ORIGINAL RESEARCH

Effect of fluoride mouth rinses on various orthodontic archwire alloys tested by modified bending test: An *in vitro* study

Kamna Srivastava, Pavan Kumar Chandra, Nandini Kamat

Department of Orthodontics & Dentofacial Orthopedics, Goa Dental College & Hospital, Bambolim, Goa, India

ABSTRACT

Objective: Fluorides can cause corrosion and degradation in mechanical properties of commonly used archwires by forming hydrofluoric acid HF and causing disruption of protective titanium oxide layer. Hence, the aim of this study was to assess the change in load deflection characteristics of Ni-Ti, Cu Ni-Ti, S.S, and β-Ti wires on immersing in fluoride mouth rinses of two types- Phosflur and neutral NaF mouth rinse utilizing a modified bending test and comparing it to control.
Materials and Methods: Round preformed wires were immersed in 10 ml of control and test solution (Phosflur and S-Flo mouth rinse) for 1.5 hours and incubated at 37°C. Modified bending test was carried out to evaluate load-deflection characteristics of different wires using Instron. Analysis of variance (ANOVA) was applied to determine if statistically significant difference exist among the mean load values obtained at various deflections in control and test solutions.
Results: There was no statistically significant reduction in load deflection characteristics of Ni-Ti, copper Ni-Ti, β-Ti, and S.S wires on immersing in Phosflur mouth rinse and neutral sodium fluoride mouth rinses as compared to control at 2.5 and 1 mm of deflection in unloading phase.
Conclusion: Phosflur and a neutral sodium fluoride mouth rinse did not affect the mechanical bending properties of Ni-Ti, copper Ni-Ti, B-Ti, and SS wires in *in vitro* conditions.

Received : 03-05-11
Review completed : 06-09-11
Accepted : 24-07-12

Key words: Bending test, fluoride mouth rinses, load deflection, orthodontic wires, unloading phase

Fluoride had been a preventive and therapeutic agent in controlling demineralization.[1-8] But, it can also cause corrosion of titanium-based and stainless steel archwire alloys[9-13] which are otherwise known to possess good corrosion resistance. This had been attributed to disruption of titanium oxide layer; hence, the archwire alloy loses its passivating effect and hydrogen embrittlement can occur.[9-12,14-17] Another issue of concern had been whether these products can affect the physical properties and the clinical performance of the orthodontic appliances.[13,18]

Address for correspondence:
Dr. Kamna Srivastava
E-mail: amitn99@gmail.com

Access this article online	
Quick Response Code:	Website: www.ijdr.in
	DOI: 10.4103/0970-9290.102253

The degradation in the mechanical properties of different archwire alloys in presence of fluorides has been reported in previous studies.[14-17,19-21] This has raised a concern on the use of fluorides throughout the course of orthodontic treatment. Generally, stainless steel and titanium based arch wire alloys are used in different stages of comprehensive orthodontic treatment in accordance with concept of "Variable modulus orthodontics".[22] Taking these facts into consideration, the effect of fluorides on these different archwire alloys popularly used in orthodontic treatment should be evaluated.

The assessment of degradation in mechanical properties of wires in presence of fluorides has been carried out previously by performing tensile strength tests,[15] delayed fracture tests,[16] microhardness tests[20,23] and by evaluating elastic modulus and yield strength.[19,21] None of these tests simulated the conditions encountered clinically when the wire is tied into the brackets.

Two of the recent studies[19,21] evaluating elastic modulus and yield strength of titanium based and S.S wires in presence of fluorides have used three point bending test. Although this test offers reproducibility and facilitates comparison across studies, it does not simulate the conditions encountered clinically at the wire-bracket interface. Clinically, as the wire is tied in the brackets, it is constrained and deflected but this is not simulated in three-point bending test.[24]

Three-bracket bending[24] and modified bending tests[25-28] are used in an attempt to evaluate mechanical behavior of archwire alloys in conditions similar to those encountered clinically. Most of the previous studies[14-17,19-21] have investigated degradation in mechanical properties of wires in high concentration fluoride gels and not in the low concentration commercially available fluoride rinses which are routinely prescribed.

Hence, this study was undertaken to evaluate the load deflection characteristics of S.S, Ni-Ti, copper Ni-Ti and β-Ti wires on immersion in commercially available, fluoride mouth rinses (acidulated and neutral) using the modified bending test and comparing the results to control.

MATERIALS AND METHODS

Wires- 0.016" round wire of Ormco Corporation were taken of four different types-Nickel titanium, copper nickel titanium, β-titanium, and stainless steel. Fifteen wire samples were taken of four different wire groups, thereby total of 60 wires were tested in the study. Composition of these wires is given in [Table 1].

Control and test solution-The control solution used was distilled, sterile water. The fluoride agents were low concentration fluoride mouth rinses-Phosflur mouth rinse (0.5% acidulated sodium fluoride; 0.044%w/v of fluoride; pH 4.39; lot no 806210, Colgate-Palmolive) and S-Flo mouth rinse (neutral sodium fluoride rinse; pH 5.28; 0.2% w/v fluoride; lot no. BSO9001, Dr. Reddy's Laboratories).

Acrylic jig for modified bending test-Heat cure acrylic jig simulating maxillary archform of ovoid form from the template-Sym-grid was made as shown in [Figure 1]. Standard edgewise brackets and tubes (022 slot, American Orthodontics) with no tip and torque were bonded at interbracket distance derived from typical tooth dimension for a male maxillary permanent dentition. Load site simulated malaligned central incisor; hence, this area was cut in acrylic.

Table 1: Composition of wires used in the study

Wires	Composition	Uses
Ni-Ti wires	54% Titanium, 45% Nickel, <1% other	Initial leveling and alignment
Copper Ni-Ti wires	49%Titanium, 45%Nickel, 5% copper, <1%	Initial leveling and alignment
β- Titanium	77.55% Titanium,11.5%molybdenum,6%Zirconium, 4.5% tin, 0.35% Iron and 0.1% carbon	Intrusion, torquing arches and loops
Stainless steel	Fe 69%, Chromium 19%, Nickel 9%, Silicon<1%, Maganese<2%, Carbon <0.08%, Sulphur and phosphorus in traces	Multistranded- Initial leveling and alignment Higher dimensions for sliding space closure

Specimen preparation-Preformed archwires were incubated at 37°C in petridish with 10 ml of either of the solution tested (acidulated and neutral fluoride rinse) or distilled water as this is the amount prescribed for daily mouth rinsing. Wires were incubated for 1.5 hrs so as to simulate exposure time of 3 months of 1-minute daily topical fluoride application as also being followed in previous studies.[19,21]

Testing apparatus- A universal testing machine (Instron) with 0.020 KN load cell, operable in reverse mode and at a cross head speed of 1 mm/min was used for modified bending testing. Preformed wires that were immersed in either fluoride mouth rinses or distilled water were ligated to the brackets using stainless steel ligature ties of 3 cm uniform length by the same operator. Each ligature wire was turned five times around each bracket and not tucked under the archwire to have uniformity in the procedure. Wire was deflected at the desired site in labio-lingual manner for greater positional accuracy and stability as shown in [Figure 2]. The wire was deflected to 3 mm and then unloaded to zero deflection at same crosshead speed. Load in kN and deflection in mm was plotted on graph paper as well as on computer attached to machine.

Statistical analysis

Descriptive statistics included mean and standard deviation. A one-way analysis of variance (ANOVA) was used to determine statistically significant differences among the mean load values obtained at various deflections in control and test solution.

RESULTS

Load value measurements were calculated at two deflection points - 1 mm and 2.5 mm as shown in [Tables 2 and 3], respectively, during unloading phase. As unloading behavior of the wire represented the force delivery characteristics of that wire during function in an orthodontic appliance, load value measurements were calculated during unloading phase.

The results of ANOVA as shown in [Tables 4 and 5] for 1 mm and 2.5 mm, respectively, indicated that there was no statistically significant reduction in load deflection characteristics of Ni-Ti, copper Ni-Ti, β-Ti, and S.S wires on immersing in Phosflur and neutral sodium fluoride mouth rinse as compared to control. Representative load deflection graphs are shown in [Figures 3-6] for different wire groups.

For intraoperative error, measurements were repeated after 20 days on two new wire samples each in control

Figure 1: Acrylic jig used for testing

Figure 2: Deflecting the wire tied to acrylic jig by load cell of Instron

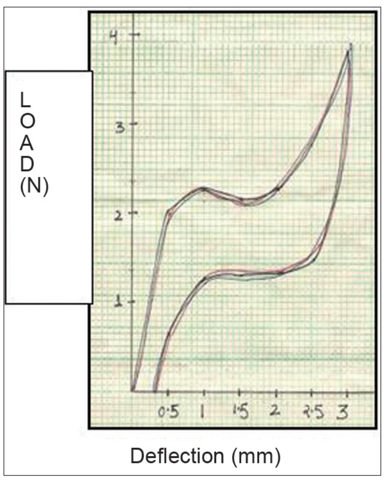

Figure 3: Representative load-deflection plots of Ni-Ti wire. Black denotes loading and unloading curve of the wire on immersion in distilled water. Blue denotes load–deflection curve on immersion in Phosflur mouth rinse. Red denotes load–deflection curve on immersion in S-Flo mouth rinse

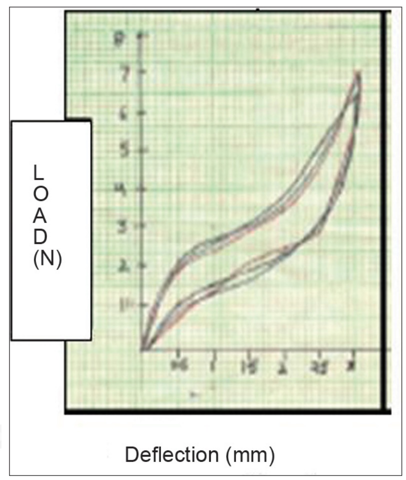

Figure 4: Representative load-deflection plots of β-Titanium wire. Black denotes loading and unloading curve of the wire on immersion in distilled water. Blue denotes load–deflection curve on immersion in Phosflur mouth rinse. Red denotes load–deflection curve on immersion in S-Flo mouth rinse

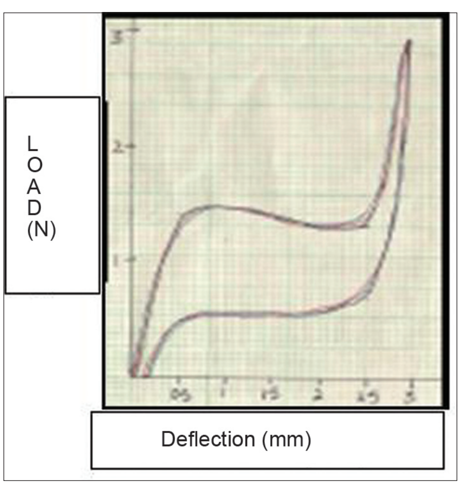

Figure 5: Representative load-deflection plots of copper Ni-Ti wire Black denotes loading and unloading curve of the wire on immersion in distilled water. Blue denotes load–deflection curve on immersion in Phosflur mouth rinse. Red denotes load–deflection curve on immersion in S-Flo mouth rinse

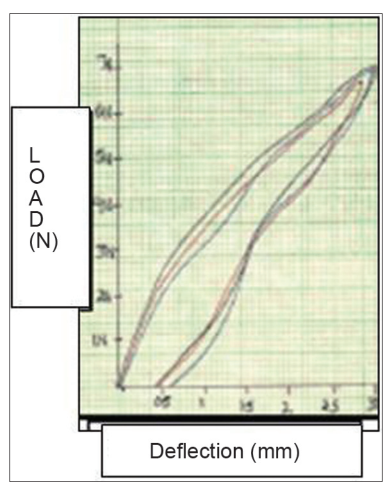

Figure 6: Representative load-deflection plots of S.S wires. Black denotes loading and unloading curve of the wire on immersion in distilled water. Blue denotes load–deflection curve on immersion in Phosflur mouth rinse. Red denotes load–deflection curve on immersion in S-Flo mouth rinse

Table 2: Load values at 1 mm of deflection in unloading phase

Wire groups	Type of solution	N	Mean (Newton)	Standard deviation
I	Control	5	1.180080	0.0556564
Ni-Ti	phosflur	5	1.098860	0.2088498
	S-Flo	5	1.174640	0.2458506
II	Control	5	1.480220	0.1302739
β- Ti	phosflur	5	1.344000	0.2709883
	S-Flo	5	1.454820	0.1115269
III	Control	5	0.412840	0.0878756
Copper	phosflur	5	0.426980	0.1219326
Ni-Ti	S-Flo	5	0.423200	0.0707005
IV	Control	5	1.382000	0.0400002
S.S	phosflur	5	1.299640	0.5616276
	S-Flo	5	1.353540	0.3782685

*N=Sample size

Table 3: Load values at 2.5 mm of deflection in unloading phase

Wire groups	Type of solution	N	Mean (Newton)	Standard deviation
I	Control	5	1.517620	0.1688689
Ni-Ti	Phosflur	5	1.476080	0.0795174
	S-Flo	5	1.522240	0.1141429
II	Control	5	2.575480	0.1568971
β- Ti	Phosflur	5	2.545360	0.1841104
	S-Flo	5	2.548660	0.1652416
III	Control	5	0.470200	0.0473355
Copper	Phosflur	5	0.470900	0.1062462
Ni-Ti	S-Flo	5	0.482000	0.0451031
IV S.S	Control	5	5.835480	0.1706096
	Phosflur	5	5.411240	0.2932228
	S-Flo	5	5.564140	0.1052888

* N=Sample size

Table 4: Results of ANOVA at 1 mm of deflection

		Sum of Squares	dF	Mean square	F	*P*-value
I	Between Grps	0.021	2	0.010	0.289	0.754
Ni-Ti	Within groups	0.429	12	0.036		
	Total	0.449	14			
II	Between Grps	0.052	2	0.026	0.765	0.487
β-Ti	Within groups	0.411	12	0.034		
	Total	0.464	14			
III	Between Grps	0.001	2	0.000	0.029	0.971
Copper	Within groups	0.110	12	0.009		
Ni-Ti	Total	0.111	14			
IV	Between GrPs	0.017	2	0.009	0.057	0.945
S.S	Within groups	1.840	12	0.153		
	Total	1.858	14			

Table 5: Results of ANOVA at 2.5 mm of deflection

		Sum of squares	dF	Mean square	F	*P*-value
I	Between Grps	0.006	2	0.003	0.203	0.819
Ni-Ti	Within groups	0.191	12	0.016		
	Total	0.198	14			
II	Between Grps	0.003	2	0.001	0.048	0.954
β-Ti	Within groups	0.343	12	0.029		
	Total	0.346	14			
III	Between Grps	0.000	2	0.000	0.042	0.959
Copper	Within groups	0.062	12	0.005		
Ni-Ti	Total	0.063	14			
IV	Between Grps	0.462	2	0.231	2.488	0.20
S.S	Within groups	0.505	12	0.042		
	Total	0.966	14			

and test solutions and there was no statistically significant difference (P<0.05) between previously recorded and repeated readings.

DISCUSSION

To prevent enamel demineralization as a result of compromised oral hygiene, fluoride mouth rinses for home use is an accepted protocol in orthodontic patients.

Many studies have reported corrosion[9-12,29] and deterioration in mechanical properties[14-17,19-21,23,30] of pure titanium and titanium-based alloys in presence of fluorides. None of these studies assessed degradation in the mechanical properties by three-bracket bending[24] or modified bending tests[25,-28] which are thought to simulate conditions encountered clinically at wire-bracket interface.

The previous studies did not try to simulate immersion time to clinical exposure in any way.[14-17,20] It was arbitrarily taken to be ranging from one to three days. The immersion time of 90 minutes was selected based on the studies that considered this time to be corresponding to 1-minute daily exposure to fluoride agents for the period of three months.[19,21] Also, this was considered to be more appropriate as this is the average time wire will stay in the mouth during orthodontic treatment.

The results of the study indicated that there was no statistically significant change in load-deflection characteristics of different wires on immersing in Phosflur and S-Flo mouth rinse as compared to control using modified bending test. There was lot of variation in between studies available regarding the type of solution selected, pH of the solution, immersion time, mechanical properties evaluated, and the methodology involved which did not allow direct comparison of the results.

It was confirmed in previous studies[9-12,14,16,17] that fluoride ions in the acidic solution combines with hydrogen ions forming HF. $H_3PO_4 + 3NaF = Na_3PO_4 + 3HF$

HF degrades or dissolves the protective oxide layer that leads to corrosion and hydrogen embrittlement which is responsible for degradation in mechanical properties of the wires.[14-17,20] The amount of HF produced depends on pH,[9,17,20] temperature,[20] and fluoride concentration.[9,17,20]

Phosflur mouth rinse has 0.05% NaF and pH of 4.39. S-Flo mouth rinse has 0.2% NaF and pH of 5.28. The amount of HF in previous studies at comparable pH and fluoride concentration was found to be ranging from 17-21 ppm at which corrosion resistance of Ti was maintained.[10,20] Even Stjáer *et al.*[31] revealed the presence of titanium oxide as surface layer in control and mouth rinse samples which got disrupted only in presence of 1% NaF solution. It can be suggested that HF concentration in the present study was not sufficient to cause degradation of titanium oxide layer.

The results of the study are similar to findings of an *in vivo* study by Ramalingam *et al.*[30] who did not demonstrate significant change in unloading elastic modulus and yield strength (using three-point bending test) of clinically retrieved (after 30 days) Ni-Ti wires in patients using Phosflur rinse.

In NaF of similar concentration and similar pH as the present study, two studies[16,17] had demonstrated deterioration in the mechanical properties of Ni-Ti and β-Ti wires, respectively. In contrast, their immersion time was more and the mechanical properties (delayed fracture test[16] and tensile strength test[17]) were evaluated in different manner.

Previous studies[14-17,19,20,21] showed deterioration in mechanical properties in high concentration fluoride preparations. Low concentration mouth rinses selected for the study stresses on the role of fluoride concentration in causing mechanical deterioration.

Many of the previous studies had used laboratory fluoride preparations[9-11,14-17,20] instead of commercially available mouth rinses or gels that had additives along with fluorides in them. Huang[32] and Stjáer *et al.*[31] did not demonstrate increase in surface roughness of Ni-Ti wires and Ti metal discs on immersing in mouthwashes, low concentration fluoride gels, and high concentration fluoride gel, respectively. It was suggested in both these studies that additives in commercial preparations might impede the formation of HF. This explanation could hold true for the present study as well where commercially available mouth rinses were used.

It had been demonstrated that corrosion resistance of copper Ni-Ti wires was maintained[12,20,29,33] and there was no significant change in mechanical properties[19,30] of these wires in presence of fluorides irrespective of its concentration and pH. It had been suggested that copper content in these wires acted as a relative inhibitor of reducing acids like HF and increased copper concentration at alloy/oxide interface protected the alloy from subsequent hydrogen absorption and degradation.[19] Hence, no degradation was observed in copper Ni-Ti wires in presence of fluoride rinses.

The degradation in mechanical properties of S.S wires was attributed to stress corrosion cracking and hydrogen embrittlement in the high concentration acidic or even neutral fluoride preparations in previous studies.[15,21] Considering these facts, it can be stated that low concentration mouth rinses used in the present study did not alter the load-deflection characteristics of S.S wires.

Within the limitations of this *in vitro* study, it can be stated that fluoride mouth rinses did not alter the load-deflection characteristics of different archwires in statistically significant manner. Hence, commercially available fluoride mouth rinses can be prescribed safely if the factors influencing its effect on mechanical behavior of archwires are understood properly.

It should also be understood that the effect of fluorides depends on concentration, pH of the solution used, and the immersion time. Though dilution by saliva will result in shorter exposure to fluorides everyday compared to constant exposure to mouth rinses in the study, but caution should be taken in patients when the same wire is in mouth for pronged periods-especially when prescribing Phosflur mouth rinse. Ni-Ti wires can remain in mouth for longer periods in leveling and alignment of severely crowded arches. In such conditions, copper Ni-Ti wires can be considered as an alternative.

As role of saliva cannot be ignored, further studies could be directed at using fluoride agents mixed in some measured ratio with artificial saliva. To confirm the findings of any *in vitro* study, it is suggested to carry out a clinical trial and retrieving the wires after different time intervals to assess mechanical properties or hydrogen absorption of the retrieved wires.

CONCLUSION

The load-deflection characteristics of Ni-Ti, copper Ni-Ti, β-Ti, and S.S wires did not change significantly on immersing in Phosflur and S-Flo mouth rinse as compared to control.

REFERENCES

1. Rosenbloom RG, Tinanoff N. Salivary streptococcus mutans levels in patients before, during, and after orthodontic treatment. Am J Orthod Dentofacial Orthop1991;100:35-7.
2. Gorelick L, Geiger AM, Gwinett AJ. Incidence of white spot formation after bonding and banding. Am J Orthod 1982;81:93-8.
3. Mizrahi E. Enamel demineralization following orthodontic treatment. Am J Orthod 1982;82:62-7.
4. Zachrisson BU. Fluoride application procedures in orthodontic practice, Current concepts. Angle Orthod 1975;45:72-81.
5. O'Reilly MM, Featherstone JD. Demineralization and remineralization around orthodontic appliances. Am J Orthod Dentofacial Orthop 1987;92:33-40.
6. Boyd RL. Comparison of three self applied topical fluoride preparations for control of decalcifications. Angle Orthod 1993;63:25-30.
7. Alexander AS, Ripa WL. Effects of self- applied topical fluoride preparations in orthodontic patients. Angle Orthod 2000;70:424-30.
8. Geiger AM, Gorelick A, Gwinett J, Griswold PG. The effect of fluoride program on white spot formation during orthodontic treatment. Am J Orthod Dentofacial Orthop 1988;93:92-108.
9. Toumelin-Chemla F, Roulle F, Burdairon G. Corrosive properties of fluoride containing odontologic gels against titanium. J Dent 1996;24:109-15.
10. Nakagawa M, Matsuya S, Shiraishi T, Ohta M. Effect of fluoride concentration and pH on corrosion behaviour of titanium for dental use. J Dent Res 1999;78:1568-72.
11. Nakagawa M, Matsuya S, Udoh K. Effects of fluoride and dissolved oxygen concentrations on the corrosion behavior of pure titanium

and titanium alloys. Dent Mater J 2002;21:83-92.
12. Watanabe I, Watanabe E. Surface Changes induced by fluoride prophylactic agents on titanium based orthodontic wires. Am J Orthod Dentofacial Orthop 2003;123:653-6.
13. House K, Sernetz F, Dymock D, Sandy J, Ireland A. Corrosion of orthodontic Appliances – Should We Care? Am J Orthod Dentofacial Orthop 2008;133:584-92.
14. Yokoyama K, Kaneko K, Moriyama K, Asaoka K, Sakai J, Nagumo K. Hydrogen embrittlement of Ni-Ti superelastic alloy in fluoride solution. J Biomed Mater Res 2003;65A:182-7.
15. Kaneko K, Yokoyama K, Moriyama 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.
16. Yokoyama K, Kaneko K, Moriyama K, Asoaka K, Sakai J, Nagumo M. Delayed fracture of Ni-Ti superelastic alloys in acidic and neutral fluoride solutions. J Biomed Mater Res 2004;69:105-13.
17. Kwon YH, Seol JH, Kim H, Hwang KJ, Lee SG, Kim KH. Effect of acidic fluoride solution on beta-titanium alloy wire. J Biomed Mater Res B.Appl Biomater 2005;73:285-90.
18. Toms AP. The corrosion of orthodontic wire. Eur J Orthod 1988;10:87-97.
19. 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.
20. Ahn HS, Kim MJ, Seol HJ, Lee JH, Kim H, Kwon YH. Effect of pH and temperature on orthodontic Ni-Ti wires immersed in acidic fluoride solution. J Biomed Mater Res Appl Biomater 2006;79:7-15.
21. Walker MP, Ries D, Kula K, Ellis M, Fricke B. Mechanical properties and surface characterization of beta-titanium and stainless orthodontic wire following topical fluoride treatment. Angle Orthod 2007;77:342-9.
22. Burstone CJ. Variable Modulus Orthodontics. Am J Orthod 1981;80:1-16.
23. Kwon YH, Jang CM, Jang JH, Park JH, Kim TH, Kim H. Effect of fluoride released from fluoride containing dental restoratives on Ni-Ti orthodontic wires. Dent Mater J 2008;27:133-8.
24. Oltjen J, Duncanson M, Ghosh J, Nanda R, Currier F. Stiffness deflection behaviour of selected orthodontic wires. Angle Orthod 1997;67:209-18.
25. Gurgel JA, Kerr S, Powers JM, LeCrone V. Force-deflection properties of superelastic nickel-titanium archwires. Am J Orthod Dentofacial Orthop 2001;120:378-82.
26. Wilkinson PD, Dysart PS, Hood JA, Herbison GP. Load-deflection characteristics of superelastic nickel-titanium orthodontic wires. Am J Orthod Dentofacial Orthop 2002;121:483-95.
27. Mallory DC, English JD, Powers JM, Brantley WA, Bussa HI. Force-deflection comparison of superelastic nickel-titanium archwires. Am J Orthod Dentofacial Orthop 2004;126:110-2.
28. Parvizi F, Rock WP. The load-deflection characteristics of thermally activated orthodontic archwires. Eur J Orthod 2003;25:417-21.
29. Schiff N, Grosgogeat B, Lissac M, Dalard M. Titanium alloys orthodontic wires: electrochemical study in fluoride dental rinses. Eur Cells Mater 2005;9:45-7.
30. Ramalingam A, Kailasam V, Padmanabhan S, Chitharanjan A. The effect of topical fluoride agents on the physical and mechanical properties of Ni-Ti and Copper Ni-Ti archwires. An in-vivo study. Aust Orthod J 2008;24:26-31.
31. Stájer A, Ungvári K, Pelsoczi IK, Polyánka H, Oszkó A, Mihalik E, *et al.* Corrosive effects of fluoride on titanium: Investigation by X-ray photoelectron microscopy, atomic force microscopy and human epithelial cell culturing. J Biomed Mater Res 2008;87:450-8.
32. Huang H. Variation in surface topography of different Ni-Ti orthodontic archwires in various commercial fluoride containing environments. Dent Mater 2007;23:24-33.
33. Schiff N, Boinet M, Morgon L, Lissac M, Dalard M, Grosgogeat B. Galvanic corrosion between orthodontic wires and brackets in fluoride mouthwashes. Eur J Orthod 2006;28:298-304.

How to cite this article: Srivastava K, Chandra PK, Kamat N. Effect of fluoride mouth rinses on various orthodontic archwire alloys tested by modified bending test: An *in vitro* study. Indian J Dent Res 2012;23:433-4.

Source of Support: Nil, **Conflict of Interest:** None declared.