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Research Article

In-vitro Evaluation of Force Decay in Thermoplastic and Thermoset Elastomeric Chains of the Same Brand

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Abstract

Objectives: To evaluate and compare the force decay of short-link transparent thermoplastic and thermoset elastomeric chains from American Orthodontics.

Materials and Methods: Thirty-three-link chain segments (with one link at each end for easy handling) were assigned to two groups: 15 thermoplastic chains and 15 thermoset chains. Initial force values were measured using an MTS Universal Testing Machine. Each group was then stretched to 20 mm (double its original length) and immersed in containers with artificial saliva at 37°C. The chains were removed at 24 hours, 7, 14 and 21 days to measure force decay and analyze statistical results.

Results: Thermoplastic chains exhibited a 9.46% greater force decay than thermoset chains at the end of the 21-day study. The greatest force loss in both groups occurred within the first 24 hours.

Conclusion: Thermoset elastomeric chains maintain more stable and consistent force values compared to thermoplastic chains, indicating their greater effectiveness in orthodontic treatments. A clear distinction should be made between these two types of chains, as each performs differently in terms of force decay.

Keywords: Elastomeric Chains; Force Decay; Thermoplastic; Thermoset; Orthodontic Chains

Introduction

Elastomeric chains are among the most commonly used materials in daily orthodontic practice due to their multiple advantages: they are cost-effective, require minimal or no patient cooperation, are practical and easy to use. However, it is well known that these chains are affected by the oral environment, as they are exposed to pH changes, mastication, fluid absorption, etc., leading to structural changes over time and resulting in a loss of force. Early studies on the physical properties and characteristics of orthodontic elastomers found that after the first 24 hours, they lose approximately 50 to 75% of their initial force, with a slower and more stable degradation rate thereafter [1-3]. Various investigations have compared chains stored in different media (air, water, artificial saliva and *in-vivo*), concluding that chains exhibit greater force decay in humid environments than in air. No significant differences were found between those stored in water and artificial saliva, but greater degradation was observed in *in-vivo* evaluations [4-9]. Other studies analyzed different configurations of elastomeric chain links, both closed and open (short/long chains), obtaining varied results. Josell, et al., Halimi, et al., Kassir, et al., concluded that closed chains exhibit less force decay compared to open chains [9-11]. Conversely, Eliades et al., found that long chains (short/long) showed greater residual elongation than continuous chains (closed chains), presumably due to the extensive interlink length [12]. However, these differences vary by brand, depending on interlink length and module shape. Closed chains possess more force but lose it more rapidly than open chains after 100% elongation, consistent with the findings of De Genova, et al., [3]. Regarding pigmentation, Williams, et al., Lu, et al., Antony, et., observed that force decay was less in transparent chains than in gray ones [1-3]. They also found that unpigmented chains not only release greater initial force but also exhibit less force degradation compared to pigmented chains.

Huget, et al., demonstrated that chains stretched to 50% of their length lose less force than those stretched to 100% or 200%. Yagura, et al., stretched chains from 10% to 100% of their initial length and found that permanent deformation was proportional to the increase in chain elongation, with the greatest percentage occurring in the first week. Companies introduced new orthodontic elastomeric chains made from thermoset elastomers with improved properties, supposedly providing greater efficacy during mechanics.

However, at that time, the dental community was not well aware of these differences and distinctions between chain types based on materials were not made, largely because companies kept their manufacturing processes and exact material compositions secret, leading to significant bias in studies where new material chains showed higher force retention values. Chains are generally composed of polyurethane, a synthetic elastomer, which can be thermoplastic or thermoset. Thermoplastic (TP) chains are conventional chains with weak Van der Waals bonds between their polymers, while Thermoset (TS) chains are newer and have strong covalent chemical bonds tightly bound together. In studies by Killiany, et al., Lu, et al., RMO elastomeric chains showed less force degradation compared to those from other manufacturers [1,2]. These chains retained up to 60% of their initial force over four weeks. It was not until Renick, et al., demonstrated that the average Tg values for RMO chains were approximately 17°C to 25°C higher than those of other brands, indicating a significant difference in the structure or composition of the polyurethane polymer marketed by RMO, thus showing a significant improvement in the manufacturing process and material development. The first distinction between chain types based on materials was made by Masoud, et al., when comparing thermoplastic and thermoset elastomeric chains from two brands [6]. Thermoplastic chains showed 20% more force loss compared to thermoset chains from the same company. On average, thermoset chains degraded 61% of their initial force, while thermoplastics degraded 41% over four weeks. Similarly, numerous authors found that thermoset chains decay less than thermoplastic ones, concluding that TS chains have superior mechanical properties compared to traditional TP chains [13-21]. Therefore, considering all the aforementioned about elastomeric chains, the purpose of this study was to evaluate and compare the force decay of thermoplastic and thermoset chains from the same brand.

Materials and Methods

Short, transparent elastomeric chains of two types, thermoplastic (Plastic Chain, American Orthodontics, Sheboygan, USA) and thermoset (Memory Chain, American Orthodontics, Sheboygan, USA), were selected for the study. Transparent chains were used to eliminate possible effects of pigments on the materials. The study was conducted under conditions similar to those present in the oral cavity. A total of 30 specimens, each with three links (plus one at each end for handling), 10 mm in length, were used. These were divided into two groups of 15 specimens assigned to each chain type: Thermoplastic (TP) or Thermoset (TS). Initial force was measured with a Universal Testing Machine (MTS Alliance RT/30) by stretching each specimen to double its length (20 mm) for 5 seconds at a speed of 5 mm/min. After measuring the force, each specimen was placed in acrylic plates according to its group and stretched to double its length with a 20 mm pin-to-pin distance (wire to wire). The plates were placed in plastic containers fully submerged in artificial saliva and maintained in an incubator (Shel-Lab 1510E) at a constant temperature of 37°C throughout the experiment. Specimens were removed from their *in-vitro* conditions only to perform force measurements at each scheduled period: 24 hours, 7, 14 and 21 days. Results were recorded for subsequent evaluation and statistical comparison.

Results

Table 1 presents the descriptive statistical results regarding the force decay in Thermoset (TS) and Thermoplastic (TP) elastomeric chains at different evaluation periods. To compare force decay between both groups, an initial measurement was taken and data were recorded in grams-force (gf). The thermoplastic chain group initially exhibited higher force values (495.41 ± 21.23) Significant statistical changes (p-value < 0.0001) in force decay were observed from the first 24 hours, especially in the thermoplastic chain group, which lost 55.36% of its initial force, while the thermoset chains lost 27.1% (Fig. 2).

gf	Valores		Inicial	24 Horas	7 Días	14 Días	21 Días	Valor p
Cadenas Termoplásticas	Media		495.41	221.19	335.97	121.11	203.25	0.0001
	I.C. al 95% p/media	Lím. inf	483.65	209.32	316.49	97.47	186.53	
		Lím. sup.	507.16	233.06	355.46	144.75	219.96	
	Mediana		489.64	219.18	335.18	117.92	207.65	
	Desviación Estándar		21.23	21.44	35.19	42.69	30.19	
	Mínimo		470.41	180.09	276.86	51.91	142.28	
	Máximo		528.73	257.00	397.35	187.78	252.51	
Cadenas Termoestables	Media		398.80	290.75	306.66	201.30	201.32	0.0001
	I.C. al 95% p/media	Lím. Inf	385.37	274.45	296.35	189.58	188.45	
		Lím. sup.	412.24	307.05	316.98	213.03	214.20	
	Mediana		402.48	292.24	298.65	205.08	205.73	
	Desviación Estándar		24.26	29.44	18.63	21.18	23.25	
	Mínimo		351.21	242.26	281.99	173.04	143.56	
	Máximo		437.09	343.52	335.83	241.29	239.05	

Table 1: Significant changes in force decay.

The thermoset group showed similar initial values to those obtained at 7 days, but at 14 days, significant changes in force decay were observed (Table 1) (Fig. 1). Both groups exhibited similar distributions throughout the study, but the forces produced by thermoset chains were more stable and continuous.

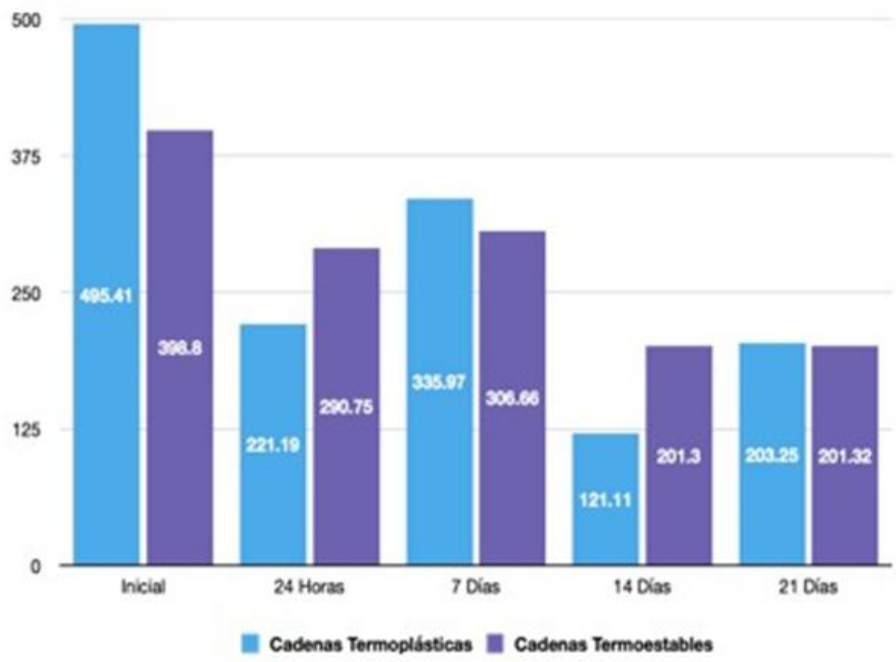

Figure 1: Significant changes in force decay.

At 21 days (equivalent to the average orthodontic treatment period), there was a decrease in force in both groups, with thermoplastic chains decaying 58.98% of their initial force and thermoset chains 49.52%, with thermoset chains showing 9.46% less force decay than thermoplastic chains (Fig. 2).

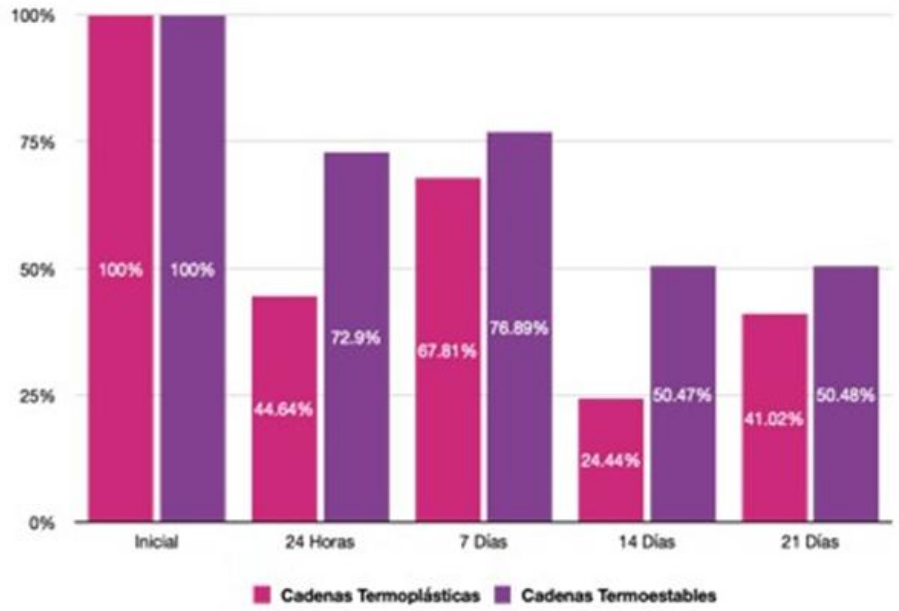

Figure 2: Observed the thermoset chains lost.

Discussion

Elastomeric chains are the most commonly used materials in orthodontic treatments, especially for dental movement mechanics. However, this material can experience significant loss of force during the activation period, which constitutes a major clinical concern, as they are affected by numerous factors, both intrinsic and extrinsic, such as exposure to beverages, foods, pH changes, fluctuating temperatures, patient hygiene, material composition, chain size and shape, etc. Due to this, commercial companies have developed new-generation chains that claim to retain a significant portion of their force over a longer period.

Therefore, the aim of our study was to evaluate and compare the results of both Thermoplastic (TP) and Thermoset (TS) elastomeric chains.

We used chains from a single brand to counteract the results of variables from different manufacturing methods of companies [22]. In this case, the brand American Orthodontics TP (Plastic Chain) and TS (Memory Chain), with short links and transparent color, as according to the findings, these present less force decay due to the lack of pigments in their structure [21-24].

The chains were stretched and maintained at 100% of their length from 10 mm to 20 mm on acrylic plates and, attempting to simulate the oral environment, were stored in plastic containers with artificial saliva in an incubator at 37°C throughout the study.

Artificial saliva was chosen as the storage medium because various studies suggest that greater force decay occurs in elastomeric chains in wet environments than in air, but this decay is not greater than those stored *in-vivo*. Since there is no universally accepted formula for artificial saliva Ferrrabone, we used the one from the commercial brand Viarden Lab.

In our results, thermoplastic chains obtained higher initial force values, coinciding with the results of Mirhashemi, et al., where thermoset chains had lower initial force values than thermoplastic ones, even though they required greater elongation to reach the desired length.

Furthermore, we found that the greatest force degradation occurs in the first 24 hours in both types of chains, agreeing with the results obtained from and differing from those where they found that the greatest force degradation occurs at 7 days [14-17].

At the end of our study, thermoset chains showed significantly lower force decay values than thermoplastic ones, in a more constant manner, thus agreeing with various authors [18-25].

Conclusion

In the present study, thermoplastic chains suffered a 58.98% degradation of their initial force and thermoset chains 49.52%, marking a difference between the degradation of TP and TS of 9.46%, compared to Masoud, et al., which was 20% (TP lost 61% of its force and TS 41%). This could be due to several factors, such as: the configuration of the chains used, as they used closed-link chains compared to our use of short-link chains and according to the literature closed chains present a lower reduction in their force decay compared to open chains (short/long); another factor could be the different conditions in the locations where the experiments were conducted, as our geographic area has a high humidity influx, which could affect the specimens during their prior storage; as well as possible expiration dates; since they used two types of commercial brands and their results were general between both; and since in their study, they used two types of controlled forces, a light (200 g) and a heavy (350 g) for both types of chains, we did not control the force as we stretched them to 100% of their length, obtaining an average of 495.41 gf for TP and 398.80 gf for TS, which would coincide with the results found, where the greater the initial force given by the chains, the greater its decay.

Both types of chains performed differently regarding their force decay, so a distinction between them should be made, emphasizing and considering that our study was *in-vitro*; *in-vivo*, the force loss could be greater as the chains are exposed to varied conditions such as fluctuating temperatures and other factors like pH changes, foods, toothpaste, chewing, etc. Chains cannot generate constant forces over a long period since their elastic

Conflict of Interest

The authors declare no conflict of interest.

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None.

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