Original Article

Assessment of force decay in orthodontic elastomeric chains: An *in vitro* study

Claudia Kochenborger*, Dayanne Lopes da Silva**, Ernani Menezes Marchioro***, Diogo Antunes Vargas****, Luciane Hahn*****

Abstract

Introduction: Elastomeric materials are considered important sources of orthodontic forces. **Objective:** To assess force degradation over time of four commercially available orthodontic elastomeric chains (Morelli, Ormco, TP and Unitek). **Methods:** The synthetic elastics were submerged in 37 °C synthetic saliva and stretched by a force of 150 g (15 mm – Morelli and TP; 16mm – Unitek and Ormco). With a dynamometer, the delivered force was evaluated at different intervals: 30 minutes, 7 days, 14 days and 21 days. The results were subjected to ANOVA and Tukey's test. **Results:** There was a force decay between 19% to 26.67% after 30 minutes, and 36.67% to 57% after 21 days of activation. **Conclusions:** TP elastomeric chains exhibited the smallest percentage of force decay, with greater stability at all time intervals tested. Meanwhile, the Unitek chains displayed the highest percentage of force degradation, and no statically significant difference was found in force decay between Ormco and Morelli elastomeric chains during the study period.

Keywords: Elastics. Synthetic elastics. Elastomeric chain.

How to cite this article: Kochenborger C, Silva DL, Marchioro EM, Vargas DA, Hahn L. Assessment of force decay in orthodontic elastomeric chains: An in vitro study. Dental Press J Orthod. 2011 Nov-Dec;16(6):93-9.

» The authors report no commercial, proprietary, or financial interest in the products or companies described in this article.

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INTRODUCTION AND LITERATURE REVIEW

Orthodontic biomechanics makes use of force systems that aim to promote tooth movement. Self-ligating appliances[7] have been designed to eliminate the use of elastomeric modules during treatment. However, elastomeric materials are considered important sources of forces used to move teeth with conventional brackets.

The term "elastomer" refers to any member of a class of polymeric materials with the ability to regain shape after deformation.[5,12]

The first common elastomer was natural rubber, probably used by the Maya and Inca civilizations.[5] However, its use was limited due to its physical properties, such as water absorption and thermal instability. With the advent of vulcanization, introduced by Charles Goodyear in 1839, the physical properties of rubbers were improved, considerably enhancing its use.[5]

In 1920, petrochemical industries began to manufacture synthetic rubber bands, which were adopted by orthodontists in the 60's. The internal composition of these materials is determined by the level of technology and quality of raw materials used in their manufacture.[17] The most widely used elastomer in orthodontics are elastomeric chains and ligatures. The main clinical applications are: Tying orthodontic archwires to brackets, replacing steel ligatures, closing extraction spaces, retracting canines, orthodontic traction of impacted teeth, correcting torsiversion and midline deviation. They are practical, efficient and are available in a variety of colors. With convenient placement, they are also comfortable to the patient.[5,12,14]

However, studies[4,9,10,16,19] have shown some disadvantages of elastomeric materials. They are sensitive to prolonged exposure to water, and intraoral conditions deteriorate due to the presence of enzymes and temperature variations,[8] which may influence the clinical performance of these materials. Furthermore, the pigments used in the manufacturing process of colored elastomeric ligatures can also interfere on force degradation.[13]

If elastics are kept continuously stretched under certain environmental factors, there may be a change in their behavior. Previous studies have reported increased force degradation over time when elastics are tested in a moist environment, compared with tests performed in a dry condition.[4,9,10,11,15,16] Rising temperatures have been considered an aggravating factor to reduce the forces generated by elastomeric modules.[11,16] Therefore, studies were performed in 37 °C water to simulate oral conditions.[6,8,9,18]

When elastomeric chains are activated around the brackets, they undergo changes in their physical properties and do not release constant force levels over a long period of time.[3,4,5,7,10]

In 1991, a study[2] evaluated four different brands of elastomeric chains: Tecnident, Unitek, Ormco and Dentaurum. Three-unit modules were stretched to twice their original size to yield an initial force of 200 g. The samples were submerged in a 10% Ringer's solution at an average temperature of 37 °C. Forces were measured over a period of 30 days. The results showed a force decay of 35% at the end of the first day and approximately 75% at the end of the experiment. No significant differences were found between the materials.

In 2008, an *in vivo* study[1] was conducted to determine the amount of force delivered by intermaxillary elastics and elastomeric chains from two different brands (Morelli and GAC). According to the results, the intermaxillary elastics manufactured by Morelli released an initial force of 175 g, which was greater than GAC (110 g). Meanwhile, the Morelli elastomeric chains had an initial force of 200 g, which was lesser than the GAC (220 g). The study suggested that intermaxillary elastics should be replaced on a daily basis to improve mechanical efficiency, and elastomeric chains should be replaced once a month. Although there is a significant force degradation after 15 days, the dissipating nature of orthodontic forces is considered ideal when using fixed orthodontic appliances.

Knowledge about the mechanical properties changes that occur in stretched elastomeric chains is important, as they often remain in the oral cavity for a relatively long time. Therefore, it would be highly desirable that these chains maintain appropriate forces throughout this time period.

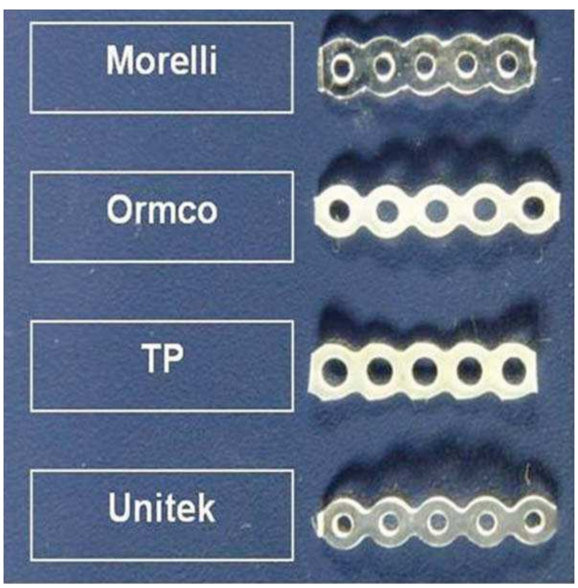

FIGURE 1 - Elastomeric chain samples.

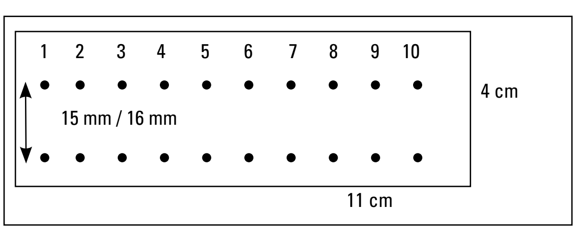

FIGURE 2 - Drawing illustrating acrylic resin plates with a 15 mm distance between the steel pins for the Morelli and TP brands, and a 16 mm for Unitek and Ormco.

The aim of this *in vitro* study was to assess the amount of force decay of commercially available orthodontic elastomeric chains that were immersed in artificial saliva at 37 °C, based on the forces delivered and stretching time.

MATERIAL AND METHODS

The study sample consisted of crystal colored short link orthodontic elastomeric chains of the brands Morelli (Sorocaba, Brazil), Ormco (Glendora, USA), TP (La Porte, Ind, USA) and 3M/Unitek (Monrovia, USA). Sealed packages of orthodontic elastomeric chains were purchased with a valid expiration date. Ten randomly selected samples, containing five-unit modules, of each brand were analyzed and stretched with a tension of 150 g.

A transparent acrylic plate (Acricenter, Porto Alegre, Brazil) of 1 cm thickness, 11 cm length and 4 cm width was fabricated with ten aligned holes (10 mm apart) that were then drilled 5 mm deep with a low speed 151 XL carbide bur (Fava, São Paulo, Brazil). Stainless steel orthodontic wires (0.9 mm - 55.01.090 Morelli, Sorocaba, Brazil) were inserted into the holes and fixed with transparent acrylic resin (Jet, Campo Limpo Paulista, Brazil). Their ends were cut off creating pins, 10 mm high.

Furthermore, ten pieces of five-unit modules of elastomeric chain were adapted to each of the 10 pins and were stretched to produce a force of 150 g, as measured by a Zeuzan 300 g dynamometer (São Paulo, Brazil PN: 800 ref. 9031.80.11). The distance in millimeters was also recorded. This procedure was repeated after 30 days for each brand. Quantifying test-retest reliability used the intraclass correlation coefficient (0.954). Each brand yielded ten specific measurements.

Each brand had its own plate as in the pilot study. The steel pins were set 15 mm apart for the Morelli and TP brands, while the Unitek and Ormco brands had a 16 mm distance between them, which corresponds to a stretching force of 150 g.

The names of the manufacturers were engraved on the sides of the plates and the samples were numbered from one to ten. The force magnitude was calibrated by a dynamometer (Zeuzan 300 g) to exert an initial force of 150 g (Fig 3).

All plates were kept immersed in artificial saliva (sodium chloride at 0.067%, natrosol 0.5%, sodium benzoate 0.05%, sorbitol 2.4%, deionized water qsp 100% neutral pH) at 37 °C, inside the incubator model 002 CB (Fanem, São Paulo, Brazil) (Fig 4).

The elastomeric chains were checked at intervals of 30 minutes, 7 days, 14 days and 21 days by the same investigator to ensure consistent handling of the dynamometer. The data were recorded and subjected to repeated measures analysis of variance (ANOVA), followed by Tukey's multiple comparisons test. A 5% confidence interval was adopted ($p \leq 0.05$). For data analysis, the Statistical Package for Social Science (SPSS) version 17.0 for Windows was employed.

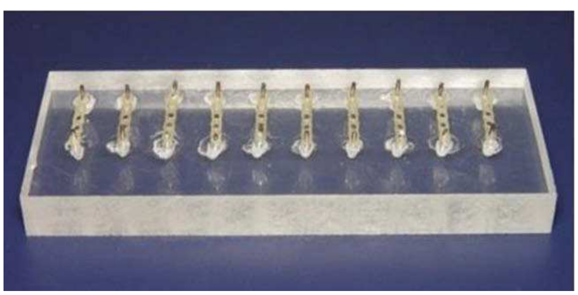

FIGURE 3 - Acrylic resin plate.

FIGURE 4 - Acrylic resin plate immersed in artificial saliva.

RESULTS

Initially, a descriptive analysis of the results was performed to evaluate force decay percentage, mean and standard deviation of each brand delivered force (Table 1).

The TP brand displayed the highest stretching force after 30 minutes (121.5 g), followed by Ormco (114 g), Morelli (112 g) and Unitek (110 g). After 21 days, the TP brand continued to deliver the greatest amount of force (95 g), followed by Morelli (74.5 g), Ormco (72 g) and finally Unitek (64.5 g).

The Unitek product exhibited a higher percentage of force degradation at almost all times, i.e.: 30 minutes= 26.67%; 7 days= 37%; 14 days= 51.67%; 21 days= 57%. The TP product displayed the lowest percentage of force decay: 30 minutes= 19%; 7 days= 29%; 14 days= 31.33%; 21 days= 36.67% (Table 2).

There was a significant difference between the stretching forces generated by the elastics at all time periods ($p<0.05$). The Tukey's HSD test showed that TP elastics delivered the highest delivering force. Ormco and Morelli elastics produced a similar force behavior. At the first two time-periods, the Unitek elastomeric chains delivered an amount of force that was similar to the Morelli and Ormco elastics. However, after 14 and 21 days, it demonstrated a greater force degradation than these two brands (Fig 5 and Table 3).

DISCUSSION

The use of elastomeric chains has been helpful in ensuring successful orthodontic treatment. This study showed that the samples of four brands (Morelli, Ormco, TP and Unitek) showed a force decay delivered during the first 30 minutes of stretching. Thereafter, forces were gradually delivered in a less intense and more stable manner.

The Unitek brand displayed the highest force degradation in almost all time-periods, while

TABLE 1 - Means and standard deviations of stretching forces according to elastomeric chain brands and stretching time.

Elastomeric chains brands	30 min	7 days	14 days	21 days
TP	121.5 ± 6.26	106.5 ± 6.34	103 ± 4.83	95 ± 5.48
Morelli	112 ± 6.32	94 ± 4.9	77.5 ± 6.77	74.5 ± 3.5
Ormco	114 ± 6.58	89.5 ± 9.6	80.5 ± 5.5	72 ± 2.45
Unitek	110 ± 4.08	94.5 ± 4.15	72.5 ± 7.55	64.5 ± 3.5

TABLE 2 - Percentage of force degradation regarding stretching time.

Elastomeric chains brands	30 min	7 days	14 days	21 days
Morelli	25.33%	37.33%	48.33%	50.33%
Ormco	24.00%	40.33%	46.33%	52.00%
TP	19.00%	29.00%	31.33%	36.67%
Unitek	26.67%	37.00%	51.67%	57.00%

TABLE 3 - Analysis of Variance and Tukey's test for intra- and inter-brand comparison of forces delivered at four different time periods.

Elastomeric chains brands	Initial		30 min		7 days		14 days		21 days	
	Diff. Intra. *	Diff. Inter. **	Diff. Intra.*	Diff. Inter. **	Diff. Intra.*	Diff. Inter. **	Diff. Intra.*	Diff. Inter. **	Diff. Intra.*	Diff. Inter. **
Morelli	a	A	b	A	c	A	d	AB	d	A
Ormco	a	A	b	A	c	A	d	B	e	A
TP	a	A	b	B	c	B	c	C	d	B
Unitek	a	A	b	A	c	A	d	A	e	C

*Comparison between different time-periods within the same row. **Comparison of different brands at the same time period within the same column. Same letters denote no significant difference between groups.

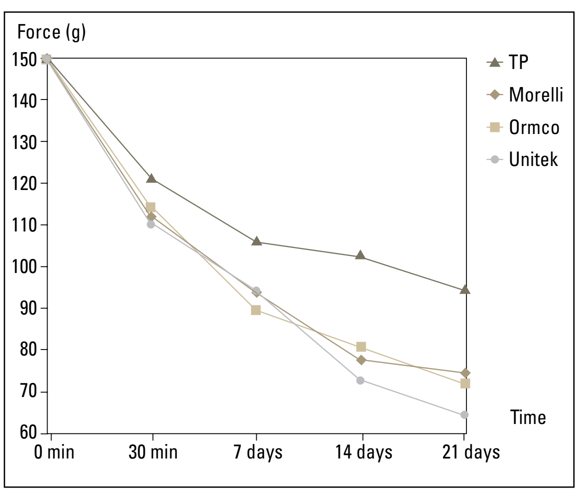

FIGURE 5 - Analysis of mean stress versus time.

the TP brand showed not only a lower percentage but also the highest stretching force when all groups were compared in all time-periods.

It is therefore essential that professionals need to learn about the features of synthetic elastics to better plan the force system to be employed and how to quantify the load. Thus, orthodontic treatment will likely be successful while preserving patients' health and comfort.

Some studies[3,5,6,8,10,13,17] have evaluated force degradation in synthetic elastics during stretching time and observed that the greatest force decay occurred in the first hour of testing, which is in agreement with the results of this study. The results also demonstrated a greater reduction in the first 30 minutes of experiment for all tested brands.

This study, however, differed from others because a pilot study was conducted to evaluate which stretching distance would yield a force of 150 g in all studied brands. The idea was to eliminate potential differences between the brands, such as:

» Cross-sectional configuration of the elastomeric chain modules.
» Distance between the links of elastomeric chain.
» Quality of the raw materials used for manufacturing chains.
» Thickness of the links of the elastomeric chains.

Thus, all brands had an initial delivered force of 150 g, unlike other studies[6,14] that used a stretching distance of 20 mm, which led to different initial forces for all studied brands.

Other studies[15,16] have found differences in the elastic ligatures properties. Therefore, if a strict quality control is not enforced during manufacture of elastomeric chains, test results may be different.

The samples were kept immersed in artificial saliva at 37 °C to simulate oral conditions. Studies[4,6,8] have shown that the force degradation experienced by synthetic elastic materials is significantly higher when tested in moist conditions than when assessed in dry conditions. Exposure of elastomers to water or saliva weakens intermolecular forces due to water absorption and, consequently, impairs the formation of hydrogen bonds between water molecules and the macromolecules of the polymer.[2,14] Rising temperatures were also considered an aggravating factor in force degradation[8,12] because the elastomeric chains lose their ability to recover their original properties after delivering the stretching forces (strain). In addition, the force decay generated by the phenomenon of relaxation tends to occur over time.

The time intervals were determined based on the activation protocols set between visits, using conventional brackets and considering the physiology of tooth movement. In addition, studies[5,8,19] have demonstrated that elastomeric chains cannot produce constant levels of force over a long period of time. Clinically, in cases where space closure is performed with elastics, the interval between activations is often set at 15 and 21 days.

CONCLUSIONS

This study revealed that the greatest stability was observed in TP elastomeric chains, as they showed a reduced loss of elastic potential in all time-periods. The 3M Unitek elastics showed the highest force decay in most time-periods under study, whereas there was no significant difference between Ormco and Morelli brands.

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Submitted: February 2, 2010
Revised and accepted: August 15, 2011

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