

Comparison of Force Degradation Between Memory Elastic Chains and Conventional Chains: An in Vitro Study

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KEYWORDS

Elastic chains, force degradation, treatments, conventional, memory elastic chain

ABSTRACT

Background: Orthodontic elastic chains are commonly used to provide continuous force for tooth movement. Conventional elastomeric chains are widely utilized, but they experience significant force degradation over time, potentially affecting treatment efficiency. This study compares the force degradation of memory elastic chains and conventional elastomeric chains under standardized in vitro conditions. To evaluate and compare the force degradation patterns of memory elastic chains and conventional elastomeric chains over a specified period and assess the impact of different chemical treatments on force retention.

Materials and Methods: This in vitro study included 150 specimens, with 75 memory elastic chains and 75 conventional chains. The chains were subjected to various chemical treatments, including mouth rinses and dentifrice, over predetermined time intervals (0, 1st, 7th, 14th, and 28th day). Force measurements were recorded using a calibrated force gauge, and statistical analysis was conducted using repeated-measures ANOVA and post hoc tests.

Results: Both memory and conventional elastic chains exhibited force degradation over time. However, memory elastic chains retained a significantly higher force compared to conventional chains, particularly in the later weeks. The interaction of time and treatment was significant, indicating variations in force degradation patterns across different treatments. Conventional chains showed moderate slopes of force decline, whereas memory chains demonstrated more stable force retention.

Conclusion: Memory elastic chains exhibit superior force retention compared to conventional elastomeric chains, making them a more efficient option for prolonged orthodontic applications. Their ability to sustain force over time may reduce the need for frequent adjustments, improving patient compliance and treatment efficiency. Further in vivo studies are recommended to validate these findings in clinical settings.

1. Introduction

Orthodontic treatment often relies on elastic chains to generate continuous force for effective tooth movement. These chains play a crucial role in closing spaces, aligning teeth, and achieving optimal occlusion¹. Traditionally, conventional elastic chains have been widely used in clinical practice. However, their primary limitation lies in force degradation over time, which can affect treatment efficiency and prolong treatment duration. To address this concern, manufacturers have introduced memory elastic chains, designed to provide more consistent force over extended periods. These chains are engineered with improved material properties to resist rapid force decay, thereby potentially enhancing the predictability of orthodontic treatment. However, there remains a need for comparative in vitro studies to evaluate the force degradation patterns of memory elastic chains versus conventional chains under standardized conditions^{2,3}.

Force degradation refers to the gradual loss of force exerted by orthodontic materials over time. This phenomenon is a critical factor in orthodontic treatment, as the effectiveness of tooth movement largely depends on the maintenance of an optimal and consistent force. The degradation of force can lead to

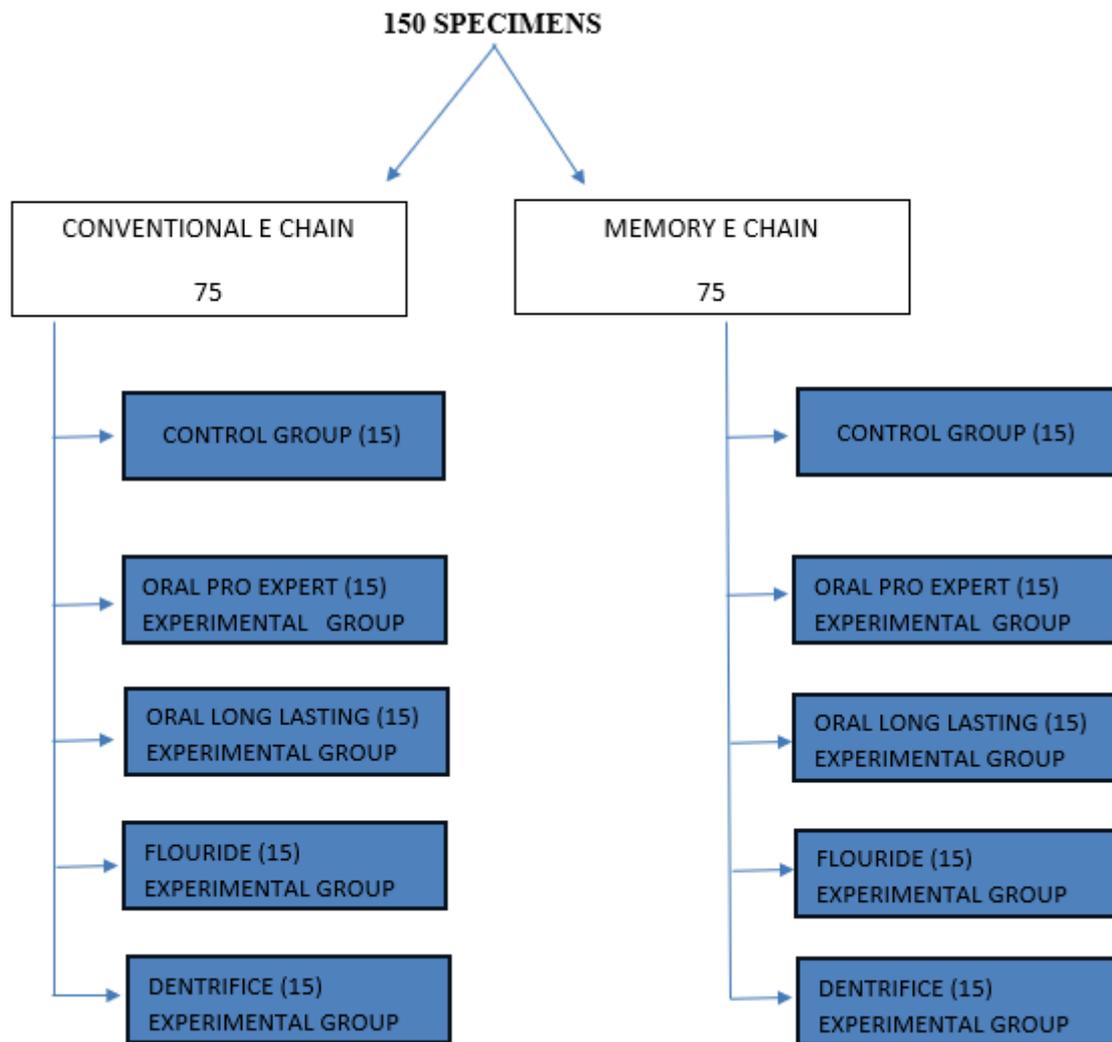
inefficiencies in treatment, requiring frequent adjustments and potentially prolonging the overall duration of orthodontic therapy. Conventional elastomeric chains exhibit significant force degradation within the first 24 hours of placement, with studies reporting force loss ranging from 30% to 50% in the initial period⁴. This rapid decline continues over the following days, necessitating frequent adjustments to maintain the required force for tooth movement. Memory elastic chains, on the other hand, are engineered to provide more stable force over an extended period. These chains incorporate advanced material properties that resist early force decay, allowing them to maintain their tension for longer durations. Studies have shown that memory elastic chains exhibit a slower and more controlled rate of force degradation compared to conventional chains, making them a potentially superior option for prolonged orthodontic applications⁵. Understanding force degradation is essential for optimizing orthodontic treatment outcomes. The rapid decline in force observed with conventional chains may necessitate more frequent replacements or activations, increasing chairside time and patient discomfort. In contrast, memory elastic chains, with their ability to sustain force for longer periods, may reduce the need for frequent adjustments, leading to improved efficiency and patient compliance⁶. By evaluating the force retention capabilities of different orthodontic elastomers, clinicians can make informed decisions on material selection to enhance treatment effectiveness. Future research focusing on long-term in vivo studies and advanced material modifications can further refine orthodontic force delivery systems, improving patient care and treatment predictability⁷.

Orthodontic elastomeric chains are commonly used to apply continuous force for tooth movement, aiding in space closure and alignment. These chains are available in various forms, with conventional elastic chains being the most widely used due to their ease of application and cost-effectiveness⁸. However, one of the major challenges associated with conventional chains is the gradual loss of force over time, which may lead to inefficiencies in orthodontic treatment and extended treatment duration. To overcome this limitation, memory elastic chains have been introduced as an alternative⁹. These chains are designed with advanced polymer technology to retain their force for a longer duration, minimizing the need for frequent adjustments. Their enhanced elasticity and resistance to rapid force degradation make them a promising option for improving the efficiency of orthodontic treatment^{10,11}. A thorough comparison between memory elastic chains and conventional chains is essential to determine their effectiveness in maintaining consistent orthodontic force. Understanding their mechanical properties and force degradation patterns can help clinicians make informed decisions regarding their use in patient care. The aim of the study is to compare and evaluate the impact of five distinct chemical treatments on force dynamics of memory elastic chains and conventional chains.

2. Materials and Methods

This in-vitro study was conducted in the Department of Orthodontics and Dentofacial Orthopaedics at Government Dental College and Hospital, Afzalgunj, Hyderabad. The study involved the evaluation of force degradation in two types of commercially available orthodontic elastomeric chains (closed) from American Orthodontics. A total of 750 elastomeric chains were divided into four experimental groups and one control group, with 15 chains per group. The study also included three types of commercially available mouth rinses and one dentifrice, each with different formulations to assess their impact on force degradation. The inclusion criteria consisted of new, unused elastomeric chains, while recycled chains or those beyond their expiry date were excluded from the study. A total of 150 specimens were selected, with 75 memory chains and 75 conventional chains, which were subjected to chemical treatment using three mouth rinses and one dentifrice at predetermined time intervals (0, 1st, 7th, 14th, and 28th day of incubation). To ensure uniformity, custom-made acrylic jigs were fabricated using self-cure acrylic resin, with stainless steel pins arranged to hold the elastomeric chains in a stretched position. The chains were extended to a standardized length of 25 mm, simulating clinical conditions. Chemical treatments were applied twice daily, with elastomeric chains immersed in mouth rinses for one minute or subjected to dentifrice treatment before being returned to artificial saliva. Force measurements were recorded at designated time intervals using a calibrated force gauge, ensuring accuracy by maintaining a consistent measuring setup throughout the study. The specimens

were stored in an incubator at 37°C to replicate oral conditions, and control group specimens remained in artificial saliva throughout the study duration.



3. Results

Elastics showed a decline in force overtime with memory chains showing slightly less declines (table 1 & 2, figures 1 and 2). The repeated-measures ANOVA showed that the force dropped over time ($P = 0.0012$) and that the force of memory chains was lesser than that of conventional chains in the beginning weeks and was greater in last three weeks (Figures 1 and 2). When both elastic types had been analysed together, no significant effect was observed for treatments ($P = 0.691$) which means that the average of each treatment of both elastic types over 5 time points was not significantly different from the other 5 averages. The interaction of time and treatment was significant ($P = 0.0000$) meaning that the slope of force reduction differed for each treatment. All most all the treatments in conventional E chain showed moderate slopes whereas as in memory E chain, no major difference was observed. (Figures 1 and 2). In order to rule out the effect of confounders, each chain type was separately analysed over time. The repeated-measures ANOVA showed a significant effect of treatments ($P = 0.032$ in the conventional group and $P = 0.0021$ in the memory group).

The Tamhane post hoc test showed only 1 significant pairwise comparison between treatments of memory chains (table 3). Except this, there was no significant difference between any two treatments in both E chain groups The interaction of time and treatment was significant in each elastic type (both P values <0.05), meaning that slopes of force decline differed for treatments (figure 2). The one sample t-test showed that all residual forces measured in the 28th day were significantly above 150 g (table 4).

Table 1: Descriptive Statistics And 95% CLS for Force Extents (Conventional E Chain Group)

		N	Mean	Std. Deviation	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Day 0	Artificial saliva	15	435.67	10.83	429.67	441.67	420.00	460.00
	Flouride	15	427.33	16.24	418.34	436.33	410.00	460.00
	Oral B Long lasting	15	432.67	12.80	425.58	439.75	410.00	460.00
	Oral B Expert Pro	15	430.00	16.48	420.88	439.12	410.00	460.00
	Dentrifice	15	428.67	11.87	422.09	435.24	410.00	450.00
	Total	75	430.87	13.79	427.69	434.04	410.00	460.00
Day 1	Artificial saliva	15	307.67	9.04	302.66	312.67	290.00	320.00
	Flouride	15	293.33	11.75	286.83	299.84	280.00	310.00
	Oral B Long lasting	15	304.33	8.42	299.67	309.00	290.00	320.00
	Oral B Expert Pro	15	295.67	4.95	292.92	298.41	290.00	305.00
	Dentrifice	15	289.67	4.81	287.01	292.33	280.00	295.00
	Total	75	298.13	10.52	295.71	300.55	280.00	320.00
Day7	Artificial saliva	15	256.67	5.23	253.77	259.56	250.00	265.00
	Flouride	15	246.67	7.24	242.66	250.67	235.00	260.00
	Oral B Long lasting	15	254.33	5.63	251.22	257.45	245.00	260.00
	Oral B Expert Pro	15	249.00	3.87	246.86	251.14	245.00	255.00
	Dentrifice	15	247.00	9.22	241.89	252.11	230.00	260.00
	Total	75	250.73	7.52	249.00	252.46	230.00	265.00
Day 14	Artificial saliva	15	244.67	7.19	240.69	248.65	230.00	255.00
	Flouride	15	234.67	7.90	230.29	239.04	220.00	250.00
	Oral B Long lasting	15	245.00	6.55	241.37	248.63	235.00	255.00
	Oral B Expert Pro	15	237.00	6.76	233.26	240.74	220.00	245.00
	Dentrifice	15	236.00	8.49	231.30	240.70	220.00	250.00
	Total	75	239.47	8.49	237.51	241.42	220.00	255.00
Day 28	Artificial saliva	15	193.00	8.19	188.46	197.54	180.00	210.00
	Flouride	15	181.33	6.67	177.64	185.03	170.00	195.00
	Oral B Long lasting	15	187.00	5.61	183.90	190.10	180.00	195.00
	Oral B Expert Pro	15	185.00	6.55	181.37	188.63	170.00	195.00
	Dentrifice	15	190.00	7.07	186.08	193.92	180.00	205.00

	N	Mean	Std. Deviation	95% Confidence Interval for Mean		Minimum	Maximum
				Lower Bound	Upper Bound		
Total	75	187.27	7.81	185.47	189.06	170.00	210.00

Table 2: Descriptive Statistics And 95% CLS for Force Extents (Memory E Chain Group)

	N	Mean	Std. Deviation	95% Confidence Interval for Mean		Minimum	Maximum	
				Lower Bound	Upper Bound			
Day 0	Artificial saliva	15	323.00	10.14	317.38	328.62	310.00	340.00
	Flouride	15	322.00	10.99	315.92	328.08	310.00	350.00
	Oral B Long lasting	15	321.00	10.72	315.06	326.94	310.00	340.00
	Oral B Expert Pro	15	324.00	11.53	317.62	330.38	310.00	345.00
	Dentrice	15	322.33	12.52	315.40	329.26	310.00	350.00
	Total	75	322.47	10.95	319.95	324.99	310.00	350.00
Day 1	Artificial saliva	15	306.00	5.73	302.83	309.17	295.00	315.00
	Flouride	15	289.67	8.76	284.82	294.52	280.00	305.00
	Oral B Long lasting	15	293.67	6.11	290.28	297.05	285.00	305.00
	Oral B Expert Pro	15	291.33	5.16	288.47	294.19	285.00	300.00
	Dentrice	15	290.33	4.42	287.89	292.78	285.00	295.00
	Total	75	294.20	8.58	292.23	296.17	280.00	315.00
Day 7	Artificial saliva	15	290.67	4.58	288.13	293.20	285.00	300.00
	Flouride	15	276.00	5.41	273.00	279.00	265.00	285.00
	Oral B Long lasting	15	283.67	5.16	280.81	286.53	275.00	290.00
	Oral B Expert Pro	15	279.00	4.31	276.61	281.39	270.00	285.00
	Dentrice	15	280.00	4.63	277.44	282.56	270.00	285.00
	Total	75	281.87	6.92	280.28	283.46	265.00	300.00
Day 14	Artificial saliva	15	277.33	4.95	274.59	280.08	270.00	285.00
	Flouride	15	261.00	5.07	258.19	263.81	250.00	270.00
	Oral B Long lasting	15	269.67	5.81	266.45	272.89	260.00	280.00
	Oral B Expert Pro	15	265.33	4.81	262.67	267.99	255.00	270.00
	Dentrice	15	267.33	4.17	265.02	269.64	260.00	275.00
	Total	75	268.13	7.30	266.45	269.81	250.00	285.00
Day 28	Artificial saliva	15	262.33	3.72	260.28	264.39	255.00	270.00

	N	Mean	Std. Deviation	95% Confidence Interval for Mean		Minimum	Maximum
				Lower Bound	Upper Bound		
Flouride	15	251.00	3.87	248.86	253.14	245.00	255.00
Oral B Long lasting	15	258.00	4.93	255.27	260.73	250.00	265.00
Oral B Expert Pro	15	256.33	5.16	253.47	259.19	245.00	265.00
Dentrifice	15	257.67	3.72	255.61	259.72	250.00	265.00
Total	75	257.07	5.58	255.78	258.35	245.00	270.00

Table 3: Results of Tamhane Post Hoc Test Comparing Treatments

Comparable groups (I,J)		Conventional E Chain					Memory E Chain				
		Dif	SE	p-value	95 CI%		Dif	SE	p-value	95 CI%	
					Upper	Lower				Upper	Lower
Artificial saliva	Flouride	10.87	13.72	.996	-28.13	49.86	11.93*	3.95	.029	0.72	23.15
	Oral B Long Lasting	2.87	13.66	1.000	-35.95	41.69	6.67	3.67	.524	-3.77	17.11
	Oral B Pro Expert	8.20	13.69	1.000	-30.71	47.11	8.67	3.83	.226	-2.23	19.56
	Dentrifice	9.27	13.56	.999	-29.28	47.81	8.33	3.73	.239	-2.27	18.93
Flouride	Oral B Long Lasting	-8.00	13.74	1.000	-47.06	31.06	-5.27	3.99	.876	-16.60	6.07
	Oral B Pro Expert	-2.67	13.77	1.000	-41.81	36.48	-3.27	4.14	.996	-15.02	8.49
	Dentrifice	-1.60	13.65	1.000	-40.38	37.18	-3.60	4.04	.991	-15.08	7.88
Oral B Long Lasting	Oral B Pro Expert	5.33	13.71	1.000	-33.64	44.31	2.00	3.88	1.000	-9.02	13.02
	Dentrifice	6.40	13.59	1.000	-32.21	45.01	1.67	3.77	1.000	-9.06	12.39
Oral B Pro Expert	Dentrifice	1.07	13.62	1.000	-37.63	39.77	-0.33	3.93	1.000	-11.50	10.83

Table 4: Results of the One-Sample T-Test, Comparing the Residual Forces of 28th Day with the Constant Force 150 G

Chain type	Treatment	Mean	p-value	Dif	95 CI%	
					Upper	Lower
Conventional	Artificial saliva	193.00	.023*	43.00	38.46	47.54
	Flouride	181.33	.007*	31.33	27.64	35.03
	Oral B Long lasting	187.00	.000*	37.00	33.90	40.10
	Oral B Expert Pro	185.00	.035*	35.00	31.37	38.63

	Dentifrice	190.00	.001*	40.00	36.08	43.92
Memory	Artificial saliva	262.33	.009*	112.33	110.28	114.39
	Flouride	251.00	.000*	101.00	98.86	103.14
	Oral B Long lasting	258.00	.036*	108.00	105.27	110.73
	Oral B Expert Pro	256.33	.004*	106.33	103.47	109.19
	Dentifrice	257.67	.000*	107.67	105.61	109.72

4. Discussion

The present study aimed to compare the force degradation of memory elastic chains and conventional elastomeric chains in an in vitro setting. The findings revealed significant differences in force retention between the two types of chains, highlighting the superior performance of memory elastic chains in maintaining consistent force over time. The results demonstrated that conventional elastic chains experienced a rapid decline in force, with a substantial reduction observed within the first 24 hours of application^{12,13}. This pattern aligns with previous research, which has reported that conventional elastomeric chains can lose nearly 30%–50% of their initial force within the first day of placement. The rapid force decay observed in conventional chains can be attributed to their material composition, which is susceptible to stress relaxation and environmental influences such as moisture and temperature variations in the oral cavity. In contrast, memory elastic chains exhibited a more gradual and controlled force degradation pattern. The force retention of memory chains was significantly higher than that of conventional chains over an extended period. This can be attributed to the advanced polymer technology used in memory chains, which enhances their elasticity and resistance to molecular breakdown^{14,15}. These findings support the hypothesis that memory elastic chains offer greater force stability, reducing the frequency of adjustments required during orthodontic treatment.

Baratieri et al¹⁶ found that only thermoset type sustained force levels exceeding 100 gm after three weeks in an in-situ setting. They concluded that thermoset chains produced less initial force and broke down considerably more slowly than thermoplastic chains, leading them to suggest that a significant separation between the two be made when applying. Furthermore, Subroto et al¹⁷. discovered that the thermoset elastomeric chain exhibits better colour stability than the thermoplastic variety. According to Khanemasjedi et al¹⁸. the canine can retract at speeds similar to those of a NiTi coil spring if a thermoset elastomeric chain is used and changed monthly. In contrast to thermoplastic chains, thermoset chains required more stretching in order to provide the necessary forces. The ability of orthodontic chains to maintain consistent force is crucial for efficient tooth movement and optimal treatment outcomes. The rapid force decay in conventional elastomeric chains necessitates frequent replacements and activations, increasing patient visits and chairside time. Additionally, inconsistent force application may lead to delayed tooth movement and prolonged treatment duration. On the other hand, memory elastic chains, with their improved force retention, may provide a more predictable and stable force for tooth movement. Their prolonged efficiency can reduce the need for frequent adjustments, thereby enhancing patient comfort and treatment compliance. Furthermore, fewer replacements may lead to reduced costs and time investment for both patients and orthodontists.

The results of this study are consistent with previous research that has evaluated the force degradation of orthodontic elastomers. Several in vitro studies have reported that memory elastic chains outperform conventional chains in terms of force retention. However, variations in study methodologies, including different brands, force measurement techniques, and environmental conditions, may influence the extent of force degradation observed^{19,20}. While in vitro studies provide valuable insights, the behaviour of elastomeric chains in the oral environment may differ due to factors such as saliva exposure, bacterial biofilm accumulation, and mechanical stress from mastication. Future research should focus on in vivo studies to assess the real-time performance of memory elastic chains in clinical settings. Despite its strengths, this study has certain limitations. First, the in vitro nature of the study does not fully replicate the complex oral conditions that may influence force degradation^{21,22}.

Additionally, variations in brand-specific formulations of elastomeric materials could impact results, necessitating further research across different manufacturers. Future studies should explore the long-term clinical effects of memory elastic chains, particularly their impact on treatment efficiency and overall patient experience. Investigating the effects of different storage conditions, humidity levels, and stretching protocols can further enhance our understanding of force degradation mechanisms²³.

5. Conclusion

The study highlights the differences in force degradation between memory elastic chains and conventional elastomeric chains, demonstrating the superior force retention of memory chains over time. The findings suggest that memory elastic chains provide a more consistent and sustained force application, potentially reducing the need for frequent adjustments and enhancing treatment efficiency. While conventional chains exhibit rapid force decay, memory chains maintain their mechanical integrity for a longer duration, making them a preferable choice for orthodontic applications. Future *in vivo* studies are recommended to validate these results and assess their clinical significance under real oral conditions.

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