

Force degradation in orthodontic elastic chains

Degradação de forças em correntes elásticas ortodônticas

Abstract

Purpose: This *in vitro* study aimed to analyze the force degradation of four commercial brands of orthodontic elastics chain (Morelli, Ormco, TP, and Unitek) over 21 days.

Methods: The elastics chains were stretched and maintained at a standardized distance equivalent to a force of 150 g. The amount of force generated by the elastics chains were measured by using a dynamometer (ZEUZAN 300 g) at intervals of 30 minutes, 7, 14, and 21 days. Data were analyzed by ANOVA and Tukey's test at the 5% level of significance.

Results: There was a reduction of 5% to 15% in the amount of force generated by the elastic chains after 30 minutes and of 22% to 47% after 21 days of elastic activation.

Conclusion: Unitek chains displayed the highest percentage of force degradation, while TP exhibited the smallest percentage of force degradation and showed the greatest stability at all intervals tested.

Key words: Elastic; elastomer; orthodontic chain

Resumo

Objetivo: Este estudo teve por objetivo analisar a degradação da força gerada por quatro marcas comerciais de elásticos ortodônticos em cadeia (Morelli, Ormco, TP e Unitek) em função do tempo.

Metodologia: Os elásticos foram mantidos continuamente estirados a uma distância equivalente à força de 150 g. A leitura da quantidade de força gerada pelas correntes elásticas foi mensurada utilizando-se um dinamômetro da marca ZEUZAN 300 g, nos intervalos: 30 minutos, 7, 14, 21 dias. Os resultados foram analisados por ANOVA e teste de Tukey ao nível de significância de 0,05.

Resultados: Verificou-se uma redução na quantidade de força gerada pelos elásticos de 5% a 15% em 30 minutos de teste e de 22% a 47% em 21 dias de estiramento constante.

Conclusão: A marca Unitek obteve um maior percentual de degradação de força, enquanto a marca TP um menor percentual de degradação de força mostrando comportamento mais estável em todos os intervalos de tempo testados.

Palavras-chave: Elásticos; elastômeros; elásticos ortodônticos

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Introduction

Corrective orthodontic treatment consists of the transmission of mechanical forces to teeth in order to adjust them to appropriate positions. Handles, springs, and elastic materials including chains and ligatures are important sources of strength in orthodontic movement.

Synthetic elastics are produced from polyurethane materials derived from oil (1). The polyurethane elastomers most used in Orthodontics are elastics chain and elastic ligatures. Chemically, elastomers are polymers, and the Greek origin of the word explains their structure, “poly” meaning “many” and “mere” designating “parts”. Thus, polymers are substances composed of several molecules that repeat to form a chain composed of fundamental units, which are called monomers (2). Polymers are composed of links with primary and secondary low molecular attraction. Initially, the polymer displays a spiral pattern, when it is deformed due to the application of a force, the polymer chains assume a linear structure with cross links at some points along their axes. The modification of the spiral standard to linear occurs due to weak secondary connections, while the recovery of a polymer’s initial structure is due to the existence of crosslinks. Permanent deformation occurs only when the polymer is stretched beyond its elastic limit, causing breakage of crosslinks.

An ideal elastomer is one that returns to its exact original configuration after it has been distended beyond its elastic limit. Such a situation seldom applies in reality because some polymer chains, when distended, slide irreversibly on each other, resulting in a new spatial arrangement (3). Synthetic elastic materials cannot be considered ideal elastics, because they are sensitive to prolonged exposure to water, enzymes, and temperature variations (4). However, they do possess some advantages, including the properties of elastic memory and biocompatibility, comfort for the patient, easy cleaning, and availability in many colors, contributing to the patients’ motivation with the orthodontic treatment. On the other hand, synthetic elastics have serious

disadvantages in that they fail to exert constant levels of force over long periods of time and that they undergo time-dependent changes in their physical properties (5-12).

Several studies with elastics chain showed that these materials cannot produce constant levels of force for a long period of time and that the greatest decrease in their strength occurs in the early hours. After this period, the loss is more gradual (4,5,12,13). Similar decreases in production of force by elastic ligatures were reported (14). A number of studies (4,6,8,10,15-22) have evaluated degradation of the force exerted by synthetic elastics as a function of the drawing time to which they were subjected. In these studies, the greatest reduction in load generated by the elastic, on average 30%, occurred during the first hour of testing. Consequently, the application of greater initial force than desired for a given orthodontic movement is often recommended in order to remedy such force reduction during the continuous use of elastic (6).

Considering these findings, knowledge of the changes that occur in the mechanical properties of elastics chain when drawn is of great interest with respect to the use of such materials in Orthodontics. As elastics may remain in a patient’s mouth for relatively long periods of time, it is highly desirable that during these intervals, they continue to exert a clinically adequate force. Thus, the objective of this study was to evaluate the force degradation in four trademarked brands of synthetic elastics chain as a function of the strength and duration of stretching to which they were subjected.

Methodology

This study used orthodontic elastic chain, short type, color crystal of the following brands: Morelli (Sorocaba, SP, Brazil), Ormco (Glendora, CA-USA), TP (La Porte, CA, USA), and 3M Unitek (Monrovia, CA, USA). Ten specimens of each brand, chosen randomly, were examined. Each specimen contained five links and was stretched to a force of 150 g (Fig. 1).



Fig. 1. Tested synthetic elastic chains and the experimental set-up.

A pilot study was conducted to quantify the distance equivalent to an elastic stretching force of 150 g for each sample. For this, a transparent acrylic resin plate 11 cm-long, 4 cm-wide and 1 cm-thick was made (Acricenter, Porto Alegre, RS, Brazil). This plate received ten aligned marks spaced 10 mm apart drilled with a carbide drill 151 XL (Fava, São Paulo, SP, Brazil) at low rotation to a depth of 5 mm. In the holes orthodontic steel wires 0.9 mm in diameter (55.01.090 Morelli, Sorocaba, SP, Brazil) were adjusted and fixed with transparent acrylic resin (Jet, Campo Limpo Paulista, SP-Brazil), resulting in pins with standard height of 10 mm. Elastic chain segments with five links each were then attached to each of the 10 pins and stretched by a force of 150 g measured by a dynamometer ZEUZAN 300 g (São Paulo, SP, Brazil. PN: 800 ref. 9031.80.11); for each segment, the distance in millimeters equivalent to this force amount was recorded. This procedure was performed with each of the four brands, so that ten records of distances, yielding an average value, were obtained for each brand.

As the pilot study, four plates were prepared, one for each elastic brand, with a distance of 15 mm between the steel pins for brands Morelli and TP and 16 mm for brands Unitek and Ormco. Each distance corresponded to an elastic stretching force of 150 g (Fig. 1). The trade name of the rubber manufacturer was recorded on the side of each plate and the samples were numbered from one to ten. Each sample was initially measured and distended by a force of 150 g measured using a ZEUZAN 300 g dynamometer. After the initial reading, the end of the elastic was withdrawn from the dynamometer, it was brought to its pin settlement at a distance equivalent to 150 g of force and kept in a dry place at environmental temperature. At time intervals of 30 minutes, 7, 14 and 21 days, the forces exerted by the elastics on the plates were measured in the dynamometer and the values were recorded.

Data were analyzed by descriptive statistics and ANOVA with repeated measures at the significance level of 5%. Using the Tukey method, multiple comparisons of all brands at all times were also performed in order to identify time points at which statistically significant differences in the magnitudes of generated forces occurred. The program Statistical Package for the Social Sciences (SPSS), version 12.0 for Windows, was used for data analysis.

Results

There were statistically significant differences of force among 30 minutes, 7, 14 and 21 days. Tables 1 and 2 show the descriptive analysis of the results, including degradation percentage, mean and standard deviation of the force exerted by each brand.

Unitek samples exhibited the greatest reduction in the amount of force generated over 21 days of testing (47%), followed by samples of Ormco (33%), Morelli (31%), and TP (22%) (Table 1). Specimens of TP, Unitek, and Morelli

suffered significant reduction in strength over a period of 30 minutes, while Ormco showed the smallest reduction in average force exerted during this time.

Ormco elastic brand exerted the highest mean force after 30 minutes of stretching, followed by elastomeric modules of Unitek, Morelli, and TP. However, TP elastic chains generated the highest average final tension over 21 days, followed by brands Morelli, Ormco, and Unitek (Table 2). TP, Unitek, and Morelli brand elastics had similar average strengths both at the first time measured (30 minutes) and after reaching relatively stable degradation of strength at 7, 14 and 21 days (Fig. 2). Unitek and Ormco elastics showed a large fall in average force generated after 7 days. Over the time interval 7 to 21 days, Ormco and Morelli brands exhibited similar behavior.

Table 1. Percentage of force reduction as a function of the time of elastic stretching in a dry environment.

Brand	30 minutes	7 days	14 days	21 days
Morelli	14%	21%	27%	31%
Ormco	5%	26%	29%	33%
TP	15%	17%	21%	22%
Unitek	13%	39%	44%	47%

Table 2. Force (g) (mean* and standard deviation values) of each elastic brand versus time.

Brands	30 minutes	7 days	14 days	21 days
Morelli	129±9	118±4	110±7	103±6
Ormco	142±5	115±6	107±5	101±4
TP	128±6	124±4	119±9	116±6
Unitek	130±7	92±10	83±5	80±4

* Means differ statistically at a significance level of 0.05 within each brand analyzed at different times.

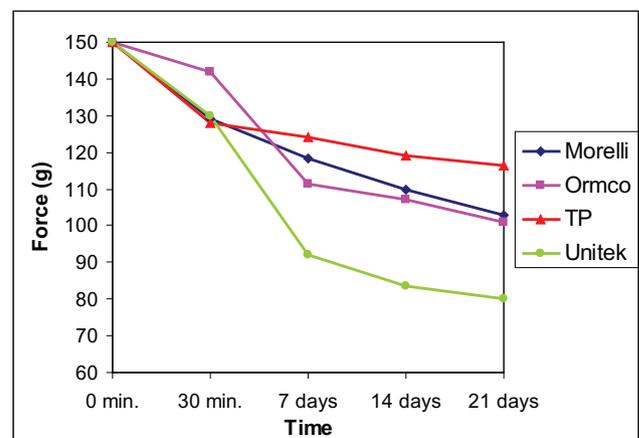


Fig. 2. Changes of force (g) of the elastic chains over 21 days.

Discussion

When extended, the synthetic elastomers used in Orthodontics suffer disruption of their molecular structure, promoting their permanent deformation. In this study, the observed reduction in elastic force over the initial 30 minutes varied from 5% to 15%. This rapid strength loss occurs due to the relaxation effect, resulting in gradual loss of the elastomer's effectiveness. It appears that Unitek brand elastics underwent a higher percentage of force degradation at each of the four time points studied. In contrast, TP brand elastics showed the lowest percentage of force degradation and exhibited the most stable behavior across all time intervals tested.

A number of studies with elastics chain have shown their inability to produce constant levels of force for long periods of time and have indicated that the greatest loss occurs in the early hours. After this period, as seen in the present study, the force exerted is more stable (4,5,9,12). A similar phenomenon occurred with elastic ligatures in the studies of Abraão (14) and Souza (23). Some authors reported a greater reduction in the amount of elastic force generated over the first hour of testing, on average 30%. This higher reduction in force generation in comparison with the present findings may be a consequence of the fact that those studies were performed in artificial saliva. This suggest that synthetic elastics are sensitive to prolonged exposure to water, enzymes, and temperature variations (4), as seen in the study of Araújo et al. (14), in which chain elastics of brands Morelli, Ormco, GAC, TP and Unitek were tested.

The pilot study was conducted to measure the distance in millimeters of each brand tested that is equivalent to a force of 150 g. This procedure was designed to eliminate possible differences between the brands that may result from any or all of the following parameters: setting the cross section of the links in the elastics chain; distance between the links of the

elastics chain; quality of raw materials used in preparation of the material; link thickness of the elastics chain. Thus, the initial strength of all brands tested was standardized at 150 g, differing from methods employed in previous studies (8,15,24) in which a stretching elastic distance of 20 mm was used, resulting in different initial forces for the brands tested. According to Wong (12), differences can be found in the properties of elastics chain, as a result, if rigid quality control during elastic manufacture is lacking, the results of similar tests may be different.

Although this study was performed in a dry environment, under the experimental conditions used, Unitek elastics exhibited the greatest force deterioration, while TP elastics showed better results, with a smaller loss of force and more stability over time. Further laboratory studies should simulate the clinical conditions of the oral cavity to determine the effects of changes in pH, temperature, and pigmentation of the elastics on the physical properties and performance of elastomers used in Orthodontics.

Conclusions

The results suggest that:

- Unitek elastic specimens showed the highest percentage reduction in the amount of force generated after 21 days.
- TP elastic chains showed the highest average final force and exhibited a degradation performance that was more stable than that of other brands studied.
- Ormco and Morelli brands showed similar behavior with respect to forces generated over the time period 7 to 21 days.
- Except for the Ormco brand, all elastics chains underwent significant reduction in the amount of force generated after 30 minutes of activation.

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