RESEARCH PAPER

Influence of Chlorhexidine and Fluoride Mouthwashes on the Frictional Behavior of Nickel–Titanium and Stainless-Steel Orthodontic Archwires: An In Vivo Randomized Clinical Study

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Abstract

Background: Changes in archwire surface characteristics caused by the intraoral environment or therapeutic mouthwashes may alter frictional resistance and consequently influence force transmission and tooth movement.

Objective: To evaluate and compare the effects of chlorhexidine and fluoride mouthwashes on the kinetic and static friction of nickel–titanium (NiTi) and stainless-steel (SS) orthodontic archwires following one month of intraoral exposure.

Materials and Methods: Eighteen patients aged 15–28 years undergoing fixed orthodontic treatment with 0.022-inch Roth appliances participated in this randomized clinical intervention study. Thirty-six 0.016 × 0.022-inch archwire samples were distributed among three groups: routine oral hygiene control, 0.12% chlorhexidine mouthwash, and sodium fluoride mouthwash. Each group contained six NiTi and six stainless-steel samples. After 30 days of intraoral exposure, friction was assessed using a metal bracket with a 0.022 × 0.028-inch slot mounted on a computer-controlled materials testing machine. Wires were pulled through the bracket at 5 mm/min for 5 mm. Static friction was defined as the maximum force recorded at initial movement, whereas kinetic friction was calculated as the mean frictional force during movement from 1 to 5 mm.

Results: Kinetic friction in NiTi wires increased in the control group with no significant (P = .827), while increase significant in the chlorhexidine group (P = .011), in the fluoride group (P = .550). The differences in kinetic-friction change among the NiTi groups were not statistically significant (P = .539). Stainless-steel kinetic friction changed with none of the within-group changes was statistically significant, and the intergroup difference was also nonsignificant (P = .399). Static friction demonstrated no statistically significant within-group or intergroup differences for either NiTi (P = .978 among groups) or stainless steel (P = .629 among groups).

Conclusions: Overall, the studied oral-hygiene regimens had limited short-term effects on archwire frictional behavior.

Keywords: orthodontic archwire; friction; kinetic friction; static friction; nickel–titanium; stainless steel; chlorhexidine; fluoride.

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INTRODUCTION

Sliding mechanics are frequently employed during fixed orthodontic therapy for procedures such as space closure and tooth translation. During these movements, part of the force generated by the orthodontic appliance is dissipated in overcoming friction between the archwire and bracket slot. Excessive frictional resistance may therefore reduce the effective force available for tooth movement and affect the efficiency of orthodontic mechanics.[1,2]

Friction at the bracket–archwire interface is influenced by multiple variables, including archwire alloy, cross-sectional dimension, bracket material and design, ligation method, bracket angulation, surface roughness, saliva, and intraoral aging.[2,3]

The composition of the archwire is particularly important. Stainless-steel wires generally exhibit relatively smooth surfaces and comparatively low frictional resistance, whereas nickel–titanium wires may present greater surface irregularity and higher friction under some experimental conditions.[2,4]

During clinical use, orthodontic wires are exposed to saliva, microbial biofilms, fluctuating temperature and pH, masticatory forces, toothpaste, and prophylactic agents. These environmental factors can modify archwire surfaces and potentially influence frictional behavior.[5,6]

Fixed orthodontic appliances also increase plaque-retentive areas and make oral hygiene more difficult. Antiseptic and fluoride mouthwashes are therefore commonly prescribed during treatment. Chlorhexidine is widely used for plaque and gingivitis control, while fluoride-containing products are important for prevention of enamel demineralization.[7-9]

Nevertheless, chemical interaction between these agents and metallic orthodontic materials has raised concerns. Fluoride may disrupt the protective titanium oxide layer of NiTi wires and promote surface degradation. Such changes could theoretically increase surface roughness and subsequently increase bracket–wire friction.[7,10-12]

Chlorhexidine has also been investigated for its potential influence on orthodontic friction. Previous studies have produced variable findings. Razavi et al. evaluated surface characteristics and frictional forces clinically in patients using mouthrinses, whereas Hosseinzadeh Nik et al. investigated chlorhexidine-containing prophylactic agents under laboratory conditions.[9,13]

Much of the evidence regarding mouthwash-induced frictional changes has originated from in vitro studies. However, continuous laboratory immersion does not reproduce intermittent clinical mouthwash exposure, salivary buffering, biofilm formation, toothbrushing, functional loading, or other intraoral factors.[9,13]

Therefore, the aim of this randomized in vivo study was to evaluate the influence of chlorhexidine and fluoride mouthwashes on the kinetic and static friction of NiTi and stainless-steel orthodontic archwires after one month of intraoral exposure.

The null hypothesis was that there would be no statistically significant differences among the control, chlorhexidine, and fluoride groups regarding changes in kinetic or static friction for either archwire alloy.

MATERIALS AND METHODS

Study Design and Participants

This study was designed as a randomized clinical intervention study involving 18 orthodontic patients and 36 archwire samples. Participants were aged 15–28 years and were undergoing fixed orthodontic treatment using pre-adjusted edgewise appliances with a 0.022-inch Roth prescription.

Eligible patients were medically healthy, had acceptable oral hygiene, demonstrated no active periodontal disease or untreated dental caries, and were able to follow standardized oral-hygiene instructions. Patients were excluded in the presence of systemic conditions affecting saliva or oral tissues, pregnancy or lactation, poor compliance, or known hypersensitivity to nickel, stainless steel, chlorhexidine, fluoride, or other materials employed in the investigation.

Ethical approval and written informed consent were obtained before participation.

Sample Size

Sample size was calculated using G*Power software version 3.1.9.4. A total sample size of 36 samples according to previous study[14], corresponding to 12 samples per study group, was considered sufficient to detect a large effect size with 80% statistical power at a significance level of 5%.

Randomization and Experimental Groups

Patients were randomly assigned to three groups, each comprising six participants and 12 samples—six NiTi and six stainless-steel specimens.

Group I – Control: routine oral hygiene using toothbrush and fluoridated toothpaste.

Group II – Chlorhexidine: routine oral hygiene supplemented with 0.12% chlorhexidine digluconate mouthwash.

Group III – Fluoride: routine oral hygiene supplemented with sodium fluoride mouthwash.

The exposure period was 30 days. Each participant had a NiTi archwire in one arch and a stainless-steel archwire in the opposing arch.

Archwires

Rectangular 0.016 × 0.022-inch NiTi and stainless-steel archwires were evaluated. The wires were placed after the leveling and alignment phase and remained intraorally for 30 days before retrieval.

Friction Testing

Frictional resistance was assessed using a metal orthodontic bracket having a 0.022 × 0.028-inch slot, 11° angulation, and 0° torque. The bracket was fixed to a rectangular metal block measuring 50 × 20 × 6 mm.[2]

Each specimen was mounted individually in a computer-controlled materials testing machine (Model LRX-plus; Lloyd Instruments Ltd., Fareham, UK) equipped with a 5-kN load cell. Data were recorded using Nexygen-MT software.[2]

The specimen was secured to the lower fixed component of the testing machine. The wire was ligated into the bracket, attached to the upper movable component, and pulled through the bracket at a constant crosshead speed of 5 mm/min over a total movement of 5 mm.

Static friction was defined as the maximum frictional force recorded during initiation of wire movement. Kinetic friction was calculated as the average frictional force during wire displacement from 1 to 5 mm. Frictional force was recorded in grams.[1]

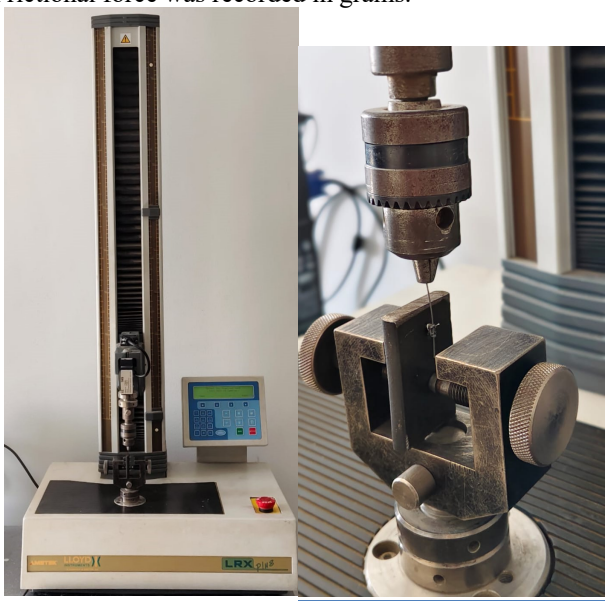


Figure (1): show friction tester machine during recording force of friction.

Statistical Analysis

Statistical analysis was performed using SPSS version 20.0. Means and standard deviations were calculated for all variables. Normality was evaluated using the Kolmogorov–Smirnov and Shapiro–Wilk tests, and the data were treated as parametrically distributed. Paired t-tests were used for intragroup comparisons, whereas one-way ANOVA was used to assess intergroup differences. Statistical significance was established at $P < .05$.

RESULTS

Kinetic Friction of NiTi Archwires

In the **control group**, mean kinetic friction increased from 196.24 ± 60.31 g before exposure to 207.51 ± 73.55 g after exposure. The reported mean change was +11.26 g, and the difference was not statistically significant (P = .867).

In the **chlorhexidine group**, mean kinetic friction increased from 195.24 ± 60.31g to 250.75 ± 27.91g, corresponding to a mean increase of +55.50g. This was the only statistically significant within-group kinetic-friction change for NiTi (P = .021).

In the **fluoride group**, kinetic friction increased from 194.24 ± 60.31 g to 210.40 ± 76.56 g. This change was not statistically significant (P = .570).

Table (1): show mean, standard deviation of Kinetic friction for NI TI wires at three groups before and after treatment

Group	T0 mean ± SD	T1 mean ± SD	Change	P value Intragroup
Control	196.24 ± 60.31	207.51 ± 73.55	+11.26	.867 NS
Chlorhexidine	195.24 ± 60.31	250.75 ± 27.91	+55.50	.021 S
Fluoride	194.24 ± 60.31	210.40 ± 76.56	+16.16	.570 NS
P value Intergroups	.629 NS			

S: statically significant p<0.05, HS: highly statically significant p<0.01, NS: non-statically significant p≥0.05.

Despite the within-group increase in the chlorhexidine group, mean kinetic-friction changes did not differ significantly among the three NiTi groups (P = .629). Therefore, the null hypothesis for the intergroup comparison of NiTi kinetic friction was not rejected.

Kinetic Friction of Stainless-Steel Archwires

In the **control group**, kinetic friction decreased from 185.85 ± 13.14 g to 174.56 ± 42.95g, with a mean change of −11.29 g (P = .638).

In the **chlorhexidine group**, kinetic friction changed from 186.85 ± 13.14g to 182.10 ± 42.95g, with a mean change of −4.74 g (P = .876).

In the **fluoride group**, kinetic friction increased from 185.85 ± 13.14g to 209.38 ± 23.66 g, corresponding to a mean increase of 23.52 g (P = .130). None of these within-group changes was statistically significant.

Comparison of the mean changes among the three groups revealed no statistically significant difference (P = .379).

Table (2): show mean, standard deviation of Kinetic friction for ST ST wires at three groups before and after treatment

Group	T0 mean ± SD	T1 mean ± SD	Mean change	P value Intragroup
Control	185.85 ± 13.14	174.56 ± 42.95	−11.29	.638 NS
Chlorhexidine	186.85 ± 13.14	182.10 ± 42.95	−4.74	.876 NS
Fluoride	185.85 ± 13.14	209.38 ± 23.66	+23.52	.130 NS
P value Intergroups	.379 NS			

S: statically significant p<0.05, HS: highly statically significant p<0.01, NS: non-statically significant p≥0.05.

Static Friction of NiTi Archwires

Static friction demonstrated no significant change within any of the three NiTi groups. The control group changed from 236.05 ± 106.99 g to 238.74 ± 62.97 g, corresponding to +2.68 g (P = .971). The chlorhexidine group changed from 249.57 ± 42.71 g to 238.74 ± 62.97 g, corresponding to −8.82 g (P = .767). The fluoride group changed from 248.16 ± 70.35 g to 241.74 ± 62.97 g, corresponding to −6.41 g (P = .842).

Intergroup comparison demonstrated no significant difference in static-friction change (P = .928).

Table (3): show mean, standard deviation of static friction for NI TI wires at three groups before and after treatment.

Group	T0 mean ± SD	T1 mean ± SD	Mean change	P value
Control	236.05 ± 106.99	238.74 ± 62.97	+2.68	.971 NS
Chlorhexidine	249.57 ± 42.71	238.74 ± 62.97	−8.82	.767 NS

Fluoride	248.16 ± 70.35	241.74 ± 62.97	−6.41	.842 NS
P value Intergroups		.928 NS		

S: statically significant p<0.05, HS: highly statically significant p<0.01, NS: non-statically significant p≥0.05.

Static Friction of Stainless-Steel Archwires

The control group changed from 206.01 ± 34.66 g to 205.08 ± 19.24 g, corresponding to +1.07 g (P = .937). The chlorhexidine group changed from 198.84 ± 59.21 g to 209.08 ± 19.24 g, corresponding to +11.24 g (P = .762). The fluoride group changed from 230.29 ± 21.93 g to 209.24 ± 18.25 g, corresponding to −21.05 g (P = .231). None of the within-group changes was statistically significant.

The differences in mean static-friction changes among the three stainless-steel groups were not statistically significant (P = .659).

Table (4): show mean, standard deviation of static friction for ST ST wires at three groups before and after treatment

Group	**T0 mean ± SD**	**T1 mean ± SD**	**Mean change**	**P value**
Control	206.01 ± 34.66	205.08 ± 19.24	+1.07	.937 NS
Chlorhexidine	198.84 ± 59.21	209.08 ± 19.24	+11.24	.762 NS
Fluoride	230.29 ± 21.93	209.24 ± 18.25	−21.05	.231 NS
P value Intergroups		.659 NS		

S: statically significant p<0.05, HS: highly statically significant p<0.01, NS: non-statically significant p≥0.05.

DISCUSSION

The present randomized in vivo study investigated whether chlorhexidine or fluoride mouthwashes affected the frictional behavior of NiTi and stainless-steel orthodontic archwires following one month of clinical exposure.

The principal finding was that neither kinetic nor static friction showed statistically significant intergroup differences among the control, chlorhexidine, and fluoride regimens for either alloy. This finding supports the null hypothesis for the primary between-group comparisons.[6]

Friction between orthodontic archwires and bracket slots plays a critical role in sliding mechanics during orthodontic treatment. High frictional resistance may impede tooth movement and reduce the efficiency of orthodontic force systems, particularly during space closure procedures.[15]

Friction is an important consideration during orthodontic sliding mechanics because part of the applied orthodontic force must overcome resistance generated at the bracket–wire interface. Excessive resistance may decrease the effective force available for tooth displacement, particularly during space closure.[13]

The behavior of the NiTi wires warrants particular attention. Kinetic friction increased numerically after clinical exposure in all three groups according to the before/after measurements. The chlorhexidine group demonstrated the greatest increase and was the only NiTi group with a statistically significant within-group difference.[16]

However, the absence of a significant intergroup difference indicates that this isolated within-group observation should not be interpreted as evidence that chlorhexidine increases friction more than the other oral-hygiene regimens. The relatively small sample size and substantial variation in friction measurements may have contributed to this result.[12]

For stainless-steel archwires, kinetic friction decreased slightly in the control and chlorhexidine groups but increased numerically in the fluoride group. None of these differences reached statistical significance either within or between groups.

The static-friction results were particularly stable. No significant within-group change was observed for either alloy under any oral-hygiene regimen, and no significant intergroup differences were identified.

This suggests that the maximum force required to initiate movement between the archwire and bracket was not substantially altered by one month of chlorhexidine or fluoride mouthwash use.

Static and kinetic friction represent related but distinct phenomena. Static friction describes the resistance that must be overcome to initiate motion, whereas kinetic friction represents resistance during continued sliding. In orthodontic treatment, both may contribute to the overall resistance encountered during tooth movement.[17]

The current results partly support this interpretation because static friction showed no significant alteration, while only one kinetic-friction subgroup demonstrated a significant within-group change. More importantly, the overall between-group analysis remained nonsignificant.

Similarly, the fluoride regimen did not cause statistically significant alterations in either kinetic or static friction compared with the other groups. Fluoride has the potential to interact with titanium-containing alloys by disrupting their protective surface oxide film, and previous studies have linked fluoride exposure with altered surface characteristics and frictional behavior. Nevertheless, the magnitude of such effects may depend heavily on fluoride concentration, pH, exposure duration, and whether testing is performed under laboratory or clinical conditions.[18]

Stainless-steel wires exhibited lower friction values compared to NiTi wires in all groups. This is consistent with literature confirming smoother surface topography and lower coefficient of friction for stainless steel.[13]

The comparative analysis of the two orthodontic alloys revealed that NiTi wires were generally more susceptible to surface and mechanical changes following intraoral exposure. These differences can be explained by

variations in alloy composition, passivation mechanisms, and microstructural characteristics between NiTi and stainless-steel materials.[12]

Titanium-based alloys rely heavily on the integrity of their oxide layer to maintain corrosion resistance. Fluoride ions can disrupt this protective layer, increasing the vulnerability of NiTi wires to corrosion and surface degradation. In contrast, stainless steel benefits from a chromium-oxide passivation layer that is more resistant to fluoride-induced breakdown, thereby providing superior chemical stability in the oral environment. [12]

These observations are consistent with previous comparative studies that reported greater corrosion resistance and mechanical stability in stainless-steel orthodontic archwires compared with nickel–titanium wires under similar conditions.[12,19]

The in vivo nature of the present study is therefore a major consideration. Unlike continuous immersion protocols, clinical mouthwash use is intermittent. Salivary clearance and buffering, plaque, acquired pellicle, functional loading, dietary factors, and individual oral conditions may substantially modify chemical interactions.

Consequently, findings from prolonged in vitro immersion experiments may overestimate the changes that occur during routine clinical mouthwash use. The results of this investigation indicate that while measurable numerical variations in friction occurred after intraoral exposure, these variations were generally not attributable statistically to the specific oral-hygiene regimen.

CLINICAL IMPLICATIONS

The findings suggest that routine short-term prescription of chlorhexidine or fluoride mouthwash does not produce a clinically obvious or statistically demonstrable deterioration in the frictional performance of NiTi or stainless-steel orthodontic archwires compared with routine oral hygiene.

This is relevant because both agents have important preventive indications during fixed orthodontic therapy. Fluoride remains valuable for prevention of enamel demineralization, while chlorhexidine may be indicated for short-term plaque and gingivitis control. Based on the present data, their use for one month did not significantly alter overall static or kinetic friction when comparisons were made among the three treatment groups.

CONCLUSIONS

Within the limitations of this randomized in vivo investigation:

1. One month of intraoral exposure resulted in numerical changes in kinetic friction of both NiTi and stainless-steel archwires.
2. NiTi kinetic friction increased significantly within the chlorhexidine group, whereas changes in the control and fluoride groups were not statistically significant.
3. Despite the significant intragroup finding in the chlorhexidine group, differences in kinetic-friction change among the three NiTi groups were not statistically significant
4. No significant within-group kinetic-friction changes were observed for stainless-steel wires, and no significant difference was identified among the three groups.
5. Static friction did not change significantly within any NiTi or stainless-steel group.
6. Intergroup differences in static-friction change were nonsignificant for both NiTi and stainless steel.
7. Overall, neither chlorhexidine nor fluoride mouthwash produced a statistically significant adverse effect on the frictional behavior of NiTi or stainless-steel orthodontic archwires compared with the control regimen during the one-month study period.

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