

Original Research Article

Effect of fluoridated alcoholic and non-alcoholic mouth rinses on the load-deflection rate of orthodontic archwires: an *in vitro* study

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Received: 02 April 2026

Revised: 31 July 2026

Accepted: 10 August 2026

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ABSTRACT

Background: Fluoride mouthrinses are routinely prescribed during orthodontic treatment; however, their interaction with different archwire materials may influence mechanical performance, particularly load-deflection characteristics. The aim of the study was to evaluate the effect of fluoridated alcoholic and non-alcoholic mouthrinses on the load-deflection properties of various orthodontic archwires.

Methods: This experiment was conducted *in vitro* and involved 75 orthodontic archwire samples of 0.016-inch thickness, consisting of stainless steel, Ni-Ti, Cu-NiTi, β -Ti, and aesthetic-coated wires. The samples were categorized based on the type of liquid medium used: distilled water, fluoride alcoholic mouthwash, and fluoride non-alcoholic mouthwash. Archwires were soaked in the medium for 1.5 hours at 37°C, after which three-point bending tests were carried out by the help of a universal testing machine, and load deflection data were analyzed statistically using one-way ANOVA and Tukey's post-hoc tests.

Results: Significant increases in load-deflection in stainless steel, Cu-NiTi, β -Ti, and aesthetic archwires were seen using fluoride-containing mouthwash, suggesting stiffness enhancement. The most changes in stiffness were noted in aesthetic and Cu-NiTi wires, but not for Ni-Ti archwires which showed no significant change.

Conclusions: Fluoride-containing mouthrinses exert material-dependent effects on orthodontic archwires, with alcoholic formulations producing the greatest alteration. Ni-Ti wires showed superior stability, whereas aesthetic and Cu-NiTi wires were most affected.

Keywords: Orthodontic archwires, Fluoride mouthrinse, Load-deflection, Nickel-titanium, *In vitro* study

INTRODUCTION

Major developments have been made within the field of orthodontics during the last hundred years owing to new developments in both material science and biomechanics. The fixed orthodontic devices continue to be the standard approach in the correction of malocclusions using archwires as the primary sources of forces responsible for dental movements.¹ The efficiency of such orthodontic wires depends on their physical properties in relation to the load-deflection rate (LDR), representing the amount of force generated per unit of wire deformation. Lighter and more continuous forces are generated by wires with low

LDR values, resulting in favorable tooth movements and preventing harm to the periodontium and pain experienced by patients.²

Orthodontic archwires have undergone tremendous advancements in terms of materials used and performance characteristics. Noble metal alloys have been substituted by stainless steel owing to their higher strength and cost efficiency, after which modern alloys, including NiTi, CuNiTi, and β -Ti, have gained popularity. These materials provide unique biomechanical characteristics, such as superelasticity, thermal effect, and formability, thus facilitating customization for different stages of the therapy process.³ In order to satisfy the demand for

aesthetic devices, researchers have developed coated archwires and fiber-reinforced composite archwires that possess a greater tendency to undergo surface changes.⁴

Properties desirable for orthodontic archwires include low stiffness, good springback ability, biocompatibility, and environmental stability, but there is currently no material that meets all requirements. Biomechanical properties of these devices can be effectively assessed based on their LDR, determined via the three-point bending test.^{5,6}

For example, within the oral cavity, orthodontic archwires experience continuous exposure to saliva, pH fluctuations, acidic foods, and microorganisms. All these factors can cause damage to orthodontic appliances through corrosion and changes in surface characteristics. This, in turn, can promote an increase in friction, mechanical behavior, and possibly ion release from nickel-containing alloys. Moreover, there is a higher risk of enamel demineralization for orthodontically treated patients, hence the recommendation for fluoride rinse use.^{7,8}

Fluoride is a well-known cariostatic agent; nevertheless, it has detrimental effects on metallic orthodontic devices due to its ability to dissolve the protective oxide film on titanium-based alloys, causing corrosion, surface pitting, and mechanical behavior modification. In addition, most fluoride mouthwashes have ethanol content, which contributes to the enhancement of the corrosive process. Alcohol-free versions are available nowadays, although research concerning this matter is insufficient.^{9,10}

Corrosion behavior, surface roughness, and the effect on friction have been mostly studied in orthodontic wires exposed to fluoride treatment with NiTi and β -Ti wires exhibiting higher vulnerability than stainless steel.¹¹ Yet, there is a lack of information on how mouth rinsing with fluorides affects the load-deflection rate of orthodontic wires with the differences between alcohol-containing and alcohol-free solutions.

Thus, the objective of this study is to investigate the effect of fluoridated alcoholic and non-alcoholic mouth rinses on the load-deflection rate of orthodontic wires employing a three-point bending test protocol.

METHODS

In the current study, an *in vitro* experimental study was designed as prospective. This study was carried out in the Department of Orthodontics and Dentofacial Orthopedics from July 2025 to September 2025 at D. J. College of Dental Sciences and Research, Modinagar, Uttar Pradesh.

In this study, an attempt was made to find the effects of fluoride-based alcoholic and non-alcoholic mouth rinses on the load-deflection properties of popularly used orthodontic wires using standardized three-point bending tests protocol.

Total seventy-five samples of round orthodontic archwires (0.016 inch) were chosen for the current research study. The following five types of commercially available orthodontic wires were selected; namely stainless steel, NiTi, CuNiTi, β -Ti and aesthetic coated orthodontic wires. Only those wires without any defect such as kinks, cracks, corrosion, surface irregularities and loss of coating were chosen to maintain uniformity in the study and eliminate any other factor that could confound the results. Rectangular wires and wires with inconsistent manufacture were not considered. Moreover, fluoride-based alcoholic and nonalcoholic mouth rinses were taken into account in this study (Figures 1 and 2).

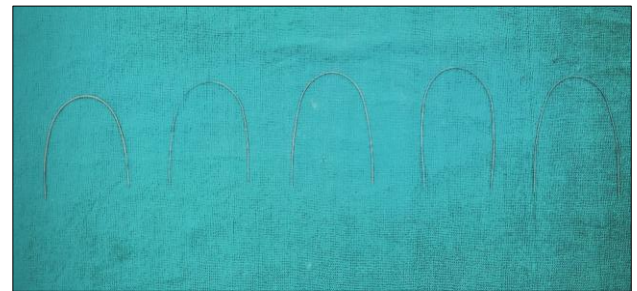


Figure 1: Different wires used in the study (aesthetic, stainless steel, NiTi, CuNiTi, and beta-titanium).

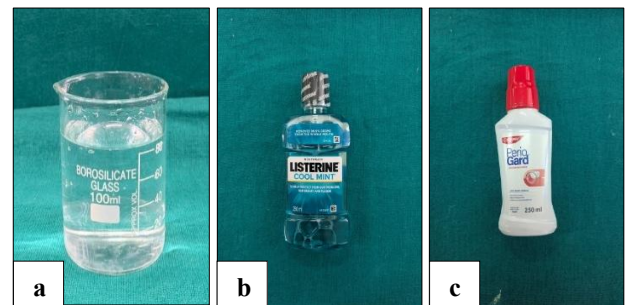


Figure 2: Different immersion medium; (a) control, (b) alcoholic mouth wash, and (c) non-alcoholic mouth wash.

Inclusion criterion

Commercially available orthodontic archwires of the following five types: stainless steel, nickel-Titanium (Ni-Ti), copper-Nickel-Titanium (Cu-Ni-Ti), β -Titanium (β -Ti), and aesthetic coated archwires were included.

Commercially available fluoride-containing alcoholic and non-alcoholic mouthwashes were used for immersion.

Duration

This study was conducted for 3 months.

The sample set was divided evenly into three broad categories depending on the immersion fluid; distilled water (control), alcoholic fluoride mouthwash, and non-

alcoholic fluoride mouthwash. In each category, there were 25 samples, with the 25 samples divided again into five smaller sub-categories of each five wires of varying materials, giving a total of 15 sub-groups analyzed. The sample size was estimated through G*Power (version 3.1.9.7), one-way ANOVA analysis, where the effect size was taken to be 0.40, power set at 80% and significance level at 5%; resulting in a recommended number of samples being 80. For practicality purposes, however, 75 samples were used.

Regarding the procedure involved in immersing the samples, the samples were individually dipped in their corresponding solutions for 1.5 hours, at 37°C, which is equivalent to 1.5 months of daily usage. After immersing the wires, they were then washed with distilled water and dried before carrying out mechanical tests (Figure 3).

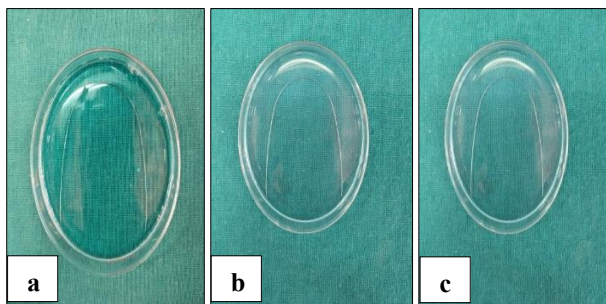


Figure 3 (a-c): Wires dipped in different medium.

For the purpose of simulating the conditions in clinical dentistry, a typodont model that mimicked the shape of an ovoid arch was employed in this study. Standard MBT prescription brackets, having a bracket slot size of 0.022×0.028 inches, were bonded to acrylic teeth, ranging from the right second premolar tooth to the left second premolar tooth. For a standardized span measurement, the maxillary right central incisor was removed, creating an interbracket distance of 16 mm between the neighboring teeth. Subsequently, each archwire was inserted in the slots and stabilized with stainless steel ligature wires (Figures 4-7).



Figure 4: Typodont setup.

The mechanical testing procedure involved the utilization of the Universal Testing Machine set up for conducting a three-point bending test (Figures 8 and 9). After mounting the typodont system with archwires on the machine, a load adequate to cause deflections of 2 mm was applied, after which the load-deflection values were acquired

electronically. Every single specimen underwent a standard loading/unloading process. Values of the forces measured during the deactivation phase were used for the determination of load-deflection curves.



Figure 5: MBT brackets.



Figure 6: Distal end cutter, pin and ligature cutter, bracket holding forceps and ligature wire.



Figure 7: Sample setup for testing.



Figure 8: Universal testing machine.

All test procedures were performed under standardized laboratory conditions for consistency and repeatability purposes. The ethical approval of the research was acquired from the Institutional Ethical Committee of D. J. College of Dental Sciences and Research, Modinagar. Being an *in vitro* study, there were no human or animal participants involved.

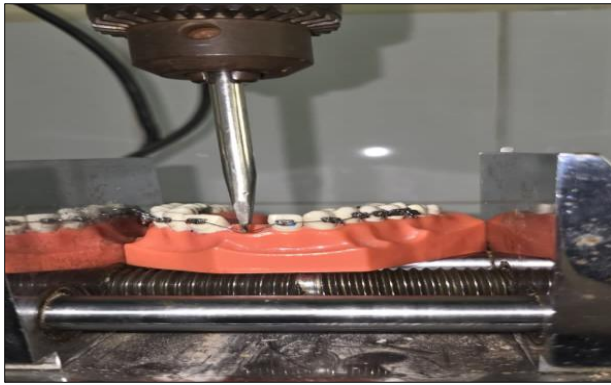


Figure 9: Mechanical testing.

The data analysis process was carried out by employing IBM statistical package for the social sciences (SPSS) statistics (version 25.0; IBM Inc., Chicago, USA). The data was classified according to types of wire and groups of solutions. Calculation of mean and standard deviation was performed. For intergroup comparisons, one-way ANOVA was used. Significance level $p < 0.05$ was set.

RESULTS

It was found that when archwires were soaked in a fluoridated alcoholic solution, the load-deflection values

were always higher, which indicated increased stiffness in the studied materials (Table 1). In particular, the greatest impact of this factor on the studied properties was noted for aesthetic and Cu-NiTi wires. At the same time, there was no difference in stiffness between the Ni-Ti wires under all immersion conditions.

ANOVA indicated significant differences for the immersed solutions in relation to stainless steel, Cu-NiTi, β -Ti, and aesthetic wires. However, there was no significant difference in stiffness between the samples made from the Ni-Ti alloy.

Overall, in terms of significance, aesthetic and Cu-NiTi archwires demonstrated the highest results, which means that they had the greatest sensitivity to the tested solutions (Table 1).

Further data analysis using post hoc test indicated that fluoridated alcoholic mouthwash had an effect on the increased load-deflection in all wires, with the exception of Ni-Ti wires. Moreover, the effect was the highest in aesthetic wires and secondly in Cu-NiTi wires.

The least impact on stiffness was noted with non-alcoholic mouthwash. Only in Cu-NiTi archwires, there was a significant reduction in stiffness (Table 2).

Table 1: Comparison of load-deflection values (mean $\pm$ SD) of different orthodontic archwires across immersion solutions.

Wire type	Solution	Mean $\pm$ SD (N)	Minimum (N)	Maximum (N)	P value
Stainless steel	Control	1.38 $\pm$ 0.014	1.36	1.40	0.004*
	Fluoridated alcoholic MW	1.41 $\pm$ 0.014	1.39	1.43	
	Fluoridated non-alcoholic MW	1.39 $\pm$ 0.014	1.37	1.41	
Ni-Ti	Control	1.18 $\pm$ 0.01	1.17	1.19	0.123
	Fluoridated alcoholic MW	1.20 $\pm$ 0.02	1.18	1.22	
	Fluoridated non-alcoholic MW	1.19 $\pm$ 0.02	1.17	1.21	
Cu-NiTi	Control	0.408 $\pm$ 0.008	0.40	0.42	<0.000*
	Fluoridated alcoholic MW	0.428 $\pm$ 0.008	0.42	0.44	
	Fluoridated non-alcoholic MW	0.388 $\pm$ 0.008	0.38	0.40	
β -Ti (TMA)	Control	1.48 $\pm$ 0.0158	1.46	1.50	0.03*
	Fluoridated alcoholic MW	1.51 $\pm$ 0.0158	1.49	1.53	
	Fluoridated non-alcoholic MW	1.49 $\pm$ 0.0158	1.47	1.51	
Aesthetic	Control	1.60 $\pm$ 0.0158	1.58	1.62	<0.000*
	Fluoridated alcoholic MW	1.80 $\pm$ 0.0158	1.78	1.82	
	Fluoridated non-alcoholic MW	1.70 $\pm$ 0.0158	1.68	1.72	

*P value obtained using one-way ANOVA; $p < 0.05$ considered statistically significant

Table 2: Post-hoc comparison of load-deflection values across study groups.

Wire type	Comparison	Mean difference (N)	P value
Stainless steel	Alcoholic versus control	+0.03	0.005*
	Non-alcoholic versus control	+0.01	0.412
	Alcoholic versus non-alcoholic	+0.02	0.018*
Ni-Ti	Alcoholic versus control	+0.02	>0.05
	Non-alcoholic versus control	+0.01	>0.05
	Alcoholic versus non-alcoholic	+0.01	>0.05

Continued.

Wire type	Comparison	Mean difference (N)	P value
Cu-NiTi	Alcoholic versus control	+0.02	<0.05*
	Non-alcoholic versus control	-0.02	<0.05*
	Alcoholic versus non-alcoholic	+0.04	<0.05*
β -Ti (TMA)	Alcoholic versus control	+0.03	<0.05*
	Non-alcoholic versus control	+0.01	>0.05
	Alcoholic versus non-alcoholic	+0.02	>0.05
Aesthetic	Alcoholic versus control	+0.20	<0.001*
	Non-Alcoholic versus control	+0.09	<0.001*
	Alcoholic versus non-alcoholic	+0.11	<0.001*

*P<0.05 considered statistically significant

DISCUSSION

The current *in vitro* investigation examined the impact of fluoridated alcoholic and non-alcoholic mouth rinses on the load-deflection properties of five widely employed orthodontic arch wires. The results clearly confirmed a material-specific phenomenon whereby fluoridated alcoholic solutions caused the most significant stiffening effect among most of the archwires tested, thus proving that chemicals can influence orthodontic force delivery systems.

A statistically significant increase was noted in load-deflection ratios for stainless steel archwires upon their exposure to fluoridated alcoholic mouth rinse solutions, whereas non-alcoholic solutions had little effect. The results coincide with those found by Srivastava et al according to which stainless steel demonstrates resistance to low concentrations of fluoride ions but may change when exposed to either alcohol or an acid component of a solution, leading to increased interaction between materials.¹² Even though stainless steel is highly resistant to corrosion due to its natural passivation film, any change to the surface may lead to enhanced friction, as also noted by Aghili et al.⁹

The mechanical properties of the Ni-Ti archwires did not show any statistically significant difference in all of the immersion media, supporting the superior mechanical properties of these wires. These results correlate with previous studies, which showed that the oxide film on the Ni-Ti alloy acts as a barrier against chemical corrosion caused by fluorides. The mechanical properties of the Ni-Ti alloy were not affected significantly by fluoride treatment, as stated by Ramalingam et al.¹³ Additionally, according to Nakano et al and Parvizi et al, the superelasticity of Ni-Ti is determined by the phase transformation within the alloy rather than the surface condition.^{14,15} Deterioration was previously shown only for very acidic or highly fluoride environments due to hydrogen embrittlement.¹⁶

For Cu-NiTi archwires, significant and reciprocal alterations were observed with alcoholic mouthwash increasing stiffness levels and non-alcoholic mouthwash decreasing load-deflection values. This indicates the sensitivity of these materials under the influence of

external factors. Srivastava et al noted the same trend of Cu-NiTi material, stating that copper is capable of regulating chemical interaction in accordance with the surrounding environment.¹² Increased stiffness with alcoholic mouthwash can be explained by the increased rate of ion diffusion and oxidative processes, while reduced load-deflection values associated with non-alcoholic preparations can be due to either surface softening or micro-etching effects.¹⁷ According to Siirilä et al, chemical substances could interfere with protective layers and thus modify their mechanical properties.¹⁸

With respect to β -Ti archwires, significant increments of load-deflection values were identified, specifically with the use of alcoholic mouthwash. In agreement with the current scientific literature, it has been established that these materials are more reactive than stainless steel and less prone to degradation than Ni-Ti alloys. Changes on the wire surface, including roughness formation and minor corrosion, can contribute to increased bending resistance without any harm, as noted by Mallory et al and Aghili et al.^{9,19}

Most dramatic modifications were observed in the group of aesthetic archwires with significant increases in load-deflection values in both experimental groups, especially for alcohol-based mouthwashes. It is consistent with the work done by Omidkhoda et al and Khalessi et al, where it was demonstrated that polymer-coated wires are prone to chemical decomposition.^{20,21} Fluorinated alcohol solutions might enhance the rate of polymer decomposition that leads to the rise of stiffness and the lack of elasticity, and possibly even damage coating materials. The importance of the problem is conditioned by the fact that aesthetical archwires are commonly used but can also be exposed to chemical effects.

Considering the data received, it can be concluded that fluoridated alcoholic mouthwashes have an ongoing impact on the mechanical properties of most orthodontic archwires owing to an increase in their chemical reactivity and the change in wire surface chemistry.

However, non-alcoholic mouthwashes had varying influence on the samples under investigation. This demonstrates that not only mechanical but also chemical environment might affect the orthodontic force system.

Still, the artificial experimental conditions restrict its use for clinical purposes as various intraoral elements, including pH levels and temperature fluctuations, can influence the archwire performance differently.

Limitations

Being an *in vitro* study, the conditions may not completely simulate the complex oral environment. Only five types of 0.016-inch orthodontic archwires were evaluated. Only one alcoholic and one non-alcoholic fluoridated mouthrinse were tested. The continuous immersion protocol may not accurately represent intermittent mouthrinse use in clinical practice.

The small sample size (five specimens per subgroup) may limit the generalizability of the findings. Only load-deflection properties were assessed; corrosion, surface roughness, ion release, and friction were not evaluated.

CONCLUSION

The Ni-Ti wires were found to be the most stable; however, the Cu-NiTi and aesthetic archwires showed sensitivity to fluoride-containing mouth rinses, especially alcohol-based ones. The above results highlight the need to consider the wire materials when recommending fluoride mouth rinse products.

Funding: No funding sources

Conflict of interest: None declared

Ethical approval: The study was approved by the Institutional Ethics Committee

REFERENCES

- Jain AK, Savana K, Singh S, Brajendu, Roy S, Priya P. Biomechanical evaluation of different orthodontic archwire materials and their effect on tooth movement efficiency. *J Pharm Bioallied Sci.* 2024;16(4):3358-60.
- Choudary D, Jnaneshwar P, Kannan R. Evaluation and comparison of load-deflection rate of four initial orthodontic arch wires: An in vitro study. *Int J Orthod Rehabil.* 2022;13(3):1-9.
- Chainani P, Paul P, Shivilani V. Recent advances in orthodontic archwires: A review. *Cureus.* 2023;15(10):38-47.
- Haryani J, Ranabhatt R. Contemporary esthetic orthodontic archwires: A review. *J Dent Mater Tech.* 2016;5(3):130-5.
- Sabbagh H, Janjic Rankovic M, Martin D, Mertmann M, Hotzel L, Wichelhaus A. Load-deflection characteristics of orthodontic Gummertal® wires compared with nickel-titanium wires: An in vitro study. *Materials.* 2024;17(2):533-40.
- Kapila S, Sachdeva R. Mechanical properties and clinical applications of orthodontic wires. *Am J Orthod Dentofacial Orthop.* 1989;96(2):100-9.
- Selvaraj M, Mohaideen K, Sennimalai K, Gothankar GS, Arora G. Effect of oral environment on contemporary orthodontic materials and its clinical implications. *J Orthod Sci.* 2023;12(1):1-6.
- Al-Blaihed D, El Meligy O, Baghlaf K, Aljawi RA, Abudawood S. White spot lesions in fixed orthodontics: Etiology, prevention, and treatment. *Cureus.* 2024;16(7):53-63.
- Aghili H, Yassaei S, Eslami F. Effect of three mouthwashes on mechanical properties and surface morphology of orthodontic wires: An in vitro study. *Dent Res J.* 2017;14(3):252-9.
- Pastor F, Rodriguez JC, Barrera JM, García-Menocal JAD, Brizuela A, Puigdollers A, et al. Effect of fluoride content of mouthwashes on metallic ion release in orthodontic archwires. *Int J Environ Res Public Health.* 2023;20(4):2780-9.
- Chitra P, Prashantha GS, Rao A. Effect of fluoride agents on surface characteristics of NiTi wires: An ex vivo investigation. *J Oral Biol Craniofac Res.* 2020;10(4):435-40.
- 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(3):341-7.
- 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(1):26-31.
- Nakano H, Satoh K, Norris R, Jin T, Kamegai T, Ishikawa F, et al. Mechanical properties of several nickel-titanium alloy wires in three-point bending tests. *Am J Orthod Dentofacial Orthop.* 1999;115(4):390-5.
- Parvizi F, Rock WP. The load-deflection characteristics of thermally activated orthodontic archwires. *Eur J Orthod.* 2003;25(4):417-21.
- Meling TR, Odegaard J. The effect of short-term temperature changes on superelastic nickel-titanium archwires activated in orthodontic bending. *Am J Orthod Dentofacial Orthop.* 2001;119(3):263-73.
- Schiff N, Grosogeat B, Lissac M, Dalard M. Titanium alloys orthodontic wires: electrochemical study in fluoride dental rinses *Eur Cells Mater.* 2005;9(2):45-7.
- Siiriliä HS, Könönen M. The effect of oral topical fluorides on the surface of commercially pure titanium. *Int J Oral Maxillofac Implants.* 1991;6(1):50-4.
- 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(1):110-2.
- Omidkhoda M, Sahebnaasagh Z, Poosti M, Yaghoobi M, Izadpanahi A. Evaluation of mechanical properties of NiTi orthodontic wire after immersion in three different mouthwashes. *Iran J Orthod.* 2011;6(1):32-8.

21. Khalessi AM, Pack AR, Thomson WM, Tomkin GR. An invitro study of the plaque control efficacy of persica: a commercially available herbal mouthwash containing extracts of salvorapersica. Int Dent J. 2004;54(5):279-83.

Cite this article as: Jha P, Misra V, Singh R, Attri S. Effect of fluoridated alcoholic and non-alcoholic mouth rinses on the load-deflection rate of orthodontic archwires: an *in vitro* study. Int J Clin Trials 2026;13(4):402-8.