



Effect of Listerine and Sodium Fluoride Mouthwashes on Force Decay of Orthodontic Memory Elastomeric Chains: An In Vitro Study

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Article Info	ABSTRACT
<p>Article type: Original Article</p>	<p>Objectives: The interaction of mouthwashes with orthodontic elastomeric materials may alter their mechanical properties. The main purpose of this study was to evaluate the impact of 0.05% sodium fluoride Oral-B PRO-Expert Multi Protection and fluoride-free Listerine Advanced with Tartar Protection mouthwashes on the force decay behavior of memory elastomeric chains.</p>
<p>Article History: Received: 10 Mar 2025 Accepted: 15 Jun 2025 Published: 5 Mar 2026</p>	<p>Materials and Methods: In this in vitro study, 90 pieces of closed gray memory elastomeric chains were randomly allocated to three distinct groups (n=30): control, sodium fluoride, and Listerine. The control samples remained fully submerged in artificial saliva over the course of the experiment. Test samples were placed daily for 1 minute in either sodium fluoride or Listerine mouthwash, then in a solution consisting of equal parts of mouthwash and artificial saliva for 30 minutes, followed by a thorough rinse with distilled water, and then placed back in the artificial saliva. Tensile tests were conducted at various time points (baseline, 1 hour, and 1, 7, and 28 days) (n=6). Data were analyzed by one-way and two-way ANOVA, and Tukey's post-hoc test (alpha=0.05).</p>
<p>* Corresponding author: Department of Orthodontics, School of Dentistry, Hamadan University of Medical Sciences, Hamadan, Iran Email: mozhde.borjali@gmail.com</p>	<p>Results: All groups exhibited a continuous force decay over time (P<0.001). The experimental groups demonstrated significantly greater force decay compared to the control group (P<0.001). The sodium fluoride group exhibited significantly greater force decay compared to the Listerine group at all measured time points (P<0.001) except on day 28 (P=0.970).</p> <p>Conclusion: Both mouthwashes accelerated the force degradation of memory elastomeric chains, with sodium fluoride causing a greater reduction except on day 28.</p> <p>Keywords: Mouthwashes; Sodium Fluoride; Tartar Control Listerine; Tensile Strength</p>

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INTRODUCTION

During orthodontic visits, forces are applied to the teeth using various means such as stainless-steel springs, elastomeric chains, and nickel-titanium coil springs. In the clinical settings, elastomeric chains are particularly

favoured due to their convenience in clinical application, lower price, and higher patient acceptance [1-3]. However, synthetic elastomeric chains have disadvantages such as tooth discoloration, plaque accumulation, and force decay [3]. Among these, force decay is

considered the most challenging issue, which varies among elastomeric chains produced by different manufacturers [4]. The gradual reduction of force of elastomeric chains leads to insufficient tooth movements, additional dental visits to replace the chains, and a longer treatment time [5].

Multiple factors including, manufacturing processes, environmental conditions (e.g., temperature, humidity), salivary enzymes, dietary habits, and chemical compositions affect the force decay and stress relaxation behavior of elastomeric materials [6,7]. Chemical agents such as mouthwashes are also among the influential factors. Since orthodontic appliances compromise oral hygiene practice, mouthwashes are recommended to reduce dental caries and gingivitis [8,9].

Clinicians usually suggest using fluoride mouthwashes to prevent the formation of white spot lesions and dental caries, especially around orthodontic bands and brackets during orthodontic treatment [10]. Listerine is another effective mouthwash to reduce microbial plaque. Evidence shows that Listerine significantly decreases dental plaque formation and gingivitis without affecting the normal microbial flora [11]. Therefore, it is highly recommended to use Listerine mouthwash during orthodontic treatment [12].

Memory elastomeric chains were recently introduced with improved mechanical properties, lower force decay in artificial saliva, and higher efficacy during orthodontic treatment compared with conventional chains [13,14]. Although memory chains have been commercially available for a considerable period of time, research examining the influence of various mouthwashes on their force kinetics and mechanical behavior remains scarce. Dadgar et al. [15] studied the impact of artificial saliva (serving as the control group), and various mouthwashes on the force decay of conventional and memory chains. Their findings indicated that memory chains delivered greater forces initially and at the final assessment, and thus, were more favorable due to their superior force maintenance over time. Their results suggest

that memory chains may demonstrate more resistance to various treatments compared to conventional chains; nevertheless, both types maintained adequate force after 4 weeks in all test groups [15]. Notably, their study did not evaluate the effect of Listerine mouthwash. According to the contradictory findings reported in earlier investigations regarding the effect of mouthwashes on conventional elastomeric chains [16-19], and limited studies regarding memory elastomeric chains [15,20], this study aimed to investigate the effects of two types of mouthwashes on the force decay of memory elastomeric chains.

MATERIALS AND METHODS

This in vitro study was performed on 90 pieces of closed gray memory elastomeric chains (American Orthodontics, Sheboygan, WI, USA), with six pieces allocated to each group (control, sodium fluoride, and Listerine Tartar Control mouthwashes) at each time point (baseline, 1 hour, and 1, 7, and 28 days). Based on the data (mean and standard deviation values) derived from an earlier study, a sample size was computed to attain a power above 80% at 0.05 level of significance [18]. The study design received approval from the Ethics Committee of Hamadan University of Medical Sciences (IR.UMSHA.REC.1397.699). Chain pieces with 4 rings and 11mm length, along with 2 extra rings on the sides, were cut. Handmade wooden jigs were fabricated, each consisting of two parallel rows of stainless-steel pins measuring 1.2mm in diameter and spaced 25mm apart that were used to stretch the chains to 25mm, to simulate the average distance that the chains are stretched for canine retraction (Fig. 1) [18]. The initial length of the chains was such to exert 0.2Kg/F when stretched to 25mm. The pieces of memory elastomeric chains were stored in Fusayama's artificial saliva solution comprised of 400mg/L KCl, 400mg/L NaCl, 1000mg/L urea, 906mg/L $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$, 690mg/L $\text{NaH}_2\text{PO}_4 \cdot \text{H}_2\text{O}$, and 5mg/L $\text{Na}_2\text{S}_9\text{H}_2\text{O}$ with a pH of 6.7 [21]. The artificial saliva solution was replaced daily. All specimens were stored in closed containers and incubated at a temperature of $37 \pm 1^\circ\text{C}$.



Fig 1. Handmade jig made from two rows of steel pins with a 25mm distance.

The effects of two mouthwashes on force decay were evaluated: 0.05% sodium fluoride Oral-B PRO-Expert Multi Protection mouthwash (Procter and Gamble, Cincinnati, USA) containing aqua, cetylpyridinium chloride, glycerin, sodium fluoride, methylparaben, poloxamer 407, cinnamal, sodium saccharin, propylparaben, aroma, and CI 42090 (brilliant blue color) and fluoride-free Listerine Advanced with Tartar Protection mouthwash (Johnson and Johnson, Rome, Italy) containing aqua, alcohol (26.9% ethanol), poloxamer 407, thymol, benzoic acid, sorbitol, zinc chloride, sucralose, eucalyptol, methyl salicylate, sodium benzoate, menthol, sodium saccharin, and CI 42090.

The samples were randomly assigned to three groups: In the first two groups, the elastomeric chains were removed daily from the artificial saliva solution and immersed in either sodium fluoride or Listerine mouthwash for 1 minute daily. To simulate clinical conditions where patients avoid eating or drinking for 30 minutes after using a mouthwash, the samples were subsequently immersed in a 50:50 mixture of artificial saliva and the respective mouthwash for 30 minutes. Afterward, the chains were rinsed with distilled water and placed back in the artificial saliva solution [22]. All the samples in the control group were continuously immersed in artificial saliva the whole time. During the experiments, force measurements were made right before incubation (baseline), after 1 hour, and on days 1, 7, and 28 using a universal testing machine (Instron 8503; Tool Works, Norwood, IL, USA). The follow-up period was 28 days to

simulate the usual time interval between two dental visits to change the elastomeric chains. An extensometer (Illinois Tool Works, Norwood, USA) was used to measure tensile extension among all groups in the same condition.

At first, the chains were disengaged from the jigs and allowed to relax. Two prefabricated steel metal hooks were used to locate the chains on the device (Fig. 2A). When placed on the hooks, the length of the chains was 14mm (Fig. 2B). The chains were stretched at a speed of 20mm/minute to reach 25mm (Fig. 2C). Due to the instability of forces in the early seconds, when chains were stretched to 25mm, forces were measured with 10 seconds delay by a technical supervisor.

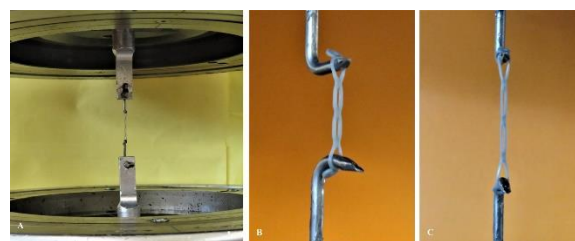


Fig 2. Prefabricated steel cylinders with sturdy metal hooks placed on Instron machine (A), chains while locating on the hooks before (B) and after (C) stretch.

Their values were recorded and their diagrams were drawn. The value of force decay compared to the initial force was calculated according to the following equation [23]:

$$FD\% = 100 \times \frac{FI - Ft}{FI}$$

FD: Force decay; FI: The force measured at the initial instant; Ft: The residual force at the specified time

Data were collected and analyzed using SPSS version 24 (SPSS Inc., Chicago, IL, USA). The Kolmogorov-Smirnov test was employed to determine whether the data followed a normal distribution. Accordingly, two-way ANOVA was used to examine the impact of group (control, sodium fluoride, and Listerine) and measurement time (baseline, 1 hour, and 1, 7, and 28 days) on the mean force of memory elastomeric chains. One-way ANOVA was conducted to compare the mean force values

across different groups at each time point. The Tukey’s post-hoc test was used to identify statistically significant differences between the mean forces of each group over time. The alpha level for statistical significance was set at 0.05.

RESULTS

Table 1 shows the mean force and its decay in the study groups at each time point. Two-way ANOVA indicated statistically significant effects of group and time on the mean force (P<0.001). Additionally, a statistically significant interaction between group and time was observed (P<0.001, Table 2). To compare the mean force among all groups at each time interval, one-way ANOVA was performed. As indicated in Figure 3, no significant difference was observed among the groups regarding their mean force at baseline

(P=0.287). However, significant differences were observed after 1 hour (P<0.001 for all groups), one day (P<0.001 for the difference between the control group and test groups, and P<0.012 between sodium fluoride and Listerine groups), and 7 days (P<0.001 for the difference between the control group and test groups, and P<0.007 between sodium fluoride and Listerine groups). On day 28, there was a significant difference between the control group and the test groups (P<0.001). However, there was no significant difference between the sodium fluoride and Listerine groups (P=0.970).

In each group, based on the Tukey’s post-hoc test, there were significant differences in the mean force values over time (P<0.001, Fig 4).

As illustrated in Figure 5, the control group demonstrated the highest residual force, and the lowest force decay compared with other groups.

Table 1. Mean force (g) and mean force decay values (%) of memory elastomeric chains in each group at baseline and after 1 hour, 1 day, 7 days, and 28 days

Group	Time	Mean force (g)	SD	Mean force decay (%)	SD
Control	Baseline	211.50	15.01	-	-
	1/24 day	169.16	11.21	19.92	3.80
	1 day	117.16	3.43	44.31	5.15
	7 days	85.16	4.99	59.66	2.01
	28 days	64	4.33	69.70	1.50
Listerine	Baseline	205.16	8.51	-	-
	1/24 day	123.16	5.98	39.95	2.11
	1 day	86.33	4.13	57.91	1.31
	7 days	65.16	3.25	68.19	1.90
	28 days	52	3.52	74.60	2.25
Sodium fluoride	Baseline	194.50	20.43	-	-
	1/24 day	83	8.53	56.80	7.65
	1 day	74.50	9.20	61.21	7.51
	7 days	57	3.16	70.50	2.52
	28 days	52.50	3.01	72.84	2.27

SD: Standard deviation

Table 2. Effect of group and time on the mean force of memory elastomeric chains

Source of variation	df	Mean SS*	Sum of squares	F index	P value
Group	2	21048.15	10524.07	137.35	<0.001**
Time	4	249848.95	62462.23	815.24	<0.001**
Time × Group	8	11041.17	1380.14	18.01	<0.001**
Total	90	1363962	-	-	-

*indicates sum of squares

**indicates a significant effect (level of significance was set at 0.05)

Generally, the Listerine group had a higher residual force and a lower force decay than the sodium fluoride group except on day 28. The slope of this diagram indicated that the greatest force decay in the test groups occurred in the first hour. However, the highest force decay in the control group was observed on the first day.

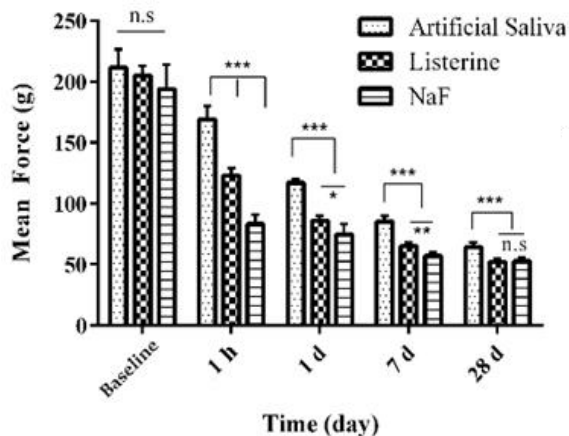


Fig 3. Comparison of the mean force of memory elastomeric chains between the control, Listerine, and sodium fluoride (NaF) groups at each time point * indicates $P \leq 0.05$; ** indicates $P \leq 0.01$; ***; and *** indicates $P \leq 0.001$.

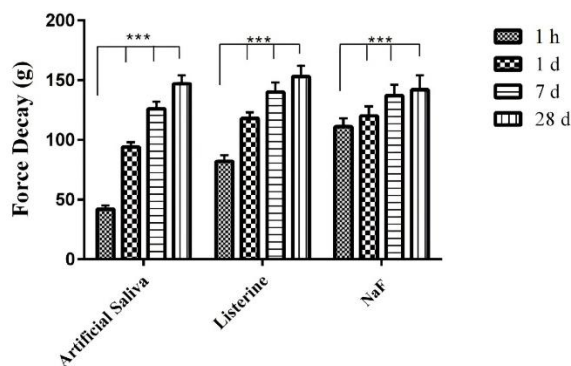


Fig 4. Differences in the mean force of memory elastomeric chains at different time points (1 hour, 1 day, 7 days, and 28 days) within each group. *** indicates $P \leq 0.001$.

DISCUSSION

Elastomeric chains are a routinely utilized orthodontic adjunct for space closure and tooth movement in clinical practice. However, their gradual force decay is a challenge that can cause insufficient movement of teeth during orthodontic treatment [5].

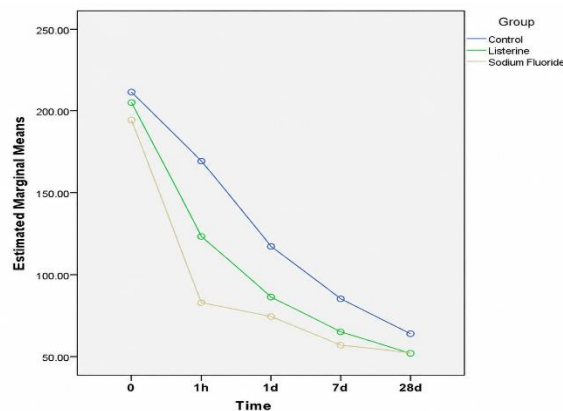


Fig 5. Mean force of memory elastomeric chains in the control, Listerine, and sodium fluoride groups over time (1 hour, 1 day, 7 days, and 28 days).

On the other hand, orthodontic appliances can disrupt the ecological balance of the oral environment and increase microbial plaque formation [24,25]. Therefore, it is recommended to use mouthwashes during orthodontic treatment [26]. This experimental study was designed to evaluate the effect of two types of mouthwashes used during orthodontic treatment, including 0.05% sodium fluoride and Listerine mouthwashes, on the force kinetics of memory elastomeric chains. Unlike previous studies, fluoride-free Listerine mouthwash was also used [18,19].

In the present study, the force decay after 1 hour, 1 day, 7 days, and 28 days was 19.92%, 44.31%, 59.66%, and 69.70%, respectively, in the control group, which was consistent with the results of Al-Kassar [27]. However, Mirhashemi et al. [28] reported a higher force degradation of memory elastomeric chains in the control group. This difference can be due to the various colors of the chains and different measuring devices. Pigmented elastomeric chains undergo a higher degree of force decay in comparison to non-pigmented chains [29].

The present study demonstrated that Listerine and sodium fluoride mouthwashes significantly decreased the force of elastomeric chains. Sadeghian et al, [18] Rafeeq et al, [30] Kumar et al, [31] and Omidkhoda et al, [32] also obtained Similar results with conventional chains. However, Ramazanzadeh et al. [17] reported no

significant difference regarding the force decay of two types of elastomeric chains using 0.05% sodium fluoride mouthwash. It can be attributed to the lower accuracy of the measuring device, and a smaller sample size.

The findings of the present study indicated that the sodium fluoride group experienced a significantly greater force decay compared to the Listerine group. However, according to Menon et al, [19] the force decay was found to be higher in elastomeric chains exposed to Listerine mouthwash compared to those treated with sodium fluoride mouthwash. This difference may be attributed to different mouthwash concentrations (0.04%) and using fluoride-containing Listerine mouthwash.

Multiple studies have examined the impact of mouthwash components on the force kinetics of conventional elastomeric chains. Larrabee et al, [5] Al-Ani [33], and Menon et al. [19] assessed the differences in force decay between Listerine mouthwash (with 26.9% alcohol content) and a 26.9% alcohol solution applied on memory elastomeric chains. Larrabee et al. [5] found no significant difference between the Listerine and alcohol solution except on day 28 where the alcohol solution led to a greater force degradation. Al-Ani [33] and Menon et al. [19] reported that elastomeric chains experienced greater force decay when exposed to the entire mouth rinse formulation than when treated solely with its individual key components. Similarly, Ramachandraiah et al. [34] found that Listerine mouthwash caused greater force loss in elastomeric chains compared to exposure to a 21.6% alcohol solution. Menon et al. [19] assessed the effects of Colgate Phos-Flur mouthwash, which contains 0.04% sodium fluoride, in comparison to 0.04% sodium fluoride solution on the force decay of memory elastomeric chains. Their results revealed that exposure to the sodium fluoride solution resulted in greater force decay in the elastomeric chains than treatment with Colgate Phos-Flur mouthwash. Aligned with the findings reported in previous studies, the present study revealed that all groups showed significant time-dependent force decay [35-38]. At every measured time point,

the control group exhibited the lowest force decay. The Listerine group demonstrated less force decay than the sodium fluoride group overall, and this difference was statistically significant at all intervals except for day 28. The experimental groups demonstrated the most significant force decay within the initial hour. However, the highest force decay of the control group (artificial saliva) was after 1 day. Baratieri et al, [13] and Weissheimer et al. [39] reported the highest force decay of elastomeric chains in the first hour. However, Mirhashemi et al, [28] and Sadeghian et al. [18] reported the maximum force decay occurring on the first day. Since there were few studies regarding the effect of mouthwashes on the force decay of memory elastomeric chains, these inconsistencies may be explained by differences in the material properties of the elastomeric chains used or by variations in how memory elastomeric chains respond to mouthwash formulations. The ongoing development of new mouthwashes for orthodontic use necessitates further investigations of the impact of a broader range of products on the mechanical properties of elastomeric chains. The clinical behavior of elastomeric materials may vary due to the wide range of thermal changes in the oral cavity, chemical composition of the food, and muscular forces. Therefore, generalization of in vitro results to the clinical features of elastomeric chains should be done with caution. Finally, Future investigations should employ in vivo models to examine the influence of mouthwashes on the performance of memory elastomeric chains.

CONCLUSION

The results of the present study revealed that both 0.05% sodium fluoride and Listerine mouthwashes may contribute to an increase in force decay in memory elastomeric chains. In general, sodium fluoride mouthwash caused higher force decay than Listerine Mouthwash; although, the difference was not significant on day 28. It is recommended to advice patients to reduce the use of mouthwashes when they have elastomeric chains.

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CONFLICT OF INTEREST STATEMENT

None declared.

GENERATIVE AI IN SCIENTIFIC WRITING

Perplexity AI and ChatGPT (OpenAI) were used solely for language editing and improving the clarity of the manuscript. All scientific content, analyses, and conclusions were produced entirely by the authors.

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