different time intervals was studied. After shaking, the solution samples were withdrawn [12] and then the release of Ni ion was measured by using an atomic absorption spectrometer. And a scanning electron microscope (SEM) was used to assess the surface characteristics of wires before and after 4-weeks of the immersion inside the solution samples. Statistical analysis of the results was done by the SPSS Statistics (version 26, USA). Normality of distribution was evaluated by Shapiro–Wilk test. Descriptive statistics (mean, range, minimum, and maximum, standard error and standard deviation) were stated. One Way (ANOVA) test was done to detect any significance at ($P \le 0.05$) among different groups. The Duncan's Multiple Range test was conducted to locate the significant differences among the groups.

RESULTS

Cr ion release result

The descriptive data for Ni ion release from SS archwire are demonstrated in Table 2. These data include the number of the samples in each group, range, minimum, maximum, mean (measured in part per billion (ppb)), standard error and standard deviation values of the Ni ions release for all the study groups. The descriptive analysis revealed that at 24hours, 2weeks and 4weeks intervals, OK showed the highest Ni ions release, while DW showed the lowest Ni ions release value. The one way (ANOVA) statistical test results were shown in Table 3 presenting a significant difference at ($P \le 0.05$) among the groups at all-time intervals. A more specific Duncan's multiple range test was performed among all the study groups as demonstrated in Table 4, and detected that at 24hours interval, the OK group had significantly the highest difference in Ni ion release value, while DW and MTW groups were not significantly differing in Ni ion release value. At 2weeks and 4weeks intervals, the OK group had significantly the highest difference in Ni ion release value followed by MTW, while DW group had significantly the lowest difference in Ni ion release value.

SEM results

The new SS archwire showed a smooth surface at 300X, while at 5000X it showed some amount of surface irregularities due to manufacturing process as seen in Figure 1Aa and Ab respectively. After 4weeks immersion period in DW, surface of SS archwire showed small localized areas of irregularities at 300X, while at 5000X the surface irregularities appear more obvious as in figure 1Ba and Bb. The surface of the archwire after 4weeks immersion period in OK mouthrinse showed a numerous diffused areas of surface defect at 300X, while at 5000X there was more irregularities and large craters as signs of corrosion reflecting the action of OK on the surface of archwire as seen in Figure 1Ca and Cb. While the archwire after 4weeks immersion period in MTW had a separated small areas of surface defects as seen in Figure1 Da and Db.

DISCUSSION

In this study, mouthrinses were used in a static in vitro conditions state. Certainly, there are limitations of in vitro study because not all in vivo influences can be simulated by in vitro experiments [12], it appears very difficult to prepare an in vitro setting that would enable studying the actual toxic load of released metal ions on oral tissues [13], due to the constantly changing oral environment with extreme pH or temperature fluctuations, bracket-to-wire type of ligation and friction, the presence of intraoral microbial flora, plaque accumulation, and biological and enzymatically composition [14], as well as tooth brushing and also the fluidity of saliva in the mouth which lead to removal of oxide layer, therefore

Table 2: Descriptive statistics for the Ni ion release from SS archwires.

Groups	N	R	Min.	Max.	Mean	S. E	S. D
DW 24hours	5	0.4	1	1.4	1.22	0.066	0.148
OK 24hours	5	0.4	1.7	2.1	1.9	0.07	0.158
MTW 24hours	5	0.4	1.2	1.6	1.4	0.07	0.158
DW 2weeks	5	0.3	2.9	3.2	3.04	0.05	0.114
OK 2weeks	5	2	18	20	19	0.404	0.905
MTW 2weeks	5	0.3	3.8	4.1	3.94	0.05	0.114
DW 4weeks	5	0.3	5.6	5.9	5.74	0.05	0.114
OK 4weeks	5	1.2	26.8	28	27.4	0.246	0.552
MTW 4weeks	5	0.8	7	7.8	7.4	0.158	0.353

N is number, R is range, Min. is minimum, max. is maximum, S.E is Standard error, S.D is Standard deviation, DW is distilled water, OK is Ortho Kin mouthrinse and MTW is magnetically treated water

Table 3: One way (ANOVA) for the mean values of Ni ions released from SS archwires after immersion in different mouthrinses at the same interval.

		Sum of Squares	df	Mean Square	F	Sig.
At 24hours	Between Groups	1.241	2	0.621	25.861	0
	Within Groups	0.288	12	0.024		
	Total	1.529	14			
At 2weeks	Between Groups	803.892	2	401.946	1425.34	0
	Within Groups	3.384	12	0.282		
	Total	807.276	14			
At 4weeks	Between Groups	1453.185	2	726.593	4920.492	0
	Within Groups	1.772	12	0.148		
	Total	1454.957	14			

df is degree of freedom, F is F test and Sig. is significant at P ≤ 0.05

Table 4: Duncan's multiple range test for multiple comparisons of the Ni ion release from SS archwires after immersion in different mouthrinses at the same interval.

	Mouthrinse	N	Mean ± SE	Duncan Groups*
At 24 hours	DW	5	1.22 ± 0.06	A
	OK	5	1.90 ± 0.07	B
	MTW	5	1.40 ± 0.07	A
At 2weeks	DW	5	3.04 ± 0.05	A
	OK	5	19.00 ± 0.40	C
	MTW	5	3.94 ± 0.05	B
At 4weeks	DW	5	5.74 ± 0.05	A
	OK	5	27.40 ± 0.24	C
	MTW	5	7.40 ± 0.15	B

DW is distilled water, OK is Ortho Kin mouthrinse and MTW is magnetically treated water

* Different letters mean significant difference in the same interval (P ≤ 0.05).

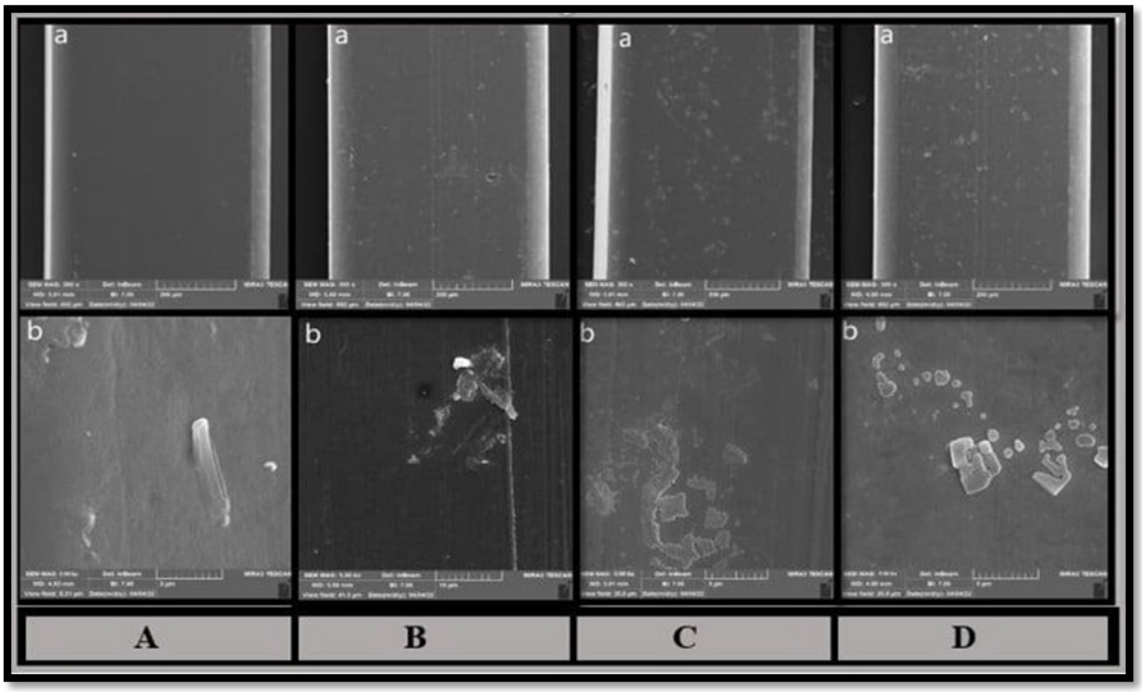

Figure 1: SEM images for SS archwires A: new, B: immersed in DW, C: immersed in OK, D: immersed in MTW, a:300X and b: 5000X.

more metal release could occur in real life [15].

In the present study, Ni ion release from SS archwire occur because Ni atoms are not strongly bonded to form some intermetallic compound, so Ni ion releases from the alloy surface, which may interfere with the biocompatibility of the alloy [16].

In this study, the release of Ni ion from SS archwires at all-time points, has its highest value in OK mouthrinse owing to the presence of corrosive ingredients in this mouthrinse such as fluoride ion that leads to increase corrosion rate. Our results regarding OK (a fluoridated mouthrinse) were agreed with the results of the study which shown that fluoridated products corroded SS archwires and brackets, as demonstrated by assessing surface roughness and release of metal ions [17]. Fluoride is a well-recognized corrosive agent [18]. Also the changes in the pH of the mouth may be influenced by mouthrinses which contains chloride and fluoride, and causes the environment of the oral cavity to become acidic and therefore increasing the corrosion process that results in the release of metal ions [9].

In the current study, the amount of Ni released from SS archwires that immersed in MTW were slightly higher than that which immersed in DW due to alteration of water properties after being magnetized therefore the corrosion process was affected. In DW group, Ni ion release from SS archwires showed the least amount among other groups, this may be attributed to neutralized pH of DW and the archwires immersed in DW group only were subjected to the temperature effect during incubation and to the effect of chemical contents of artificial saliva. The result of another study which was conducted to measure the ions release from orthodontic brackets in three mouthrinses and DW presented that the highest amount of metal ions release was occurred in DW which disagreed with our result concerning DW [7].

The result of the present study, according to the time of immersion, showed that the amount of Ni ions released from SS archwires increased gradually and reach the maximum value after 4weeks immersion period for all the tested solutions, this mean that the corrosion process was still continued and metal ions were still released.

SEM findings in this study for SS archwires include signs of corrosion of all archwires when compared with new one due to the corrosion process which occurred in aqueous environment, but the archwires immersed in OK were more affected and showed more signs of corrosion than other archwires, this is reflecting the effect of OK mouthrinse on the corrosion of the SS archwires due to its acidity and the presence of aggressive fluoride ions in its contents which cause an opening in the protective oxide layer and allowing the process of corrosion to start [19].

A study evaluating fluoride effects by SEM analysis of brackets and archwires, displayed more grooves and lines in the fluoridated archwires when compared to the other groups, in similarity to our study findings about OK fluoridated mouthrinse [17]. In another study, the examination of fluoridated, non-fluoridated and unused brackets by SEM showed that the fluoridated brackets had the maximum signs of surface degradation which supporting the assumption of the effect of long term fluorides exposure on brackets that leads to decrease their corrosion resistance especially in the presence of high concentrations of fluoride [20]. Also the destructive effects of fluoride were obvious in archwires when evaluated under SEM as maximum degradation in the form of striations, pitting, crack formation, globular defects and white spots after exposure to fluoride agents in the course of the clinical orthodontic treatment [19]. In a study which was used SEM to examine the bracket slot, the photomicrographs of the immersed brackets showed only little pits in artificial saliva while there was an extreme heterogeneous patchy area in sodium fluoride (NaF) containing mouthrinse. This diverse patchy area that occurred in the bracket's slot surface when immersed in NaF mouthrinse may be the result of the breakdown of Cr oxide passive layer of the SS bracket due to the effect of fluoride ion that leads to the formation Cr fluoride complex [21].

This study showed that the effect of MTW on the release of Ni ion and on the surface characteristic of archwires is slightly more than DW, this may be due to the alteration of water properties after exposure to magnetic field with considerable change in the pH, conductivity, dissolved oxygen, evaporating temperature, salinity, minerals, organic matter, total dissolved solids and total count of bacteria [22]. Therefore, the corrosion process was affected.

In the current study, the pH of MTW was 0.1 higher than pH of DW as measured by pH-Meter. This little amount of elevation in pH was negligible and has no effect on corrosion rate.

Water after passing through magnetic field becomes electrical conductor and have more solubility for minerals and acids, in addition to increasing in soluble oxygen percentage and that could be speed up biochemical reactions. Furthermore, decreasing in water surface tension to enhance the physical characteristics [23]. Goyal et al. stated that the MTW has lots of oxygen that can be dissolved immediately in that water [10]. Gases dissolve in water and the most essential ones from the corrosion risk point of view are carbon dioxide and oxygen. Oxygen acts as a depolarizer in the cathodic half-cell, and it enhances corrosion risk [24]. Mghaiouini, et al. concluded that the magnetic field reduced the dielectric constant and resistance of treated water, and increased its EC [25]. These results about EC of MTW were agreed with the results obtained in this study which also showed an increase of EC of DW after being magnetized as measured by EC Meter. Accordingly, the corrosion in MTW may be happened because of the fact that when EC of water increases the corrosion rates also tend to increase [24].

CONCLUSION

MTW can be used as a substitute or adjunct to other commercially available chemical mouthrinses (as OK) during the course of orthodontic treatment especially in patients who are allergic to Ni because most of these mouthrinses have high effects on the release of Ni ion from SS archwire. Meanwhile, MTW has a slight effect on Ni ion release from SS archwire, so it may be considered as a promising natural mouthrinse.

REFERENCES

1. Manam NS, Harun WSW, Shri DNA, et al. Study of corrosion in biocompatible metals for implants: A review. J Alloys Compd 2017; 701:698-715.
2. Du XQ, Yang QS, Yu CHEN, et al. Galvanic corrosion behavior of copper/titanium galvanic couple in artificial seawater. Trans Nonferrous Met Soc China 2014; 24:570-581.
3. Ahmed RA, Farghali RA, Alshahrani WA. Influence of fluoride and/or bovine albumin on electrochemical properties of bare and ionic liquid-coated Ni47Ti49Co4 orthodontic archwires in artificial saliva solution. Int J Electrochem Sci 2021; 16:2.
4. Al-Kawari HM, Al-Jobair AM. Effect of different preventive agents on bracket shear bond strength: *In vitro* study. BMC Oral Health 2014; 14:1-6.
5. Tonetti MS, Eickholz P, Loos BG, et al. Principles in prevention of periodontal diseases: consensus report of group 1 of the 11th European workshop on periodontology on effective prevention of periodontal and peri-implant diseases. J Clin Periodontol 2015; 42: 5-11.
6. Dehghani M, Abtahi M, Hasanzadeh N, et al. Effect of propolis mouthwash on plaque and gingival indices over fixed orthodontic patients. J Clin Exp Dent 2019; 11:244.
7. Danaei SM, Safavi A, Roeinpeikar SM, et al. Ion release from orthodontic brackets in 3 mouthwashes: an in-vitro study. Am J Orthod Dentofac Orthop 2011; 139:730-734.
8. Mirhashemi A, Jahangiri S, Kharrazifard M. Release of nickel and chromium ions from orthodontic wires following the use of teeth whitening mouthwashes. Prog Orthod 2018; 19:1-5.
9. Mahmood RA, Mohsin MK, Mohammad MH, et al. Evaluation of metallic ion release from fixed orthodontic appliance in two different mouthwashes and distilled water: An *in vitro* study. Dent J 2021; 8:61-66.
10. Goyal AK, Rathore AS, Garg M, et al. Effect of magnetized water mouthrinse on Streptococcus mutans in plaque and saliva in Children: An in vivo study. Int J Clin Pediatr Dent 2017; 10:335-339.
11. Taqa A, Sulieman R, Al-Sarraf HA. Artificial saliva sorption for three different types of dental composite resin (An *in vitro* study). EC Dental Science 2019; 18:2339-2344.
12. Wendl B, Wiltsche H, Lankmayr E, et al. Metal release profiles of orthodontic bands, brackets, and wires: An in vitro study. J Orofac Orthop 2017; 78:494-503.
13. Faccioni F, Franceschetti P, Cerpelloni M, et al. *In vivo* study on metal release from fixed orthodontic appliances and DNA damage in oral mucosa cells. Am J Orthod Dentofac Orthop 2003; 124:687-693.
14. Kovac V, Poljsak B, Bergant M, et al. Differences in metal ions released from orthodontic appliances in an *in vitro* and *in vivo* setting. Coatings 2022; 12(2): 190.

15. Hwang CJ, Shin JS, Cha JY. Metal release from simulated fixed orthodontic appliances. Am J Orthod Dentofac Orthop 2001; 120:383-391.

16. Sharmila R. Wires in orthodontics-A short review. J Pharm Sci Res 2016; 8:895.

17. Yanisarapan T, Thunyakitpisal P, Chantarawaratit PO. Corrosion of metal orthodontic brackets and archwires caused by fluoride-containing products: Cytotoxicity, metal ion release and surface roughness. Orthod Waves 2018; 77:79-89.

18. Castro SM, Ponces MJ, Lopes JD, et al. Orthodontic wires and its corrosion—The specific case of stainless steel and beta-titanium. J Dent Sci 2015; 10:1-7.

19. Chitra P, Prashantha GS, Rao A. Effect of fluoride agents on surface characteristics of NiTi wires. An ex vivo investigation. J Oral Biol Craniofac Res 2020; 10:435-440.

20. Houb-Dine A, Bahije L, Zaoui F. Fluoride induced corrosion affecting titanium brackets: A systematic review. Int Orthod 2018; 16:603-612.

21. Bhushan R, Ramanna PK, Kumar S, et al. Impact of fluoridated and non-fluoridated mouth rinses on frictional resistance between orthodontic archwire and bracket: A comparative study. J Contemp Dent Pract 2020; 21:1337-1341.

22. Ebrahim SA, Azab AE. Biological effects of magnetic water on human and animals. Biomed Sci 2017; 3:78-85.

23. Al-Bayar MA, Mahmood RM, Saieed AY. Magnetic treated water, reality and applications: A review. Plant Arch 2020; 20:732-737.

24. Zakowski K, Narozny M, Szocinski M, et al. Influence of water salinity on corrosion risk—the case of the southern Baltic Sea coast. Environ Monit Assess 2014; 186:4871-4879.

25. Mghaiouini R, Elmlouky A, El Moznine R, et al. The influence of the electromagnetic field on the electric properties of water. Mediterr J Chem 2020; 10:507-515.