Original Article

Evaluation of the Effect of an Experimental Herbal versus Fluoridated Mouthwash on Frictional Resistance and Surface Roughness between Orthodontic Brackets and Two Types of Archwire: In Vitro Study

Naser Abdelgader Alwafe [1], Shaza Mohammad Hammad [2], Noha AbdelMawla El-wassefy [3], Ahmad Mohammed Hafez [4]

[1] Orthodontic department, Faculty of dentistry, Mansoura University, Mansoura, Egypt
[2] Professor of Orthodontic, School of Dentistry, Mansoura University, Mansoura, Egypt
[3] Associate Professor of Dental Biomaterial, School of Dentistry, Mansoura University, Mansoura, Egypt
[4] Associate Professor of Orthodontic, School of Dentistry, Mansoura University, Mansoura, Egypt

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Abstract

Introduction: The present study aimed to evaluate an experimental herbal mouthwash, as compared to sodium fluoride mouthwash on the frictional resistance and surface roughness between brackets and two rectangular archwire types. **Methods:** A total of 60 premolar's brackets engaged with 0.019×0.025 archwires made of stainless steel and nickel-titanium alloys were used in this study. The samples were assigned into three groups, each group contained ten stainless steel archwires-brackets and ten nickel titanium archwires-brackets combination. Thereafter, these samples were immersed in herbal mouthwash, sodium fluoride mouthwash (study groups) and artificial saliva (control group) for 90 minutes. Universal testing machine was used to test the friction resistance in the three groups. Atomic force and scanning electron microscopes were used to evaluate the surface roughness of wires and bracket surface topography, respectively. **Results:** The samples immersed in sodium fluoride mouthwash illustrated the highest mean friction resistance and mean surface roughness, followed by herbal mouthwash and the least was for artificial saliva. **Conclusion:** The 90-minute immersion in herbal mouthwash did not exert any significant effect on frictional resistance or surface roughness among orthodontic brackets and archwires made of stainless steel and nickel titanium. Based on the results, herbal mouthwash may be prescribed as a non-destructive prophylactic agent on materials evaluated in the present study for the orthodontic patient.

Keywords: Mouthwashes, Friction, Surface roughness, Stainless steel, Nickel titanium

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Introduction

Friction which is defined as the resistance to motion as a result of solids sliding over each other is of two types: static friction and dynamic friction. Static friction occurs at the beginning of actual sliding motion, while dynamic friction occurs during motion (1). In orthodontics, friction resistance occurs between archwire and bracket during phases of tooth movement. Some mechanical and biological factors can affect friction in orthodontics. Mechanical factors include wire properties, bracket properties, and methods of ligation, while biological factors involve saliva and dental plaque accumulation (2).

Successful orthodontic treatment depends on good oral hygiene; therefore, orthodontists should recommend that patients regularly use mouthwash and dentifrices to protect against dental cavities and plaque accumulation. However, mouthwash ingredients may increase the corrosion of both stainless steel (SS) and nickel titanium (NiTi) archwires. Counteraction of corrosion requires the formation of a passive oxide layer on the wire surface. If this layer deteriorates, the wire surface roughness may be increased (3) leading to increased friction between bracket and wire. The effect of fluoride agents on frictional resistance between wires and brackets have been estimated (4-7). In this regard, the use of 0.2% and 0.05 % sodium fluoride (NaF) mouthwash on a daily or weekly basis is usually recommended by orthodontists, resulting in the constant exposure of archwires and brackets to fluoride. Wire frictional resistance was found to be higher in fluoride mouthwash with high fluoride concentration, compared to varieties with low fluoride concentration(8). Despite the anti-carious and anti-plaque inhibitory effect of fluoride mouthwash, it exerts an adverse effect on both passive protective chromium oxide-coated and titanium oxide-coated layers of SS and NiTi archwire, respectively. NiTi archwire was investigated by Huang after immersion in fluoride mouthwash for 28 days and he observed significant changes in surface roughness of archwire (9).

Aghili et al. (10) concluded that the immersion of SS and NiTi archwires in 0.05 % NaF mouthwash brought about significant changes in the wire surface. Kaneko et al.(11) suggested that the immersion of NiTi wire in 2.0% acidulated phosphate fluoride solution may degenerate the passive titanium oxide layer on the wire surface resulting in the deterioration of surface morphology which in turn affects the friction at wire bracket interface.

Herbal mouthwash (HMW) has recently been introduced for the maintenance of oral hygiene using the natural cleansing and healing properties of herbs for teeth and gingiva. Moreover, it is free of alcohol or any chemical compounds (12). Furthermore, HMW has no side effects due to its natural ingredients and can be used as a good alternative to chlorhexidine mouthwash for patients who are recommended to avoid alcohol present in chlorhexidine mouthwash (13). Many fruit extracts, such as pomegranate, guava, cranberry, and grapefruit are used in mouthwashes. Pomegranate extract has the ability to undo the adherence of microorganisms to tooth surface by protective barrier formation; therefore, it restrains dental plaque accumulation (14). Green tea extracts are able to control dental plaque accumulation (15). To our best knowledge, no research has been conducted on the effects of HMW on friction resistance of orthodontic brackets and wires. This in vitro study aimed to estimate the effect of herbal versus fluoridated mouthwashes on frictional resistance and surface roughness among orthodontic brackets and two archwire types.

Materials and Methods

1. Sample preparation

This study was conducted on 60 upper premolar SS. metal brackets (Roth, Leone, Italy) with a slot size of 0.022 inches. Both SS and NiTi archwires with dimensions of 0.019x0.025 (Ortho-organizer, USA) were cut into specimens of 5cm in length, and each specimen was ligated to bracket by elastomeric modules (O-Tie 120 diameter latex-free, Ortho-organizer, USA). They were divided into three main groups, including HMW, NaF mouthwash (study groups), and artificial saliva (control group). Each group consisted of 20 specimens (10 SS archwire-brackets combination and 10 NiTi archwire-brackets combination).

2. Herbal mouthwash preparation

Herbal mouthwash was prepared in Pharmacognosy Department, Faculty of Pharmacy, Mansoura University, Egypt, from extractions: (200mg pomegranate, 200mg propolis, 200mg green tea and 200 mg myrrh). Extractions were added to 1000ml distilled water at 70-80°C for 30 minutes. Thereafter, they were filtered using a cloth filter. A rotary evaporator was then used to concentrate extracted substances at low pressure (R-210V-700V850, Buchi, Switzerland).

3. Assessment of frictional resistance

Distilled water was used to clean specimens. Thereafter, the experimental specimens were immersed in 500 ml HMW and 500 ml NaF mouthwash (220 part per million, EZ-Fresh, Alexandria, Egypt), while the specimens for the control group were immersed in 500 ml artificial saliva containing: ($NaCl$ 400mg/L), (KCl 400 mg/L), ($NaH_2PO_4.H_2O$ 690mg/L), ($CaCl_2.2H_2O$ 795mg/L), ($NaHCO_3$ 100 mg/L), ($Na_2S.9H_2O$ 5mg/L) and Urea (1,000 mg/L) with pH level of (6.75). All specimens in each group were immersed within separated plastic containers of 500 ml at 37°C for 90 minutes. The specimens were then removed and washed with distilled water. Universal testing machine (Lloyd LR5K, England) was used for the measurement of friction resistance. A rectangular custom-made metal bar of 15 cm long was used for fixing the sample test unit. The bar fitting surface was sandblasted with 50 µm Al_2O_3 particles which created coarseness tags on the bar surface. Buccal tube (Leone-Italy) was bonded to the sandblasted surface by metal primer (R-Reliance, Itasca, USA). Fixture unit was held in plumb direction at the attachment point of upper grips, while the sample was placed in the machine between lower grips (Figure 1). At the onset of each test, a trial was performed without any force to verify that no binding was exhibited among archwire and bracket. A cross-head speed of 10 mm/ min over a 5 mm segment movement with a load cell of 10 N was then utilized to withdraw the archwire.

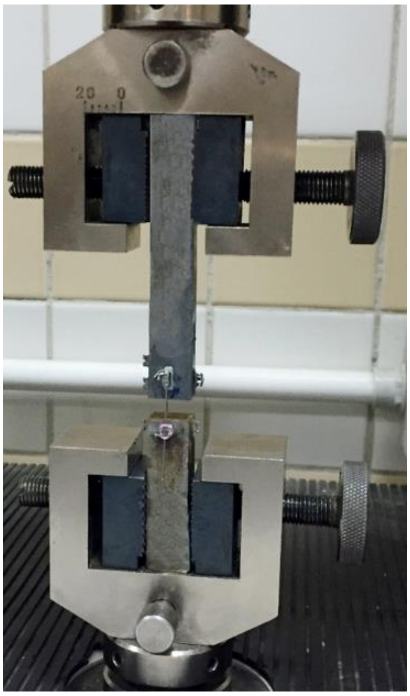


Figure 1. Universal testing machine with friction sample engaged

4. Archwires surface roughness evaluation

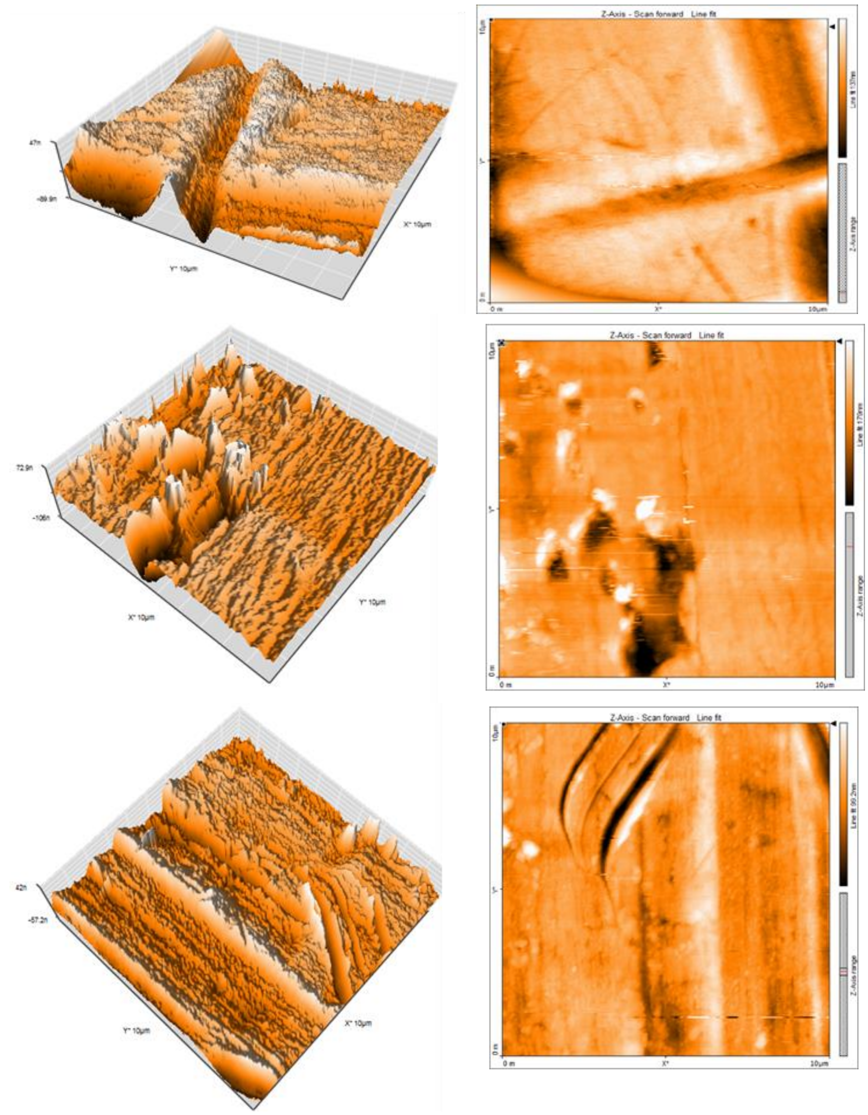
Surface roughness of archwire samples was estimated via an atomic force microscope (AFM) (Nanosurf Flex AFM- Switzerland). Three specimens were scanned for each group of the study. The wire was scanned over an area of (l0µm x l0µm). Consequently, 2D and 3D images were displayed by software scanning controller of AFM after scanning all wires (Figs. 2 A, B).

5. Bracket surface morphology evaluation

The surface morphology for bracket slot, after immersion in HMW, NaF mouthwash, and artificial saliva, was estimated using a scanning electron microscope (SEM) (JEOL JSM-6510LV-Akishima-Japan). The brackets were washed with distilled water. Thereafter, they were mounted on sample holder by means of a double-sided carbon adhesive tape. After that, they were conveyed to the vacuum chamber of SEM where samples were evacuated from the air. Samples underwent scrutiny with suitable magnification X1000 and 20KV. Finally, photomicrograph images were created (Fig. 3).

Statistical analysis

Obtained data were tested for normality using Shapiro-Wilk test and statistically analyzed in SPSS software (version 20.0). The data were described using mean and standard deviation between groups. One-way ANOVA test, followed by Post hoc was used to investigate the significance of friction resistance and surface roughness of immersed archwire groups. P-value less than 0.05 was considered statistically significant.



HMW

(A)

NaF mouthwash

(B)

artificial saliva

(C)

Figure 2A. AFM observation (left: three dimensions, right: two dimensions) for surface roughness (Nm) of SS archwire after immersion in (a) HMW (b) NaF mouthwash and (c) artificial saliva

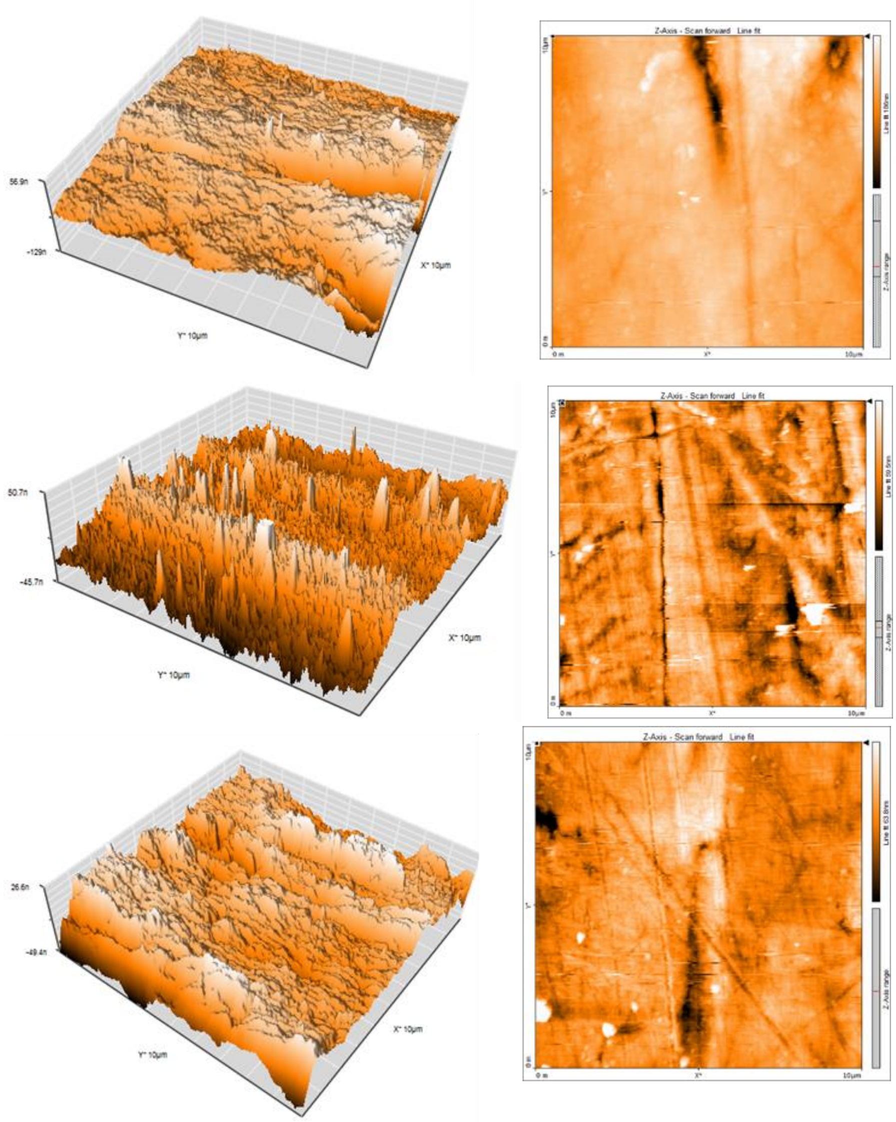


Figure 2B. AFM observation (left: three dimensions, right: two dimensions) for surface roughness (Nm) of NiTi archwire after immersion in (a) HMW (b) NaF mouthwash and (c) artificial saliva

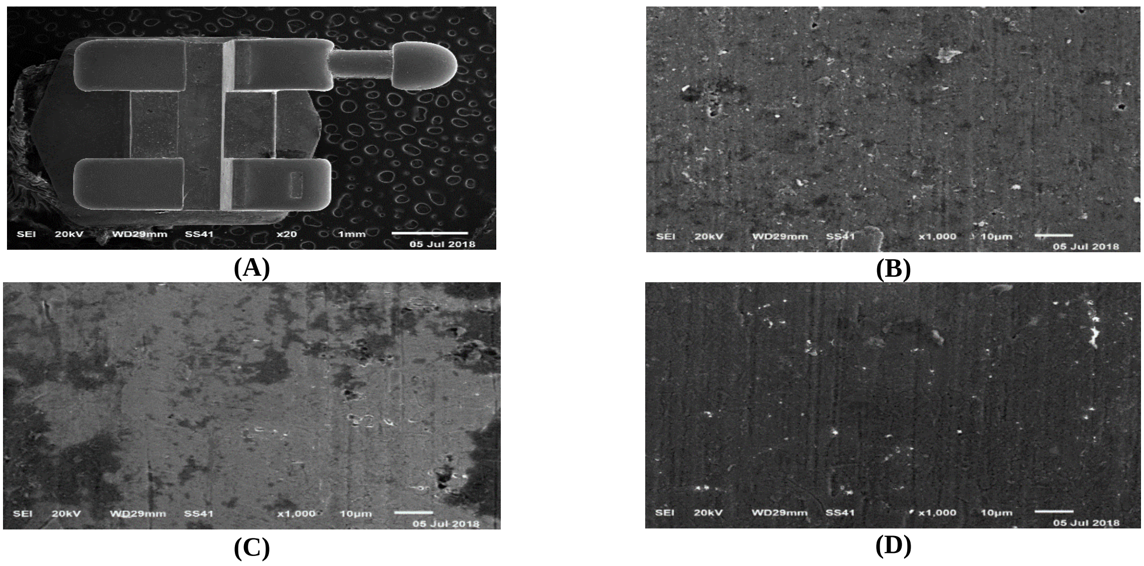


Figure 3. SEM photomicrograph (x1000) of SS metal bracket (A) photomicrograph of brackets (B), (C), (D) illustrated the slot surface of bracket after the immersion in HMW, NaF mouthwash, and artificial saliva, respectively**.**

Results

Based on the results of the study, SS wire showed statistically significant lower mean friction resistance and lower mean surface roughness, compared to NiTi wire (P<0.05; Table I). In addition, the friction resistance of SS and NiTi wires immersed in HMW, NaF mouthwash and artificial saliva suggested a statistically significant difference between two wires in HMW (P=0.02). Moreover, there was a statistically significant difference between the two groups of wire in terms of NaF mouthwash (P=0.031). Artificial saliva showed no statistically significant difference between the two groups of wire (P=0.09; Table II). On the other hand, SS wires immersed in NaF mouthwash revealed

Higher mean frictional resistance, compared to those immersed in HMW, it was not significantly different (P=0.11). NiTi wires immersed in NaF mouthwash exerted higher mean friction resistance, as compared to NiTi wires immersed in HMW; however, they were not statistically significant (P=0.06; Table II).

Regarding the mean surface roughness between SS and NiTi groups, there was a statistically significant difference between the two groups in terms of all types of solutions (P<0.001), with a higher mean surface roughness in NiTi group, compared to SS group (Table III).

Table I. Comparison of friction resistance (N) and surface roughness (Nm) between immersed Stainless steel and immersed nickel titanium groups

	Stainless Steel N=30	**Nickel Titanium N=30**	**Test of significance**
Friction resistance Mean ± SD	0.787±0.27	1.197±0.55	t=3.66 P=0.001*
Surface roughness Mean ± SD	17.27±5.37	26.91±4.28	t=7.69 P<0.001*

t: Student t test P: probability *statistically significant (P<0.05)

Table II. Comparison of friction resistance (N) for archwire groups between different groups of mouthwash

	Herbal mouthwash	Sodium fluoride mouthwash	Artificial saliva	Test of significance
Stainless steel Mean ±SD	0.789±0.29	0.92±0.28^{A}	0.66±0.20^{A}	F=2.39 P=0.11
Nickel Titanium Mean ± SD	1.25±0.47	1.45±0.67^{A}	0.89±0.34^{A}	F=3.13 P=0.06
Test of significance	t=2.64 P=0.02*	t=2.35 P=0.031*	t=1.83 P=0.09	

F: One-way ANOVA test t: Student t test p: probability *statistically significant (P<0.05)

Similar superscripted letters in the same row denote significant difference between groups

Table III. Comparison of surface roughness (nm) for archwire groups between different groups of mouthwash

	Herbal mouthwash	Sodium fluoride mouthwash	Artificial saliva	Test of significance
Stainless steel Mean ± SD	19.28±1.36^{AB}	22.25±1.8^{AC}	10.27±1.19^{BC}	F=180.18 P<0.001*
Nickel Titanium Mean ± SD	27.53±3.8^{A}	29.96±4.2^{B}	23.24±1.01^{AB}	F=10.38 P<0.001*
Test of significance	t=6.4 P<0.001*	t=5.29 P<0.001*	t=26.21 P<0.001*	

F: One-way ANOVA test t: Student t test P: probability *statistically significant (P<0.05)

Similar superscripted letters in same row denote significant difference between groups

Discussion

In the present study, the effect of HMW mouthwash on frictional resistance and surface roughness between brackets and archwires made of SS and NiTi was explored, when compared to NaF mouthwash. Based on the obtained data, the frictional resistance value of SS archwire was less than that of NiTi archwire. This can be attributed to the variability in the surface of the material itself, as SS wire has a passive protective chromium oxide layer which prevents the dissolution of oxygen into the surface and in doing so prevents the binding of elements and permits the smooth sliding of SS wires within the bracket slot. This finding is consistent with the results of the study conducted by Nishio et al. (16) and Kapila et al. (17). On the other hand, although the NiTi archwire is covered by a titanium oxide layer, it may release nickel and titanium contents particularly in acidic environmental conditions resulting in surface roughness and increased frictional resistance of NiTi archwires. This finding is in line with the results of the research carried out by Huang et al. (18). The obtained data revealed that the mean friction resistance of specimens at HMW is less than that of NaF mouthwash. The higher frictional resistance at NaF may be attributed to the fluoride ions that attack the protective layer of wire leading to layer decay and solubility. This finding is comparable to the finding suggested by Heravi et al. (19) Friction resistance was found to be less in artificial saliva, as compared to NaF mouthwash which is in line with the finding of the study performed by Geramy et al. (20) and Kao et al. (6). In addition, the obtained data revealed a non-significant difference of frictional resistance between HMW and artificial saliva. This may be attributed to the anti-oxidative activity of phytochemical natural herbs which may prevent oxygen diffusion into the surface of archwire. Accordingly, this anti-oxidative effect of HMW contents may inhibit the degradation of the passive layer of the archwire (21). A recent study conducted by Choudhary et al. (22) compared the effect of tea tree oil (TTO) mouthwash and chlorhexidine (CHX) mouthwash on frictional resistance and revealed that frictional resistance was less in the TTO mouthwash, compared to CHX mouthwash.

Method of ligation is considered one of the variables that affect friction; therefore, it was standardized in the present study. On the other hand, the 90 minutes immersion time selected in this study was imputed for a three-month application of mouthwash twice a day. It is difficult to determine the concentration of mouthwash following 30 seconds expectoration; consequently, immersion depended on one-minute daily rinsing with mouthwash for three months. In this study, the archwire size was kept constant so that the forces required for movement or sliding be based on the surface roughness and not on dimensional changes by increased wire size, compared to bracket size, which is also standardized in this study. The surface roughness of orthodontic archwires is an essential factor in determining the effectiveness of the archwire-guided tooth movement.

The AFM is considered the most effective tool for the measurement of surface topography since it provides three-dimensional information on surface topography (23). Therefore, AFM was utilized in this study for the assessment of archwires surface roughness. In the current study, the mean surface roughness of the SS wire was significantly lower than that of NiTi wire. This may be due to the combination of extreme hardness, high strength, highly polished surface and lower sliding resistance of SS wire, particularly when used in passive configuration (24). The significantly high surface roughness of NiTi wires may be attributed to its manufacturing processes, where the part of crystallographic structures of NiTi alloys exhibits a phase of transformation from martensitic to the austenitic structure at the given transformation temperature. The transformation of the alloy composition of the wire starts between room temperature and the application temperature of 37°C along with dramatic changes in the wire surface structure (25). In addition, manufacturing technique may provoke the creation of rough surface where the particles of nickel and titanium were pulled out during the handling process of wire, resulting in micro cavitation trace formation, which affects the surface texture of the wire (26). There is a significant difference in the mean of surface roughness for both SS and NiTi archwires after immersion in NaF mouthwash and artificial saliva ($P<0.05$). The higher surface roughness of wires immersed in NaF mouthwash may be imputed to deterioration of passive titanium oxide layer under the influence of fluoride ion free radicles resulting in the formation of titanium fluoride destructive layer instead of titanium oxide protective layer. Furthermore, the loss of the oxide film may lead to the absorption of hydrogen from various solutions due to the high affinity of titanium to hydrogen (27). The surface roughness of both SS and NiTi wires after immersion in HMW was significantly higher, as compared to those immersed in artificial saliva ($P > 0.05$). These results are comparable to previous results obtained by Omidkhoda et al. (28) and Aghili et al. (10).

Dilipkumar et al. (29) revealed no significant change in the NiTi the wire surface topography after immersion in Noni extract HMW. These conflicting results may be attributed to the difference in materials and methodological tests. In the present study, the AFM was used to evaluate large size rectangular archwire surface topography, while Dilipkumar et al. (29) utilized SEM to evaluate small size round NiTi archwire surface topography. The bracket slot was examined by SEM and the formed photomicrographs of the immersed brackets exhibited multi small pits, extreme heterogeneous patchy area, and little pits, in HMW, NaF mouthwash, and artificial saliva, respectively. However, similar vertical crack lines appeared in all SEM photomicrographs. The heterogeneous patchy area in the slot surface of the bracket immersed in NaF mouthwash may be attributed to the degradation of chromium oxide passive layer under the influence of fluoride ion resulting in the formation of chromium fluoride. This is consistent with the finding of the study performed by Schiff et al. (30) who revealed that under SEM observations for slot surface of metal bracket immersed in fluoride mouthwash, there are changes in its surface texture which can be ascribed to the damaged passive chromium oxide layer under the influence of fluoride ions. On the contrary, artificial-saliva-immersed brackets exhibited little pits and a more homogeneous slot surface. This is in line with the finding of Lin et al. who observed small pits with vertical cracks on the slot surface of artificial saliva immersed SS bracket (31).

Another study carried out by Saporeti et al. (32) revealed that there are small white deposits on the slot surface of the SS bracket immersed in artificial saliva when examined under SEM. These reports are comparable to the results of the present study. The photomicrograph of HMW-immersed bracket exhibited multi white pits with an almost homogeneous pattern. There was a similarity in surface morphology between immersed brackets in both HMW and artificial saliva with more irregularly arranged pits in HMW, as compared to that of artificial saliva, while the more irregular surface seems to be more obvious in NaF mouthwash immersed bracket.

Intraorally, friction may be affected by many factors, such as the force of mastication, dental plaque, and saliva pH level. Therefore, the current study had some limitations since it did not include these variables. On the same note, other types of archwire were not taken into account. Consequently, future clinical studies are required to investigate the effects of HMW on frictional resistance in the case of orthodontic archwire.

Conclusion

Based on the results of the current study, HMW did not exert any significant effect on frictional resistance and surface roughness between SS brackets and the two types of orthodontic archwires made of SS and NiTi alloys. Therefore, HMW may be prescribed in orthodontics as a non-destructive prophylactic agent on materials evaluated in this study.

Conflict of interests

Authors do not have any conflicts of interest.

References

1. Burrow SJ. Friction and resistance to sliding in orthodontics: a critical review. Am J Orthod Dentofacial Orthop. 2009;135(4): 442-447.
2. Downing A, McCabe J, Gordon P. A study of frictional forces between orthodontic brackets and archwires. Br J Orthod. 1994;21(4): 349-357.
3. Grímsdóttir MR, Hensten-Pettersen A, Kullmann A. Proliferation of nickel-sensitive human lymphocytes by corrosion products of orthodontic appliances. Biomaterials. 1994;15(14): 1157-60.
4. Huang H-H. Effects of fluoride concentration and elastic tensile strain on the corrosion resistance of commercially pure titanium. Biomaterials. 2002;23(1): 59-63.
5. Watanabe I, Watanabe E. Surface changes induced by fluoride prophylactic agents on titanium-based orthodontic wires. Am J Orthod Dentofacial Orthop. 2003;123(6): 653-656.
6. Kao C-T, Ding S-J, Wang C-K, He H, Chou M-Y, Huang T-H. Comparison of frictional resistance after immersion of metal brackets and orthodontic wires in a fluoride-containing prophylactic agent. Am J Orthod Dentofacial Orthop. 2006;130(5): 568. e1- e9.
7. Lee T-H, Huang T-K, Lin S-Y, Chen L-K, Chou M-Y, Huang H-H. Corrosion resistance of different nickel-titanium archwires in acidic fluoride-containing artificial saliva. Angle Orthod. 2010;80(3): 547-553.
8. Alavi S, Farahi A. Effect of fluoride on friction between bracket and wire. Dent Res J. 2011;8(Suppl1): S37.42
9. Huang H-H. Variation in surface topography of different NiTi orthodontic archwires in various commercial fluoride-containing environments. Dent Mater. 2007;23(1): 24-33.
10. Aghili H, Yassaei S, Eslami F. Evaluation of the effect of three mouthwashes on the mechanical properties and surface morphology of several orthodontic wires: An in vitro study. Dent Res J. 2017;14(4): 252-259.

11. Kaneko K, Yokoyama Ki, Moriyama K, Asaoka K, Sakai Ji. Degradation in performance of orthodontic wires caused by hydrogen absorption during short-term immersion in 2.0% acidulated phosphate fluoride solution. Angle Orthod. 2004;74(4): 487-495.
12. Biswas G, Anup N, Acharya S, Kumawat H, Vishnani P, Tambi S. Evaluation of the efficacy of 0.2% chlorhexidine versus herbal oral rinse on plaque induced gingivitis-A randomized clinical trail. J Nurs Health Sci. 2014;3(2): 58-63.
13. Malhotra R, Grover V, Kapoor A, Saxena D. Comparison of the effectiveness of a commercially available herbal mouthrinse with chlorhexidine gluconate at the clinical and patient level. J Indian Soc Periodontol. 2011;15(4): 349-352.
14. Vasconcelos L, Sampaio FC, Sampaio MCC, Pereira MdSV, Higino JS, Peixoto MHP. Minimum inhibitory concentration of adherence of Punica granatum Linn (pomegranate) gel against S. mutans, S. mitis and C. albicans. Brazilian Dental Journal. 2006;17(3):223-227.
15. Kukreja BJ, Dodwad V. HMWes-A gift of nature. Int J Pharma Bio Sci. 2012;3(2):46-52.
16. Nishio C, da Motta AFJ, Elias CN, Mucha JN. In vitro evaluation of frictional forces between archwires and ceramic brackets. Am J Orthod Dentofacial Orthoped. 2004;125(1): 56-64.
17. Kapila S, Angolkar PV, Duncanson MG, Nanda RS. Evaluation of friction between edgewise stainless steel brackets and orthodontic wires of four alloys. Am J Orthod Dentofacial Orthoped. 1990;98(2): 117-26.
18. Huang H-H, Chiu Y-H, Lee T-H, Wu S-C, Yang H-W, Su K-H, et al. Ion release from NiTi orthodontic wires in artificial saliva with various acidities. Biomaterials. 2003;24(20): 3585-3592.
19. Heravi F, Moayed MH, Mokhber N. Effect of fluoride on nickel-titanium and stainless steel orthodontic archwires: an in-vitro study. J Dent (Tehran). 2015;12(1): 49-59.
20. Geramy A, Hooshmand T, Etezadi T. Effect of Sodium Fluoride Mouthwash on the Frictional Resistance of Orthodontic Wires. J Dent (Tehran). 2017;14(5):254-258.
21. Lee J, Kim HY, Zhou H, Hwang S, Koh K, Han D-W, et al. Green synthesis of phytochemical-stabilized Au nanoparticles under ambient conditions and their biocompatibility and antioxidative activity. J Mater Chem. 2011;21(35): 13316-13326.
22. Choudhary J, Shashikumar B, Patil AK. Evaluation and Comparison of Two Different Mouthwashes on Frictional Resistance Between Orthodontic Bracket and Archwire: An in Vitro Study. J Indian Orthod. Soc. 2019;53(2):117-125.
23. D'Antò V, Rongo R, Ametrano G, Spagnuolo G, Manzo P, Martina R, et al. Evaluation of surface roughness of orthodontic wires by means of atomic force microscopy. Angle Orthod. 2012;82(5): 922-928.
24. Kusy RP, Whitley JQ, de Araújo Gurgel J. Comparisons of surface roughnesses and sliding resistances of 6 titanium-based or TMA-type archwires. Am J Orthod Dentofacial Orthoped. 2004;126(5): 589-603.
25. Miura F, Mogi M, Ohura Y, Hamanaka H. The super-elastic property of the Japanese NiTi alloy wire for use in orthodontics. Am J Orthod Dentofacial Orthoped. 1986;90(1): 1-10.
26. Gravina MA, Canavarro C, Elias CN, Chaves MdGAM, Brunharo IHVP, Quintão CCA. Mechanical properties of NiTi and CuNiTi wires used in orthodontic treatment. Part 2: Microscopic surface appraisal and metallurgical characteristics. Dental press J Orthod. 2014;19(1): 69-76.
27. Yokoyama Ki, Kaneko K, Moriyama K, Asaoka K, Sakai Ji, Nagumo M. Hydrogen embrittlement of Ni-Ti superelastic alloy in fluoride solution. Journal of Biomedical Materials Research Part A: An Official Journal of The Society for Biomaterials, 2003;65(2): 182-187.
28. Omidkhoda M, Poosti M, Sahebnasagh Z, Zebarjad SM, Sahebnasagh Z. Effects of three different mouthwashes on the surface characteristics of nickel-titanium and Stainless steel archwires in orthodontics. J Dent Mater Techniques. 2017;6(1): 19-26.
29. Dilipkumar D, Dhinahar S, Deenadayalan P, Tandon A, Suresh P. Repercussion of noni mouthwash on surface characterization of Nickel-Titanium archwire. Indian J Dent Res. 2017;28(6): 671674.
30. Schiff N, Dalard F, Lissac M, Morgon L, Grosgogeat B. Corrosion resistance of three orthodontic brackets: a comparative study of three fluoride mouthwashes. The Eur J Orthod. 2005;27(6): 541-549.
31. Lin M-C, Lin S-C, Lee T-H, Huang H-H. Surface analysis and corrosion resistance of different stainless steel orthodontic brackets in artificial saliva. Angle Orthod. 2006;76(2): 322-329.
32. Saporeti MP, Mazzieiro ET, Sales WF. In vitro corrosion of metallic orthodontic brackets: influence of artificial saliva with and without fluorides. Dental Press J Orthod. 2012;17(6): 24e1-24e7.

Corresponding Author
Naser Abdelgader Alwafe
Post graduate student in Orthodontic department,
School of Dentistry, Mansoura University, Mansoura, Egypt
Phone number: (002)01121566477
E-mail address: nassar.198311@gmail.com