Frontiers in Dentistry

The Effect of Different Soft Drinks on the Force Degradation of Conventional and Memory Orthodontic Elastic Chains: An In-Vitro Study

Mahboobe Dehghani[1], Neda Alavian[2], Niloofar Noori[3], Maryam Omidkhoda[4*]

1. Dental Research Center, Mashhad University of Medical Sciences, Mashhad, Iran
2. Private practice, Mashhad, Iran
3. Department of Orthodontics, Faculty of Dentistry, Tehran Medical Sciences, Islamic Azad University, Tehran, Iran
4. Dental Materials Research Center, Mashhad University of Medical Sciences, Mashhad, Iran

Article Info

Article type:
Original Article

Article History:
Received: 12 May 2022
Accepted: 24 Jan 2023
Published: 06 Aug 2023

**** Corresponding author:***
Dental Materials Research Center, Mashhad University of Medical Sciences, Mashhad, Iran

Email: maryamomidkhoda@gmail.com

A B S T R A C T

Objectives: The aim of this study was to assess how different soft drinks affect the deterioration of conventional and memory orthodontic elastomeric chains.

Materials and Methods: We used 500 five-loop segments of elastomeric chains, which were divided into two equal groups of conventional and memory chains. The samples were kept in artificial saliva during the study period. Each group was further divided into 5 subgroups consisting of artificial saliva (controls), Coca-Cola®, non-alcoholic beer (ISTAK®), and carbonated and non-carbonated yoghurt-based drinks (Alis®). Treatment with the soft drinks consisted of immersion in the test liquids twice a day for 3 minutes each time. Force measurements were taken on days 1, 7, 14, 21, and 28. Data were analyzed using One- and three-way ANOVA tests, and independent t-test, with a significance level of 5%.

Results: The mean initial force for the conventional and memory elastomeric chains was 3.34±0.112N and 2.49±0.209N, respectively. Conventional chains showed significantly greater degradation than memory chains (P<0.01). Soft drinks had a significant impact on force degradation for both types of chains at all time points (P<0.01). Coca-Cola® had the highest level of force degradation, while non-carbonated yoghurt-based drinks had the lowest (P<0.01).

Conclusion: Based on the findings of this study, it is recommended that orthodontic patients choose non-carbonated yoghurt-based drinks during their treatment. Memory elastomeric chains may be more suitable for patients who consume large amounts of carbonated soft drinks, due to their lower amount of force degradation compared to conventional chains.

Keywords: Orthodontic Appliances; Elasticity; Materials Testing; Carbonated Beverages

➢ **Cite this article as:** Dehghani M, Alavian N, Noori N, Omidkhoda M. The Effect of Different Soft Drinks on the Force Degradation of Conventional and Memory Chains: In-Vitro Study. *Front Dent*. 2023:20:29.

INTRODUCTION

Physiologic and effective tooth movement is possible with light and continuous forces [1]. One of the space closing methods in orthodontics is the usage of elastomeric chains [2]. These materials are economical and relatively hygienic, their utilization is simple and doesn't need the patient's cooperation [2]. On the other hand, due to viscoelastic properties, force degradation is inevitable and many studies have considered this property [1-8]. The mechanism of this degradation is mainly in the vicinity of molecular chain slippage and tension. The mechanical properties of polyurethane products are related to their molecular structure and different additives. Due to force degradation of orthodontic chains, there has been an increasing trend toward the use of elastomers that offer shape memory and durability [9]. Memory chains are one of the elastomeric chains that were introduced in the early 1990s. It is claimed that they preserve force for a longer duration. However, this type of chain is usually more expensive and their application should be justifiable [10].

It has been confirmed that elastomeric chains experience degradation over time, particularly in dry conditions, and their properties can be influenced by temperature and humidity [8]. For instance, research has shown that in dry air, the force degradation of elastomeric chains can range between 42-63% after just 21 days, depending on the brand [7]. Furthermore, a significant portion of the initial force diminishes within 24 hours after force loading, typically ranging from 13-75% [2,11,12-14].

However, the extent of force decay can vary depending on different factors, such as the shape, color, and type (short, medium, and long) of the elastomeric chain, as well as the patient's dietary habits and changes in the oral environment. Additionally, factors such as the use of mouthwash and the evaluation methods used to measure the applied initial force can also influence the rate of force degradation reported in different studies [1-3,8,15-17]. Notably, investigations have indicated that greater initial loading and moisture in the environment can accelerate force degradation. For example, immersion in a water bath at 37 ˚C and exposure to alkaline solutions have been shown to significantly increase the velocity of degradation [2,18].

Several studies have been done on the effect of environmental conditions on the degradation of orthodontic elastomeric chains such as temperature, humidity, PH alterations. Nattrass et al. [19] evaluated the effects of Water, Coca-Cola, and Turmeric Solution on elastomeric chains at 10, 22, and 37 ˚C. Their results showed elastomeric chains were affected by all of these conditions. Larrabee et al. [2] reported that mouthwashes with different concentrations of alcohol (Cepacol 14% and Listerine 26.9%) increase force degradation compare to deionized water during time. Kardach et al [20] evaluated the mechanical properties of plastic and memory chains and showed that after 7 days, the residual force in plastic chains was half of the initial force while it was only 20% of the initial force in memory chains. Also, after 3 weeks, the plastic chain length reached from 8cm to 13.5cm but the Memory chain was 9.5cm. Oshagh et al [8] used hot tea, hot water (65°), chlorhexidine, and a fluoride mouthwash to evaluate force degradation of elastomeric chains, tie-back rings, and Niti coil springs compared to water at 37° (control), during a 3-week period. Their results showed that tea increased force decay in the elastomeric chain and tie-back groups. The type of immersion media had the highest and lowest effect on the tie-back group and Niti coil springs, respectively. Another research [1] compared the effect of Coca-Cola, tea, and Listerine mouthwash on the force delivered by elastomeric chains in vitro. The results showed that tea caused the highest force decay followed by Listerine and Coca-Cola when compared to the control group. Omidkhoda et al [15] focused on the effects of three different types of mouthwash (Persica, Chlorhexidine 0.2%, Sodium fluoride 0.05%) on the force decay of orthodontic chains. They demon-strated that after 4 weeks, Persica caused the lowest, while chlorhexidine induced the highest percentage of force loss [15]. On the other hand, some studies did not find any effect of immersion treatments on the decay of elastomeric forces [11].

Coca-Cola is the most consumed carbonated drink (50%) in developed countries, followed by lemon flavored (22%) and orange-flavored drinks (7%). “Doogh”, a yogurt-based, salty drink, and non-alcoholic beer are two popular drinks in the Iranian diet [21]. Understanding the risk factors associated with force degradation is the first step in their effective management. The aim of this research was to evaluate and compare the effects of different soft drinks on the force degradation of orthodontic memory and conventional chains.

MATERIALS AND METHODS

Elastomeric chains were used to simulate the retraction of canines into premolar extraction spaces. Memory and conventional clear closed elastomeric chains (American Orthodontics (AO), USA) (Figure 1) and were stored in plastic bags at room temperature (22-24°C) until the beginning of the study [15]. Each chain segment included five loops and an extra half-loop at each end to compensate for the probable damage caused by pre-stretching.

Fig.1. Closed elastomeric conventional (left) and memory (right) chains

The chains were pre-stretched to 100% of their initial length for 10 seconds. A jig with two secured posts was designed (Figure 2), so that the distance between the posts would be fixed at 25mm to simulate the distance between the first molar hook and distal wings of the canine brackets [15]. Each piece of chain was stretched between the two posts. In this way, a constant force was exerted on the elastomeric chain during the test period.

Fig 2. Designed holding-jig for retaining each of the chain segments

A total of 500 segments of memory and conventional chains (250 each) were included in this study. Each group was divided into 5 subgroups (N=50) according to the media type, which consisted of artificial saliva, Coca-Cola®, non-alcoholic beer (ISTAK®), and carbonated, and non-carbonated yoghurt-based drinks (Alis®). These subgroups were further divided into 5 groups (N=10), based on evaluation-time points performed at 1, 7, 14, 21 and 28 days.

During the test period, the jigs holding the elastomeric chains were kept in artificial saliva in a light-free environment. The controls received no further treatments but the samples of the experimental groups were immersed in each of the test liquids for 3 minutes, at 8-hour intervals [22]. They were then removed and washed with distilled water, and placed back into the artificial saliva medium. Force was measured after 1, 7, 14, 21, and 28 days using a force gauge (Lutron, model DC-515, Taiwan).

The pH of the drinks was measured with a pH meter (WTW™ inoLab™ Multi 9420 IDS™, Germany) three times for each drink and the mean was recorded (artificial saliva: 6.24, non-carbonated yoghurt: 3.37, carbonated yoghurt: 3.71, non-alcoholic beer: 3.21, Coca-Cola®: 2.47).

Statistical analysis:

The amount of force loss (%) was compared among the experimental and control groups in the memory and conventional elastomeric chain groups. The normality of data distribution was confirmed using the Shapiro-Wilk test. Three-factor analysis of variance and one-factor analysis of variance and independent t-test were used for data analysis. The significance level was set at 5%. The interaction between the three factors as well as the interaction between each of the two factors was significant ($P<0.05$ for all).

RESULTS

Based on our findings, the mean and standard deviation of the initial force was 3.34±0.112N and 2.49±0.209N in the conventional and memory elastomeric chain groups, respectively. Tables 1 and 2 show the amount of force degradation percentage in both chain types, in all experimental solutions, during the evaluated time-points and demonstrate the results of two-by-two comparisons using Tukey's post hoc test.

Table 1. Mean (± standard deviation) percentage of force decay (N) of conventional elastic chains in the tested solutions at each time point

Groups	Time (days)					P
	1	7	14	21	28	
Control (artificial saliva)	-5.8 ± 1^{Aa}	-10.8 ± 2.4^{Ba}	-16.1 ± 2.4^{Ca}	-21.5 ± 2.4^{Da}	-26.2 ± 2.1^{Ea}	<0.01
Non-carbonated yoghurt-based drink	-6.9 ± 3.9^{Aab}	-16.9 ± 4.5^{Bb}	-23.5 ± 3.6^{Cb}	-29.4 ± 3.3^{Db}	-33.7 ± 2.2^{Db}	<0.01
Carbonated yoghurt-based drink	-8.8 ± 1.5^{Ab}	-21.1 ± 5.3^{Bbc}	-27.5 ± 5.3^{Cb}	-33.2 ± 3^{Db}	-37.4 ± 2.9^{Dc}	<0.01
Non-alcoholic beer	-12.3 ± 2.5^{Ac}	-24.6 ± 2.0^{Bcd}	-34.3 ± 1.6^{Cc}	-38.2 ± 1.8^{Dc}	-42.0 ± 1.9^{Ed}	<0.01
Coca- Cola®	-14.0 ± 3.6^{Ac}	-28.4 ± 3.4^{Bd}	-37.1 ± 4.2^{Cc}	-40.3 ± 4.2^{Cc}	-46.7 ± 3.7^{De}	<0.01
P	<0.01	<0.01	<0.01	<0.01	<0.01	

Lowercase letters indicate significant differences between groups and capital letters indicate significant differences between time-points (P<0.05)

Table 2. Mean (± standard deviation) percentage of force decay (N) of memory elastic chains in the tested solutions at each time point

Groups	Time (days)					P
	1	7	14	21	28	
Control (artificial saliva)	-5.0 ± 1.1^{Aa}	-10 ± 1.6^{B}	-14.1 ± 2.5^{Ca}	-17.9 ± 2.5^{Da}	-20.8 ± 2.6^{Ea}	<0.01
Non-carbonated yoghurt-based drink	-5.5 ± 1.5^{Aa}	-10.1 ± 2^{B}	-16.0 ± 2^{Cabc}	-18.3 ± 3.4^{Ca}	-23.4 ± 3.6^{Da}	<0.01
Carbonated yoghurt-based drink	-7.9 ± 1.6^{Ab}	-11.2 ± 3.2^{AB}	-15.6 ± 3.6^{BCab}	-19.8 ± 3.6^{Cab}	-26.4 ± 4.7^{Dab}	<0.01
Non-alcoholic beer	-8.7 ± 2.5^{Ab}	-13.0 ± 4.3^{A}	-20.2 ± 5.2^{Bbc}	-24.3 ± 5.2^{Bb}	-31.9 ± 5.2^{Cb}	<0.01
Coca-Cola®	-8.4 ± 3.8^{Aab}	-13.9 ± 4.8^{A}	-20.6 ± 4.3^{Bc}	-24.7 ± 5.4^{BCb}	-30.0 ± 5^{Cb}	<0.01
P	<0.01	<0.01	<0.01	<0.01	<0.01	

Lowercase letters indicate significant differences between groups and capital letters indicate significant differences between time-points (P<0.05)

Table 3 shows comparison of the mean percentages (± standard deviation) of force decay between the two memory and conventional elastic chain groups in all test solutions and time points.

The results showed that the difference in the force decay of Conventional and Memory chains over time went through a significant reduction in force in different environments at an all-time of 1 to 28 days (P<0.01).

In the conventional chain group, the highest rate of force loss in comparison to the control group at any time point, was related to Coca-Cola® and the lowest force decay was due to the non-carbonated yoghurt-based drink. The force decay sequence was determined as follows, starting with the highest force decay: Coca-Cola®, non-alcoholic beer, carbonated yogurt drink, non-carbonated yogurt drink, and artificial saliva (control).

Similarly, the memory chains showed a gradual decrease in force from day 1 to day 28 for all tested soft drinks.

The greatest force decay on the 1st and 28th day was related to non-alcoholic beer and on the 7th, 14th, and 21st days was related to Coca-Cola®. We did not find statistically significant differences at any of the time points between non-alcoholic beer and Coca-Cola® drinks.

A comparative chart of the two chains types tested in different soft drinks at different times is presented in Figure 3.

Table 3. Comparison of the mean percentages (± standard deviation) of force decay between memory and conventional elastic chains in the studied soft drinks at all time points

Group	Chain type	1day	7days	14days	21days	28days
Control	Conventional	-5.8±1	-10.8±2.4	-16.1±2.4	-21.5±2.4	-26.2±2.1
	Memory	-5±1.1	-10.0±1.6	-14.1±2.5	-17.9±2.5	-20.8±2.6
	P	<0.001	0.003	<0.001	<0.001	<0.001
Non-carbonated yoghurt drink	Conventional	-6.9±3.9	-16.9±4.5	-23.5±3.6	-29.4±3.3	-33.7±2.2
	Memory	-5.5±1.5	-10.1±2	-16.0±2	-18.3±3.4	-23.4±3.6
	P	0.051	<0.001	<0.001	<0.001	<0.001
Carbonated yoghurt drink	Conventional	-8.8±1.5	-21.1±5.3	-27.5±5.3	-33.2±3	-37.4±2.9
	Memory	-7.9±1.6	-11.2±3.2	-15.6±3.6	-19.8±3.6	-26.4±4.7
	P	0.002	<0.001	<0.001	<0.001	<0.001
Non-alcoholic beer	Conventional	-12.3±2.5	-24.6±2	-34.3±1.6	-38.2±1.8	-42.0±1.9
	Memory	-8.7±2.5	-13±4.3	-20.2±5.2	-24.3±5.2	-31.9±5.2
	P	<0.001	<0.001	<0.001	<0.001	<0.001
Coca- Cola®	Conventional	-14.0±3.6	-28.4±3.4	-37.1±4.2	-40.3±4.2	-46.7±3.7
	Memory	-8.4±3.8	-13.9±4.8	-20.6±4.3	-24.7±5.4	-30.0±5
	P	<0.001	<0.001	<0.001	<0.001	<0.001

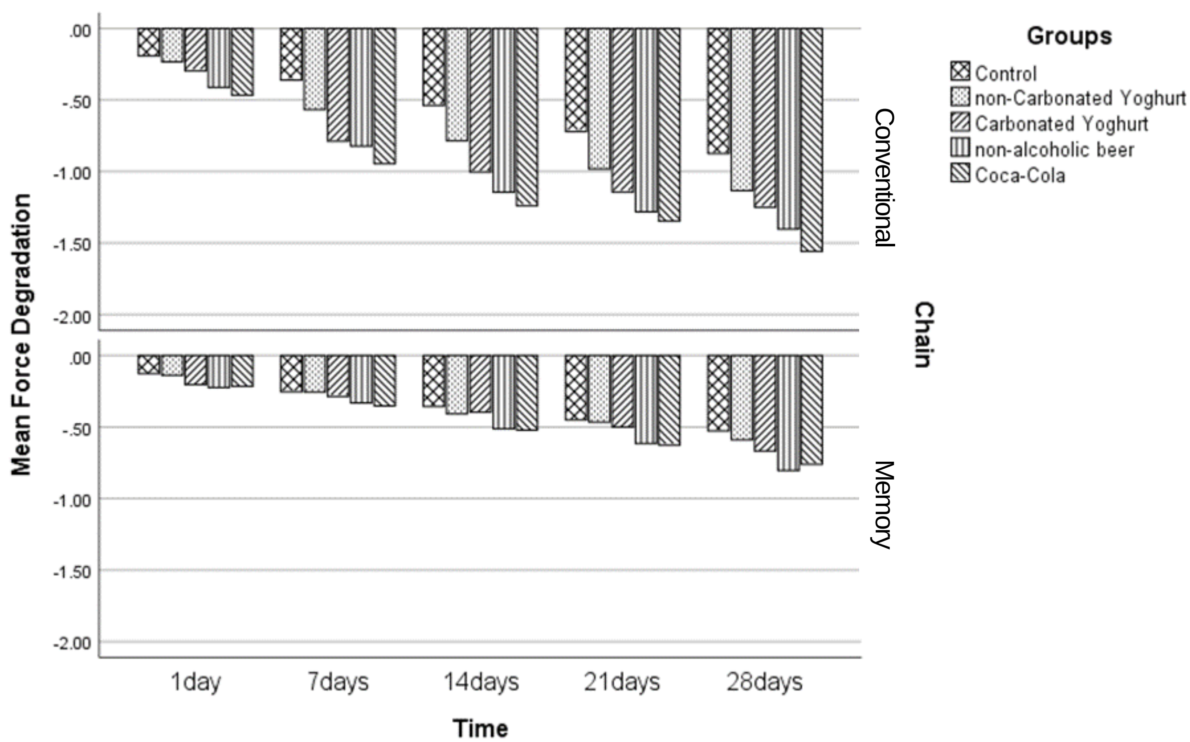

Fig. 3. Comparison of memory and conventional elastic chains in various soft drinks at different time points

DISCUSSION

In this in-vitro study, the effect of four types of drinks on the degradation of memory and conventional orthodontic elastic closed chains was compared with artificial saliva. An ideal elastomer returns to its original state after being stretched and released [23]. However, in reality, this does not occur and the force of orthodontic chains degrades over time and under different conditions [1-4,24]. Our findings were related to three factors affecting chain degradation: time, type of chain, and environment (drinks). Since the 1970s, several studies on force degradation of elastomers in orthodontics have been published [25-32,4-7] and have shown a wide range of force degradation after 28 days (24-85%) based on the environment and the quality of materials used in the elastomers. The present study compared conventional and memory elastomeric chains in different beverages including Coca-Cola®, non-alcoholic beer (ISTAK®), and carbonated, and non-carbonated yoghurt-based beverage (Alis®)) to provide a better understanding of their decay rate and how they change over time.

In this study, conventional chains showed greater force decay than memory chains, despite the fact that they were both clear and of the same brand. This was confirmed in all groups and time points and the difference between them was statistically significant. Previous studies have also reported differences between different types of chains [27,17,31].

Generally, force degradation results are typically reported after a 28-day period, which is the typical time interval for orthodontic follow-ups. In this study, it was observed that the conventional chain experienced a significant decrease in force, ranging from 34 to 47%, when exposed to different drinks after 28 days. On the other hand, the memory chains only showed a 23 to 30% force loss after the same time period.

The current investigation confirmed that the environment plays a significant role in the decay of force in conventional and memory chains. This finding aligns with previous studies that have also shown the impact of environmental factors on orthodontic force degradation [9,24,25,16,1-3]. One study conducted by Pithon et al. [22] specifically investigated the effect of acidic beverages such as Coca-Cola, Sprite, Guarana Antarctica, and Fanta on elastomeric chains. They found that Coca-Cola had the greatest detrimental effect on the destruction of elastomeric chains. This result is consistent with our findings, as we also observed that Coca-Cola had a greater impact on force decay compared to other drinks when it came to conventional chains. Another study by Braga et al. [33] immersed memory elastomeric chains in Cola and compared it with artificial saliva. They discovered that Cola caused more force degradation at both 7 and 21 days. However, in our research, we found that there was a significant reduction in force decay compared to artificial saliva only at 21 and 28 days for the memory chain groups. It should be noted that our research ensured temperature stability, which was identified as a significant factor in Barretto's study.

The difference between the effect of carbonated yogurt drink and non-carbonated yogurt drink with other beverages in reducing the force of elastomeric chins in our study was significant. We did not find any similar studies in the literature to compare our results.

Suprayugo et al. [34] conducted a study on power chains immersed in various beverages and found that Coca-Cola caused the greatest force decay over a period of 48 to 336 hours, compared to sweet tea, distilled water, and juice. Surprisingly, acidity did not have a significant influence on the force decay of the power chains [34]. While the pH factor has been examined in previous research, there are still differing opinions on its effects [22, 34, 35]. In addition to pH, other factors such as pigments, chlorides, and phosphates present in acidic beverages may also play a role in force decay. For example, our study found that the non-carbonated yogurt drink (pH=3.37) had a lesser impact on force decay compared to the carbonated yogurt drink (pH=3.71). On the other hand, Coca-Cola® caused the most force decay in conventional chains, and non-alcoholic beer (pH=3.21) and Coca-Cola® (pH=2.47) caused the most force decay in memory chains, suggesting a strong correlation with acidity.

In a recent study on the effect of carbonated and non-carbonated yogurt drinks, as well as sodas like Seven Up and Pepsi Cola, it was found that lactic acid had no significant effect on shear bond strength [36]. These findings were also supported by Hobson et al. [37]. However, it was observed that yogurt drinks have high levels of acidity and the accumulation of acid molecules in these beverages can reduce shear bond strength in orthodontic brackets [37]. In our study, the impact of these yogurt drinks was examined on force degradation, revealing that the non-carbonated type behaved similarly to artificial saliva, while the carbonated type, although milder than Coca-Cola and non-alcoholic beer, had a similar effect.

In the current investigation, average force degradation of conventional and memory chains in artificial saliva after 4 weeks was about 26% and 21% respectively, which is in contrast to an in situ study by Baratieri et al [10]. They reported a force decay of about 44% and 33% for conventional and memory chains, respectively, after 3 weeks. The difference may be related to oral media conditions and the elastomeric chain types as well as the stretching mount.

Mirhashemi et al [9] reported 60-70% force loss after 4 weeks for three different brands of conventional elastic chains which were immersed in distilled water. They found that memory chains retained more than 60% of the force during this period, under the same circumstances. These findings are relatively close to our study. Another study showed that memory chains are more effective in orthodontic treatment due to diminished loss of mechanical and elastic capabilities when compared to plastic chains. [20]. This agrees with our observations in that force decay in conventional elastic chains was about 1.5 times higher than that of the memory chains, after 28 days.

CONCLUSION

This study showed that memory elastomeric chains experience less force degradation compared to conventional chains. We found that different soft drinks had varying effects on the degradation process. In conventional chains after a period of 28 days, the most significant negative impact was found to be caused by Coca-Cola ®, while non-carbonated yogurt drinks had the least effect. However, for memory chains, Coca-Cola, non-alcoholic beer, and carbonated yogurt drinks showed maximum degradation, while non-carbonated yogurt drinks had the minimum effect. In light of these findings, we recommend to our orthodontic patients that if they must consume soft drinks, they should at least opt for non-carbonated yogurt drinks in their diet. Also in patients with high consumption of carbonated drinks, use of memory chains should be considered.

ACKNOWLEDGEMENT

This study was extracted from an undergraduate thesis. Hereby, we extend our gratitude to the Research Deputy of Mashhad University of Medical Sciences for their financial support towards this research project (grant number: 960259).

CONFLICT OF INTEREST STATEMENT

None declared.

REFERENCES

1. Kumar K, Shetty S, Krithika MJ, Cyriac B. Effect of commonly used beverage, soft drink, and mouthwash on force delivered by elastomeric chain: a comparative in vitro study. J Int Oral Health. 2014 Jun;6(3):7-10. Epub 2014 Jun 26.
2. Larrabee TM, Liu SS, Torres-Gorena A, Soto-Rojas A, Eckert GJ, Stewart KT. The effects of varying alcohol concentrations commonly found in mouth rinses on the force decay of elastomeric chain. Angle Orthod. 2012 Sep;82(5):894-9.
3. Halimi A, Benyahia H, Doukkali A, Azeroual MF, Zaoui F. A systematic review of force decay in orthodontic elastomeric power chains. Int Orthod. 2012 Sep;10(3):223-40. English, French.
4. Eliades T, Eliades G, Silikas N, Watts DC. In vitro degradation of polyurethane orthodontic elastomeric modules. J Oral Rehabil. 2005 Jan;32(1):72-7.
5. Ferriter JP, Meyers CE Jr, Lorton L. The effect of hydrogen ion concentration on the force-

degradation rate of orthodontic polyurethane chain elastics. Am J Orthod Dentofacial Orthop. 1990 Nov;98(5):404-10.
6. Lu TC, Wang WN, Tarng TH, Chen JW. Force decay of elastomeric chain--a serial study. Part II. Am J Orthod Dentofacial Orthop. 1993 Oct;104(4):373-7.
7. Ren Y, Maltha JC, Kuijpers-Jagtman AM. Optimum force magnitude for orthodontic tooth movement: a systematic literature review. Angle Orthod. 2003 Feb;73(1):86-92
8. Oshagh M, Khajeh F, Heidari S, Torkan S, Fattahi HR. The effect of different environmental factors on force degradation of three common systems of orthodontic space closure. Dent Res J (Isfahan). 2015 Jan-Feb;12(1):50-6.
9. Mirhashemi A, Saffarshahroudi A, Sodagar A, Atai M. Force-degradation pattern of six different orthodontic elastomeric chains. J Dent (Tehran). 2012 Fall;9(4):204-15. Epub 2012 Dec 31.
10. Baratieri C, Mattos CT, Alves M Jr, Lau TC, Nojima LI, de Souza MM, et al. In situ evaluation of orthodontic elastomeric chains. Braz Dent J. 2012;23(4):394-8.
11. Teixeira L, Pereira Bdo R, Bortoly TG, Brancher JA, Tanaka OM, Guariza-Filho O. The environmental influence of Light Coke, phosphoric acid, and citric acid on elastomeric chains. J Contemp Dent Pract. 2008 Nov 1;9(7):17-24.
12. Masoud AI, Tsay TP, BeGole E, Bedran-Russo AK. Force decay evaluation of thermoplastic and thermoset elastomeric chains: A mechanical design comparison. Angle Orthod. 2014 Nov;84(6):1026-33.
13. Balhoff DA, Shuldberg M, Hagan JL, Ballard RW, Armbruster PC. Force decay of elastomeric chains - a mechanical design and product comparison study. J Orthod. 2011 Mar;38(1):40-7.
14. Masoud AI, Tsay TP, BeGole E, Bedran-Russo AK. Force decay evaluation of thermoplastic and thermoset elastomeric chains: A mechanical design comparison. Angle Orthod. 2014 Nov;84(6):1026-33.
15. Omidkhoda M, Rashed R, Khodarahmi N. Evaluation of the effects of three different mouthwashes on the force decay of orthodontic chains. Dent Res J (Isfahan). 2015 Jul-Aug;12(4):348-52.
16. Al-Kassar SS. The force degradation of elastic chain in different environments and for different intervals (an in vitro study). Al-Rafidain Dent. J. 2011 Jun 1;11(2):231-7.
17. Ramazanzadeh BA, Jahanbin A, Hasanzadeh N, Eslami N. Effect of sodium fluoride mouth rinse on elastic properties of elastomeric chains. J Clin Pediatr Dent. 2009 Winter;34(2):189-92.
18. Van Eygen I, Vannet BV, Wehrbein H. Influence of a soft drink with low pH on enamel surfaces: an in vitro study. Am J Orthod Dentofacial Orthop. 2005 Sep;128(3):372-7.
19. Nattrass C, Ireland AJ, Sherriff M. The effect of environmental factors on elastomeric chain and nickel titanium coil springs. Eur J Orthod. 1998 Apr;20(2):169-76.
20. Kardach H, Biedziak B, Olszewska A, Golusińska-Kardach E, Sokalski J. The mechanical strength of orthodontic elastomeric memory chains and plastic chains: An in vitro study. Adv Clin Exp Med. 2017 May-Jun;26(3):373-378.
21. Sajadi SS, Eslami Amirabadi G, Sajadi S. Effects of two soft drinks on shear bond strength and adhesive remnant index of orthodontic metal brackets. J Dent (Tehran). 2014 Jul;11(4):389-97. Epub 2014 Jul 31.
22. Pithon MM, Lacerda-Santos R, Santana LR, Rocha M, Leal RO, Santos MM. Does acidic drinks vs.controls differents interfere with the force of orthodontic chain elastics? Biosci J. 2014;30:1952–8..
23. Sarkar SR, Tan KF. Changes in the force degradation of orthodontic elastomeric chains when subjected to different formulations of chlorhexidine mouthrinse-an in vitro study. Contemp Res J Multidisciplinary Sci. 2017 Dec 3;1(1):29-44.
24. Rafeeq RA, Al-Mashhadany SM, Hussien HM, Al-Groosh DH, Effect of Three Types of Mouth Washes on the Force Decay of Elastomeric Chains: An in Vitro Study. IJSR 2017;6(6):1561-65
25. Kanuru RK, Azaneen M, Narayana V, Kolasani B, Indukuri RR, Babu PF. Comparison of canine retraction by in vivo method using four brands of elastomeric power chain. J Int Soc Prev Community Dent. 2014 Nov;4(Suppl 1):S32-7.
26. Yuwana CP, Christnawati C, Farmasyanti C. The Effect of Immersion Time in Three Kinds of Carbonated Beverages on Orthodontic Elastic Latex's Tensile Strength (In Vitro). UIP Health Med. 2017 Jan 3;1:63-7.
27. Crawford NL, McCarthy C, Murphy TC, Benson PE. Physical properties of conventional and Super Slick elastomeric ligatures after intraoral use. Angle Orthod. 2010 Jan;80(1):175-81.
28. Bousquet JA Jr, Tuesta O, Flores-Mir C. In vivo comparison of force decay between injection molded and die-cut stamped elastomers. Am J Orthod Dentofacial Orthop. 2006 Mar;129(3):384-9.
29. Fernandes DJ, Fernandes GM, Artese F, Elias CN, Mendes AM. Force extension relaxation of medium force orthodontic latex elastics. Angle Orthod. 2011 Sep;81(5):812-9.
30. Aldrees AM, Al-Foraidi SA, Murayshed MS, Almoammar KA. Color stability and force decay of clear orthodontic elastomeric chains: An in vitro study. Int Orthod. 2015 Sep;13(3):287-301. English, French.

31. Singh V, Pokharel P, Pariekh K, Roy D, Singla A, Biswas K. Elastics in orthodontics: A review. Health Renaiss. 1970;0:49–56.
32. Renick MR, Brantley WA, Beck FM, Vig KW, Webb CS. Studies of orthodontic elastomeric modules. Part 1: glass transition temperatures for representative pigmented products in the as-received condition and after orthodontic use. Am J Orthod Dentofacial Orthop. 2004 Sep;126(3):337-43.
33. Braga E, Souza G, Barretto P, Ferraz C, Pithon M. Experimental evaluation of strength degradation of orthodontic chain elastics immersed in hot beverages. J Indian Orthod Soc. 2019;53:244–8.
34. Suprayugo M, Eriwati YK, Santosa A. Effect of pH of soft drinks on force decay in orthodontic power chains. J Physics. 2018;1073:62016.
35. Khaleghi A, Ahmadvand A, Sadeghian S. Effect of citric acid on force decay of orthodontic elastomeric chains. Dent Res J (Isfahan). 2021 May 24;18:31.
36. OmidKhoda M, Heravi F, Shafaee H, Mollahassani H. The effect of different soft drinks on the shear bond strength of orthodontic brackets. J Dent (Tehran). 2012 Spring;9(2):145-9. Epub 2012 Jun 30.
37 Hobson RS, McCabe JF, Hogg SD. The effect of food simulants on enamel-composite bond strength. J Orthod. 2000 Mar;27(1):55-9.