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Influence of pH-cycling in de-remineralization environment on the strength degradation of orthodontic elastics

Influência da ciclagem de pH em meio des-remineralizante na degradação de força de elásticos ortodônticos

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ABSTRACT

Objective: Factors related to the elastic composition and oral conditions may influence the strength in its decomposition during orthodontic treatment. This study aimed to evaluate the effect of pH on the force degradation of orthodontic elastics. **Material and Methods**: A total of 180 elastics were analyzed, comprising 90 Morelli elastics (Group A) and 90 American Orthodontics elastics (Group B), each stretched to an initial extension of 15 mm. Samples were divided into six subgroups (n=30) based on the immersion medium: distilled water (control), pH 5.0 solution (acidic), and solutions with pH 4.3 and pH 7.0 (de-remineralizing), which were refreshed daily. The strength evaluation was performed at the hours 0, 24, 48, 72 and 96. The strength was measured by a digital dynamometer to evaluate its degradation. **Results**: Force degradation of the elastics occurred over time in all immersion media, including distilled water. In Group A, after 48 hours, elastics immersed in the acidic pH solution exhibited greater force degradation compared to those in the de-remineralizing solution ($p < 0.05$). In Group B, the degradation was greater in the de-remineralization solution within 48 hours. **Conclusion**: All elastics exhibited progressive force degradation, which varied with pH and material brand. Acidic conditions increased force loss in Morelli elastics, while de-remineralizing conditions had greater impact on American Orthodontics elastics.

KEYWORDS

De-remineralization environment; Elastomers; Hydrogen ion concentration; pH-cycling; Orthodontics.

RESUMO

Objetivo: Fatores relacionados à composição dos elásticos e condições do meio bucal podem influenciar na decomposição de força durante o tratamento ortodôntico. O objetivo desse estudo foi avaliar a influência de pH na decomposição de força de elásticos ortodônticos. **Material e Métodos**: Foram avaliados 90 elásticos Morelli (Grupo A) e 90 elásticos da American Orthodontic (Grupo B), distendidos em 15mm de tensão inicial e subdivididos em seis subgrupos (n=30) de acordo com a solução de imersão: água destilada (controle), solução pH 5.0 (meio ácido) e solução com pH 4.3 e pH 7.0 (des-remineralizante), trocadas diariamente. A avaliação da força foi realizada nos tempos 0, 24, 48, 72 e 96 horas. A força foi mensurada por meio de dinamômetro digital para avaliação da sua degradação. **Resultados**: A degradação de força dos elásticos ocorreu no decorrer do tempo nas duas soluções e na água destilada. No Grupo A a partir de 48 horas a degradação de força foi maior na solução de pH ácido do que em solução des-remineralizante ($p < 0,05$). No Grupo B a degradação foi maior na solução des-remineralizante em 48hs ($p < 0,05$). **Conclusão**: Todos os elásticos apresentaram degradação progressiva da força, que variou de acordo com o pH e a marca do material. Condições ácidas aumentaram a perda de força nos elásticos Morelli, enquanto condições de de-remineralização tiveram maior impacto nos elásticos da American Orthodontics.

PALAVRAS-CHAVE

Meio des-remineralizante; Elastômeros; Concentração de íons de hidrogênio; Ciclagem de pH; Ortodontia.

INTRODUCTION

Orthodontic elastics are active force-delivery components commonly used in clinical practice to correct dental discrepancies by applying continuous forces that promote dentoskeletal modifications [1,2]. The proper selection of elastics, the knowledge about their characteristics, and the strength released at different time intervals during orthodontic mechanics are indispensable data for the planning of therapy [1,3].

As a generally auxiliary method, latex elastics are characterized by high flexibility, relatively long lasting strength, low cost, easy handling, maintenance of oral hygiene and greater ability to return to their original dimensions after deformation when compared to non-latex elastics [4,5].

The elastic properties of these latex materials depend on their molecular composition, formed by twisted arrangements of long molecular chains, linked at certain points by covalent bonds between different atoms [5,6]. When the latex elastic is subjected to a strength beyond its stress limit, the friction between molecular chains and the lack of internal or superficial homogeneity initiates a dynamic process of fatigue of orthodontic elastics, and as a result, there is the occurrence of the strength degradation applied during orthodontic movements [6]. Knowledge of the biomechanics of using intermaxillary elastics is essential to achieve the planned effects [7].

Factors present in the oral cavity, such as variations in pH, temperature, salivary composition, food texture and pigments, associated with the stretching of intermaxillary elastics in this environment, may influence the strength decomposition of elastomers [8,9,10].

The use of orthodontic appliances induces physicochemical changes in the oral environment [11]. During the ingestion of acid drinks, the high concentration of hydrogen ions can affect the strength degradation of latex elastics, even if the pH level is reversed over time [12]. Elastics can reduce 20% of their initial strength when subjected to pH variation within 48 hours [5,12].

Salivary pH changes and strength degradation of orthodontic elastics have been evaluated in previous studies [12,13,14]. However the synergistic impacts of these changes in pH-cycling in a de-remineralization environment have not been evaluated. The null hypothesis of the study is that the pH of the immersion medium does not affect the force degradation of orthodontic elastics, and no difference exists between brands. Therefore, the aim of this study was to evaluate the influence of pH variation on the strength decomposition of orthodontic elastics.

MATERIAL AND METHODS

For this study, two commercially available brands of 3/16” medium-force intermaxillary latex elastics (3/16” M or 4.8 mm) were evaluated: Morelli – Group A (Sorocaba, SP, Brazil) and American Orthodontics – Group B (Washington, USA). Custom-made positioning plates were fabricated using transparent acrylic resin (MMA Acrílicos, Salvador, Bahia), measuring 15.5 cm in length, 7.5 cm in width, and 2 cm in thickness. Each plate contained sixty evenly spaced markings and metal pins, aligned 15 mm apart, to secure the elastics under consistent tension throughout the experiment. The elastics, each with a 4.8 mm diameter, were stretched to three times their original length to achieve the recommended force level, thereby justifying the 15 mm spacing between pins [12]. Specimens were randomly selected by a single researcher, and the study was approved by the Research Ethics Committee (Approval nº. 644/2019).

The pH-cycling

A total of 180 intermaxillary elastics were selected and divided into two groups based on brand: 90 Morelli elastics (Group A) and 90 American Orthodontics elastics (Group B). Each group was further subdivided into six subgroups (n = 30) and exposed to different treatment solutions. Immersion media included distilled water (control) and a pH 5.0 solution (acidic), while cycling media consisted of pH 4.3 and pH 7.0 solutions (de-remineralizing medium) following the protocol by Toda and Featherstone (2008) [15]. Solutions were refreshed every 24 hours throughout the experiment. Specimens underwent daily cycles of demineralization (6 hours) and remineralization (17 hours). Force measurements were taken at 0, 24, 48, 72, and 96 hours using a digital dynamometer (Instrutherm™ model DD-200). Elastics were stretched to 15 mm between the dynamometer hook and a fixed metal pin on an acrylic resin block to maintain tension during measurement. After each assessment, elastics were returned to their respective solutions and stored in a temperature-controlled microprocessor oven (Quimis model Q316M4) at 37°C.

Statistical analysis

The strength data analysis was performed by models for repeated measures and Tukey-Kramer test, with significance level of 5%, by the SAS Institute Inc. 2018 and R Core Team (2018) programs. The strength degradation data, at each time, were analyzed by one-way analysis of variance (ANOVA) and the Tukey test.

RESULTS

The results were analyzed based on the strength (gf) of orthodontic elastics exposed to different immersion solutions and pH conditions (Table I). Both groups demonstrated a progressive decrease in force over time when immersed in pH 5.0 solution, de-remineralizing solution, and distilled water. At the 48-hour mark, Group B exhibited lower force values in the acidic medium, compared to the de-remineralizing medium. ($p < 0.05$).

Elastics subjected to pH cycling exhibited significant differences in force degradation (%) over time in both A and B groups. However, overall immersion conditions (pH variation) did not result in statistically differences when compared across all solutions ($p > 0.05$). Notably, elastics of Group A showed greater force degradation in the acidic pH 5.0 solution compared to the de-remineralizing solution ($p < 0.01$) (Table II). In contrast, Group B elastics demonstrated greater force degradation in the de-remineralizing solution than in the acidic solution at 48 hours ($p < 0.04$) (Table III).

Table I - Average (± standard deviation) of strength (gf) of orthodontic elastics of Group A (Morelli) and Group B (American Orthodontics) regarding the initial time, according to the solution, in each immersion time

Time (hours)	Solution – Group A		
	distilled water	acidic	de-remineralization
0	149.11 (3.02) Aa	149.78 (3.27) Aa	148.55 (4.35) Aa
24	146.56 (3.66) Ab	145.33 (3.46) Ab	145.00 (4.08) Ab
48	127.33 (3.75) Ac	128.55 (3.98) Ac	125.11 (4.17) Ac
72	126.67 (4.29) Ac	124.56 (3.96) Ad	123.44 (3.55) Ad
96	121.33 (2.85) Ad	122.22 (4.32) Ae	121.89 (3.24) Ad
		Solution – Group B	
0	132.22 (14.86) Aa	126.67 (10.36) Aa	133.22 (14.24) Aa
24	119.22 (12.46) Ab	113.33 (7.93) Ab	120.11 (11.19) Ab
48	115.61 (12.18) ABc	106.89 (8.39) Bc	117.00 (11.32) Abc
72	111.89 (11.70) Ad	105.44 (8.23) Ac	113.67 (12.27) Acd
96	111.67 (11.83) Ad	103.44 (7.66) Ad	112.89 (12.02) Ad

Different uppercase letters indicate statistically significant differences ($p \leq 0.05$) between solutions at the same time point (horizontal), while different lowercase letters indicate differences over time within the same solution (vertical).

Table II - Average (± standard deviation) of strength degradation (%) of orthodontic elastics of Group G (Morelli) regarding the initial time, according to the solution at the same time point

Time	Solution – Group A			p-value
(hours)	distilled water	acidic solution	de-remineralization	
24	9.7% (2.8%) A	10.4% (3.3%) A	9.6% (3.6%) A	0.6591
48	12.4% (3.2%) B	15.6% (2.7%) A	12.0% (3.4%) B	<0.0001
72	15.3% (2.5%) AB	16.7% (2.4%) A	14.6% (3.2%) B	0.0142
96	15.4% (2.6%) B	18.2% (2.6%) A	15.2% (2.8%) B	<0.0001

Different uppercase letters indicate significant differences ($p \leq 0.05$) between solutions at the same time point (horizontal).

Table III - Average (± standard deviation) of strength degradation (%) of orthodontic elastics of Group B (American Orthodontic) regarding the initial time, according to the solution at the same time point

Time	Solution – Group B			p-value
(hours)	distilled water	acidic solution	de-remineralization	
24	1.7% (1.5%) A	3.0% (1.9%) A	2.4% (1.9%) A	0.6201
48	14.6% (2.3%) B	14.1% (2.7%) B	15.8% (2.7%) A	0.0489
72	15.0% (2.6%) B	16.8% (2.7%) A	16.9% (2.9%) A	0.0171
96	18.6% (1.6%) A	18.4% (3.2%) A	17.9% (2.5%) A	0.5500

Different uppercase letters indicate significant differences ($p \leq 0.05$) between solutions at the same time point (horizontal).

DISCUSSION

The present study confirms that pH variation plays a significant role in the force degradation of orthodontic elastics over time. Due to the widespread clinical use and biomechanical importance of these materials, it is essential to understand how different environmental conditions affect their performance [7]. Consistent with previous in vitro studies [9,16], our results demonstrated a reduction in elastic strength when exposed to acidic and de-remineralizing environments. The null hypothesis was rejected and the extent of degradation was influenced by the pH of the medium and differed between elastic brands, suggesting brand-specific differences in material composition and response to pH cycling.

The present study demonstrated a progressive reduction in the strength of latex elastics from both brands tested when immersed over time in distilled water (pH 7.0), acidic solution (pH 5.0), and de-remineralizing solutions (pH 4.3 and 7.0). This decline in force aligns with findings reported in previous studies [17,18]. Teixeira et al. (2008) [19] observed that orthodontic elastics exposed to beverages with pH values below 7.2 exhibited less strength degradation, corroborating with our results. American Orthodontics elastics showed less force degradation after 48 hours of immersion in the acidic environment. These findings suggest that factors beyond pH may influence the mechanical stability of orthodontic elastics.

However, subjected to similar conditions, the elastics of Group A, after 48 hours in an acid solution, showed lower strength than those immersed in the de-remineralization solutions. The remineralization process may have contributed to stabilizing the strength of the elastics in this group during the pH-cycling process. The pH-cycling has been used in studies due to its ability to reproduce *in vitro* the intraoral dynamics of demineralization and remineralization. Therefore, it is important to clinically understand the performance of materials in situations with varying pH in the environment, as they should be able to provide the best clinical performance in situations of high and low cariogenic challenge, as well as ensuring the patient's oral health [20,21].

Ajami and Zare (2017) [12] reported no significant correlation between pH variation and elastic strength degradation, identifying time as the primary factor influencing force loss. Importantly, despite some degradation, the elastics maintained sufficient strength after 48 hours to support orthodontic tooth movement. Similarly, previous studies involving 24-hour immersion in acidic solutions did not observe substantial force degradation [3,13]. In contrast, the present study found significant strength reduction in elastics of Group A after 48 hours of immersion in acidic solution and in Group B elastics when exposed to the de-remineralizing solution. These findings underscore the complexity of the oral environment [22], where multiple interacting factors—including salivary pH fluctuations, dietary habits, and oral hygiene—affect elastic performance. Consequently, the in vitro conditions used here may reflect, but not fully capture, the more dynamic and severe challenges elastics face in clinical settings [23].

Elastics of Group B, immersed in acidic and de-remineralizing solutions for 72 hours, exhibited greater force degradation compared to those immersed in neutral pH solutions. This degradation in both conditions is attributed to the wet environment, which weakens intermolecular forces through water absorption and the formation of hydrogen bonds between water molecules and polymer chains [24].

Given the continuous use of latex elastics throughout orthodontic treatment, it is crucial for clinicians to understand the mechanical properties of these materials and to monitor oral environmental factors, particularly pH fluctuations. Such environmental variables can significantly influence the mechanical integrity of orthodontic elastics and potentially compromise treatment outcomes.

CONCLUSION

Strength degradation occurred in all conditions and increased over time; however, the extent of degradation was influenced by the pH of the medium and differed between elastic brands. Acidic environments intensified force loss in Morelli elastics, whereas de-remineralizing conditions produced greater degradation in American Orthodontics elastics. These findings suggest that oral pH variations may differentially affect elastic performance during orthodontic treatment and should be considered in clinical planning and replacement intervals.

These findings emphasize the importance of considering both the brand of elastics and the oral environment—particularly pH fluctuations—when planning orthodontic treatments. Understanding how external conditions affect elastic performance allows clinicians to make more informed decisions regarding replacement intervals and patient instructions, ultimately improving treatment efficiency and outcomes. Further in vivo research is recommended to validate these results under real clinical conditions.

Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author's Contributions

GMF, MJPL, EJC, MSJ: Conceptualization. GMF, EJC, MSJ: Data Curation. GMF, MJPL, EJC, MSJ: Investigation. GMF, MJPL, EJC, MSJ: Methodology. EJC, MSJ: Project Administration. MJPL, EJC, MSJ: Supervision. RBR: Validation. GMF, EJC, MSJ: Writing – Original Draft Preparation. RBR, MSJ: Writing – Review & Editing.

Conflict of Interest

No conflicts of interest declared concerning the publication of this article.

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Regulatory Statement

This study was conducted in accordance with all the provisions of the local committee guidelines and policies of: University Center of the Hermínio Ometto Foundation – FHO. The approval code for this study is: no. 644/2019.

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