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Original Article

Effect of fluoride on friction between bracket and wire

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ABSTRACT

Background: Friction is usually encountered during sliding technique for orthodontic space closure. This study aims to investigate the effect of fluoride on frictional resistance between stainless steel orthodontic brackets and steel and NiTi arch wires.

Materials and Methods: A total of 144 standard 022 stainless steel brackets were used in this experimental study. 0.016 and 0.019 × 0.025 inch steel and NiTi arch wires were tested. The frictional resistance between wires and brackets immersed in the following three solutions were measured: Sultan fluoride gel containing 1.23% acidulated phosphate fluoride at pH 3.5 for 4 minutes, aquafresh mouth wash containing 0.05% sodium fluoride at pH of 5.1 for 1 minute twice a day for 8 weeks and physiologic serum (pH=7) as the control group. Static and dynamic frictional forces were measured using Testometric machine. Surface topography of wires and brackets was qualitatively assessed using electron microscopy. Three-way and two-way variance analysis and complementary Tuckey analysis were applied to compare the groups for any significant differences ($P<0.05$).

Results: The average static and dynamic frictional forces for all bracket-wire combinations immersed in Sultan fluoride gel were higher than those immersed in NAF and control groups ($P<0.001$). The forces measured for rectangular wires were higher than round wires ($P<0.001$). Frictional resistance of 0.016 inch NiTi wire was more than that of the steel one but the difference between steel and NiTi 0.019 × 0.25 arch wires was not significant.

Conclusion: Friction between steel brackets and nickel titanium and steel wires is affected by prophylactic agents containing high doses of fluoride and acidity.

Key Words: Fluoride, friction, orthodontic bracket, sliding mechanics

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INTRODUCTION

A method of tooth movement in orthodontic treatment is the sliding technique. Friction plays an important role in the sliding technique; therefore it is called frictional technique.[1] Surface roughness of bracket increases the frictional resistance between bracket and wire.[2] It is confirmed in frequent studies that surface quality is an important factor in friction.[1] Probster *et al*.[3] and Tuomelin *et al*.[4] reported that the affected surface of the titanium wire by acidic content in fluorided prophylactic agents showed corrosion and roughness. Reclaru *et al*.[5] reported that corrosive and pitting changes on titanium surface occurred at the pH under 3.5. Kaneko *et al*.[6] evaluated the effects of fluoride on orthodontic wires. They incubated titanium molybdenium alloy (TMA), stainless steel (SS), and nickel titanium (NiTi) wires in (APF) 2% at the temperature of 37°C for 60 minutes. Surface roughness of all wires was obvious under electron microscope. Huang,[7] noticed the significant increase in surface roughness with the fluoride content more than 2500 ppm. Kwon *et al*.[8] compared the effects of different concentrations (0.2%, 0.05%) and pH values (4, 6) of acidulated sodium fluoride mouth washes on wire surfaces. They reported severe changes in surface morphology and color with the concentration of 0.2 and at pH of 4. Kao *et al*.[9] reported that the frictional resistance following immersion of TMA,

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NiTi, and SS wires in APF 0.2% was higher than artificial saliva at pH of 6.75. Li *et al*.[10] evaluated the effects of chloride and fluoride on orthodontic wires, chloride and fluoride induced localized and generalized corrosion on NiTi wires respectively; and when both chemicals applied, the wires suffered from severe corrosion indicating synergistic effect of these two chemicals.

A high frictional resistance may lead to debonding of bracket, loss of anchorage, and restricting dental movement; therefore, lowering the frictional resistance is an important issue.

Several factors may directly or indirectly affect the friction between wire and bracket. Some factors are related to orthodontic wires (i.e., alloy type, shape and diameter of wires); type of ligation and bracket production method (sintering vs. casting) are other factors. The biological factors affecting frictional resistance include saliva, acquired pellicle, plaqueetc.[1]

Among the factors, which have rarely been investigated, fluoride has a possible effect on orthodontic appliances in the mouth. Maximum fluoride concentration in different types of tooth pastes and mouth washes is 1%. Agents containing fluoride have a pH between 3.5 and 7. These agents contain fluoride ions which can damage the oxidized layer formed on titanium surface. A low amount of fluoride in an acidic agent leads to hydrofluoric acid (HF) formation according to the following reaction: $Naf + H^{+}$àHF + Na^{+}.[2] The resulting HF may react with inactive oxidized layer on stainless steel alloys and damage this layer ($Cr_2O_3 + 6HF$ à $2CrF_3 + 3H_2O$).[3]

This study aimed to evaluate the effect of fluoride on frictional resistance between stainless steel brackets and the wires made of steel, and nickel–titanium. It also aimed to investigate the surface topography of wires and brackets before and after immersion in solutions containing fluoride.

MATERIALS AND METHODS

In this experimental laboratory study, 144 sets of bracket-arch wire were placed equally and similarly in two test groups and one control group, which formed four subgroups in each group. Standard stainless steel brackets (Ortho-Organaizer, Carlsband, CA) with slot size of 0.022 inches were used in all sets. The wires were made of steel and nickel–titanium (G and H, Franklin, IN) in sizes of 0.016 and 0.019 × 0.025 inches that formed the four subgroups. Therefore the combination of sets in all three groups was the same. In order to insert arch wire into the bracket's slot, conventional elastomeric modules (Ortho Organaizer, Carlsband, CA) were used.

Sets of one test group (APF group) were immersed in a Sultan fluoride gel (Sultan Health care, Engle wood, USA) containing 1.23% available fluoride, hydrofluoric acid, phosphoric acid, sodium fluoride at pH of 3.5 and 37°C for 4 minutes, then were kept in a closed container with 150 ml of physiologic serum at 37°C for 8 weeks. Sets of the other test group (NAF group) were immersed in aquafresh fluoride mouth wash (Glaxo-Smith Kline, Brent ford, UK) containing sodium fluoride 0.05% w/w, cetylpyridinium chloride 0.05% w/w at pH of 5.1 and 37°C for 1 minute two times a day during 8 weeks and were kept in a closed container same as the APF group in intervals. Sets of the control group were immersed and kept in 150 ml of physiologic serum (Iran, Tehran, Darupakhsh) at pH7 and 37°C for 8 weeks. The physiologic serum was replenished every day.

Finally, to measure frictional force, the brackets were precisely placed on the center of the cross section of aluminum cylinders so that the bracket slots were in the direction of the specified diameter. For doing this a wire jig, 0.021×0.028 inches in thickness was used. The jig allows passive and similar positioning of brackets so that friction is not affected by undesirable movements.[9] Pieces of the orthodontic wires 6.5 centimeters in length were shaped as a hook at the terminal part to hang the 150 g counterweight and ligated in the bracket slots using O-rings. The set of bracket–arch wire–cylinder was installed in an appliance designed for this purpose. The appliance had a circular hole 1 cm in diameter located 1.5 cm off the upper edge to install the bracket and wire containing cylinder. The appliance had two 2 cm long pins which were located 1 cm off the center of cylinder to guide the arch wire while the tensile test was applied. To test the friction, Testometirc machine (London, UK, series M50-25 CT) at the speed of 0.5 mm/min was used for 4 minutes and the wire was moved 2 mm in slot in each test. A graph of applied force was plotted on the monitor screen and recorded in Newton scale. The peak of the applied force was considered as the static frictional force and the mean of points on horizontal part of the graph following the peak was considered as the dynamic frictional force.

Using an electronic microscope with magnification of 1500 times, micrographs were taken of the brackets and wires.

The data were analyzed applying Statistical package for the social sciences (SPSS) software (version 11).

A three-way two-way variance analysis (ANOVA) test was applied to compare static and dynamic frictional forces and a two-way ANOVA test was also applied as a complementary test. A Tuckey test was used to compare group means ranking at $P<0.05$.

RESULTS

Three-way ANOVA test indicated that there was a significant difference between static and dynamic frictional forces in all groups.

Two-way ANOVA and Tuckey complementary tests showed that the mean static and dynamic frictional forces for 0.016 inch NiTi wire was higher than 0.016 inch steel wire ($P<0.05$). However, comparing the same value for 0.019 × 0.025 inch NiTi and steel wire showed no statistically significant difference [Tables 1 and 2].

Tables 3 and 4 indicate that static and dynamic frictional forces of the APF group were higher than NAF and control groups and the differences between these media were significant ($P<0.001$). The same value was not significantly different for NAF and control groups.

Qualitative assessment of images of steel brackets and NiTi wires by electronic microscopy suggested that surface roughness of brackets and wires placed in a Sultan gel was more than that of control and aquafresh groups. The roughness of the control and aquafresh groups seemed to be identical [Figures 1-6].

Table 1: Descriptive statistic data of static and dynamic frictional forces of wires

Wire	*N*	Solution	Static (μ ± SD) (Nioton)	Dynamic (μ ± SD) (Nioton)
16ss	12	NAF (aquafresh)	1.07 (0.211)	0.98 (0.19)
	12	APF (Sultan)	1.55 (0.57)	1.42 (0.51)
	12	Serum (control)	1.06 (0.13)	0.97 (0.13)
	36	Total	1.23 (0.41)	1.12 (0.38)
16NiTi	12	NAF (aquafresh)	1.30 (0.25)	1.23 (0.25)
	12	APF (Sultan)	1.76 (0.39)	1.58 (0.41)
	12	Serum (control)	1.36 (0.20)	1.26 (0.20)
	36	Total	1.47 (0.35)	1.36 (0.33)
19 × 25ss	12	NAF (aquafresh)	1.87 (0.28)	1.67 (0.26)
	12	APF (Sultan)	2.47 (0.74)	2.30 (0.78)
	12	Serum (control)	1.93 (0.37)	1.70 (0.29)
	36	Total	2.09 (0.56)	1.89 (0.57)
19 × 25NiTi	12	NAF (aquafresh)	1.76 (0.35)	1.67 (0.35)
	12	APF (Sultan)	2.23 (0.26)	2.10 (0.27)
	12	Serum (control)	1.94 (0.25)	1.80 (0.28)
	36	Total	1.98 (0.34)	1.86 (0.34)

Table 2: Two-way ANOVA of static and dynamic frictional forces in different wires

Wire	Wire groups	*P* value (static)	*P* value (dynamic)
SS 0.016	NiTi 0.016	0.031	0.039
	SS 0.025 × 0.019	0.000	0.000
	NiTi 0.025 × 0.019	0.000	0.000
NiTi 0.016	SS 0.016	0.031	0.039
	SS 0.025 × 0.019	0.000	0.000
	NiTi 0.025 × 0.019	0.000	0.000
SS 0.025 × 0.019	SS 0.016	0.000	0.000
	NiTi 0.016	0.000	0.000
	NiTi 0.025 × 0.019	0.561	0.981
NiTi 0.025 × 0.019	SS 0.016	0.000	0.000
	NiTi 0.016	0.000	0.000
	SS 0.025 × 0.019	0.561	0.981

ANOVA: Analysis of variance

DISCUSSION

There is not enough information on the effect of fluoride containing prophylactic agents on the friction between steel brackets and orthodontic steel and nickel titanium wires. Toothpastes and mouth washes normally contain fluoride. Evaluating the effect of fluoride on orthodontic devices is a necessity. In the present study, several combinations of wire-bracket setups were immersed in two different fluoride solutions to simulate the condition of mouth and they were all compared to the control group. The reason of 4-minute immersion time for the APF group was that according to the instruction of the Sultan fluoride gel manufacturer, the application of gel is every 3 months and since the orthodontic wire is kept in the mouth for an average of 2 months, the bracket and arch wire are exposed to the gel once. According to the instruction of the aquafresh (NAF 0.05%) manufacturer, the mouth wash is used twice a day for 1 minute each time. Orthodontic wire is kept in the mouth for 2 months; therefore it is exposed to mouth wash for 8 weeks which means a total exposure of 120 minutes.

Pulling speed adjustment of the Testometric machine was according to previous studies.[11,12] The present study showed that the mean of static and dynamic frictional forces of the 0.016 inch NiTi wire was higher than that of the 0.016 inch steel wire ($P<0.05$). This was due to titanium content in the NiTi wire, and increased surface activity of this type of wire against steel brackets. However, the values were not significantly different for 0.019 × 0.025 inch NiTi and steel wires.

Table 3: Descriptive statistic data of static and dynamic frictional forces of solutions

Solution	Wire	N	Static (μ ± SD) (Nioton)	Dynamic (μ ± SD) (Nioton)
NAF (aquafresh)	16ss	12	1.0 (0.21)	0.98 (0.19)
	16 NiTi	12	1.30 (0.25)	1.23 (0.25)
	19*25ss	12	1.87 (0.28)	1.67 (0.26)
	19*25 NiTi	12	1.76 (0.35)	1.67 (0.35)
	Total	48	1.50 (0.43)	1.39 (0.40)
APF (Sultan)	16ss	12	1.55 (0.57)	1.42 (0.51)
	16 NiTi	12	1.76 (0.39)	1.58 (0.41)
	19*25ss	12	2.47 (0.74)	2.30 (0.78)
	19*25 NiTi	12	2.23 (0.26)	2.10 (0.27)
	Total	48	2.00 (0.63)	1.85 (0.62)
Serum (control)	16ss	12	1.06 (0.13)	0.97 (0.13)
	16 NiTi	12	1.36 (0.20)	1.26 (0.20)
	19*25ss	12	1.93 (0.37)	1.70 (0.29)
	19*25 NiTi	12	1.94 (0.25)	1.80 (0.28)
	Total	48	1.57 (0.45)	1.43 (0.41)

The results of our study are consistent with Kusy's study on round wires.[2] However Cassiafesta and Wadhawa did not find any significant different frictional force between steel and NiTi wires.[13,14] This is probably due to using of full size wires in their study which filled a large space of the slot and

Table 4: Two-way ANOVA of static and dynamic frictional forces in different solutions

Solution	Type of solutions	*P* value (static)	*P* value (dynamic)
Aquafresh	Sultan	0.000	0.000
	Control	0.648	0.818
Sultan	Aquafresh	0.000	0.000
	Control	0.000	0.000
Control	Aquafresh	0.648	0.818
	Sultan	0.000	0.000

ANOVA: Analysis of variance

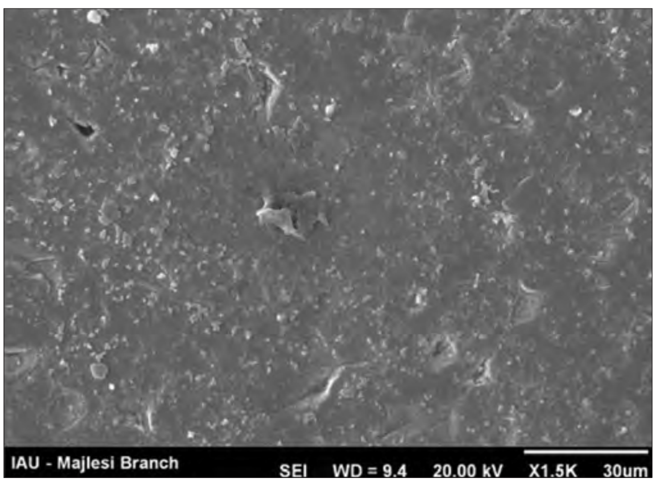

Figure 1: Steel bracket in sultan gel

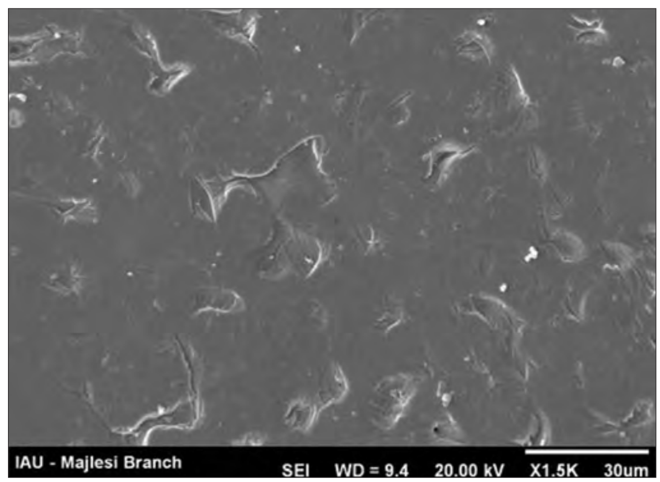

Figure 2: Steel bracket in Aquafresh solution

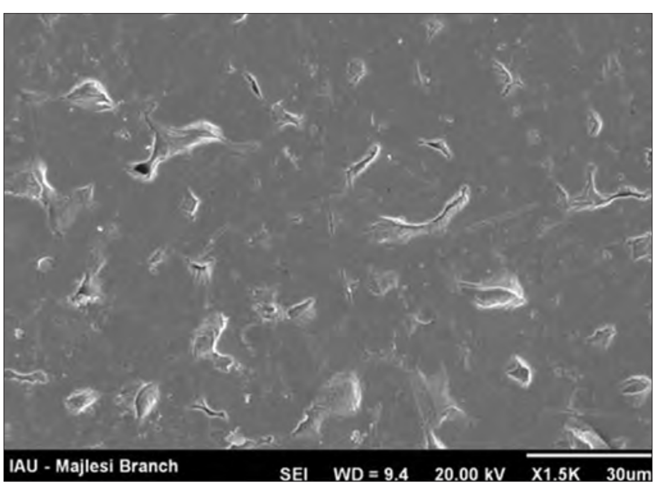

Figure 3: Steel bracket in control solution

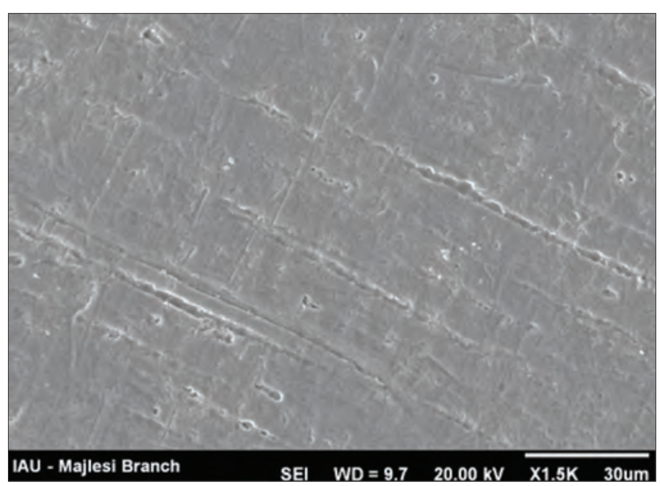

Figure 4: 0.019 × 0.025 inch NiTi in sultan gel

Figure 5: 0.019 × 0.025 inch NiTi in Aquafresh solution

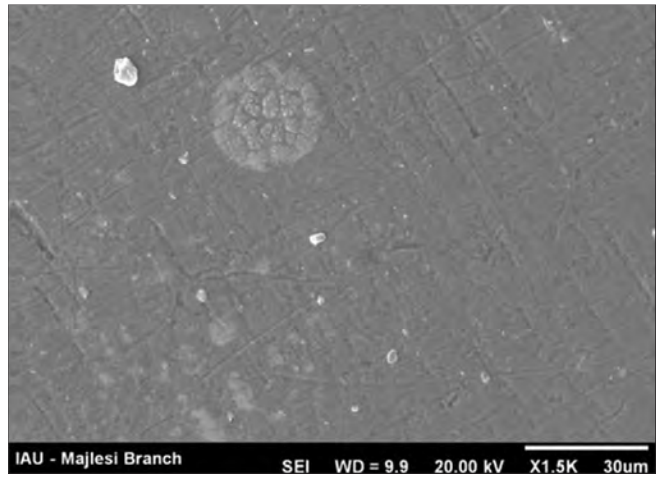

Figure 6: 0.019 × 0.025 inch NiTi in control solution

caused the difference in frictional force related to the material of wire to be eliminated. In our study, this issue was true in the case of rectangular wires.

In the present study, the frictional force of 0.019 × 0.025 inch wires was higher than that of 0.016 inch wires. This was true for both steel and NiTi wires (P<0.001) [Tables 1 and 2]. In rectangular wires, the contact surface between wire and bracket is increased which is an important factor in friction.

Bedenar, Tanne and Cassiafesta[13,15,16] also suggested that dynamic and static frictional forces are increased in larger wire diameters. It is consistent with our findings.

However, Frank and Nicolai[17] reported that the friction of round wires was higher than rectangular ones. The reason of their statement was that in cases with angular bracket, effective factor on friction is contact points between wire and bracket edge. In a round wire, the bracket slot contacts with wire in one point with the wire which causes the wire to be indented. However, in a rectangular wire, contact points are labio-lingual and distributed on the surface which leads to less pressure; therefore, there is less resistance against movement.

In our study, no significant difference in fictional force was found between control and NAF (0.05%) groups. However, the mean of static and dynamic frictional force in the APF group (1.23% flouride) was higher and significantly different from that of the control and NAF groups (P<0.001).

Fluoride-containing agents have pH between 3.5 and 7 which have fluoride ions that are able to damage the oxidized layer formed on the titanium and steel surfaces and causes corrosion and roughness of the wire surface. The results of our study are consistent with Kao's study on APF. In this study, the dynamic and static frictional force of the APF group was higher than that of the artificial saliva (pH 6.75) group for NiTi, TMA, and steel wires.[9] This was due to increased frictional force caused by corrosion of titanium containing wires and steel brackets in fluoride and acid containing agents.

In our study, the mean values of dynamic and static frictional forces of the NAF group (0.05%) was not significantly different from control group which was due to lower concentration of fluoride ions and lower acidity in NAF group compared to APF group. This fact may be the reason of less corrosion and surface roughness of steel and NiTi brackets and wires of NAF group which leads to lower static and dynamic frictional forces of NAF group compared to the Sultan gel group.

Our results are consistent with Schiff's results. He suggested that nickel titanium alloy is prone to high corrosion in the presence of monoflurophosphate.[18] Two years later, Schiff obtained the same results as ours.[19] He found that Meridol mouth wash which contains higher fluoride concentration and lower acidity than Elmex mouth wash, leads to more corrosion of NiTi wires. As it can be seen in Figures 1-6, the wire's and bracket's roughness that had been placed in APF Sultan was higher than those placed in NAF and physiologic serum.

This is due to more corrosion of steel and NiTi wires and steel brackets in solutions with higher fluoride concentration and acidity.

Walkers found that changes in surface topography of NiTi and copper NiTi wires after being placed in the Phosflur gel (pH=5.1) were more than those placed in a Prevident solution (pH=7).[20] His study's results were consistent with ours in that the higher acidity caused more changes in surface topography of wires.

Through a similar study Haung stated that more roughness and change in surface topography of NiTi wires were seen with higher fluoride concentration.[7]

CONCLUSION

The present *in vitro* study indicated that using Sultan topical fluoride gel (APF 1.23%, pH=3.5) in the presence of steel bracket and NiTi and steel wires can increase frictional forces. Therefore, we recommend using prophylactic agents that have high pH and low concentration of fluoride during sliding mechanics for tooth movement.

REFERENCES

1. Nanda R. Biomechanics in clinical orthodontics. First ed.Chap 10. Philadelphia: WB Saunders; 1997. p. 188-214.
2. Kusy RP, Whitley JQ. Effects of surface roughness on the coefficients of friction in model orthodontic systems. J Biomech 1990;23:913-25.
3. Probster L, Weili L, Horst H. Effect of Fluoride prophylactic agents on titanium srufaces. Int J Oral Maxillofac Implants 1992;7:390-4.
4. Toumelin-Chemla F, Rouelle F, Burdairon G. Corrosive properties of fluoride-containing odontologic gels against titanium. J Dent 1996;24:109-15.
5. Reclaru L, Meyer JM. Effects of fluorides on titanium and other dental alloys in dentistry. Biomaterials 1998;19:85-92.
6. Kaneko K, Yokoyama K, Morivama K, Asaoka K, Sakai J. Degradation in performance of orthodontic wires caused by hydrogen absorption during short-term immersion in 2.0% acidulated phosphate fluoride solution. Angle Orthod 2004;74:487-95.
7. Huang HH. Variation in surface topography of different NiTi orthodontic arch wires in various commercial fluoride-containing environments. Dent Mater 2007;23:24-33.
8. Kwon Y, Cho H, Noh D, Kim H, Kim K. Evalueation of the effect of fluoride containing acetic acid on nickel titanium wires. J Biomed Mater 2005;72:102-8.
9. Kao CT, Ding SJ, Wang CK, He H, Chou MY, Huang TH. Comparison of frictional resistance after immersion of metal brackets and orthodontic wires in a fluoride – containing prophylaticagent. Am J Orthod Dentofacial Orthop 2006;130:568-77.
10. Li X, Wang J, Han EH, Ke W. Influence of fluoride and chloride on corrosion behavior of NiTi orthodontic wires. Acta Biomater 2007;3:807-15.
11. Tecco S, Festa F, Caputi S, Traini T, Di Iorio D, D'Attilio M. Friction of conventional and self-ligating brackets using a 10 bracket model. Angle Orthod 2005;75:1041-5.
12. Edwards GD, Davies EH, Jones SP. The exvivo effect of ligation technique on the static frictional resistance of stainless steel brackets and archwire. Br J Orthod 1995;22:145-53.
13. Cacciafesta V, Sfondrini MF, Scribante A, Klersy C, Auricchio F. Evaluation of friction of conventional and metal-insert ceramic brackets in various bracket- arch wire combinations. Am J Orthod Dentofacial Orthop 2003;124:403-9.
14. Kapur Wadhawa R, Kwon HK, Sciote JJ, Close JM. Frictional resistance in ceramic and metal brackets. J Clin Orthod 2004;38:35-8.
15. Bedenar JR, Gruendeman GW, Sandrik JL. A comparative study of frictional forces between orthodontic brackets and arch wires. Am J Orthod Dentofacial Orthop 1991;100:513-22.
16. Tanne K, Matsubara S, Shibaguchi T, Sakuda M. Wire friction from ceramic brackets during simulated canine retraction. Angle Orthod 1991;61:285-90.
17. Frank CA, Nikolai RJ. A comparative study of frictional resistances between orthodontic bracket and arch wire. Am J Orthod 1980;78:593-609.
18. Schiff N, Grosgogeat B, Lissac M, Dalard F. Influence of fluoridated mouthwashes on corrosion resistance of orthodontics wires. Biomaterials 2004;25:4535-42.
19. Schiff N, Boinet M, Morgon L, Lissac M, Dalard F, Grosgogeat B. Galvanic corrosion between orthodontic wires and brackets in fluoride mouthwashes. Eur J Orthod 2006;28:298-304.
20. Walker MP, White RJ, Kula KS. Effect of fluoride prophylactic agents on the mechanical properties of nickel titanium based orthodontic wires. Am J Orthod Dentofacial Orthop 2005;127:662-9.

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