

Force-Degradation Pattern of Six Different Orthodontic Elastomeric Chains

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Abstract

Objective: An ideal orthodontic force system should exert continuous light force. Thus, many efforts have been made to improve the memory characteristics of elastomeric chains. The aim of this study was to compare elastomeric chains (ECs) claimed by their manufacturers to offer high memory with traditional ones according to their force-extension diagrams.

Materials and Methods: In this in-vitro study, ECs were divided into six groups, each containing 40 pieces of chain, from three brands (American Orthodontics, GAC and Ortho-Technology). Each brand was divided into two groups with respect to their claimed characteristics (with or without memory). Each sample was stretched to twice its original length and kept constant in 37°C distilled water. Force-extension diagrams were drawn by universal testing machine at 0,1,8,24,72 hours and 1, 2, 4-week intervals. Additionally, the amounts of elongation required to deliver 200 g force were calculated. To compare the results, ANOVA and Tukey tests were performed.

Results: Force-decay rate was significantly different between traditional and memory chains ($p < 0.05$). For traditional chains, there was a substantial decay in force in the first hour and 30-40% of the force was retained at 4 weeks. The memory chains demonstrated more constant force and retained 60% of the force. The maximum amount of elongation required to deliver 200 g force belonged to American Orthodontics memory chains (61.9% after 24hr) and the minimum to Ortho-Technology ECs (23.4% initially).

Conclusion: Memory chains exhibited superior mechanical properties compared to traditional ones. For delivering the same force, memory chains required more elongation. Memory chains of GAC and American Orthodontics showed better characteristics among all chains.

Key Words: Elastomeric, Orthodontic Appliance Design

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INTRODUCTION

A primary goal in orthodontic treatment is to exert a light continuous force to ensure maximum effective tooth movement with minimal

side-effects such as root resorption and bone resorption, which in turn adversely affect tooth movement [1-2]. Space clouser system should meet the aforementioned characteristics.

Among the most common systems i.e. NiTi coil springs and elastomeric products, the latter are more popular due to ease of application and low cost [3]. In addition, they are comfortable for patients and clinicians, not suitable for microorganism proliferation [4] and available in a variety of colors [5]. These polyurethane elastomeric products offer a wide range of applicability from the correction of intermaxillary jaw discrepancies to intramaxillary tooth movements, particularly in straight-wire technique and lingual orthodontics by providing arch-guided tooth movements [6]. However, they are not ideal elastics as they undergo permanent deformation and force decay over time. The mechanism of these deformations is predominantly adjacent molecular chain slippage and molecular stretching [7-8]. With regard to force decay, it is believed that 50 to 70% of the initial force is lost in the first 24 hours, with most of the loss within the first hour and a steady decline over 3 to 4 weeks ensues [9-10].

Some clinical and *in vitro* studies have claimed that NiTi coil springs are superior to other systems due to a lighter initial force value and a slower force degradation [3, 11-13]. However, according to a systematic review held by Barlow *et al.*, the rate of retraction by elastomeric chain is similar to 150 and 200 g NiTi coil springs, besides the latter is more expensive [14].

Thus, it is prudent for clinicians to be aware of the characteristics of space closure devices in order to make a good choice. Force decay characteristics and force relaxation patterns of elastomeric materials are influenced by various factors such as manufacturing techniques, environmental conditions and chemical composition as well as morphology and dimensions of the chains [15]. The fact that temperature and moisture increase force loss is well known [16]; however, the exact effects of the aforementioned factors are still controversial in the literature. Bousquet *et al.* and Elaides *et al.* reported that variations in geometrics and

the manufacturing processes of power chains seemed not to influence the force delivered [17-18], while Dittmer *et al.* concluded that the tensile properties of different elastomeric chains (ECs) differ significantly [19]. Mechanical properties of polyurethane products are mainly related to their molecular structure [10, 18] and various additives. These additives (usually confidential) have resulted in different commercial products. Due to the force degradation of elastomeric chains, there has been an everyday increasing trend toward applying elastomers which offer shape memory and durability. Newer elastomeric ECs termed the memory type have been introduced and claimed to provide an adequate force maintained over larger periods than conventional elastomeric chains with minimal decay.

In case it is proved, this would be of many advantages for dependable and more efficient controlled tooth movement. However, newer products are usually more expensive and their application should be rationalized. Although there are numerous studies on the mechanical properties of common ECs, little information is available on the properties of the memory type chains.

This is crucial for clinicians to know the properties of the products they use. Thus, this study was conducted with the aim of comparing three different commercially available conventional elastomeric chains with the chains whose manufacturers claimed have memory. This was done with respect to ECs force-degradation diagrams in *in vitro* conditions.

MATERIALS AND METHODS

Two hundred and forty pieces of elastomeric chains, all clear and without intermodular links from three orthodontic companies (Ortho Technology, GAC and American Orthodontics) were studied.

Two types of chains (conventional and memory type) from each brand were selected. This classification was based on the properties claimed in each product's catalog.



Fig 1. Custom made device comprising six rows of 40 pairs of pins which kept the elastomers stretched at the length of 25mm

If the product offered memory, we involved it in a group named memory type group (M). Otherwise, it was recruited in another group named the conventional group (C). The specimens were ultimately divided into six subgroups: conventional American Orthodontics (C1), conventional GAC (C2), conventional Ortho Technology (C3), memory American Orthodontics (M1), memory GAC (M2) and memory Ortho Technology (M3) -each containing about 40 pieces of chain.

The products and their catalog codes are shown in Table 1. The test specimens were cut using a sharp ligature cutter to the initial length of about 12 millimeters.

The initial lengths were a little different for different groups, since we did not want to cut the chain in the middle of the loop.

Additionally, two extra loops remained on each side to avoid excessive force on the terminal loops. This was done meticulously in order to avoid extended handling which may place stress on the elastomers prior to testing.

A custom made steal device comprising six rows of 40 pairs of rigid pins which kept the elastomers stretched at the length of 25mm (about twice their original length or 100% elongation) was applied (Fig 1).

One hundred percent extension had been suggested by the former authors and manufacturers for clinical use [7].

In order to simulate oral condition, the specimens were stored in an incubator at body temperature ($37\pm 1^{\circ}\text{C}$) immersed in distilled water. The specimens in each group were divided into eight categories and were tested at zero, 1, 8, 24 and 72 hours plus 1, 2 and 4 weeks. Mechanical tests were performed by means of a universal testing machine (Zwick) in the mentioned intervals.

At each testing interval, the related specimens were demounted from the pins and allowed to relax toward their original length.

Table 1. Custom made device comprising six rows of 40 pairs of pins which kept the elastomers stretched at the length of 25mm

Test Groups	Subgroups	Type	Chain Designation	Brand (Manufacturer)
Conventional Type (C)	C1	E-chain	850-235	American orthodontics
	C2	E-chain	KI-30-01-25	GAC
	C3	E-chain	35444	Ortho Technology
Memory Type (M)	M1	Memory chain	854-255	American orthodontics
	M2	Super elastic chain	KIT-34-012-068	GAC
	M3	Memory chain	430-902	Ortho Technology

Subsequently, to clamp the chains on the machine, they were attached to steel hooks made of 0.050 inch stainless steel wire.

Round wires were selected to eliminate the potential stresses induced by the edges of the rectangular ones. Elastomers of each group were stretched at the rate of 20 millimeters per minute.

The amount of force delivered at 25 mm (100% elongation of the initial length) was recorded at the testing intervals.

Additionally, the elongation required to deliver 200 gr force was observed for each type at different intervals. Statistical analysis of the data was performed using the one-way and two-way analysis of variance (ANOVA) tests to determine the differences between the groups and within each group. The level of significance was set at $P=0.05$. Tukey-Kramer HSD test was used as post hoc test ($\alpha=0.05$).

All tests were conducted using SPSS 12.0[®] for Windows (SPSS Inc., Chicago, Illinois, USA).

Comparison of the total force at various intervals

In this study, the mean initial force at 25 mm extension was 733.0 gr and 530.9 gr for the conventional group and the memory group, respectively.

As shown in Table 2, the initial forces of all specimens are notably higher than the ideal orthodontic force with the highest value belonging to C3 (835.3 gr) and the lowest to M2 (436.5 gr). Based on Tukey's test results, the initial force delivered by different elastics can be divided into three groups: M1 and M2 in group 1 with the mean force of 462.9 gr; M2, C1 and C3 in group 2 with the mean force of 677.0 gr and C3 in group 3 (835.3 gr). The mean values of forces for each group are given in Table 3.

After 1 hr, the mean force of group C1 dramatically decreased and there was also a notable variation in the rate of force decay over the whole study time.

Table 2. Mean and Standard Deviation of Force Values (gf) for the Studied Elastomeric Chains After Specific Time Intervals

	American Orthodontics		GAC		Ortho Technology	
	C1	M1	C2	M2	C3	M3
	M(SD)	M(SD)	M(SD)	M(SD)	M(SD)	M(SD)
0hrs	683.9(17.2)	489.3(6.5)	679.8(10.7)	436.5(23.5)	835.3(18.5)	667.0(26.7)
1hrs	549.8(15.3)	459.2(10.8)	585.1(16.7)	418.8(5.8)	666.3(16.7)	638.9(16.3)
8hrs	533.4(13.6)	481.5(7.3)	561.7(23.2)	419.3(17.2)	631.8(21.2)	638.0(22.0)
24hrs	504.8(10.9)	444.1(9.2)	539.1(15.3)	382.4(5.1)	574.9(49.2)	625.3(46.0)
72hrs	491.8(33.6)	479.7(20.6)	473.9(42.0)	409.5(2.7)	534.1(30.5)	634.2(40.6)
1 weeks	488.1(28.6)	430.3(29.5)	501.6(7.09)	380.6(14.2)	499.7(48.0)	548.8(7.6)
2 weeks	367.2(32.7)	406.8(40.3)	396.8(23.0)	404.0(17.8)	480.3(97.7)	527.2(57.0)
4 weeks	271.0(7.6)	295.5(12.2)	180.5(31.9)	279.4(17.0)	350.6(35.9)	357.9(19.1)

M = Mean; SD = Standard deviation; C= Conventional type; M = Memory type; 1=American orthodontics; 2=GAC; 3=Ortho Technology

Significant values of force after every time interval are presented by Tukey’s test (Table 4). Overall, the highest amount of force was presented by M3 and C3 and the lowest by M1 and M2.

Force Degradation

The mean force decay percentage within the first hour was 17.93% of the original force for the conventional groups and 4.83% for the memory groups (Table 5).

At the third follow-up session (after 24hr), the remaining force in the conventional type and the memory type groups were 74% and 90.7% of the initial force, respectively.

Table 5 shows that by 4 weeks, the elastics of C1 and C3 subgroups had reserved about 40% of their initial force, while this amount was 26% for C2. At the identical intervals, M1, M2 and M3 subgroups reserved 60, 64 and 63% of their initial force, respectively.

As can be seen in the Table 5, the results of conventional chains follow a harmonious raising trend of force loss over time and this disparity of results is observed only for memory type chains. All specimens delivered force which was adequate for tooth movement in this time interval.

The fact that memory chains do not follow an orderly pattern of force loss is an important finding of this study, but the reason is unknown for the authors despite vast searching. This needs further studies focused on the chemical behavior of memory elastomeric products.

As it is illustrated in Table 6, the differences between the initial force value and the last follow up were significant for all groups.

Elongation required to deliver 200 gr force

The mean and standard deviation of the amount of elongation required to deliver 200 gr force are described in Table 7.

As can be seen, at the initial phase, the specimens in M1 and M2 groups had to be extended more than 30 percent of the initial length to exert forces equivalent to 200 gr, while the specimens in C1 and C3 groups merely required a 23% extension to exert the same amount of force.

After one day, the mean amount of elongation required for the memory type groups and the conventional groups were 55.03% and 40.0%, respectively. Overall, C3 was able to deliver 200 gr force with minimum elongation in comparison with the other types.

Table 3. Categorization of the Studied Elastomeric Chains Determined by Their Initial Force Value (gf) Based on Tukey’s Test Results

EC Type	Tukey Group	1	2	3
M2		436.47		
M1		489.34		
M3			667.03	
C2			679.78	
C1			684.00	
C3				835.28
Sig		0.622	0.995	1.000

Subset for $\alpha=0.05$

C= Conventional type; M = Memory type; 1=American orthodontics; 2=GAC; 3=Ortho Technology

Table 4. Mean Difference and Standard Deviation of Force Values (gf) Between Studied Elastomeric Chains After Specific Time Intervals Using the Tukey’s Test

	0hrs	1hrs	8hrs	24hrs	72hrs	1weeks	2weeks	4weeks
C1 vs. C2	4(30.0)	-35.2(8.9)*	-28.4(11.5)	-34.3(19.0)	17.9(19.9)	-13.5(19.2)	-30.0(35.5)	90.5(17.3)*
C1 vs. C3	-151.2(30.0)	-116.5(9.5)*	-98.5(11.5)*	-70.2(19.0)*	-42.2(23.0)	-11.6(18.2)	-113.2(35.5)*	-80.0(18.5)*
C1 vs. M1	194.7(33.5)	90.7(8.9)*	51.9(11.5)*	60.7(20.2)	12.0(19.9)	57.8(19.2)	-40.0(35.5)	-24.5(17.3)
C1 vs. M2	247.5(33.6)	131.1(8.9)*	114.1(11.5)*	122.4(20.2)*	82.3(19.9)*	107.5(18.2)*	-36.9(35.5)	-8.3(17.3)
C1 vs. M3	17.0(33.5)	-89.1(8.9)*	-104.6(12.2)*	-120.5(19.0)*	-142.4(19.9)*	-60.7(18.2)*	-160.0(35.5)*	-86.9(17.3)*
C2 vs. C3	-155.3(30.0)	-81.3(9.5)*	-70.1(11.5)*	-36.0(19.0)	-60.1(23.0)	1.8(18.2)	-83.5(33.5)	-170.1 (17.3)*
C2 vs. M1	190.7(33.6)	126.0(8.9)*	80.2(11.5)*	95.0(20.2)*	-5.8(19.9)	71.3(19.2)*	-10.0(33.5)	-114.9(16.0)*
C2 vs. M2	243.5(33.7)	166.3(8.9)*	142.4(11.5)*	156.7(20.2)	64.4(19.9)*	121.0(18.2)*	-7.2(33.5)	-98.8(16.0)*
C2 vs. M3	13.0(33.5)	-54.0(8.9)*	-76.3(12.2)*	-86.2(19.0)*	-160.3(19.9)*	-47.2(18.2)	-130.4(33.5)*	-177.4(17.3)*
C3 vs. M1	346.0(33.6)	207.2(9.5)*	150.3(11.5)*	131.0(20.2)*	54.3(23.0)	69.5(18.2)*	73.5(33.5)	55.1(17.3)
C3 vs. M2	398.8(33.6)	248.0(9.5)*	212.6(11.5)*	193.0(20.2)*	124.5(23.0)*	119.2(17.2)*	76.3(33.5)	71.3(17.3)*
C3 vs. M3	168.3(33.6)	27.4(9.5)	-6.2(12.2)	-50.3(19.0)	-100.2(23.0)*	-49.0(17.2)	-46.9(33.5)	-7.3(17.3)
M1 vs. M2	52.8(36.8)	40.4(8.9)*	62.2(11.5)*	61.7(21.3)	70.3(19.9)*	49.7(18.2)	2.8(33.5)	16.2(16.0)
M1 vs. M3	-177.7(36.8)	-179.8(8.9)*	-156.5(12.2)*	-181.2(20.2)*	-154.5(19.9)*	-118.5(18.2)*	-120.4(33.5)*	-62.4(16.0)*
M2 vs. M3	-230.5(36.8)	-220.2(8.9)*	-218.7(12.2)*	-242.9(20.2)*	-224.7(19.9)*	-168.2(17.2)*	-123.2(33.5)*	-79.0(16.0)*

C= Conventional type; M = Memory type; 1=American orthodontics; 2=GAC; 3=Ortho Technology; *.Significance level of 5% (p < 0.05)

DISCUSSION

Elastomeric chains have long been a popular means of force immersion in orthodontic treatments.

Concerned about the importance of applying forces as much light and continuous as possible, this study was designed to compare the force delivered by elastomeric chains which were commercially claimed to have memory with the conventional elastomeric chains.

The addition of various substances in the manufacturing process of the memory type chains is an example of the modifications made in these products, this was supposed to result in providing continuous gentle force with optimum force memory.

However the exact advantages of these modifications are still open to dispute.

For instance, in a study comparing physical properties of conventional and Super Slick elastomeric ligatures, Crawford et al. reported no statistical differences in the static friction and failure load between the study groups [20]. Moreover, due to the high cost of modern products, greater considerations should be taken into account in order to rationalize their application.

According to the results of this study, the mean initial force value of different types of specimens at the 25 mm extension ranged from 436 gr to 835 gr which is higher than the ideal orthodontic force.

This is especially true about C1, C2, C3 and M3. Several studies have evaluated the ideal magnitudes of force for orthodontic space closing.

About bodily movement for instance, it varies from 100 gr to 350 gr [21-23], but since friction is inevitable during sliding, a force magnitude between 150 and 200 gr has been suggested for space closure in orthodontics [3, 11]. Our findings revealed that after the first hour, a high percentage of force was lost in the conventional type group (about 17.93%) while the mean force loss for M1, M2 and M3 were merely about 4.83% (Table 5).

An identical pattern was observed in the subsequent follow-ups. At the third follow-up (24 hr) the percentage of force loss ranged from 20.7 to 31.2% for the conventional group and 9.3 to 12.4% for memory types.

Probably because this study was in the *in vitro* condition and the effect of variable oral environment was neglected.

Table 5. Percentages of Force Loss of Initial Forces for Studied Elastomeric Chains in Different Time Intervals

	C1	C2	C3	MC	M1	M2	M3	MM
1hr	19.7	13.9	20.2	17.9	6.2	4.1	4.2	4.8
8hrs	22.1	17.4	24.4	21.3	1.6	3.9	4.4	3.3
24hrs	26.2	20.7	31.2	26.0	9.3	12.4	6.3	9.3
72hrs	28.2	30.3	36.1	31.5	2.0	6.2	4.9	4.4
1 week	28.6	26.2	40.2	31.7	12.1	12.8	17.7	14.2
2 weeks	46.3	41.4	42.5	43.4	16.9	7.4	21	15.1
4 weeks	60.4	73.4	58.0	63.9	39.6	36.0	46.3	40.6

C= Conventional type; M = Memory type; 1=American orthodontics; 2=GAC; 3=Ortho Technology; MC= mean of conventional types; MM= mean of memory types

These force loss values are much lesser than those reported by previous studies [9-10]. Besides, the samples were held constantly in this study and simulation of progressive reduction of EC stretch as the teeth get closer over time, was not possible. After 4 weeks, the remaining force in relation to the original value followed the order: M2> M1> M3> C1, C3> C2 in different products. These results strongly confirm the claims of manufacturers that elastomeric chains with memory can preserve the force more efficiently than other chains. According to the last measurement of force (Table 2), the least amount of force was delivered by C2 (180.5 ± 31.9 gr) while the highest was delivered by M3 (357.9 ± 19.1 gr). The force value of all memory chains were higher than C1 and C2 (Table 4). M1 and M2 were significantly higher than C2 ($p < 0.05$). The value of M3 was higher than all other groups and the differences were significant ($p < 0.05$), except between M3 and C3 ($p = 0.99$). Comparing the initial results, the differences between the first and last follow ups were significant for all groups (Table 6). Although all the studied elastomeric chains were stretched to the same length, the magnitudes of their delivered force varied significantly and were generally higher in the conventional type group than the memory group (Table 2).

The factors affecting the amount of force exerted by ECs can be categorized in two groups: those which are under the control of the clinician and those which are innate characteristics of the elastomeric material and are influenced by the manufacturing process.

Not surprisingly, there is a wide range of force applied by different individuals [24].

However, Rock et al. suggested that elastomeric chains should undergo an initial extension not more than 50% to prevent excessive force [7]. On the other hand, since the highest rate of force loss occurs in the first 24 hr of force immersion, Bishara and Anderson believed that elastics should be extended to four times as long as their initial length at the first stage to compensate the innate force decay that ensues [25]. The amount of activation accomplished by this study was steadied to twice the original length in accordance with recent studies [3] and the results showed that initial force values were extremely high for some studied ECs especially conventional ones (Table 2) which can have biological adverse effects (in the present research the adverse effects have not been studied).

At the final stage, some force values were still enough for tooth movement. Conclusively, 100% elongation may not be an appropriate extension for all EC brands.

Table 6. Comparison of Initial and Final Force Values for Each Elastomeric Group Based on Tukey's Test

	C1	C2	C3	M1	M2	M3
Mean Difference (SE) between the initial value and the final value (gr)	412.94 (15.5)*	499.2 (15.1)*	484.63 (46.9)*	193.8 (14.8)*	157.1 (10.2)*	309.1 (24.3)*

*Significance level of 5% ($p < 0.05$)

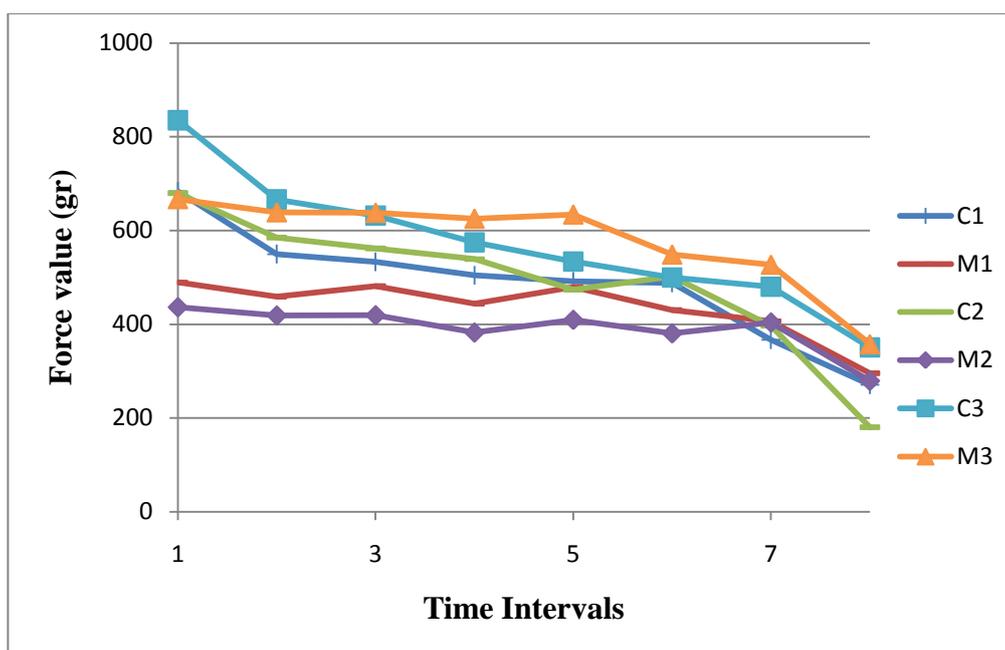


Fig 2. Force degradation pattern of all studied specimens. C1: Conventional chain of American orthodontics, C2: Conventional chain of GAC, C3: Conventional chain of Ortho Technology, M1: Memory chain of American orthodontics, M2: Super elastic chain of GAC, M3: Extreme chain of Ortho Technology. In horizontal axis time intervals of 1-8 represents 0, 1, 8, 24 and 72 hours and 1, 2 and 4 weeks, respectively

Loading rate is also subjected to clinicians' control and can modify the behavior of the EC. Generally, at a high loading rate, time is not sufficient for polymeric chain slippage, thus the material behave like a stiff body.

By contrast, at low strain rate, chain segments can be mobilized and make the product more compliant [18]. Another manipulative factor is pre-stretching which is proved to have a decisive effect on the chains' initial force level [26]. However, generally in practice, pre-stretching does not occur because of the large inter-bracket distance and the potential risk of chain rapture. Fattahi et al. [27] in their study on the effect of pre-stretching on force degradation of the synthetic elastomeric chains, concluded that the pre-stretching (200%) group underwent less force degradation than the control group.

According to them, "synthetic elastomeric chains from several companies have different

effects from different distances of pre-stretching, so the appropriate pre-stretching length must be defined for each kind of synthetic elastomeric chain." Comparing the products of different brands, we can say that M3's mechanical properties were more similar to the conventional type rather than the M1 (memory American Orthodontics) and M2 (memory GAC). This means that the two aforementioned brands offer more acceptable properties than Ortho Technology ones. The variations in different EC mechanical properties can be attributed to the manufacturing process. Although ECs overall share similar fabrication methods, there are several processing variations such as cutting or injection molding of the raw material or various additives that applied such as fillers or pigments. Besides, different morphologic (ellipsoid or circular) or dimensional characteristics are supposed to modify the product characteristic [28,29].

Taloumis et al. illustrated the correlation between the inside and outside diameter as well as the thickness of the elastomeric chains with the delivered force [5].

The environmental condition can also affect the behavior of elastomeric products. In this experiment, all specimens were kept in distilled water at 37°C. The exact effect of solutions is not obvious. In a study conducted by Natrass *et al.* [16] acidic solution with a PH as low as 2.01 demonstrated the greatest force loss among different experimental environments. More recent studies showed no significant difference among the force exerted in different treatment immersions [30]. The effect of temperature is also important. As the temperature rises, stress relaxation becomes more pronounced.

This can be attributed to a move that occurs toward the viscous fluid end of the viscoelastic spectrum [18]. One of the limitations of *in vitro* studies such as this one, is that the fluctuations in intra oral temperature on the consumption of different foods and beverages is impossible to stimulate. However, the exact behavior of ECs to temperature change is complex because of the different processes such as thermoelastic inversion.

This means that in an under strain EC when the L/L_0 ratio (L =length) is less than 1/1, as the temperature is raised, the stress decreases; while at a larger L/L_0 , the stress increases with the increase in temperature [18].

Considering the follow-up results, it appears that the greater the initial force delivered by an elastic type, the higher the force degradation rate. This finding was consistent with Nightingale's findings [31]. Many investigations have reported high early force losses in elastomeric chains. Santos et al. believed that a high percentage of force decay was presented during the first 24 hours followed by a progressive force loss [3]. Comparing NiTi coil springs with elastomeric chains, they concluded that NiTi springs generated lower initial force values than those generated by elastomeric chains and presented a gentle and progressive force decay over time. In the present study, we came to a similar conclusion about memory type chains. As can be seen in the force-degradation diagrams, the memory type products do not show a marked force loss (Fig 2).

About required elongation for delivering 200 gr force, it was observed that memory types needed to be stretched more than conventional ECs to exert the same force.

Table 7. Mean (SD) of Percentage of Elongation Required to Deliver 200 g Force in Different Time Intervals

	0hrs	1hrs	8hrs	24hrs	72hrs	1weeks	2weeks	4weeks
C1	23.3(1.7)	45.8(1.7)	47.8(1.6)	45.0(1.0)	39.9(4.5)	37.4(2.1)	39.9(5.2)	30.2(0.8)
C2	27.6(3.8)	43.8(3.5)	42.6(2.8)	44.0(3.0)	39.5(5.3)	34.4(2.0)	41.8(3.0)	33.9(3.3)
C3	23.9(4.5)	33.7(4.4)	38.1(1.5)	30.7(4.0)	29.5(3.0)	29.1(2.4)	33.0(5.8)	25.1(1.1)
M1	31.3(0.5)	58.0(3.8)	61.0(3.6)	59.7(0.8)	58.4(2.1)	61.9(5.3)	57.9(3.4)	37.2(1.8)
M2	38.1(3.6)	52.5(3.7)	56.9(5.6)	58.8(3.9)	56.1(1.6)	56.2(6.0)	54.4(4.6)	38.4(4.0)
M3	23.6(3.7)	37.1(2.5)	48.3(6.1)	46.5(1.7)	45.4(0.9)	46.9(1.3)	35.1(3.1)	27.9(0.9)

CONCLUSION

1. Mechanical properties, behavior and force decay characteristics of different brands of elastomeric chains differ significantly. This should be taken into consideration in clinical practice.
2. Compared to conventional ECs, elastomers with memory properties, delivered a lower level of force at an initial 100% elongation; however, their rate of force decay over 4 weeks was slower.
3. Force-loss pattern of conventional and memory type ECs differed significantly, although they follow a similar pattern within each group.
4. Memory type ECs should be elongated to higher degrees to deliver 200 gr force in comparison to conventional types.
5. Overall, ECs with memory properties yield more favorable clinical behaviors and should be applied more widely in orthodontic practice.

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