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# The Effect of Sodium Fluoride and Listerine Mouthwashes on the Force Decay of Orthodontic Elastomeric Chains

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**ABSTRACT**

*Elastomeric chains are commonly used in orthodontic treatments. If their force decreases, the need for changing them will increase. This study aims to evaluate the effects of three different mouthwashes on the force loss of two different orthodontic chain brands. Forty five chains from each American Orthodontics (AO) and Dentaurum (DR) brands were divided into three subgroups. The chains of all6 groups were stretched 25 mm and immersed in related solutions (sodium fluoride 0.05% (SF), Listerine (LS) and artificial saliva (control group). The specimens were incubated at 37˚c between the test intervals. Elastics force was tested before the test and after one hour, twenty four hours, one week, two weeks and three weeks by Electromechanical Universal Testing Machine. To compare the results, ANOVA, Tukey and T-test were (level of significance= 0.05) performed. The mean force in control group was higher than those of two other solutions (PV<0.001) but the differences between sodium fluoride and Listerine groups were not statistically significant (P=0.527). Before (P<0.001) and one hour (P<0.001) after the test, the mean chain force in AO was higher than that of DR brand. Twenty four hours after the test, there was no significant difference between the two brands (P=0.519).However, one week (P<0.001), two weeks (P<0.001) and three weeks (P=0.035) after the test, the mean forces in DR brand were higher. These of Sodium fluoride and Listerine mouthwashes can speed up force degradation in chains. The force loss in DR brand is less and slower than that of AO brand.*

**Key words:** Elastomeric Chains, Force Decay, Mouthwash

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## INTRODUCTION

Application of the forces lightly and constantly to ensure the maximum tooth movement with minimum resorption is one of the primary goals in orthodontics [1, 2]. Space closure with orthodontic dental movement is clinically important [3]. Variable systems, including Ni-Ti Coil springs and elastomeric products are used for space closure [4]. Among these, elastomers are more common because of their lower cost and simplicity [5]. These materials are amorphous polymers that have been used by orthodontists for space closure and rotation corrections since 1960[6-8]. Elastomeric chains are appropriate alternatives for latex materials in orthodontics whose protein content is allergen and causes allergic reactions in patients [9]. Patients are comfortable with Elastomeric chains [10]. Theses elastics are not appropriate for microorganisms and exist in variable colors [10].Despite the mentioned favorable features, these chains aren't ideal since they undergo force decay [11]. Chain forces are dependent on some factors, including the materials used in factory, added colors, shape of chains ( open or closed), stretching chains before using them, and sterilization and preservation techniques[3]. Deformation, force

decay and relaxation behaviors of elastomers are also dependent on environmental factors like teeth movement, temperature changes, environmental PH, mouth washes, salivary enzymes and mastication forces [12].

A decrease of 50-70% of primary force has been reported after 24 hours; whereas the most has been found in the first hour, followed by a continuous decrease happening in weeks 3 to 4 [13, 14]. A part of elastomer force is decreased due to sliding resistance between bracket and wire, which includes friction between wire and bracket, contact between wire and sides of bracket slot(binding) and permanent deformation in bracket- wire contact(notching)[15, 16]. The rapid decrease in forces of viscoelastic chains causes insufficient tooth movement that result in increased appointments for activating the appliance [17]. Appropriate plaque control for orthodontic patients is difficult, especially when ligature, wire and band are placed on the teeth [18]. Bacterial plaque is more likely to be created around brackets and bands [19, 20]. Dentists recommend using mouthwashes during orthodontic treatment to promote oral hygiene and decrease caries lesions [21]. It is shown that using chemical agents along with tooth brushing and flossing is better than mechanical control alone, in the way that both plaque and gingival inflammation decrease [7]. Recent systematic reviews have shown that chlorhexidine and Listerine have the most anti-plaque and anti-gingival inflammatory effect. Chlorhexidine causes long term disadvantages like tooth color change and taste alteration, but Listerine does not show these disadvantages, so it's the first choice for daily and long term use for orthodontic patients [22]. Applying sodium fluoride as an ionized fluoride on the tooth surface causes calcium fluoride sedimentation on the enamel surface. In the natural conditions, this layer can stay on the tooth for weeks or even months [23].

In 1992, Von Fraunhofer *et al.,* evaluated the effect of artificial saliva and local fluoride on the degradation characteristics of chains and concluded that using fluoride increased the need for stretching the same amount of forces [24]. In 2008, Ramezanzadeh *et al.,* reported that application of sodium fluoride mouthwash did not have any statistically significant effect on the force degradation of the studied chains [25]. In the study of Bratu DC in 2013, the efficacy of artificial saliva and fluoride was evaluated, and it was concluded that both of them increased the force decay in chains [26]. In 2014, Kumar *et al.,* evaluated the effect of common mouthwashes and beverages on the force transmission characteristics of the chains. In this study, Listerine mouthwash increased the force decay of the chains [27].

Evaluating the probability of force transmission disability in systems is essential because in such situations the dentist cannot estimate the actual force transferred to the dentition [13]. Considering the probable effect of mouthwashes on reducing elastomeric chain forces, this study was aimed to evaluate and compare the effect of Listerine and sodium fluoride mouthwashes on two commercial chain brands.

## MATERIAL AND METHODS

Ninety gray elastomeric chains with short inter loop space from two different brands -American orthodontics (Sheboygan, Wisconsin, USA) and Dentaurum (Ispringen, Germany) were studied. Pieces with a length of five rings were prepared. To prevent probable damages to the chains, the loops adjacent to the terminal rings were cut using a sharp ligature cutter. Forty five chains from each brand were randomly divided into three subgroups of artificial saliva (Hypozalix, biocodex, France) as control group, sodium fluoride 0.05% mouth wash(Epimax, Emad pharmaceutical co, Iran) and Listerine mouthwash(Zero, Johnson& Johnson, Italy). Finally 6 groups of 15 elastics were obtained:

Group A: (control group): American orthodontics brand in artificial saliva.

Group B: American orthodontics brand in sodium fluoride mouthwash.

Group C: American orthodontics brand in Listerine mouthwash.

Group D (control group): Dentaurum brand in artificial saliva.

Group E: Dentaurum brand in sodium fluoride mouthwash.

Group F: Dentaurum brand in Listerine mouthwash.

To simulate an oral condition, all of the specimens were incubated (Behdad, Tehran, Iran) at 37 °C in artificial saliva. Artificial saliva ingredients were water, Mgcl2, Nacl and cellulose materials as viscous agent, with PH=7.2 and 110 cps viscosity.

For the two control groups, the chains were just placed in artificial saliva and incubated at

$37^0$C.For the other four groups, the chains were brought out of the artificial saliva every day and for one minute immersed in the mouthwash that was specified for each group. After bringing the chains out of the mouthwash, to simulate the real method of mouthwash use, the chains were immersed in the 50% artificial saliva and 50% mouthwash for 30 minutes (sodium fluoride or Listerine depending on the group) and then kept again in artificial saliva and incubated at $37^0$C. (Clinical mouthwash use method: oral rinsing with one measure of mouthwash, avoiding eating or drinking for half an hour [28].).

A custom device containing 2 rows of sixteen stainless steel fixtures with 1.2 mm diameter was created. The fixtures were mounted in self cure acrylic resin (Acropas, Marlik Co., Iran) (figure1-a)and set 25 mm from each other to simulate the distance between the hook of the first molar and distal wing of canine bracket[29, 30].

In this distance, the chain force is about 100_300 grams, which is suitable for canine retraction [13]. The chains were stretched between two fixtures. Elastic force was tested before the test and after one hour, 24 hours, 1week, 2 weeks and 3 weeks.The force was measured by Electromechanical Universal Testing Machine (k_21046, Lohringen, Switzerland) in the mentioned intervals (figure1- b).

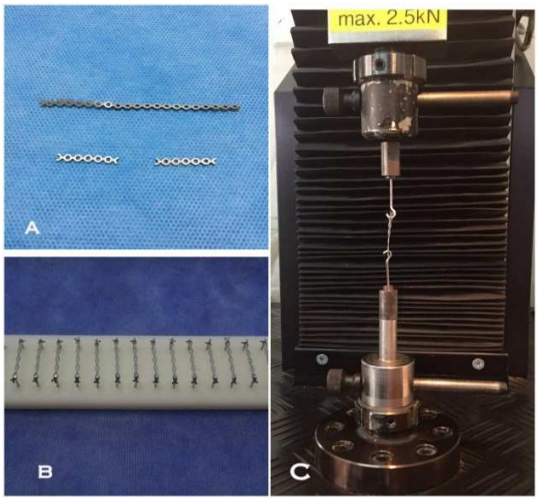


**Figure 1: (a) elastomeric chains mounted on fixtures (b) Electromechanical Universal Testing Machine (k_21046, Lohringen, Switzerland)**

For testing, the elastics were demounted from the fixtures and allowed to be relaxed. To transfer the elastics from the fixtures to the testing machine, a modified separating plier was used. The head of the modified separating plier opened upto25 mm to stretch all the elastics in the same way (figure2).

**Figure 2: modified separating plier doesn't open more than 25mm**

Elastics were attached to the steel hooks made of 1.2 mm stainless steel wire. The distance of hooks was adjustable. The machine was set in the way that initially the distance between the hooks was 20 mm and as the elastics clamped, this distance increased to 25 mm with 0.5 mm in second speed. The tensile force was shown on the monitor in Newton. Because of the changes in the forces, especially in the first seconds, when the elastics stretched to 25 mm, the force was measured with 10 seconds delay .In each group the percentage of force decay was calculated according to the initial force. The collected data were analyzed using SPSS software (SPSS Inc., Chicago, IL, USA). The mean and standard deviation were calculated for the groups. To evaluate the normality of data, Kolmogorov –Smirnov test was used and the analysis of variance (ANOVA), Tukey' test and T-test were used to compare the force decay among the studied groups. Differences were considered statistically significant when $P<0.05$.

## RESULTS

In this experimental prospective study, the effect of three different solutions (artificial saliva, Listerine and sodium fluoride mouthwashes) on the force decrease of two different chain brands were evaluated at six time intervals. The three way ANOVA analysis showed that the effect of chain brand on elastic force was statistically significant and the mean force of American

orthodontic brand was totally higher than that of Dentaurum brand (P=0.001). Generally, as the time passed the elastic chain force decreased, which was statistically significant (P<0.001) (table 1).

The difference between different solutions was found to be statistically significant (P<0.001). Chain brand and solution did not show any interaction (P=0.956). Time and group showed no interaction as well (PV=0.133). Interaction of chain brand, time and solution were not shown to be statistically significant (PV= 0.995). But the interaction between chain and time was significant (P= 0.001), so the two way ANOVA analysis was performed.

The findings of Tukey test showed that the mean force difference between sodium fluoride groups and Listerine groups was not statistically significant (P=0.527) but in control groups, it was higher than those of sodium fluoride or Listerine mouthwash groups (P<0.001) (figure3- a).

The results of two-way ANOVA analysis showed that in American orthodontics brand groups, there was a significant difference between different solutions (P=0.001). The post-hoc Tukey test showed that the difference between sodium fluoride groups and Listerine groups was not statistically significant (P=0.827), but in control group, it was higher than SF (P=0.011) or Listerine groups (P=0.002). Also, in Dentaurum brand groups, there was a significant difference between different solutions (P=0.002). The post-hoc Tukey test showed that the difference between sodium fluoride groups and Listerine groups was not statistically significant (P=0.625), but in control group, it was higher than SF (P=0.031) or Listerine groups (P=0.002).

The results of t-test showed that before (P<0.001) and one hour (P<0.001) after the test, of the mean chain force in AO brand was higher than that of DR brand. Twenty four hours after the test, there was no statistically significant difference between the two brands (P=0.519). However, 1 week (P<0.001), 2 weeks (P<0.001) and 3 weeks (P=0.035) after the test, the mean forces in Dentaurum brand were higher.

**Table1: Mean forces of AO and DR chain brands in different solutions at different times**

| Solution | Chain brand | Before test | One hour | 24hours | 1week | 2weeks | 3weeks |
|---|---|---|---|---|---|---|---|
| Control | AO | 312± 6.53 | 290±8.25 | 247±10.17 | 205±9.10 | 186±9.43 | 166±10.25 |
| | DR | 285±6.98 | 276±7.56 | 250±9.19 | 214±9.27 | 198±12.37 | 169±12.54 |
| Listerine | AO | 313±5.20 | 288.5±6.19 | 244±9.89 | 201±8.17 | 176±7.55 | 156.5±11.93 |
| | DR | 286± 5.70 | 274±7.69 | 244±7.56 | 206±8.77 | 191±11.99 | 161±12.01 |
| Sodium fluoride | AO | 312±5.715 | 289.5±7.15 | 246.5±8.855 | 202±8.62 | 178±8.165 | 156±10.68 |
| | DR | 285±6.66 | 273±7.33 | 247±8.82 | 209±6.88 | 191±12.96 | 164±11.54 |

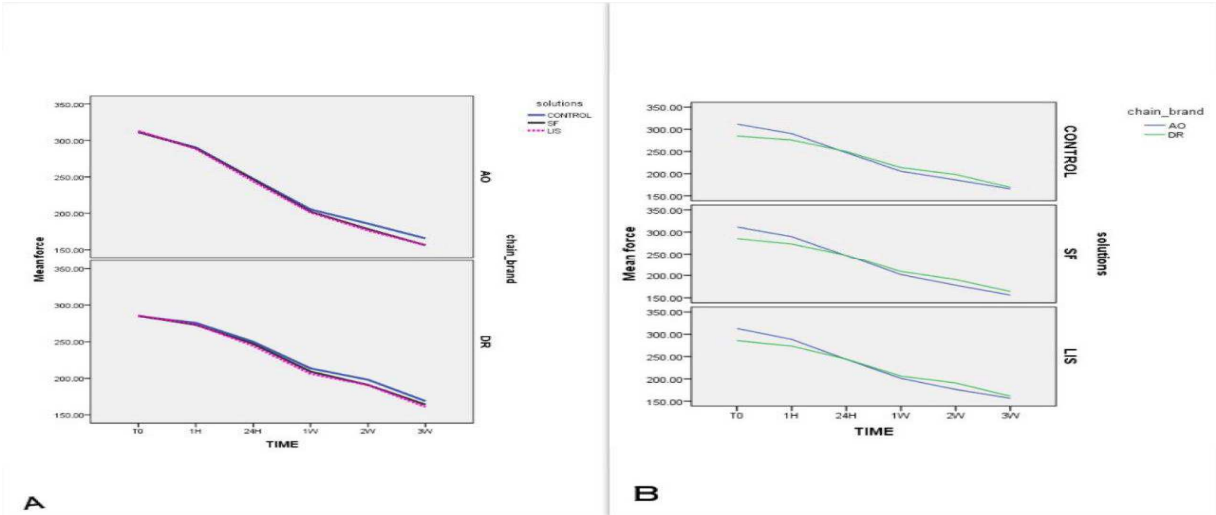


**Figure 3: (a) Comparison of force (g) changes for study solutions**
**(b) Force (g) changes of chain brands over 3 weeks in different solutions**

**Table 2. Percentage of the force decay of AO and DR brands in study solutions at different times in proportion to initial time**

| Solutions | Chain brand | One hour | 24hours | 1week | 2weeks | 3weeks |
|---|---|---|---|---|---|---|
| Control | AO | 93.1% | 79.3% | 65.8% | 59.5% | 53.1% |
| | DR | 96.8% | 87.7% | 75% | 69.5% | 59.3% |
| Listerine | AO | 92.1% | 77.8% | 64.2% | 56.3% | 49.9% |
| | DR | 95.7% | 85.5% | 72.1% | 66.7% | 56.3% |
| Sodium fluoride | AO | 92.9% | 79.1% | 64.9% | 57.2% | 50% |
| | DR | 95.7% | 86.6% | 73.3% | 66.9% | 57.5% |

## DISCUSSION

In the present study, the effects of two different mouthwashes on the force decay of two different chain brands were evaluated.

An ideal elastomer material turns back to its exact major shape when it is stretched. This rarely happens in the reality because when some of the polymeric chains are stretched, they slide irreversible and lay out in a new way [31, 32].The applied force makes the molecules of polymer uncoiled; at first, the activated chain is stretched but as the time passes, the molecules slip on each other, which results in a new layout and permanent deformation [33].Slippage of the molecules as a result of the force continuity reduces the force transfer to the teeth [33]. Based on a study, chain forces reduced 42-63% (dependent on the chain brands) after 21 days in dry condition. When the elastomers were immersed in the water bath, the reduction was faster. The maximum force decay was reported in the first 3 hours [34].

In another study, to simulate oral condition, the elastomers were placed in the water bath with heat circulation. The force reduction after 30 minutes was 23-37% and after 21 days was 39-61%. Also, with preservation of the study conditions, tooth movement was simulated with 0.5 mm reduction in stretch distance of chains weekly. In comparison with heat circulation condition, the force loss was controlled better [17]. Force reduction in elastomeric chains evaluated in vivo was faster than those evaluated in vitro [17].It is claimed that saliva and water desorption in oral environment causes permanent deformity in elastic chains [30].

The solutions used in this study were Listerine, sodium fluoride and artificial saliva. Artificial saliva was considered for control group to simulate oral condition. It is reported that the force loss in dry environment is more than wet environment [35, 36].

In this study, the difference between mouthwashes and control group was reported to be statistically significant, and as the time passed in both chain brands, the diagrams diverged (figure3- a).

The force decay in Listerine groups was higher than those of control groups.

Listerine is a combination of 4 essential oils as its active agents (including: thymol 0.064%, menthol 0.042%, eucalyptol 0.092% and methyl salicylate 0.060%) in water- ethanol dissolvent [37].

in the study conducted by Pithon *et al.* [10], the effects of the number of alcoholic beverages on force degradation of elastomeric chain were evaluated and at the end of the study, no significant differences were found between alcoholic beverages and distilled water group. But, Effect of containing alcohol mouthwashes on structure and molecular changes in elastomeric chains and the following force degradation is explained [38, 39]. In the study carried out by Larrabeeet *et al.*, the chains exposed to alcohol containing mouthwashes showed higher amount of force loss in comparison with water. So, to eliminate probable effect of alcohol on chain's force, alcohol free Listerine mouthwash used in this study. But still the amount of force decay was higher than control group [39].

Sodium fluoride mouthwash caused greater force loss than control groups did, which was in agreement with the results of Omidkhoda et al.'s study [40] in which sodium fluoride 0.05 caused greater force loss in comparison with control group. However, in the study of Ramezanzadeh *et al.*, no significant differences were observed [25].

The diagram slope of AO brand was greater than DR brand, showing that the decrease in chain force in the AO brand was higher and more rapid. At the beginning, the mean force in AO brand was higher but at the end of the study, it was lower than that of Dentaurm brand (figure3- b).

The range of force decay. That was calculated in proportion to the initial force, in AO brand in all of the time intervals was higher than that of the DR brand (Table 2). In the study of Ramezanzadeh et al. [25], after 3 weeks, the force decay in AO brand was more than that of Dentaurum brand.

Totally, After 24 hours, the force loss was 12-22% of the initial force and at the end of the study; it was 41-50% of the initial force. This range of force loss is close to other studies [40, 41] although, it was lesser than some of the studies [13, 14]. It is claimed that the elastomeric chains properties may be different. So, lack of strict quality control in elastics production may cause different results from same studies [42].

## CONCLUSION

The use of sodium fluoride and Listerine mouthwashes can intensify the force loss in the elastomeric chains. However, the force loss effect of these two mouthwashes seems to be the same. The force loss in Dentaurum brand is less and slower than that of American orthodontics brand.

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## REFERENCES

1. Melsen B. Tissue reaction to orthodontic tooth movement - a new paradigm. Eur J Orthod. 2001;23(6):671-81.
2. Weltman B, Vig KW, Fields HW, Shanker S, Kaizar EE. Root resorption associated with orthodontic tooth movement: a systematic review. American Journal of Orthodontics and Dentofacial Orthopedics. 2010;137(4):462-76.
3. Josell SD, Leiss JB, Rekow ED. Force degradation in elastomeric chains. In Seminars in Orthodontics. WB Saunders. 1997;3(3):189–197.
4. Santos AC, Tortamano A, Naccarato SR, Dominguez-Rodriguez GC, Vigorito JW. An in vitro comparison of the force decay generated by different commercially available elastomeric chains and NiTi closed coil springs. Braz Oral Res. 2007;21(1):51-7.
5. Moresca R, Vigorito JW. Avaliação *in vitro* da degradação da for çaproduzidapormóduloselásticosutilizados no fechamento de espaços com a mecânicapordeslizamento. Ortodontia. 2005;38(2):151-61.
6. 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.
7. RembowskiCasaccia G, Gomes JC, Alviano DS, de Oliveira Ruellas AC, Sant' Anna EF. Microbiological evaluation of elastomeric chains. Angle Orthod. 2007;77(5):890-3.
8. Stroede CL, Sadek H, Navalgund A, Kim DG, Johnston WM, Schricker SR, et al. Viscoelastic properties of elastomeric chains: an investigation of pigment and manufacturing effects. Am J Orthod Dentofacial Orthop. 2012;141(3):315-26.
9. Santos R, Pithon M, Pereira A, Romanos M. Evaluation of the cytotoxicity of polyurethane and non-latex orthodontic chain elastics. Matéria (Rio de Janeiro). 2012;17(1):939-45.
10. Taloumis LJ, Smith TM, Hondrum SO, Lorton L. Force decay and deformation of or-thodontic elastomeric ligatures. Am J orthod Dentofacial Orthop. 1997;111(1):1-11.
11. Pithon MM, Barretto JR, Andrade CS, Novaes FP, Luz MD, Andrade AC, Coqueiro RD. Do alcoholic beverages interfere in the force of orthodontic elastics?.Revista de Odontologia da UNESP. 2014;43(3):191-5.
12. Evangelista MB, Berzins DW, Monaghan P. Effect of disinfecting solutions on the mechanical properties of orthodontic elastomeric ligatures. Angle Orthod. 2007;77(4):681-7.
13. Baty DL, Storie DJ, Von Fraunhofer JA. Synthetic elastomeric chains: a literature re-view. Am J Orthod Dentofacial Orthop. 1994;105(6):536-42.
14. Mayberry D, Allen R, Close J, Kinney DA. Effects of disinfection procedures on elas-tomeric ligatures. J Clin Orthod. 1996;30(1):49-51.
15. Kusy RP, Whitley JQ. Influence of archwire and bracket dimensions on sliding mechanics: derivations and determinations of the critical contact

angles for binding. Eur Orthodontic Soc. 1999;21(2):199-208.
16. Kusy RP, Whitley JQ. Friction between different wire-bracketconfigurations and materials. semortho. 1997 ;3(3) 166-177.
17. De Genova DC, McInnes-Ledoux P, Weinberg R, Shaye R. Force degradation of orthodontic elastomeric chains—aproduct comparison study. Am J Orthod. 1985;87(5):377–384
18. Lundström FR, Hamp SE. Effect of oral hygiene education on children with and without subsequent orthodontic treatment. Eur J Oral Sci. 1980 1;88(1):53-9.
19. Ai H, Lu HF, Liang HY, Wu J, Li RL, Liu GP, Xi Y. Influences of bracket bonding on mutans streptococcus in plaque detected by real time fluorescence-quantitative polymerase chain reaction. Chin Med J. 2005;118(23):2005-2010.
20. Santos RL, Pithon MM, Vaitsman DS, Araújo MT, Souza MM, Nojima MG. Long-term fluoride release from resin-reinforced orthodontic cements following recharge with fluoride solution. Braz. Dent. J. 2010;21(2):98-103.
21. Ahmed I, saif-ul-haque, nazir r, carious lesion in patients undergoing orthodontic treatment.J Pak Med Assoc. 2011;61(12):1176-9.
22. Gunsolley JC. Clinical efficacy of antimicrobial mouthrinses. J Dent. 2010;38(1):S6-10.
23. Moezizadeh M, Alimi A. The effect of casein phosphopeptide-amorphous calcium phosphate paste and sodium fluoride mouthwash on the prevention of dentine erosion: An in vitro study. J Conserv Dent. 2014;17(3):244.
24. Von Fraunhofer JA, Coffelt MP, Orbell GM. The effects of artificial saliva and topical fluoride treatments on the degradation of the elastic properties of orthodontic chains. The Angle Orthod. 1992 ;62(4):265-74.
25. Ramazanzadeh B, Hassanzadeh N, Eslami N, Mohammadabadi MD, Esmaeeli H. Evaluation of the Effect of Sodium Fluoride Mouth Rinse Application on the Elastic Properties of Elastomeric Chains. Journal of Mashhad Dental School. 2008;32(3):199-206.
26. Bratu DC, Pop SI, Balan R, Dudescu M, Petrescu HP, Popa G. Effect of Different Artificial Saliva on the Mechanical Properties of Orthodontic Elastomers Ligatures. Materiale Plastice. 2013;50(1):49-52.
27. 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;6(3):7-10.
28. Agarwal P, Nagesh L. Comparative evaluation of efficacy of 0.2% Chlorhexidine, Listerine and Tulsi extract mouth rinses on salivary *Streptococcus* mutans count of high school children--RCT. Contemp Clin Trials. 2011 Nov;32(6):802-8.
29. Kim KH, Chung CH, Choy K, Lee JS, Vanarsdall RL. Effects of prestretching on force degradation of synthetic elastomeric chains. Am J Orthod Dentofacial Orthop 2005;128:477-82.
30. 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;38(1):40-7.
31. Da Silva DL, Kochenborger C, Marchioro EM. Force degradation in orthodontic elastic chains. Revista Odonto Ciência. 2009;24(3):274-8.
32. Matta ENR, Chevitarese O. Avaliação laboratorial da forçaliberadaporelásticosplásticos. Rev Soc Bras Ortod. 1997;3(4):131-6..
33. Huget EF, Patrick KS, Nunez LJ. Observations on the elastic behavior of a synthetic orthodontic elastomer. J Dent Res. 1990;69(2):496-501.
34. Ren Y, Maltha JC, Kuijpers-Jagtman AM. Optimum force magnitude for orthodontic tooth movement: a systematic literature review. Angle Orthod. 2003;73(1):86-92.
35. Hwang CJ, Cha JY. Mechanical and biological comparison of latex and silicone rubber bands. Am J OrthodDentofacialOrthop 2003;124(4):379-86.
36. Kanchana P, Godfrey K. Calibration of force extension and force degradation characteristics of orthodontic latex elastics. Am J OrthodDentofacialOrthop 2000;118(3):280-7.
37. Chen Y, Wong RW, Seneviratne CJ, Hägg U, McGrath C, Samaranayake LP.

Comparison of the antimicrobial activity of Listerin and Corsodyl on orthodontic brackets in vitro. Am J OrthodDentofacialOrthop. 2011;140(4):537-42.

38. Eliades T, Eliades G, Silikas N, Watts DC. *In vitro* degradation of polyurethane orthodontic elastomeric modules. J Oral Rehabil. 2005;32:72-7.
39. 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;82(5):894-9.
40. Omidkhoda M, Rashed R, Khodarahmi N. Evaluation of the effects of three different mouthwashes on the force decay of orthodontic chains. Dent Res J. 2015;12(4):348-352.
41. Buchmann N, Senn C, Ball J, Brauchli L. Influence of initial strain on the force decay of currently available elastic chains over time. Angle Orthod.2012;82(3):529-35.
42. Ash JL, Nikolai RJ. Relaxation of orthodontic elastomeric chains and modules in vitro and in vivo. J Dent Res. 1978;57:685–690.