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Comparison of force decay pattern in orthodontic elastomeric chains and NiTi closed coil springs, affected by five different mouthwashes: An in vitro study

AmirHossein Mirhashemi [1], Niloofar Habibi Khameneh [2], Keyvan Shahpoorzadeh [3], Atefe Saffar Shahroudi [4]

[1] *Associate professor, Department of Orthodontics, School of Dentistry, Tehran University of Medical Sciences, Tehran, Iran*

[2] *Dental student, School of Dentistry, Tehran University of Medical Sciences, Tehran, Iran*

[3] *Dental student, School of Dentistry, Tehran University of Medical Sciences, Tehran, Iran*

[4] *Assistant professor, Dental research center, Dentistry research institute, and Department of Orthodontics, Dental school, Tehran University of Medical Sciences, Tehran, Iran*

Abstract

Background: The aim of this study was to compare the force decay pattern of elastomeric chains and NiTi coil springs which were exposed to five different commercially available mouthwashes.

Methods: In this *in vitro* study, 60 pieces of elastomeric chain (EC) and 60 NiTi closed coil springs (CS) were divided into 6 groups. The specimens were exposed to one of these mouthwashes twice a day for 60 seconds: Listerine, chlorhexidine, Orthokin, Persica, fluoride and artificial saliva as the control group. The elastomeric chains and NiTi springs were stretched so that they exert the initial force of 250 gr. Their force was measured on the 1, 7, 14 and 28 following days by means of a digital gauge.

Results: Elastomeric chains and coil springs had force decrease over time, but EC' force reduction was greater with the highest reduction rate in the first week. However, in the CS group, the force decrease wasn't statistically significant in the first two weeks. After 28 days in the control groups, 49.8% of the initial force was remained in ECs while the value was 93.3% for CSs. In comparison between mouthwashes, in EC groups, in all mouthwashes except Persica, the remained force was statistically less than control group.

Conclusion: Force degradation of elastomeric chains could be exacerbated by use of mouthwashes. About coil springs, force decay was also observed. However, it was not statistically significant. Force reduction was detectable after four weeks of coil springs usage, but in EC groups, the greatest reduction was after the first week.

Keywords: Force reduction; orthodontics; mouthwash; elastomeric chain; closed coil spring.

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Email: a-shahroudi@tums.ac.ir

Introduction

In orthodontic treatment different materials have been used as force delivery systems for space closure such as elastomeric chains and modules, and nickel titanium (NiTi) coil springs [1-3]. To obtain the most efficient orthodontic tooth movement, light continuous and constant forces are preferred [4,5]. Elastomeric products are more frequently used force delivery system in orthodontics due to simplicity of handling, low chair time, low cost, patient comfort and being biocompatible [1,6,7]. However, these materials are affected by different factors such as oral environment, duration of force application and nutritional factors. They undergo deformation and thereby their force decreases which results in an

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impairment in the rate of tooth movement and elongation of treatment process [6-9]. This deformation occurs due to structural changes in elastomers such as adjacent molecular chains slippage and molecular stretching [10,11]. The greatest degree of force loss was observed in the first 3 hours with a relatively steady force loss rate in the following days [11,12].

Nickel-titanium coil springs has been also vastly used for force exertion in orthodontics due to its promise to deliver low constant forces [13]. This has been attributed to super-elasticity of Nickel-titanium alloy which means that under an increasing strain its structure undergoes phase transformation (austenitic phase to martensitic phase) instead of permanent deformation. Its force-displacement plots have a long plateau region and if the release of the strain begins within this region there is a mix of the two phases, and the material generally returns completely to the austenitic phase [14]. NiTi coil springs have also been found to lose some of their force over time and some studies have shown 8% to 20 % force loss in 4-12 weeks [15,16]. However, the amount of force decay was less than elastomeric chains [17,18]. it has been reported that NiTi coil springs force is also affected by environmental factors although to a lesser extent than elastomers [18,19].

One of the most important solutions that deserves investigation are mouthwashes since they are commonly prescribed for orthodontic patients. Orthodontic patients are at a higher risk of plaque accumulation around their fixed appliances and subsequently greater risk of having cariogenic bacteria in their oral environment [20-25].

The effect of commonly used mouthwashes such as chlorhexidine [20], sodium fluoride [21], Listerine, Persica [22] and Orthokin [19] on the force of elastic chains as well as their potential influential factors such as the Ph of the mouth rinses [23], bleaching agents [24] and alcohol content [25] have been investigated.

Although many researchers investigated the effect of mouthwashes on force degradation of orthodontic elastomeric materials, very few studies have compered the effect of these chemicals on the force exertion of elastomeric chains and NiTi coil springs. Accordingly, this study was done with the aim of comparing the force decay pattern of elastomeric chains and NiTi coil springs which were exposed to five different commercially available mouthwashes including Listerine, Chlorhexidine, Orthokin, Persica and fluoride, over time.

Methods

In this experimental in vitro study, the effect of five different mouthwashes was investigated: 1. Chlorhexidine 0.2% (Behsa Pharmaceutical company, Arak, Iran) containing 0.2 gr Chlorhexidine gluconate in 100 ml solution. 2. Sodium Fluoride mouthwash 0.2% (Behsa Pharmaceutical company, Arak, Iran) containing 0.2 gr sodium Fluoride in 100 ml solution. 3. Persica mouthwash (Poursina pharmaceutical company, Tehran, Iran) containing effective materials such as tooth plant, mint and yarrow. The most important organic and mineral materials of the drop include Tannins, Flavonoids, essence, calcium, Fluoride and chloride. 4. Total care Zero Listerine mouthwash (Johnson and Johnson, Italy) and 5. Orthokin alcohol free mouthwash (Kin factory, Spain). Ten samples of NiTi coil springs and ten samples of elastomeric chains were allocated to each group of the mouthwashes.

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The elastomeric chains which were clear and without intermodular link (American Orthodontics) were cut to the initial length of 12 millimeter. Additionally, two extra loops were remained on each side to avoid excessive force on terminal loops. This was done meticulously in order to avoid extended handling which may place stresses in the elastomers prior to testing. The applied NiTi specimens were superelastic 9 mm closed coil 150 g springs (GAC International, Bohemia, NY).

A custom-made jig was designed with a series of pins which held the stretched specimens at a constant length of 25 mm (about twice their original length or 100% elongation). One hundred percent extension had been suggested by former authors and manufacturers for clinical use [12] and 25 mm was considered as an average distance between canine and first molar [18]. The device included vertical parallel rods arranged 25 mm apart from each other on a plexiglass plate. The rods were 1.2 mm in diameter and made of steel and covered by a layer of lac to prevent stains during the study. The coil springs were mounted on the vertical rods by stainless steel orthodontic wires. The wires were wrapped around themselves several times to prevent loosening and opening (figure 1A). The initial force of the specimens was measured using a digital force gauge (model: SF-50, Germany) with newton and gr units and up to 1 gr accuracy (figure 1B)

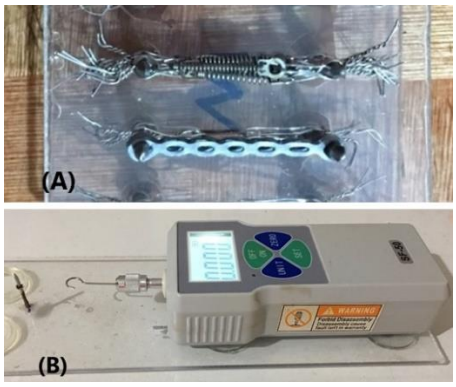

Figure 1: **A)** specimens are held at a constant length of 25 mm on a custom-made jig. **B)** The force was measured using a digital force gauge.

In order to simulate oral condition, all six jigs were immersed in artificial saliva and stored in an incubator at body temperature (37±1°C). One jig was considered as control group and the other 5 group was exposed to one of the aforementioned mouthwashes. The specimens were soaked in their intended mouthwashes twice a day for 60 seconds each time with 12-hour interval. Following each immersion, the samples were washed for 10 seconds with distilled water before being transferred to the artificial saliva and incubator again. The force exerted by each group was measured by means of the explained digital force gauge, at 0, 1-day, 7-day, 14-day and 28-day intervals.

To compare the effect of time and type of the mouthwashes on the force exerted by elastomeric chains and NiTi coil springs, three-way analysis of variance (ANOVA) was performed. However, since none of the triple and double interactions were significant, each group was analyzed by means of one-way ANOVA and post-hoc Tukey's test.

Results

In this study, the mean initial force for elastomeric chains at 25 mm extension was 249.8±0.6 gr and in NiTi coil spring groups the initial force was 150.2±0.3 gr. The force exerted by elastomeric chains and NiTi coil springs in different mouthwash groups at different time intervals are presented in Table 1 and 2 respectively. The percentage of remaining force relative to the initial force is also given in all study groups.

The effect of time on samples' force

In both groups of EC and CS a steady decrease over time in the exerted force was observed. However, among coil springs, this force decay was more gradual and

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totally less than elastomeric chains after 4 weeks. The elastomeric chains had the greatest force reduction over one week, followed by a more gradual force reduction in the next intervals. (Table 1). In CS groups, there was not a significant difference between different time intervals (p>0.05). (Table 2)

Table 1. Mean Force in gram and the remaining force percentage(numbers in parenthesis) in elastomeric chains in different times in different mouth rinse groups during the study

MR	**Day 0**	**Day 1**	**Day 7**	**Day 14**	**Day 28**
Control	249.4 (100)	155.0* (62.0)	133.2 (53.3)	131.2 (52.5)	124.4 (49.8)
Persica	249.4 (100)	150.0* (60.0)	132.4 (53.0)	130.4 (52.2)	117.6 (47.0)
Fluoride	250.8 (100)	146.8* (58.7)	112.6+ (45.0)	110.6+ (44.2)	101.6+ (40.6)
Chlorhexidine	249.8 (100)	147.6* (59.0)	121.2 (48.5)	120.8+ (48.3)	102.8*+ (41.1)
Orthokin	250.6 (100)	153.6* (61.4)	113.6+ (45.4)	111.6+ (44.6)	100.6+ (40.2)
Listerine	249.6 (100)	145.8*+ (58.3)	116.0*+ (46.4)	112.4+ (45.0)	100.2+ (40.1)

MR: mouth rinse

**: significantly different from the previous follow-p in the same group*

+: significantly different from the control group at the same follow-up time

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Table 2. Mean Force in gram and the remaining force percentage(numbers in parenthesis) in NiTi closed coil spring in different times in different mouth rinse groups

MR	Day 0	Day 1	Day 7	Day 14	Day 28
Control	150 (100)	149.5 (99.7)	146.1 (97.4)	141.3 (94.2)	140.0 (93.3)
Persica	150 (100)	146.8 (97.9)	137.9 (91.9)	139.5 (93.0)	130.9 (87.3)
Fluoride	150 (100)	151.6 (101.1)	146.7 (97.8)	134.4 (89.6)	132.5 (88.3)
Chlorhexidine	150 (100)	152.4 (101.6)	147.0 (98.0)	134.1 (89.4)	133.4 (88.9)
Orthokin	150 (100)	148.9 (98.5)	145.25 (96.8)	140.0 (93.3)	131.5 (88.3)
Listerine	150 (100)	147.8 (98.5)	148.6 (99.1)	144.6 (96.4)	132.4 (88.0)

MR: mouth rinse

**: significantly different from the previous follow-p in the same group*

+: significantly different from the control group at the same follow-up time

The effect of mouthwashes on samples' force

The results of statistical analysis showed that there was a statistically significant difference between some groups of mouthwashes in elastomeric chain samples on the first day. (P = 0.005). Listerine showed the least

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force among all groups. (Table 1) In coil spring groups, there was no statistically significant difference between the different groups (P = 0.183).

On the seventh day, all the EC groups showed a significant difference (P = 0.000) and the control group had a significantly higher force than all groups but the difference with Persica and Chlorhexidine was not significant (p>0.05). The lowest force on the seventh day belonged to the Fluoride group, followed by Orthokin, Listerine, Chlorhexidine, Persica and control, respectively. In CS groups, on the seventh day there was no significant difference among groups (P = 0.24) but Persica had the lowest force, followed by Orthokin, Control, Fluoride, Chlorhexidine, and Listerine respectively.

On the 14th day, there was a significant difference in the EC groups (P = 0.000) and the control group had statistically significant difference with all groups except Persica. Fluoride, Orthokin and Listerine were not significantly different. The lowest force on the 14th day belonged to the Fluoride group (Table 1). In CS groups on day 14, no significant different was observed between the mouth washes and control group (P>0.05) but Listerine group had a significant difference with Fluoride and Chlorhexidine. The lowest force belonged to the Chlorhexidine group.

On the 28th day, there was a significant difference in the EC groups (P = 0.000) so that control group had statistically significant difference with all except Persica group. Other mouthwash groups were not different. In the control group about 49.8 % of the initial force was remained and in the Listerin group about 60% of the initial force was lost.

There were no statistically significant differences in the coil springs groups on the 28th day. However, the maximum force belonged to the control group which was 140 gr and 93.3% of the initial force was remained in this group. Even in the lowest force group which was Persica, 87.3 % of the initial force was remained. (Table 2)

Discussion

Elastomeric chains and coil springs are common means of applying force in orthodontics. The amount of force applied to the teeth over time is important. In this study, we investigated the effect of Persica, Fluoride, Chlorhexidine, Orthokin and Listerine mouthwashes on force reduction of elastomeric chains and coil springs.

The present study showed that elastomeric chains lost a great amount of force overtime and this force loss was less for coil springs. It was also shown that force loss of elastomeric chains was exacerbated by mouthwashes. Coil springs was affected by mouthwashes to a lesser extent. In elastomers, the greatest force reduction was related to Orthokin and Listerin, while in coil springs it was related to Persica. The highest force reduction in elastomeric chains was also observed in the first week of use.

In this study, the initial force of 250 grams for elastomers and 150 grams for coil springs was used. This initial force is similar to the force that is used in the clinic and consistent with previous studies. In the study of Omidkhoda et al. in 2015 an initial force of 200 gram for elastomers was used [26]. In a 2018 study by Patel et al., they used an initial force of 242 to

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304 grams for four types of elastomeric chains [7]. Javanmardi et al., used an initial force of 200 g for elastomeric chains and a force of 180 g for coil springs [19]. It is stated in studies that for bodily movement of teeth an average of 100 to 350 gr power is needed [27]

In 2014, Kumar et al., examined the effect of various beverages, such as distilled water, Coca-Cola, tea and Listerine mouthwash on elastomeric chains' force. This study was performed in 28 days similar to the present study and samples were exposed to liquid of their target group twice a day for 60 seconds. But in their study, unlike the present study, an initial force of approximately 5 Newton (500 g) was used. In that study, the control group showed a 22.18% decrease in force and the Listerine group had a 23.15% force decay at the end of the study [28]. In the present study, the control group showed a 50.24% reduction in force and the Listerine group caused a 55.92% force decay in elastomeric chains. The amount of force reduction was different in the two studies, but in both studies, Listerine caused a greater decrease in elastomeric chains' force compared to the control group. Another difference between these two studies is that in the present study artificial saliva was used to hold the specimens but Kumar et al. used distilled water throughout their study [28].

In 2016, Javanmardi et al. Investigated the effect of Orthokin, sensikin and Persica mouthwashes on the force reduction of elastomeric chains and Ni-Ti coil springs. They concluded that both types of specimen experience force decrease over time. In elastomeric chains, Orthokin had less force decay than Persica and in coil springs there was no significant difference between the different groups. In the present study, Orthokin had the greatest force reduction. Our study was performed in four weeks but the duration of their study was 3 weeks. Moreover, the initial force of elastomers in their study, unlike the present study, was 200±5 g since the specimens were stretched 15.5 mm initially [19].

Omidkhoda et al., examined the effect of Persica, Chlorhexidine and Fluoride mouthwashes on the force reduction of elastomeric chains. The researchers concluded that Chlorhexidine caused the greatest reduction in force while, Persica caused the least reduction between the three mouthwashes [26]. these results are concurrent with the present study. However, there were some methodologic differences in the way that in the present study, the temperature of the samples was maintained at 37 ° C but in that study a temperature cycle of 5 to 55 ° were used. The initial force of this study was also about 200 gr.

In a recent study by Mirhashemi et al. (2020) the effect of different mouthwashes on active tiebacks was evaluated and it was concluded that Persica mouthwash caused greater force loss in comparison with control group. They also reported that active tiebacks of different colors had a different force loss pattern and different response to chemical agents such as mouth rinses [29].

Kardach et al., in a study in 2017, examined the force reduction of elastomeric chains in the two groups of plastic and memory. They concluded that plastic chains had a significant

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force reduction after one week of use. (50% lost in primary force which is similar to the 49% reduction of the current study's control group). The memory chains also showed a force reduction after one week which was less than plastic chains (20% lost in primary force) [30].

A review of literature showed that few studies have investigated the comprehensive effect of various mouthwashes used in the present study, and in few research two common and applicable orthodontic means of force exertion such as elastomeric chains and coil springs, have been compared. Although it was concluded that coil springs undergo less force loss and they are less vulnerable to chemicals it should be considered that they are more expensive and they exert less initial force at the same amount of extension than elastomeric chains. However, in cases that light continues force is essential such as intrusion, single tooth movement or patients with compromised alveolar bone supports, NiTi coil springs could be a more prudent choice. Moreover, in cases that application of mouth rinse is crucial, such as cases with vulnerable gingiva and periodontium, immunosuppressed patients, pregnant cases or post-surgical phases, application of NiTi coil springs which are less adversely affected by chemical agents such as mouthwashes is advisable.

Coil springs were most affected after 28 days while elastomers lost most force during the first week. The use of mouthwash in elastomers reduced the force more. But in coil springs, the use of mouthwashes did not significantly change the force reduction. Because orthodontics patients are more likely to use mouthwash during treatment, and according to statistical results, if necessary, use of Persica mouthwash is more recommended for these patients. In patients using coil springs there is no restriction for mouthwash use. According to the present study's results which shows the gradual force reduction, it is recommended to replace elastomers after 2 week and coil springs at least once a month.

This study examines the effect of mouthwashes in invitro condition and there is certainly a need for further clinical studies to achieve more reliable results.

Conclusion

In general, both elastomeric chains and NiTi coil springs underwent force degradation over time which was significantly less in coil springs than chains.

In control group after 4 weeks, 49% of initial force was preserved in elastomeric chains while in coil spring it was 93.3%.

In elastomeric chains the highest force loss was observed in the first week while in NiTi coil springs the difference with the initial force was noticeable after four weeks.

The force loss of elastomeric chains and NiTi coil springs could be exacerbated by use of some mouthwashes. However, this effect was not significant in NiTi coil springs.

In elastomeric chains, all mouthwashes caused greater force loss than the control group but Persica had the least force degradation in comparison with other mouthwashes including Chlorhexidine, Flouride, Orthokin and Listerin.

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Disclosure of interest

The authors declare that they have no competing interest.

Authors' contributions

AHM developed the idea of research and coordinated the project and he was the advisor professor.

ASS was the co-advisor professor and she did the scientific writing of the article.

KS and NHK made the samples, conducted the experiments and did the measurements.

References

1. A randomized clinical trial to compare three methods of orthodontic space closure. Dixon V, Read MJ, O'Brien KD, Worthington HV, Mandall NA. Journal of orthodontics. 2002;29(1):31-6. PMID: 11907307

2. A clinical investigation of force delivery systems for orthodontic space closure. Nightingale C and Jones SP. J Orthod 2003;30: 229–236. PMID: 14530421

3. Forces of various nickel titanium closed coil springs. Maganzini AL, Wong AM, Ahmed MK. The Angle Orthodontist. 2010 Jan;80(1):182-7. PMID: 19852659

4. Tissue reaction to orthodontic tooth movement – a new paradigm. Melsen B. Eur J Orthod 2001; 23: 671–681. PMID: 11890063

5. The application of continuous forces to orthodontics. Burstone CJ, Baldwin JJ and Lawless DT. Angle Orthod 1961;31:1-14. https://doi.org/10.1043/0003-3219(1961)031<0001:TAOCFT>2.0.CO;2

6. Comparative Assessment of Force Decay of the Elastomeric Chain With the Use of Various Mouth Rinses in Simulated Oral Environment: An In Vitro Study. Menon VV, Madhavan S, Chacko T, Gopalakrishnan S, Jacob J, Parayancode A. J Pharm Bioallied Sci. 2019;11(Suppl 2):S269-s73. PMID: 31198351

7. In vivo evaluation of the force degradation characteristics of four contemporarily used elastomeric chains over a period of 6 weeks. Patel A, Thomas B. J World Fed Orthod. 2018;7(4):141-5 https://doi.org/10.1016/j.ejwf.2018.09.001

8. Effect of disinfecting solutions on the mechanical properties of orthodontic elastomeric ligatures. Evangelista MB, Berzins DW, Monaghan P. Angle Orthod 2007 Jul;77(4):681-7. PMID: 17605480

9. The environmental influence of Light Coke, phosphoric acid, and citric acid on elastomeric chains.Teixeira L, Pereira Bdo R, Bortoly TG, Brancher JA, Tanaka OM, Guariza-Filho O. J Contemp Dent Pract. 2008 Nov 1;9(7):17-24. PMID: 18997912

10. A laboratory investigation of orthodontic elastomeric chains. Rock WP, Wilson HJ, Fisher SE. Br J Orthod 1985 Oct;12(4):202-7. PMID: 3863676

11. Force degradation of orthodontic elastomeric chains--a product comparison study. De Genova DC, McInnes-Ledoux P, Weinberg R, Shaye R. Am J Orthod 1985 May;87(5):377-84. PMID: 3857862

12. Force-degradation pattern of six different orthodontic elastomeric chains. Mirhashemi

Vol 9 No 1 (2021) DOI 10.5195/d3000.2021.158

A, Saffarshahroudi A, Sodagar A, Atai M. J Dent (Tehran). 2012;9(4):204-15. PMID: 23323182

13. The super-elastic Japanese NiTi alloy wire for use in orthodontics. Part III. Studies on the Japanese NiTi alloy coil springs. Miura F, Mogi M, Ohura Y, et al. Am J Orthod Dentofac Orthop 1988; 94: 89–96. PMID: 3165245

14. Thermal and mechanical characteristics of stainless steel, titanium-molybdenum, and nickel-titanium archwires. Kusy RP and Whitley JQ. Am J Orthod Dentofacial Orthop 2007; 131: 229–237. PMID: 17276864

15. Force degradation of closed coil: an in vitro evaluation. Angolkar PV, Arnold JV, Nanda RS, et al. Force degradation of closed coil: an in vitro evaluation. Am J Orthod Dentofacial Orthop 1992; 102: 127–133. PMID: 1636629

16. In-vivo force decay of nickel-titanium closed-coil springs. Cox C, Nguyen T, Koroluk L, et al. Am J Orthod Dentofacial Orthop 2014; 145: 505–513. PMID: 24703289

17. An in vitro comparison of the force decay generated by different commercially available elastomeric chains and NiTi closed coil springs. Santos AC, Tortamano A, Naccarato SR, et al. Braz Oral Res 2007; 21: 51–57. PMID: 17384855

18. The effect of environmental factors on elastomeric chain and nickel titanium coil springs. Nattrass C, Ireland AJ, Sherriff M. Eur J Orthod 1998 Apr;20(2):169-76. PMID: 9633170

19. Effects of Orthokin, Sensikin and Persica mouth rinses on the force degradation of elastic chains and NiTi coil springs. Javanmardi Z, Salehi P. J Dent Res Dent Clin Dent Prospects. 2016;10(2):99-105. PMID: 27429726

20. Does chlorhexidine in different formulations interfere with the force of orthodontic elastics? Pithon MM, Santana DA, Sousa KH, Farias IMAO. Angle Orthod. 2012;83(2):313-8. PMID: 22928936

21. Effect of sodium fluoride mouth rinse on elastic properties of elastomeric chains. Ramazanzadeh BA, Jahanbin A, Hasanzadeh N, Eslami N. J Clin Pediatr Dent. 2009;34(2):189-92. PMID: 20297715

22. Effect of sodium fluoride mouth rinse on elastic properties of elastomeric chains. Mirhashemi A, Farahmand N, Saffar Shahroudi A, Ahmad Akhoundi MS. Orthodontic Waves. 2017;76(2):67-72. https://doi.org/10.1016/j.odw.2016.11.007

23. The effect of pH levels on nonlatex vs latex interarch elastics. Sauget PS, Stewart KT, Katona TR. The Angle orthodontist. 2011;81(6):1070-4. PMID: 21609184

24. Do mouthwashes with and without bleaching agents degrade the force of elastomeric chains? Pithon MM, Rodrigues AC, Sousa ÉLSM, de Souza Santos LP, dos Santos Soares N. The Angle orthodontist. 2013;83(4):712-7. PMID: 23311601

25. The effects of varying alcohol concentrations commonly found in mouth rinses on the force decay of elastomeric chain. Larrabee TM, Liu SS-Y, Torres-Gorena A, Soto-Rojas A, Eckert GJ, Stewart KT.. The Angle orthodontist. 2012;82(5):894-9 PMID: 22309124

26. Evaluation of the effects of three different mouthwashes

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on the force decay of orthodontic chains. Omidkhoda M, Rashed R, Khodarahmi N. Dental research journal. 2015;12(4):348-52. PMID: 26288625

27. A clinical investigation of the concepts of differential and optimal force in canine retraction. Boester CH, Johnston LE. Angle Orthod. 1974;44(2):113-9. PMID: 4597626

28. Effect of commonly used beverage, soft drink, and mouthwash on force delivered by elastomeric chain: a comparative in vitro study. Kumar K, Shetty S, Krithika MJ, Cyriac B. J Int Oral Health. 2014;6(3):7-10. PMID: 25083025

29. Comparative evaluation of force decay pattern in orthodontic active. Mirhashemi AH, Shahroudi AS, Shahpoorzadeh K, Khameneh NH. J Dent Res Clin Dent Prospects. 2020;14(4):244-249. PMID: 33575015

30. The mechanical strength of orthodontic elastomeric memory chains and plastic chains: An in vitro study. Kardach H, Biedziak B, Olszewska A, Golusinska-Kardach E, Sokalski J. Adv Clin Exp Med. 2017;26(3):373-8. PMID: 28791809