Regeneration, Reconstruction & Restoration

Original Article
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The Effect of Fluoride Mouthwash on Force Degradation of Orthodontic Elastomeric Chains

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Submitted: 31 May, 2022; **Accepted:** 14 August, 2022; **Published Online:** 25 September, 2022; **DOI:** *10.22037/rrr.v7.30696*

Background and objectives: Fluoride mouthwash is an over-the-counter product that has been considered effective for daily oral hygiene maintenance in orthodontic patients, particularly to inhibit enamel demineralization around orthodontic brackets. We sought to evaluate the effect of fluoride mouthwash on the force degradation of four different orthodontic elastomeric chains.

Materials and methods: In this in-vitro study, 120 orthodontic elastomeric chains of four different trademarks were investigated. The study involved three different environments. The experimental groups used pre-stretched elastomeric chains at initial, 50%, and 100% lengths, which were then stored in either water or fluoride media (n=5 in each group). The control group's chains were stored in the air throughout the entire experimental period. After three weeks, tensile strength measurements were performed. One-way analysis of variance (ANOVA) was used to assess the effect of the storage environment and pre-stretching extent on the tensile strength. Observed data were analyzed by means of Multifactorial ANOVA at a significance level of 0.05%.

Results: The tensile strength in fluoride storage medium was generally lower than in water for all trademarks, except for the conventional and Energy chains (RMO) at 50% pre-stretching, with no significant difference for the Super chain™ (GAC) and conventional chain (RMO) at this level. After three weeks, all samples showed increased length, with the conventional chain (GAC) having the highest and the Energy chain (RMO) having the lowest elongation percentile. The tensile force at 50% elongation was lower than at 100% elongation for all elastomeric chains.

Conclusion: The tensile strength in a fluoride storage medium was generally lower compared to that in water.

Keywords: Elastomeric chains, Force decay, Fluoride, Mouthwashes, Orthodontics.

1. Introduction

With regard to the potentially adverse effects of orthodontic appliances in terms of enhancing bacterial plaque accumulation, application of an individualized oral hygiene program during fixed orthodontic treatment has been advocated as an essential part of treatment programs [1]. In patients with poor oral hygiene, use of supplemental chemical plaque control agents concomitant with mechanical plaque removal plays a pivotal role in maintaining oral health [2]. The effects of these frequently used chemical agents on corrosion of orthodontic appliances, frictional resistance of wires and mechanical properties of elastic chains over the course of time are important in the treatment protocol [3, 4].

Elastomeric polyurethane-based chains are the most commonly used materials in clinical orthodontics for space closure, a time-consuming phase of fixed orthodontic treatment [5, 6]. There is a possibility for the construction of shape memory elastic modules based on their material formula, application technology, and mechanical properties. These shape memory elastic materials can undergo large deformations and recover their original shape upon exposure to external stimuli like heat, chemicals, or pH changes [7]. Despite the distinct advantages of elastomeric chains such as ease of adjustment, minimal need for patient cooperation and being more hygienic than other techniques, they have some inevitable disadvantages namely force degradation over time [8]. The degradation of orthodontic elastomeric chains with environmental alterations has important clinical implications [9]. Environmental factors such as exposure to moisture, various enzymes, and chemical substances (different mouthwashes), in addition to some clinical factors such as design and amount of initial strain, might impact the amount of observed released force [10]. The percentage of this force decay depends on the trademarks and must be taken into account to precisely determine the required load in different types of orthodontic tooth movement [11]. Chlorhexidine and fluoride mouthwashes are often prescribed to reduce the count of mutans streptococci in dental plaque and saliva [12]. Fluoride mouth rinse (0.05%) is an over-the-counter product that has been considered effective for daily oral hygiene maintenance in orthodontic patients, particularly to inhibit enamel demineralization around orthodontic brackets [13, 14]. To this date, several studies have been conducted in an attempt to study the effect of possible environmental factors on force degradation of elastomeric chains [15]. However, there are few information regarding the longitudinal effect of fluoride mouthwash on the force degradation properties of different orthodontic elastomeric chains with various chemical formulations and manufacturing processes. Considering the lack of well-proven recommendations on the use of fluoride mouth rinses during orthodontic treatment, the purpose of the present study was to investigate the effect of fluoride mouthwash on force degradation characteristics of four brands of elastomeric chains at in different environmental conditions and compare the elongation percentile between the conventional and smart types of elastomeric chains.

2. Materials and methods

In this in- vitro study, four trademarks of orthodontic elastomeric chains were studied: Super chain™ (International DENTSPLY GAC, USA), GAC conventional chain (International (DENTSPLY GAC, USA), RMO Energy chain (Rocky Mountain Orthodontics, Inc. USA), and the conventional chain (Rocky Mountain Orthodontics, Inc., USA). All the samples were polyether-based polyurethane products and had a closed-linked loop with short-spacing type configuration. They were also within their useable date in sealed plastic packages. The Super chains™ were kept in brown sealed plastic bags. Thirty specimens of each brand were examined. Each specimen contained 10 closed-linked loops with one extra loop at each end (12 ringlets).

2.1. Specimen conditioning

The experimental groups contained pre-stretched elastomeric chains at initial, 50%, and 100% lengths before storage in three different testing environments. The underlying reason for this degree of pre-stretching was based on a previous study which indicated that 100% pre-stretching generated more uniform force levels (16). An appliance was designed to keep the stretched elastomeric chains in the desired distance. This appliance contained two stainless steel supporting rods to grasp 10 linked loops of each specimen which were adjusted and inserted in exact customized distances measured by means of a digital caliper (Mitutoyo, Tokyo, Japan) to an identical length for each brand.

The testing environments included air, water and diluted fluoride solution (Oral-B Pro-Expert Multi-Protection Alcohol Free; containing SnF and cetyl pyridinium chloride). Five specimens were stored under each condition at 37±1°C for 14 days. At the end of three weeks, the specimens were taken-out of the solutions and immediately mounted on a testing machine.

2.2. Specimen testing

Tensile strength testing was done on all specimens in each group using a Universal Testing Machine (Model 5566; UTM; Instron Corp, Canton, MA, USA) at a crosshead speed of 50 mm/minute at room temperature. Two stainless steel loops were formed to fit the machine crosshead and facilitate chain maintenance of this distraction during the testing procedure. Load per tensile strength (%) measurements of pre-stretched length, were noted for each specimen.

2.3. Statistical analysis

After three weeks, descriptive statistics including the mean values and standard deviations of automatically recorded tensile loads were calculated for each sample exactly at their pre-stretched distance. One-way analysis of variance (ANOVA) was used to assess the effect of the storage environment and pre-stretching extent on the tensile strength. Data were analyzed by means of Multifactorial ANOVA at a significance level of 0.05. Comparison between different brands was also performed with Chi-square test in order to identify the magnitude of generated forces. All statistical analyses were performed using SPSS ver. 12.0 (SPSS Inc., Chicago, IL, USA).

3. Results

Descriptive statistics including the mean values and standard deviations of tensile force for the specimens stored in air (control) and in the other two test media over the three weeks are summarized in Table 2, based on the amount of pre-stretched values (50% or 100%). The data in Table 2 indicated that the recorded tensile force at 50% elongation of the elastomeric chains was lower than that at 100% elongation for each type. In all three environments, the highest force value for both 50% and100% elongation was for the conventional chain (GAC). Furthermore, both for the water and fluoride environment, Superchain™ (GAC) had the lowest value for 50% elongation,

Table 1. The mean value and standard deviation of the tensile strength for each environment extension group at 50% and 100% elongation.

Experimental groups	Fluoride (n= 40) Mean ± SD (N)		Water (n= 40) Mean ± SD (N)		Control (n= 40) Mean ± SD (N)	
Elongation percentile	50%	100%	50 %	100%	50 %	100%
Super chain™ (GAC)	1.87± 0.14	3.37±0.06	2.09±0.17	3.83±0.15	2.23±0.21	3.28±0.11
Conventional chain (GAC)	3.72±0.06	6.99±0.09	4.50±0.15	7.98±0.15	4.25±0.04	5.38±0.02
Energy chain (RMO)	2.46±0.04	3.16±0.14	2.38±0.03	3.47±0.02	3.13±0.01	4.18±0.01
Conventional chain (RMO)	2.81±0.18	3.53±0.26	2.67±0.06	4.43±0.19	3.05±0.01	4.14±0.02

Table 2. Comparison of means values of tensile strength among different brand types regardless of the environment and length.

Comparison of test groups	Comparison group	Mean difference	Sig.
Conventional chain (GAC)	Super chain™ (GAC)	2.69201	.000*
	Conventional chain (RMO)	2.03098	.000*
	Energy chain (RMO)	2.33973	.000*
Super chain™ (GAC)	Conventional chain (RMO)	-.66103	.052
	Energy chain (RMO)	-.35228	.513
Conventional chain (RMO)	Energy chain (RMO)	.30875	.621

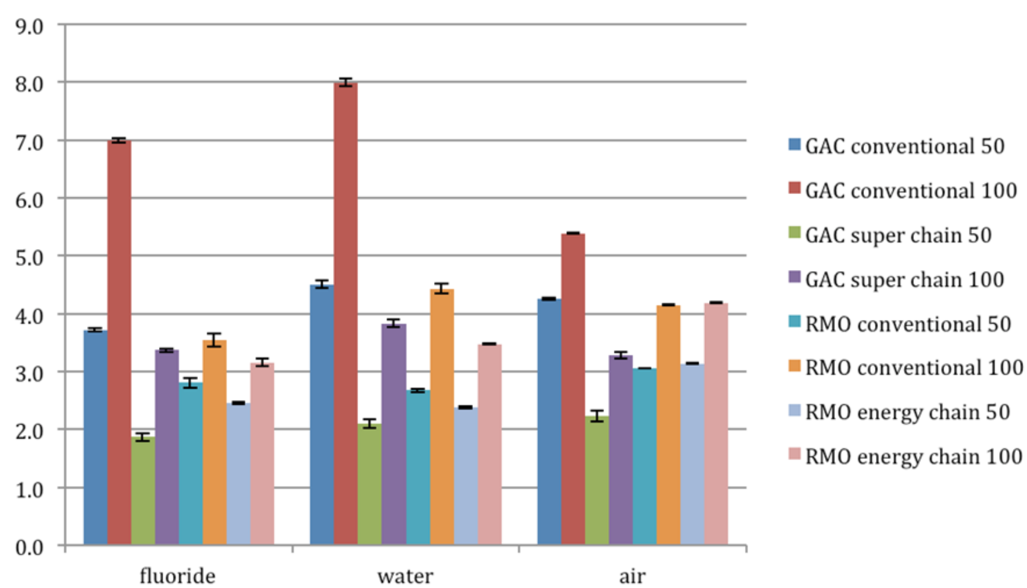

Figure 1. Comparison of different experimental groups at two elongation percentiles based on the three storage media.

Table 3. Comparison of tensile strength in water (W) and fluoride (F) storage media, by brand type and pre-stretching status.

Brand type		Elongation Percentile	Tensile strength	Sig.
GAC	Conventional chain	50%	W> F	.000*
		100%	W>F	.000*
	Super chain	50%	W>F	.178
		100%	W>F	.000*
RMO	Conventional chain	50%	F>W	.060
		100%	W>F	.000*
	Energy chain	50%	F>W	.000*
		100%	W>F	.000*

Table 4. The mean elongation and elongation percentile (in parentheses) of all experimental groups at both strain levels in various test environments in millimeters at the end of three weeks

Experimental group	Water 50%	Fluoride 50%	Water 100%	Fluoride 100%
Super chain (GAC)	4.11 (12.8%)	4.37 (13.6%)	10.16 (31.6%)	8.23 (25.6%)
Conventional chain (GAC)	7.04 (27.5%)	8.29 (32.4%)	15.56 (60.9%)	16.9 (66.2%)
Energy chain (RMO)	2.28 (8.1%)	3.46 (12.2%)	3.34 (11.8%)	4.14 (14.7%)
Conventional chain (RMO)	3.61 (12.8%)	4.11 (14.6%)	7.36 (26.1%)	5.88 (20.8%)

whereas, for 100% elongation, Energy chain (RMO) showed the lowest value (Table 1). In the control group, the lowest values belonged to the Super chain™ (GAC) group. Table 2 demostrates tensile strengh of different brands regardless of the environment, indicating the tensile strength was significantly higher in the conventional chain (GAC) group, irrespective of the amount of elongation ($P < 0.001$). Conventional chain (GAC) demonstrated a significant difference in the mean load with other brand types. Such statistically significant difference was not observed in pairwise comparisons between other brand types (Table 2). The tensile strength values of elastomeric chains of different trademarks stored in water and fluoride media are listed in Figure 1. According to data presented in Table 3, the tensile strength in fluoride storage medium was lower than that in water in all trademarks except for the conventional chain (RMO) and Energy chain (RMO) at 50% pre-stretching. However, this difference was between the two storage media in all groups, except for Super chain™ (GAC) and the conventional chain (RMO) at their 50% pre-stretching status.

At the end of three weeks of pre-stretching and storage in the testing media, all samples demonstrated progressively increased length of elastic chains. The conventional chain (GAC) and Energy chain (RMO) groups exhibited the highest and the lowest elongation percentile values, respectively (Table 4). Furthermore, the conventional chain (RMO) and Energy chain (RMO) exhibited similar amounts of elongation percentile at their 50% pre-stretching state.At the end of three weeks of pre-stretching and storage in the testing media, all samples demonstrated progressively increased length of elastic chains. The conventional chain (GAC) and Energy chain (RMO) groups exhibited the highest and the lowest elongation percentile values, respectively (Table 4). Furthermore, the conventional chain (RMO) and Energy chain (RMO) exhibited similar amounts of elongation percentile at their 50% pre-stretching state.

4. Discussion

This in vitro study examined the ultimate effect of fluoride on elastic properties of four different elastomeric chains brands. Regarding variable contributing factors present in vivo, such as microbial flora, diet, and biting forces, the results of studies demonstrate considerable variety, which limits their clinical applicability. Therefore, we conducted an in vitro study with similar testing conditions, different storage environments, and two pre-stretching states.

Previous studies have revealed distinct differences between dry storage and in vivo storage media. However, they have reported only minor differences between storage in water and saliva. Therefore, artificial saliva was not used in this study, as previous investigations reported no significant differences in force degradation between modules stored in saliva and those stored in water [16, 17]. Also, the use of thermocycling, while significant, resulted in only small differences in previous studies [18]. Furthermore, 0.2% chlorhexidine mouthwash was not used in this study since it has demonstrated that result in more force decay compared to sodium fluoride 0.05% mouthwash [19].

In this study, except for the conventional chain (GAC) at 100% pre-stretching status, all the brands showed lower tensile strength in fluoride storage medium compared to the control group (Figure 1). Therefore, fluoride may increase the elasticity property of elastomeric chains. This is in accordance with a study by Ramazanzadeh et al. who found that 0.05% sodium fluoride mouthwash cause force degradation mostly in high levels of tensile force [20].

Comparing the water and air environments, the conventional chain (GAC) at both pre-stretching states (50% and 100%) and also Super chain™ (GAC) and the conventional chain (RMO) at their 100% pre-stretching state demonstrated significant increase in their tensile strength. This may be due to the fact that the presence of water can strengthen the hydrogen bonds of polyurethane-based elastomeric chains [21]. In this study, fluoride generally exhibited greater adverse effects on the perceived tensile strength in elastomeric chains in most groups. This observation was not so for the conventional chain (RMO) and Energy chain (RMO) at their 50% pre-stretching states.

The results of the current study indicated that the amount of elongation percentile for Super chain™ (GAC), and the conventional chains (both GAC and RMO) at their 100% pre-stretching status, was approximately two times more than the value at their 50 % pre-stretching status, which could be explained by low modulus of elasticity of the afore-mentioned elastomeric chains and also, by lower crystallinity of soft segments and weaker hydrogenic bonds in their main structures [22]. In contrast to other trademarks, the Energy chain (RMO) did not exhibit a considerable increase of elongation percentile from its 50 to 100% pre-stretching states. This observed alteration of the elongation percentile of elastomeric Energy chains may improve their efficacy for orthodontic tooth movement in clinical situations. Orthodontic visit intervals are scheduled usually every 3 or 4 weeks, depending on the type and stage of treatment. Therefore, most studies evaluate the behavior of applied orthodontic materials over a period of approximately 28 days [9,23]. Further clinical research in this field, with more comparable clinical situations is needed to determine the most suitable orthodontic mouthwash for use.

5. Limitations

A limitation of this study might be that it was conducted in vitro, meaning the elastomeric chains were tested under controlled laboratory conditions rather than in the more variable and complex environment of the human oral cavity. Factors such as saliva composition, temperature fluctuations, pH variations, and the presence of other oral hygiene products were not replicated, which may affect the real-world applicability of the findings.

6. Conclusion

Based on the results of this study, it can be concluded that elastomeric chains show a higher tensile strength in water environment in comparison with fluoride mouthwash, and they show lower elasticity in fluoride environment, which is more obvious at 100% pre-stretching of the elastomeric chains.

Acknowledgment

This study was extracted from an undergraduate thesis under the supervision of Dr. Hoori Mirmohamadsadeghi. The authors wish to thank the Dental School of Shahid Beheshti Medical University, and Dentofacial Deformities Research Center for support of this project.

Authors' contribution

Mahmood Dashti: Writing - Original draft, Writing - Review & editing, Formal analysis, Software, Methodology
Hoori Mirmohamadsadeghi: Supervision, Validation, Conceptualization
Farnaz Younessian: Supervision, Validation, Conceptualization, Writing Original Draft
Amir Bayatian, Nozhan Azimi: Methodology, Writing - Original draft
Alireza Akbarzadeh Baghban: Project administration, Visualization, Data curation, Resources
Gity MirMohamadSadeghi: Investigation, Writing original draft

Conflict of Interest

None.

Funding/support

None.

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References

1. Bisht S, Khera AK, Raghav P. White spot lesions during orthodontic clear aligner therapy: A scoping review. J Orthod Sci. 2022 May 4;11:9.
2. Benson PE, Parkin N, Dyer F, Millett DT, Furness S, Germain P. Fluorides for the prevention of early tooth decay (demineralised white lesions) during fixed brace treatment. The Cochrane database of systematic reviews. 2013;12:Cd003809.
3. Hosseinzadeh Nik T, Hooshmand T, Farazdaghi H, Mehrabi A, Razavi ES. Effect of chlorhexidine-containing prophylactic agent on the surface characterization and frictional resistance between orthodontic brackets and archwires: an in vitro study. Prog Orthod. 2013;14:48.
4. Brandão GAM, Simas RM, Almeida LMd, Silva JMd, Meneghim MdC, Pereira AC, et al. Evaluation of ionic degradation and slot corrosion of metallic brackets by the action of different dentifrices. Dental press journal of orthodontics. 2013;18(1):86-93.
5. Kroczek C, Kula K, Stewart K, Baldwin J, Fu T, Chen J. Comparison of the orthodontic load systems created with elastomeric power chain to close extraction spaces on different rectangular archwires. American Journal of Orthodontics and Dentofacial Orthopedics. 2012;141(3):262-8.
6. Halimi A, Azeroual M-F, Doukkali A, El Mabrouk K, Zaoui F. Elastomeric chain force decay in artificial saliva: An in vitro study. International Orthodontics. 2013;11(1):60-70.
7. Bruni A, Serra FG, Deregibus A, Castroflorio T. Shape-Memory Polymers in Dentistry: Systematic Review and Patent Landscape Report. Materials (Basel). 2019;12(14).
8. 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. Advances in Clinical and Experimental Medicine. 2017;26:373-8.
9. Weissheimer A, Locks A, Menezes LMd, Borgatto AF, Derech CDA. In vitro evaluation of force degradation of elastomeric chains used in Orthodontics. Dental press journal of orthodontics. 2013;18(1):55-62.
10. Pithon MM, Santana DA, Sousa KH, Farias IMAO. Does chlorhexidine in different formulations interfere with the force of orthodontic elastics? The Angle Orthodontist. 2012;83(2):313-8.
11. Elshazly TM, Keilig L, Alkabani Y, Ghoneima A, Abuzayda M, Talaat S, et al. Primary Evaluation of Shape Recovery of Orthodontic Aligners Fabricated from Shape Memory Polymer (A Typodont Study). Dent J (Basel). 2021;9(3).
12. Lakade LS, Shah P, Shirol D. Comparison of antimicrobial efficacy of chlorhexidine and combination mouth rinse in reducing the Mutans streptococcus count in plaque. Journal of Indian Society of Pedodontics and Preventive Dentistry. 2014;32(2):91.
13. Guideline on fluoride therapy. Pediatric dentistry. 2013;35(5):E165-8.
14. Marinho VC. Cochrane fluoride reviews: an overview of the evidence on caries prevention with fluoride treatments. Faculty Dental Journal. 2014;5(2):78-83.
15. Datana S, Agarwal S, Chopra S. Comparison of in vivo and in vitro force decay of elastomeric chains/ modules: a systematic review and meta analysis. Journal of the World Federation of Orthodontists. 2021;10.
16. Kim K-H, Chung C-H, Choy K, Lee J-S, Vanarsdall RL. Effects of prestretching on force degradation of synthetic elastomeric chains. American journal of orthodontics and dentofacial orthopedics. 2005;128(4):477-82.
17. Halimi A, Azeroual MF, Doukkali A, El Mabrouk K, Zaoui F. Elastomeric chain force decay in artificial saliva: an in vitro study. International orthodontics. 2013 Mar 1;11(1):60-70.
18. Buchmann N, Senn C, Ball J, Brauchli L. Influence of initial strain on the force decay of currently available elastic chains over time. The Angle Orthodontist. 2011;82(3):529-35.
19. 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.
20. 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.
21. Amrollahi M, Sadeghi GMM, Kashcooli Y. Investigation of novel polyurethane elastomeric networks based on polybutadiene-ol/polypropyleneoxide mixture and their structure–properties relationship. Materials & Design. 2011;32(7):3933-41.
22. Haghayegh M, Mir Mohamad Sadeghi G. Synthesis of shape memory polyurethane/clay nanocomposites and analysis of shape memory, thermal, and mechanical properties. Polymer Composites. 2012;33(6):843-9.
23. Silva Chaves-Filho ACD, Costa AR, Borges LPS, Santos ECA, Crepaldi MV, Vedovello SAS, Correr AB, Correr-Sobrinho L. Force Degradation of Elastomeric Chains after Storage Time and Mechanical Brushing. Braz Dent J. 2021 Jul-Aug;32(4):55-61.

Please cite this paper as: Dashti M, Mirmohamadsadeghi H, Bayatian A, Younessian F, Akbarzadeh Baghban A, Mirmohamadsadeghi G. The Effect of Fluoride Mouthwash on Force Degradation of Orthodontic Elastomer Chains. Journal of "Regeneration, Reconstruction & Restoration"(Triple R). 2022; Volume 7: e1. Doi: 10.22037/rrr.v7.30696