

## Original Article

# Synergic effect of salivary pH baselines and low pH intakes on the force relaxation of orthodontic latex elastics

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## ABSTRACT

**Background:** Latex elastics are still in common use due to their low cost and high flexibility to improve sagittal discrepancies or interdigitation of teeth. Mechanical properties of elastics are influenced by several environmental factors such as pH changes. This study evaluated similar latex elastics to define the influence of synergic effect of intermittent low pH and various baselines pH of saliva.

**Materials and Methods:** Four groups of latex elastics (3-M Unitek, 3/16 inch) were tested ( $n = 15$  in each group). Two groups of elastics were immersed in two tanks of artificial saliva with different pH levels of 7 and 5, and two groups were immersed in two tanks of artificial saliva with intermittent drop of pH to 4. The force was measured when the elastics were stretched to 25 mm. These measurements were taken in 0, 4, 8, 12, 24, 36, and 48 h for each group. Repeated measures analysis of variance (RMANOVA) and *post-hoc* Tukey's test were used to assess the findings. The level of significance was 0.05%.

**Results:** The interaction between pH and time analyzed with RMANOVA showed no significant differences ( $P > 0.05$ ) except in 36 h ( $P = 0.014$ ). The Tukey's analysis showed that each comparison between any two groups did not indicate significant differences ( $P > 0.05$ ) except between Groups 1 and 3 and between Groups 2 and 3 ( $P < 0.05$ ).

**Conclusion:** No significant correlation was seen between fluctuation of pH and force degradation in latex elastic band except in 36 h.

**Key Words:** Orthodontic appliances, latex, orthodontic

Received: January 2016  
Accepted: November 2016

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## INTRODUCTION

The natural latex contains 25%–40% of isoprene polymer with high molecular weight and small amount of proteins and fatty acids.<sup>[1,2]</sup> The latex elastics are still in common use to correct sagittal discrepancies or to improve the interdigitation of the teeth due to their low cost and high flexibility.<sup>[3]</sup> With the light

force provided by these elastic bands, proper rate of tooth movement with the least patient discomfort can be provided during interact mechanotherapies.<sup>[3,4]</sup>

Rule of “3” is applied for interarch elastics, indicating that the elastics would exert the repeated force when they were extended 3 times of their diameter.<sup>[5,6]</sup> The

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**How to cite this article:** Ajami S, Farjood A, Zare M. Synergic effect of salivary pH baselines and low pH intakes on the force relaxation of orthodontic latex elastics. Dent Res J 2017;14:68-72.

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elastic properties of these latex materials depend on the twisted long molecular chains arranged irregularly and linked together with covalent bond at certain points.<sup>[7]</sup>

Force decay of rubber elastic bands can be explained by the fatigue and creep force relaxation which can be accentuated under adverse environmental conditions. As a result, although these elastic bands are used extensively, their mechanical properties are not well defined. Particularly, these properties are influenced by several factors related to the material such as loss of elasticity, amount of force decay, and composition of the elastics,<sup>[4]</sup> and also, the environmental factors such as composition of saliva, intraoral pH and temperature variations, food texture and pigments.<sup>[4,8-10]</sup> A few studies have evaluated the effect of salivary pH and its changes on the force degradation of latex elastics.<sup>[8,11]</sup> Previous studies found no correlation between changes of salivary baseline pH and the force relaxation of elastic.<sup>[8,9]</sup> The pH of the oral environment which is determined by pH of both saliva and dental plaque can affect these intraoral latex elastics.<sup>[12]</sup> Ferriter *et al.*<sup>[12]</sup> reported that the pH of the normal resting saliva was in the range of 5.6–7.6 which can fluctuate with diet solutions. Even when strong acidic solutions are ingested, the salivary pH quickly reverts to the baseline pH of oral cavity.

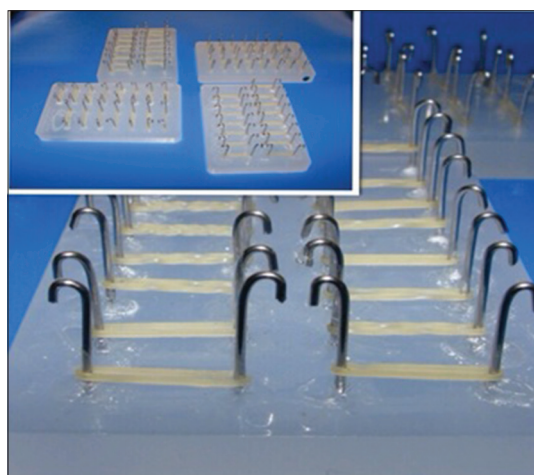
Although intermaxillary elastics might be removed easily by the patient, it is not possible to expect them to remove and reinsert them for every food intake in a 24 h duration.<sup>[4]</sup> During ingesting of very low pH representing very sour beverages, the high concentration of hydrogen ion may affect the force – degradation rate of latex elastic bands even if it reverts to baseline pH over time. Changes in salivary pH have been evaluated in previous studies; however, synergic impact of these changes with low pH liquid intake was not evaluated. The purpose of the present study was to assess a group of latex elastics in a static environment to define the influence of synergic effect of the intermittent's low pH and various baselines pH of saliva.

## MATERIALS AND METHODS

This study was designed to evaluate the effect of baseline salivary pH and synergic impact of exposure to intermittent lower pH level on the force relaxation of elastic bands. This study included four groups of

3/16 inch (4.8 mm), 4.5 oz (128 g) natural rubber latex elastic (3M Unitek, Monrovia, CA, USA).

Four acrylic boards on which the distance between two rows of stainless steel pins was 15 mm were constructed to test, 15 latex elastics in each group [Figure 1]. The elastics were within their shelf life period and had been stored in the plastic packages in a cool and dark place before the test. All elastics were randomly selected from different packs of the same type/brand to decrease the bias might be induced by variations in form and diameter of these latex elastic in a pack. Preferably, elastics with the same diameter and thickness were blindly selected by unmagnified eyes. The artificial saliva solutions were provided by the Pharmacy School of Mashhad University of Medical Sciences (Mashhad, Iran). Each group of elastics was immersed in a tank of artificial saliva with given pH level. Groups 1 and 2 were in a solution set at pH level of 7 and 5, respectively, representing variation of salivary baseline pH. Groups 3 and 4 were immersed in the solutions that every 120 min, their pH dropped (from pH 7 to 4) and (from pH 5 to 4) for 10 min in the first and third quarters of the 48 h experiment, respectively. No pH changing occurred in the second and the fourth quarters representing the rest time. pH levels were measured every hour with a calibrated pH/ion meter manufactures related (Crison, Spain) and were adjusted accordingly with 1 M citric acid and 1 M sodium hydroxide.<sup>[9]</sup> Samples were incubated at approximately 37°C in an incubator (Memmert, Germany) through the whole experiment. Force measurement was carried out using a calibrated digital force gauge (Lutron FG5020; Taiwan, accuracy



**Figure 1:** The acrylic plates constructed with two rows of 15 mm separated stainless steel pins and the mounted elastic bands.

$\pm [0.5\% +2 \text{ digit}]$  [Figure 2]. The force was measured when the elastics were stretched to 25 mm.<sup>[4,8,9]</sup>

These measurements were taken in 0, 4, 8, 12, 24, 36, and 48 h for each plate by one investigator blindly. The force was recorded using two fixed jig separated 25 mm on a stand (Lutron FS1001;Taiwan). The lower jig is attached to the stand (Lutron FS1001;Taiwan) and the upper jig is a part of the force gauge (Lutron FG5020;Taiwan, accuracy  $\pm [0.5\% +2 \text{ digit}]$ ). A consistent reading was established usually within 4–5 s for each elastic, and the plates were immersed in the solution immediately after each measurement. Data were gathered for statistical analysis. Repeated measures analysis of variance (RMANOVA) and the *post-hoc* Tukey's test were used to find statistically relevant differences between the groups. The chosen level of confidence for all statistical calculations is 95% or  $\leq 0.05$ .

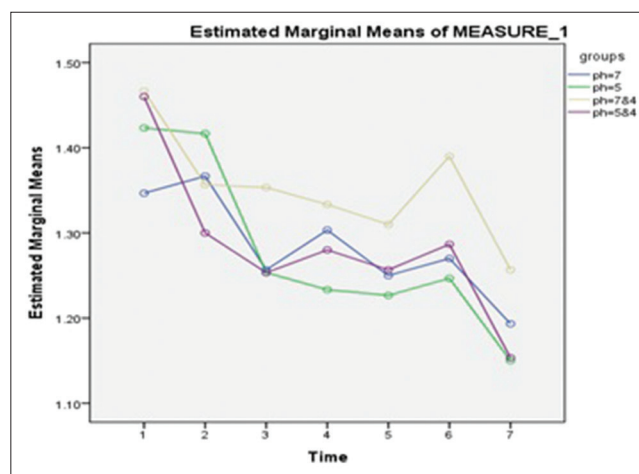
## RESULTS

Means and standard deviation of the force values generated by each group of elastics when stretched to 25 mm are shown in Table 1. RMANOVA showed a significant interaction effect between time and group ( $P = 0.014$ ). Therefore, the changes

in the force relaxation were not the same for all groups. The interaction between pH and time showed no significant differences ( $P > 0.05$ ) except at 36 h ( $P < 0.05$ ). We employed one-way ANOVA/Tukey's tests for subgroup (between group) comparison. The *post-hoc* Tukey's test was used among different groups and times. The further analysis showed that each comparison between any two groups did not indicate significant differences ( $P > 0.05$ ) except between Groups 1 and 3 ( $P < 0.05$ ) and between Groups 2 and 3 ( $P < 0.01$ ) [Table 1]. Even though no significance was found, in the first 4 h, the force decay of the Group 4 was 10% of their initial force [Figure 3], exhibiting the changes in the percentage of the initial force during the 48 h of the experiment in four groups. It is a representative force-time curve of elastics immersed in different pH levels. It shows a curve with four distinct phases of force decay: A high initial rate and the second lower rate of force degradation and the third slight force increase from 24 to 36 h and the fourth high rate of force decay. The percentage of the initial force remaining after 48 h was around 89.36% in Group 1, 81.41% in Group 2, 86.45% in Group 3, and 79.53% in Group 4.



**Figure 2:** The digital gauge with an elastic band staked on its hooks. The magnitude of the required force  $F$  is measured.



**Figure 3:** Line graph of force decay over time for elastic.

**Table 1: Means $\pm$ standard deviations of force magnitudes in four groups of latex elastics with different pH levels over time**

Groups	Time (h)						
	0	4	8	12	24	36	48
Group 1 (pH=7)	1.34 $\pm$ 0.17	1.36 $\pm$ 0.12	1.25 $\pm$ 0.14	1.3 $\pm$ 0.08	1.25 $\pm$ 0.08	1.27 $\pm$ 0.11 <sup>A</sup>	1.19 $\pm$ 0.13
Group 2 (pH=5)	1.42 $\pm$ 0.15	1.41 $\pm$ 0.12	1.25 $\pm$ 0.12	1.23 $\pm$ 0.10	1.22 $\pm$ 0.14	1.24 $\pm$ 0.85 <sup>A</sup>	1.15 $\pm$ 0.10
Group 3 (pH=7 and 4)	1.46 $\pm$ 0.14	1.35 $\pm$ 0.11	1.35 $\pm$ 0.10	1.33 $\pm$ 0.11	1.31 $\pm$ 0.13	1.39 $\pm$ 0.12 <sup>B</sup>	1.25 $\pm$ 0.12
Group 4 (pH=5 and 4)	1.46 $\pm$ 0.18	1.30 $\pm$ 0.14	1.25 $\pm$ 0.13	1.28 $\pm$ 0.13	1.25 $\pm$ 0.10	1.28 $\pm$ 0.10 <sup>AB</sup>	1.15 $\pm$ 0.16

Groups with at least one common letter do not have statistically significant difference (Tukey's test was used)

## DISCUSSION

Many recent studies have investigated the mechanical and environmental factors that impact the force decay of the interarch elastics.<sup>[12-14]</sup> The effect of individual salivary pH variability on the force decay of latex elastics has been investigated. They concluded that pH levels of 5 and 6 in the 24 h investigation were not significant contributors to the force relaxation of interarch elastics in comparison to pH of 7.<sup>[8,9]</sup>

This study evaluated the synergic effect of pH=4 presenting very sour liquids, with pH=5 which present a decline of the pH from the baseline during intakes. Lowering the pH to 4 for 10 min twice during 4 h enhanced the force decay in the first 4 h in comparison to the salivary pH baseline even though it was not significant. This primary rapid decrease of force in the first 4 h is consistent with the result of other studies in the literature.<sup>[8,9]</sup> A gradual reduction of the force occurred over time which was confirmed by the statistically significant difference existed between each time of testing, through the experiment. However, more than 80% of the initial force was preserved after 48 h in all tested groups. This amount of force is still close to those required for the orthodontic tooth movements. The use of 4 times greater force magnitude at the beginning as suggested by Andreasen and Bishara<sup>[15]</sup> could increase the risk of damage to the teeth and periodontal tissue. Also, in other studies investigating the influence of hydrogen ion concentration, the amount of forces of inter-arch elastic after 12 hours and 24 hours were still in the acceptable range for the tooth movements.<sup>[8,9]</sup>

This study was conducted in a static situation; however, the studies which evaluated the impact of cyclic stretching on interarch elastic did not report a significant influence on the force degradation except in the 1<sup>st</sup> h of the experiment.<sup>[7,16]</sup> This study, similar to the most recent studies investigated the effect of pH on the force decay of elastic bands, was conducted in a static situation. However, the combination of these environmental impacts, different salivary pH baseline, beverages with low pH, and cyclic stretching at the same time may enhance the force degradation significantly which needs to be evaluated in the future. In the study by Leão Filho *et al.*,<sup>[17]</sup> they did not report significant differences in the force decay of the interarch elastics immersed in different beverages. The duration of the investigation was almost 15 min and the intermaxillary elastic acted the same in

exposure to the tested beverages. In their study, beverages were not subjected to any pH analysis, also the duration of the experiment was very short. Moreover, salivary pH recovery following acidic beverage in the orthodontic patients was reported to be slower than nonorthodontic cases.<sup>[18]</sup>

In our study, reduction of the force in the first 8 h can be explained by the “swelling phenomenon.” The molecular chains with cross-linked points enable the absorption of liquid in the latex reticular structure.<sup>[17]</sup> After the plateau phase of force decay between 8 and 24 h, even intraoral water can plasticize cross-linked polymers including latex rubber,<sup>[19,20]</sup> which leads to the reduction in the creep compliance during the experiment that may lead to the reduction of flexibility and an increase in the force for a few hours from 24 to 36 h. The fluctuation of pH had a considerable effect on this matter.

The high rate of force decay from 36 to 48 h is due to the removal of the plasticizers by dissolution from the polymers molecular chain and elongation and decrease of elasticity from physical aging and environmental degradations. However, the remaining force was more than 79.53% after 48 h. This is consistent with the study by Wang *et al.*,<sup>[11]</sup> who also reported the remaining force of 86% after 48 h. Although the length of time of exposures to the chemical and thermal insults is an important factor in the force reduction, the amount of force remained after 48 h is acceptable, if not ruptured due to accumulation of insults. Referring to the results of this study, less compliance from the patients in 24 h and even in 48 h for elastic removal during low pH beverages ingestion scan still exerts an acceptable amount of force for the tooth movements. So far, with the limitations of this study, the results cannot be fully extrapolated to the clinical situations.

## CONCLUSION

No significant correlation was seen between the fluctuation of pH and the force degradation in the latex elastic bands. Time may be the main contributors to the force decay; however, after the 48 h of experiment, the amount of exerted force was still in an acceptable range for orthodontic movements. Although size and thickness of the product were controlled with unmagnified eyes, a more accurate method should be used to unify the samples in conducting these types of studies which evaluate the behavior of interarch elastics.

## Acknowledgment

The authors would like to thank the Vice Chancellery of Shiraz University of Medical Science for supporting this research (Grant No. 7711). This article is based on the thesis by Dr. Mahbubeh Zare. The authors would also like to thank Dr. Mehrdad Vossoughi of the Dental Research Development Center of the School of Dentistry for the statistical analysis in the manuscript.

## Financial support and sponsorship

The financial support for the progress of this study was provided by Shiraz University of Medical Sciences.

## Conflicts of interest

The authors of this manuscript declared that they had no conflicts of interest, real or perceived, financial or nonfinancial in this article.

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