

Original Article

Surface characterization and frictional force between stainless steel brackets and archwires in orthodontic patients using chlorhexidine- and Persica-containing mouthrinses: A randomized controlled trial

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ABSTRACT

Background: The aim of this study was to compare the effect of chlorhexidine- and Persica-containing mouthrinses on the surface characterization of orthodontic appliance and friction between the orthodontic stainless steel wires and brackets.

Materials and Methods: In this randomized controlled trial, 75 orthodontic patients (aged 13–30) were allocated ($n = 25$) into two experimental groups (prescribed by Persica- or chlorhexidine-containing mouthrinse) and one control group (no prescription). The ovoid stainless steel archwires were placed, and the maxillary first premolar stainless steel edgewise brackets were ligated to wires by elastomeric rings. The patients were recalled after 2 weeks, and then, the archwires were removed and replaced. The surface analysis of archwires and brackets was evaluated using scanning electron microscopy and atomic force microscopy. The frictional forces between the archwires and brackets were measured using a universal testing machine. The data for surface roughness were analyzed by the nonparametric Kruskal–Wallis and Mann–Whitney tests. The frictional forces data were analyzed using a two-way analysis of variance and Tukey's *post hoc* test using SPSS software. The level of significance was $P < 0.05$.

Results: The retrieved brackets showed minor changes in their surface topography. The surface roughness of archwires after the intervention was significantly greater for the chlorhexidine than that of Persica ($P < 0.05$). The friction force between the archwires and brackets was also significantly higher for the chlorhexidine than that of Persica ($P < 0.05$).

Conclusion: The Persica-containing mouthrinse from the biomechanical and biochemical standpoints may be a better option for oral hygiene in orthodontic patients compared with the chlorhexidine.

Key Words: Friction, mouthrinse, orthodontic bracket, surface, wire

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INTRODUCTION

Implementation of an individualized oral hygiene care program for every patient during orthodontic treatment is necessary to achieve successful outcome. Brushing and cleaning the teeth will become difficult when orthodontic appliances are in place.^[1] Furthermore, after bonding of orthodontic attachments, the level of *Streptococcus mutans* and lactobacilli increases in the oral cavity.^[2]

Chlorhexidine is a well-known mouthwash and is usually used for the treatment of gingivitis and/or periodontitis which many clinicians prescribe it for orthodontic patients. It has antiplaque effects, can inhibit the activity of acidogenic bacteria, and thus, can prevent dental caries.^[3-5] Therefore, chlorhexidine has been considered as a gold standard for testing the efficacy of other mouthrinses in most studies.^[6-10] On the other hand, chlorhexidine has some side effects such as tooth discoloration and sense of burning or dryness in the mouth.^[11,12]

Persica is an herbal antibacterial agent; it is prepared from *Salvadora persica* extract and assumed useful for dental and periodontal health. Several studies have evaluated the efficacy of Persica products.^[5,13,14] The available literature shows that using Persica or its extract is effective in the reduction of dental plaque accumulation and bleeding on brushing, can control gingivitis and periodontal diseases, and also can reduce the number of *S. mutans* colonies. Therefore, it could be effective in the prevention of dental caries.^[13,15-20] There is some evidence that Persica and chlorhexidine are equally effective in control of gingival inflammation.^[20] However, the mouthrinses due to their ions and pH can be harmful to orthodontic appliances. Several studies have investigated the role and effect of prophylactic agents on the corrosion, mechanical properties, surface characterization of the orthodontic appliance, and the friction of sliding movement.^[21-25]

In the mechanical terminology, friction is a force that resists the relative motion of two objects in contact and its direction is tangential to the shared interface of the surfaces. In orthodontic practice, friction is usually an unfavorable force; it opposes the sliding mechanics of tooth movement, can disturb light continuous forces, and can destroy guided tooth movement along the archwire. However, sometimes, the orthodontist decides to burn anchorage for specific purposes and benefits from the frictional forces.^[26]

Another issue that is of much interest to be investigated is surface roughness. Surface characterization of orthodontic wires and brackets after immersion in the fluoride-containing mouthrinses has been already investigated, and the derived conclusion was that fluoride could increase the surface roughness of fixed orthodontic appliances.^[23,27-30]

Aghili *et al.*^[31] evaluated the effect of chlorhexidine-, fluoride-, and herbal-containing mouthwashes on the surface characterization and mechanical properties of stainless steel, nickel–titanium (NiTi), and coated archwires. They concluded that all mouthwashes changed the mechanical properties and surface quality of the orthodontic wires during treatment. Huang *et al.*^[21] introduced diamond-like carbon (DLC) films onto NiTi orthodontic archwires in order to protect the archwire against fluoride-induced corrosion and also to reduce the friction. Their results showed that after immersion in a high fluoride ion environment, the variation in the surface roughness was less than that of other groups. In addition, the friction tests showed that applying a DLC coating, both in ambient air and artificial saliva decreased the fretting corrosion and the coefficient of friction significantly. Hosseinzadeh Nik *et al.*^[32] investigated the effect of chlorhexidine-containing prophylactic agent on the surface roughness and static friction of stainless steel and NiTi wires and stainless steel brackets *in vitro*. They concluded that immersion in the chlorhexidine solution did not have a significant influence on the surface roughness of archwires or on the frictional resistance between brackets and archwires.

To our knowledge, the majority of the studies in this field are *in vitro* and laboratory-based and the clinician cannot extrapolate the obtained results to the real oral conditions. In the present study, we aimed to compare the effect of chlorhexidine and Persica-containing mouthrinses on the surface characterization of orthodontic appliance and the friction between stainless steel archwires and brackets in patients with orthodontic treatment.

MATERIALS AND METHODS

This study was a randomized, parallel-group, and active-controlled trial with a 1:1 allocation ratio. The patients who were under orthodontic treatment with fixed appliances were considered. The inclusion criteria for the participants were as follows: healthy controls with no history or presence of metabolic, salivary gland, or systemic diseases, age between 13 and 30 years, and

ability to control oral hygiene. The treatment plans for the patients were 2 or 4 premolar extractions, and the patients were at the phase of anterior retraction with 19×25 stainless steel wires. At the time of intervention, anterior retraction had not been yet started. Therefore, there was a free space on the wire at the extraction site which we ligated the brackets. The exclusion criteria were as follows: consuming medicated ions that affect the amount or consistency of saliva, consuming any other mouthrinse, smoking and drug abusing, and pregnancy or breastfeeding.

One hundred patients (between 13 and 30 years) participated in this study. By considering the exclusion criteria, 25 patients were excluded from the study. The remaining 75 patients were randomly allocated into two experimental groups (prescribed by Persica or chlorhexidine mouthrinse) and one control group with no prescription ($n = 25$), as shown in Figure 1. Written ethical consent approved by the Medical Ethics

Committee of National University (ethical approval ID. IRCT2014032117067N1) was obtained from the patients according to the Declaration of Helsinki.

Three paper cards were prepared, and the letters “A,” “E,” and “L” were written on them. There are the last letters of “Persica,” “chlorhexidine,” and “control.” Each patient took the card, and the clinician gave her/him the hygienic package. When any of the groups was completed, the attributed card was removed. Patients with completely healthy gingiva without manifestation of gingivitis were excluded from the chlorhexidine group and the randomization performed again for new samples. The hygienic package contained an orthodontic toothbrush, toothpaste, and the mouthrines for the two experimental groups.

The ovoid stainless steel archwires of 0.019×0.025 -inch (3M Unitek, Monrovia, California, USA) were placed in the mouth, and

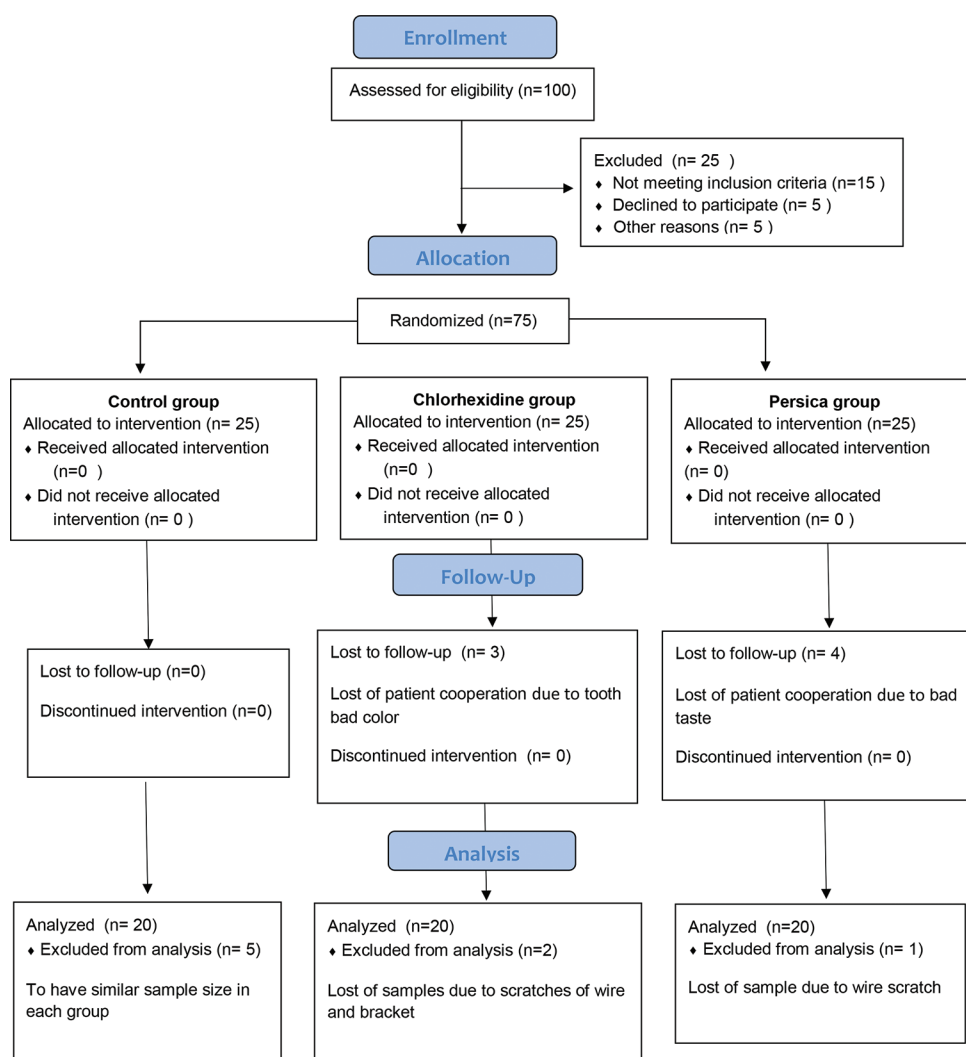


Figure 1: Participant flowchart.

the maxillary first premolar stainless steel edgewise brackets (Master Series, American Orthodontics Ltd., Sheboygan, WI, USA) were ligated to wires by elastomeric rings (American Orthodontics Ltd., Sheboygan, WI, USA). The bracket which we planned to analyze its surface roughness was not bonded to any tooth because, at the end of the intervention, it must have been debonded. Furthermore, the bracket became useless for friction and surface analysis during debonding. Therefore, for the prevention of inevitable changes in the bracket face during debonding, they were freely attached to the wire, as shown in Figure 2. It was obvious that during 2 weeks of intervention, the bracket had some movement on the wire. Thus, the segment of the wire which was approximate to the bracket was used nor for the surface characteristics neither the friction analysis. The ligation of brackets was done with orthodontic ligature gun for minimizing the bracket deformation. The brackets were ligated firmly to the archwires such that they did not move even with tongue movement. As only the slot of brackets was analyzed for surface topography evaluation, there were minimum concerns about surface deformation or alteration during ligation of brackets. It should be also noted that saliva acted as a lubricant in this clinical study.

After allocation of the patients in any of the three groups, the hygienic package instructions were given to the patients as follows:

Persica group

Rinse your mouth with 30 ml (2 tablespoons) of diluted Persica herbal mouthwash (Poursina Pharmaceutical Laboratories) containing extracts of *S. persica*, mint, and yarrow with the main ingredients



Figure 2: The ligated brackets to archwires in a patient's mouth.

of tannin, flavonoid, calcium, fluoride, chloride, and essence (15 cc Persica and 15 cc water) twice daily (morning and night) for 30 s after brushing for 2 weeks. You must not rinse your mouth with water or mouthwashes, brush your teeth, or eat immediately after using Persica for half an hour. You should clean your teeth with Oral-B toothbrush and Crest Gum Protection toothpaste.

Chlorhexidine group

Rinse your mouth with 30 ml (2 tablespoons) of undiluted chlorhexidine (Behsa Laboratories, Tehran, Iran) with 0.2% chlorhexidine digluconate and 13.65% ethanol twice daily (morning and night) for 30 s after brushing for 2 weeks. You must expectorate the chlorhexidine after rinsing and must not rinse your mouth with water or mouthwashes, brush your teeth, or eat immediately after using chlorhexidine for half an hour. You should clean your teeth with Oral-B toothbrush and Crest Gum Protection toothpaste.

Control group

You should clean your teeth with Oral-B toothbrush and Crest Gum Protection toothpaste twice daily for 2 weeks.

Two weeks after using hygienic package, the patients were recalled and the archwires were removed and replaced by the same orthodontist. An attempt was made to maintain arch dimensions by replacing the wires. The retrieved brackets and archwires were cleaned with 70% ethanol and cotton roll. Three patients from the chlorhexidine group because of tooth coloration and four patients in the Persica group because of bad taste were lost. In addition, two wires and brackets in the chlorhexidine group and one in the Persica group had major scratches that made surface analysis very difficult, and thus, we decided to exclude them. In order to have similar sample size in each group, five samples from the control group were excluded.

Then, the surface roughness of stainless steel archwires was quantitatively measured by atomic force microscopy (AFM). Ten millimeters of each as-received and retrieved preformed archwire was referred for surface analysis. AFM (Dualscope/Rasterscope C26, DME, Denmark) was operated in contact mode under ambient conditions. Before surface analysis, the archwires were cleaned in acetone in an ultrasonic bath at 37°C for 10 min. Then, five points of the archwire were chosen and the measurement areas were 50 μm \times 50 μm . The following parameters were used to assess the surface

roughness of the archwires: Sz (average of ten highest and lowest points), Sa (arithmetical mean deviation of the surface), Sdr (developed surface area ratio), Sbi (surface bearing index), and Sq (the root-mean-square deviation).

The surface characteristics and topography of the slot floors of brackets were randomly and qualitatively analyzed using scanning electron microscopy (SEM). AFM could not be used because of the morphology and dimension of the wings and slots of brackets. Nine as-received brackets were observed by SEM. Then, the brackets were randomly allocated to three groups. After 2 weeks of intervention, any changes in the surface topography of retrieved brackets were evaluated using SEM.

The frictional forces between the archwires and brackets were measured using a universal testing machine (Zwick/Roell Z050, Germany). A custom-made fixture was designed for carrying wires, as shown in Figure 3. A plumb line was hanging to ensure that the bracket mount was parallel to the vertical line engraved on the steel bar base of the bracket mount assembly. A load cell was calibrated between 0 and 5 N, and the bracket was drawn through the straight portion of the archwire as the crosshead moved up over a 5-mm section of archwire at a rate of 0.5 mm/min for 10 min. Care was taken to avoid inserting torsion into the test specimen during clamping. The frictional force values were recorded, and three parameters were selected for analysis of friction:

- Static friction (F_s): The maximum force (in N) recorded before the bracket started to sliding
- Maximum dynamic friction ($F_k \text{ max}$): The maximum force (in N) recorded in each minute

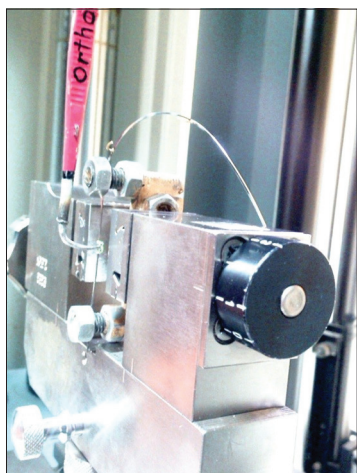


Figure 3: Friction testing apparatus.

during sliding

- Mean of dynamic friction ($F_k \text{ mean}$): The maximum force (in N) recorded during sliding.

The test was repeated for five times, and the mean values were recorded for analysis. After each test, the bracket-wire complex was removed and a new assembly was placed.

The statistical analysis were carried out using SPSS 20 (SPSS Inc., Chicago, IL, USA), with a significance level of 0.05. The data for the surface roughness analysis were expressed as median and 95% confidence interval for the median. The nonparametric Kruskal–Wallis test was used to identify the statistically significant differences among groups. In addition, the Mann–Whitney test was used to analyze further significant differences between two groups. The data for the friction were analyzed using a two-way analysis of variance and Tukey's *post hoc* test.

RESULTS

Figures 4a-c and 5a-c show the representative SEMs of the slot floors of brackets in three test groups before and after the intervention with low and high magnifications, respectively. As-received brackets were similar in topography with no visible crack, defect, or scratches. The retrieved brackets showed minor changes in the surface topography after intervention. These minor defects in the slot floors of brackets were higher in the chlorhexidine group.

Topography images of the archwires in each group before and after intervention are shown in Figure 6a-c. The analysis of surface roughness parameters for the as-received archwires by AFM showed no significant difference between groups ($P < 0.05$). The parameters of surface roughness for the as-received and retrieved archwires are shown in Table 1, which were significantly changed after the intervention ($P < 0.05$). The results showed that:

- Sz in the order of control, Persica, and chlorhexidine increased
- Sa in the order of control, Persica, and chlorhexidine increased, and there was a significant difference between the value for chlorhexidine and that of two other groups ($P < 0.05$)
- Sdr in the order of chlorhexidine, control, and Persica increased, but there was no significant difference between groups ($P > 0.05$)
- Sbi in the order of control, Persica, and chlorhexidine increased, but there was no

significant difference between groups ($P > 0.05$)

- Sq in the order of Persica, control, and chlorhexidine increased, and there was a significant

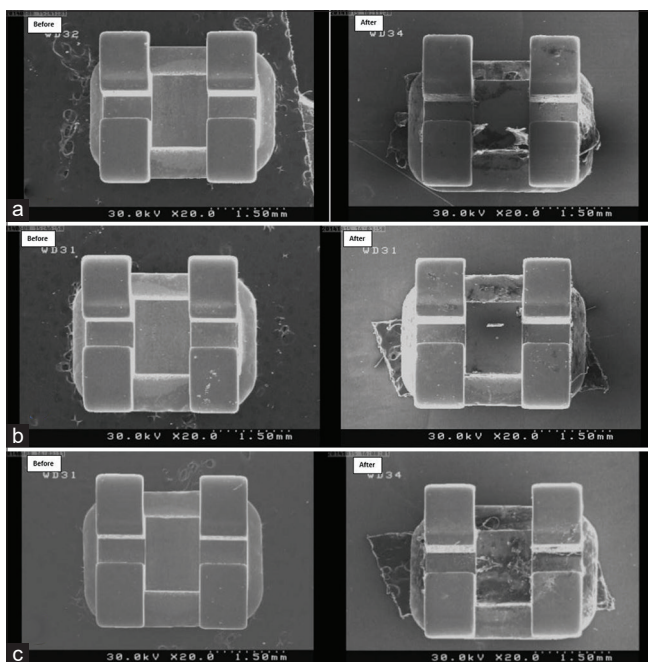


Figure 4: Scanning electron micrographs of brackets before and after intervention at low magnification (x20). (a) Control (no mouthrinse); (b) Chlorhexidine mouthrinse, and (c) Persica mouthrinse

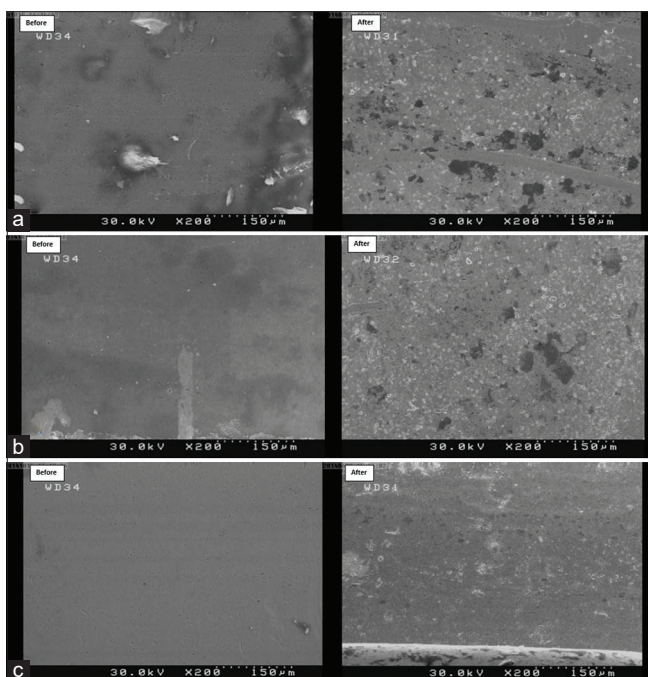


Figure 5: Scanning electron micrographs of brackets before and after intervention at high magnification (x200). (a) Control (no mouthrinse); (b) Chlorhexidine mouthrinse, and (c) Persica mouthrinse

Table 1: Mean and standard deviations of surface roughness parameters (nm) for the as-received and retrieved archwires before and after the intervention by mouthrinses

Study group	Surface roughness parameters (nm)															
	Sa			Sz			Sq			Sdr			Sbi			
	Mean	SD	Significant	Mean	SD	Significant	Mean	SD	Significant	Mean	SD	Significant	Mean	SD	Significant	
Chlorhexidine	Before	24.57	13.45		613.48	367.88		40.51	21.89		1.31	1.58		0.11	0.12	
	After	188.86	157.60	S*	2065.52	1382.91	S	253.63	198.80	S	12.47	17.17	S	0.44	1.17	S
Persica	Before	29.31	12.30		759.76	332.20		64.89	74.83		2.01	2.07		0.11	0.13	
	After	141.17	79.12	S	1796.12	796.34	S	190.59	92.27	S	7.72	5.80	S	0.13	0.03	S
Control (no mouthrinse)	Before	33.64	21.96		748.21	452.59		52.85	32.54		1.66	1.59		0.09	0.03	
	After	163.20	189.55	S	1791.37	1351.30	S	218.77	233.92	S	7.24	7.29	S	0.13	0.07	S

*S means statistically significant difference ($P < 0.05$). Sa: Arithmetical mean deviation of the surface; Sz: Average of ten highest and lowest points; Sq: The root-mean-square deviation; Sdr: Developed surface area ratio; Sbi: Surface bearing index; SD: Standard deviation, S: Significant

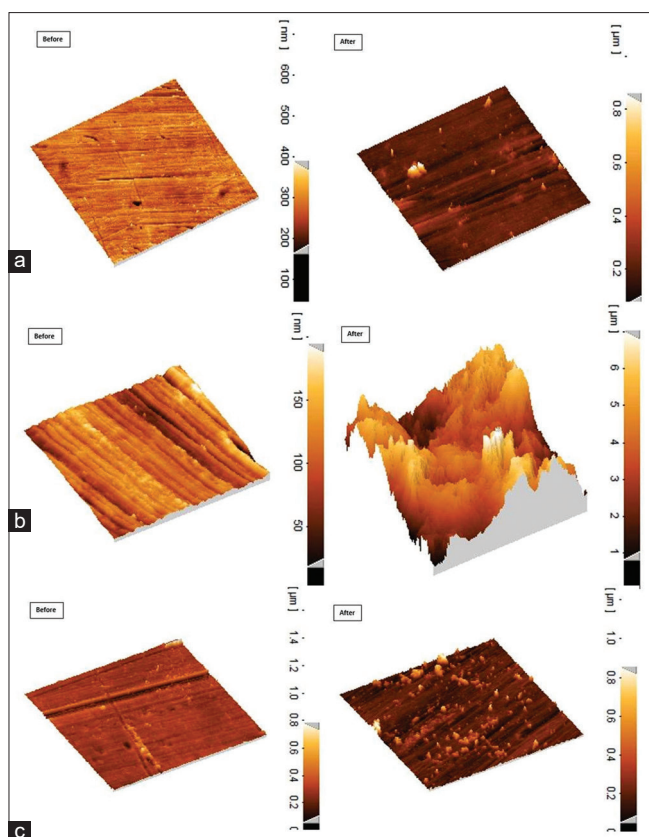


Figure 6: Atomic force micrographs of archwires before and after intervention. (a) Control (no mouthrinse); (b) Chlorhexidine mouthrinse, and (c) Persica mouthrinse retrieved archwires before and after the intervention by mouthrinses.

difference between the value for chlorhexidine and that of two other groups ($P < 0.05$).

The data of friction parameters for the test groups are provided in Table 2. As shown, there were statistically significant differences in the Fk mean and Fk max values between the three groups ($P < 0.05$). The Fk mean value for the chlorhexidine group was higher than that of control and for the control group was higher than that of Persica, but the differences were not statistically significant ($P > 0.05$). The Fk max value for the chlorhexidine group was significantly higher than that of two other groups ($P < 0.05$). This value for the control group was also higher than that of the Persica group, but the difference was not significant ($P > 0.05$). The Fs value for the chlorhexidine group was significantly higher than that of two other groups ($P < 0.05$). This value (Fs) for the control group was also higher than that of the Persica group, but the difference was not significant ($P > 0.05$).

Table 2: Friction parameters (in N) for the three test groups

Parameter	Group	Mean	Comparison	Significant
Fs	Chlorhexidine	2.238575	Persica	S*
			Control	NS**
	Persica	1.731167	Chlorhexidine	S
Fk mean	Chlorhexidine	1.792883	Control	NS
			Persica	NS
	Persica	1.514912	Chlorhexidine	NS
Fk max	Chlorhexidine	1.5970	Control	NS
			Persica	S
	Persica	0.8300	Chlorhexidine	S
Control	Control	1.1424	Chlorhexidine	S
			Persica	NS

*S means statistically significant difference ($P < 0.05$), **NS means nonsignificant difference ($P > 0.05$). Fk max: Maximum dynamic friction, Fk mean: Mean of dynamic friction, Fs: Static friction, NS: Nonsignificant, S: Significant

DISCUSSION

This study was a clinical trial on patients under fixed orthodontic treatment. The patients who met the inclusion criteria were allocated into two experimental and one control groups. The amounts of friction between the archwires and brackets were measured after the intervention (use of mouthrinse during orthodontic treatment). In our study, we did not use placebo in the control group because placebo must be used in the form of liquid as mouthrinse by patients and even the use of distilled water or artificial saliva as placebo could have affected the viscosity and pH of their saliva. This could have been considered as another variable affecting the friction force in the control group. Therefore, we decided to exclude any other variable affecting the results in the control group and also to evaluate the real clinical condition in patients who are not using any type of mouthrinse during orthodontic treatment.

The topography of brackets and surface roughness of the wires were also measured before and after the intervention. The results showed that the extent of surface roughness for the chlorhexidine group was significantly greater than that of two other groups ($P < 0.05$). However, no statistically significant difference in the surface roughness between the Persica and control groups was found ($P > 0.05$).

With regard to the friction, a higher amount of friction for the chlorhexidine group compared with other groups was observed significantly ($P < 0.05$). There was lower friction for the Persica group than that of control, but the difference was not significant ($P > 0.05$). In another study done by Alwafe *et al.*,^[33] the samples immersed in sodium fluoride mouthwash illustrated the highest mean friction resistance and surface roughness, followed by herbal mouthwash, and the least was for artificial saliva. In the literature, a number of articles have evaluated the effect of fluoride-containing mouthwashes on the surface roughness^[33-35] and/or the friction of orthodontic archwires and brackets.^[33] However, the effect of chlorhexidine-containing mouthwash in this regard has not been fully investigated. In a previous *in vitro* study,^[32] the effect of chlorhexidine on the surface characterization and friction of orthodontic wires and brackets was evaluated. The results showed that a 1.5-h immersion in the 0.2% chlorhexidine mouthrinse did not have a significant influence on the surface roughness of archwires or the frictional resistance between stainless steel brackets and the two types of orthodontic wires made of stainless steel and NiTi alloys. On the other hand, another study on the surface topography of orthodontic archwires reported that the 0.12% chlorhexidine and Peroxide-containing mouthwashes showed a higher pitting view on stainless steel and NiTi wires, respectively, compared to the Persica mouthwash.^[36] As we know, chlorhexidine molecules can be bonded to the teeth and oral mucosa, and thus, the results of an *in vitro* study might be different to the *in vivo* one. Because the presence of saliva acts as a lubricant, the laboratory studies in which the sliding mechanism is performed under dry conditions may also overestimate the resistance to friction.

Studies have investigated the effect of mouthwashes on the corrosion of orthodontic wires and brackets. In a study done by Danaei *et al.*,^[37] the ion release of orthodontic stainless steel brackets by three types of mouthrinses was investigated. Their results showed that the nickel and chromium release for the chlorhexidine was higher than that of Persica and Oral-B mouthrinses. The authors suggested that Persica and Oral-B mouthrinses were better options for oral hygiene care in orthodontic patients. The main ingredients of Oral-B mouthrinse are cetylpyridinium chloride, methylparaben, sodium saccharin, cinnamal, propylparaben, and eugenol. Other studies have also shown greater

corrosion of stainless steel and NiTi endodontic files in chlorhexidine solution.^[38] In addition, the effect of Listerine, chlorhexidine, and inorganic mouthwashes on the corrosion of two commercial NiTi archwires has been studied.^[39] The inorganic mouthwash contained alkaloid margosine, resins, gum, chlorides, fluoride, sulfur, tannins, oils, saponins, flavonoids, and calcium. Some of these ingredients are similar to that of Persica mouthwash. They concluded that the chlorhexidine mouthwash had a higher corrosion rate than that of the inorganic solution. This rate of corrosion might be due to the acidity of chlorhexidine, which is proportional to hydrogen ion concentration. Furthermore, the results of a study done by Deriaty *et al.*^[40] showed that chlorhexidine had the highest nickel ion release from the stainless steel brackets, followed by a herbal mouthwash. If there is a direct relationship between the corrosion and surface roughness, the results of the mentioned studies are in agreement with the results obtained in the present study.

It should be also noted that in addition to the corrosion effects on the surface roughness and sliding mechanics, esthetic and biocompatibility of orthodontic appliance should be considered. Some ions such as nickel and chromium can lead to toxic and allergic symptoms. These symptoms might be intense and short term or moderate and long term; some may be resolved and some may result in chronic problems.^[41] Finally, further *in vitro* and *in vivo* studies are required to confirm the results obtained from this study.

CONCLUSION

From the results obtained in this study, the surface roughness of orthodontic stainless steel archwires and the friction force between the stainless steel archwires and brackets after the intervention was significantly greater for the chlorhexidine-containing mouthrinse than that of Persica. Therefore, the Persica-containing mouthrinse from the biomechanical and biochemical standpoints may be a better option for oral hygiene in orthodontic patients.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

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