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The Environmental Influence of Light Coke™, Phosphoric Acid, and Citric Acid on Elastomeric Chains

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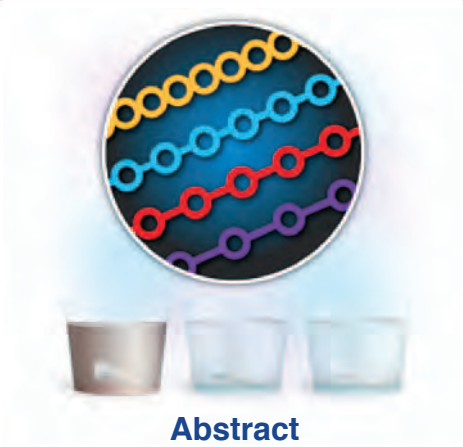

Abstract

Aim: The purpose of this study was to evaluate the *in vitro* effect of Light Coke™, phosphoric acid, and citric acid on the force decline pattern of two types of elastomeric chains.

Methods and Materials: One hundred sixty gray colored elastomeric chain modules, 80 Chainette (GAC) and 80 Sunburst™ (GAC) chains, were divided into four groups for immersion into Light Coke, phosphoric acid, citric acid, and artificial saliva. The initial stretched force of the elastomeric chains ranged from 220gf to 250gf. During the experiment, all elastomeric chains were kept immersed in artificial saliva at 37ºC (pH≈6.24) to simulate the oral environment. To simulate daily consumption of Light Coke, the elastomeric chains were immersed in the solutions twice a day for 15 minutes. The control group was kept immersed in artificial saliva continuously with no further treatment. Force (gf) was measured with a Dial-Type dynamometer (Dentaurum®), initially (baseline), 24 hours, 7, 14, and 21 days. Data were analyzed using the Tukey test at a 5% level of probability.

Results: A statistically significant reduction on the force produced by the elastomeric chains was seen at different time points. The greatest reduction in force occurred in the first 24 hours ($p=0.01$).

Conclusion: Force decay of the Chainette elastomeric chains were lower than the Sunburst™ chain ($p<0.05$). The immersion treatments caused no statistically significant difference in force for either chain module ($p>0.05$).

Clinical Significance: Good elastomeric chain properties are necessary for effective tooth movement, and knowledge of force-decay rates is an important factor in achieving the best orthodontic outcome.

Keywords: Elastomeric chain, phosphoric acid, citric acid, Light Coke

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Introduction

Synthetic elastomeric chains have been used by orthodontists since the 1960s. These polyurethane based materials have largely replaced latex elastics for intraoral arch tooth movement.[1] Placement and removal of elastic chains require little chair time, involve minimal patient cooperation during treatment, and have good compatibility with oral mucosa. These factors have contributed to a high level of elastic chains acceptance by clinicians. One disadvantage of these materials is their quick degradation in the oral environment and consequent decay of continuous force production, required for effective tooth movement.[2]

Previous studies have shown polyurethane elastomers undergoing stress relaxation lose the largest amount of force in minutes with little additional force lost thereafter.[1,3,4] Once the chains are activated, they begin to permanently elongate and increase in size, thus, decreasing the force exerted on the teeth.[5]

Another unfavorable characteristic of elastomeric chain modules is the change in the force decay behavior as stress relaxation occurs on immersion in different mediums. After 24 hours of liquid medium storage in distilled water and artificial saliva, the amount of elastomeric chain distraction needed to produce 150gf and 300gf substantially increased.[5]

Environmental factors present in the mouth have been individually simulated in *in vitro* studies to evaluate their influence on orthodontic polyurethane elastic chains force-degradation rates. The results show elastomeric products lose force over time, even under dry conditions,[6,7] and their properties are modified by liquids7 and temperature.[6]

Eliades[8] investigated the structural conformation of aged orthodontic elastomeric modules *in vitro* and *in vivo*. However, the effect of environmental factors, such as food and drinks on the force delivery properties of the elastomeric materials used for space closure, is less well known.

Nattrass[7] found that Coke™ (The Coca-Cola Company, Sao Paulo, Brazil) and turmeric solution had a greater effect on elastomeric chain force loss than just water alone, suggesting that some factor within the former two solutions might be modifying the properties of the

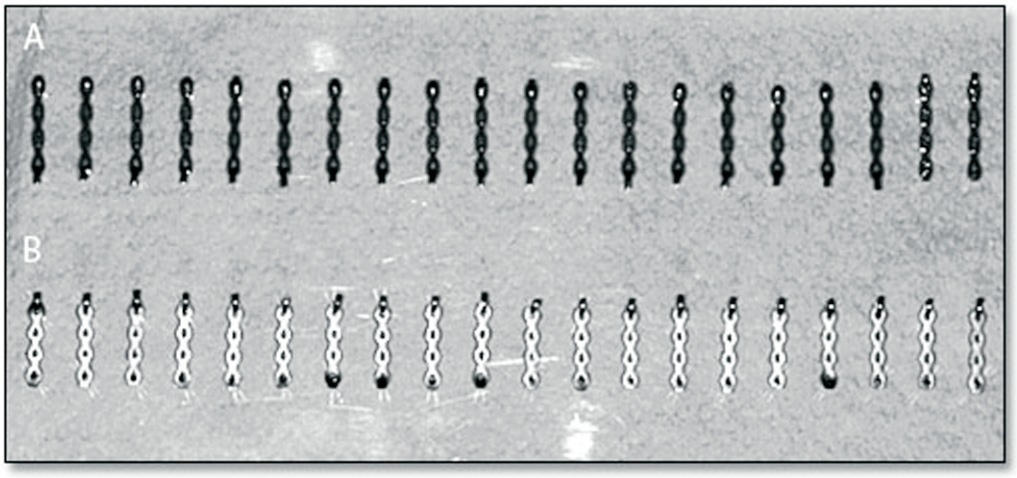

Figure 1. Device made to keep the Sunburst (A) and Chainette (B) chains stretched during the 21 days.

chains. In the case of Coke this could be related to the pH of the drink (pH 2.01). However, this is unlikely the complete answer since these results differ from the study of Ferriter[10] who found a fluoride acid environment reduced the force decay level. It is questionable whether the observed effect of these food-stuffs would be clinically significant since the elastomeric chains were stored in those solutions continually.

The objectives of this study were to:

- Determine the effect of pH on elastomeric chain force decline patterns.
- Compare the force decline patterns of two elastomeric chain types with different elastic properties.

Methods and Materials

Two gray medium size elastomeric module products were selected for evaluation: Chainette and Sunburst™ chains (GAC International Inc., Bohemia, NY, USA).

Four devices were fabricated for testing purposes. Devices were made of an acrylic base size of 8x10x22 mm, with four columns of 1 mm diameter stainless steel pins. There were 21 pins perpendicular to the base and parallel to each other in each row. The inter-pin distance was 1.7 mm for Chainette and 1.4 mm for Sunburst chains (Figure 1). Each chain module was standardized to four units per module, and the different distances produced approximately the same initial force of 230gf when the elastomeric chains were stretched. Four units were chosen as representative of what orthodontists would use to retract the canine into a premolar extraction space.[5]

Elastomeric chains were stretched onto each of the four devices and stored in synthetic saliva at 37ºC. One device served as a control group and did not receive further treatment. Three devices were immersed in one of the three mediums for 15 minutes, at room temperature, twice a day for 21 days.

1. Light Coke™ (Coca-Cola Export Co., London, UK)
2. Phosphoric acid 0.06%
3. Citric acid 0.06% (Figure 2)

Both phosphoric acid (0.06%) solution, contained in Light Coke, and citric acid (0.06%) solution, not contained in Light Coke, presented a pH of 2.60, similar to soft drinks. The purpose of immersing in these acidic solutions was to evaluate the effect of pH on elastomeric chains.

The pH value of Light Coke was determined using a microelectrode. The phosphoric and citric acid solutions were prepared at the same pH (2.60). The microelectrode was used to monitor the pH of the test solutions every day before baths. The Light Coke bath was made with a fresh can of soda. Five people where observed

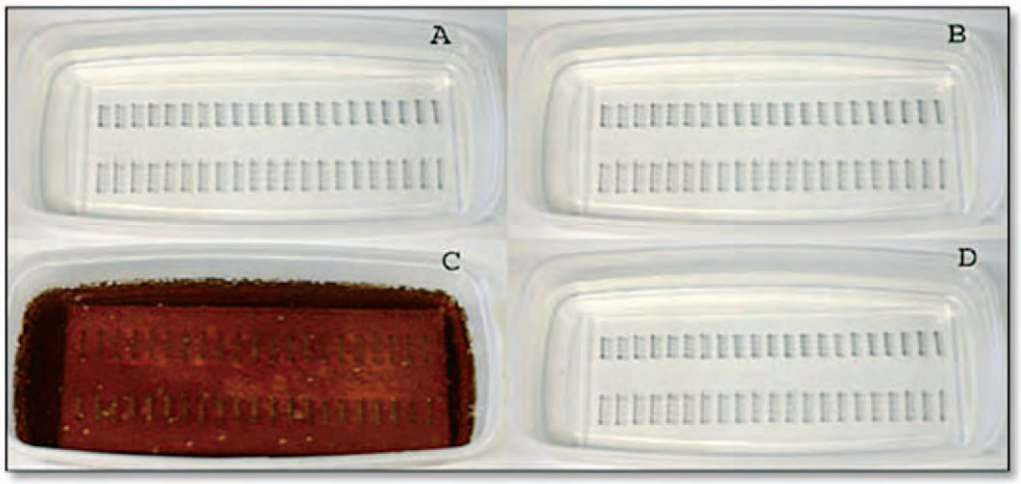

Figure 2. Device submerged in the immersion treatments: **A.** Control - artificial saliva; **B.** phosphoric acid; **C.** Light Coke, and **D.** citric acid.

Table 1. Mean force value (gf) of elastomeric chain Chainette according to the immersion treatment and time.

Time	Saliva		Light Coke™		Phosphoric Acid		Citric Acid	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Initial	215.00	11.24	215.00	8.89	214.50	7.24	209.25	7.66
24 hours	156.50	7.63	156.25	5.82	154.75	6.78	156.75	8.47
7 days	125.25	7.34	131.00	4.47	129.00	6.41	132.00	4.70
14 days	120.75	5.91	128.25	4.67	126.25	6.46	125.75	4.94
21 days	118.25	6.54	116.75	4.94	116.75	5.45	115.50	5.60

to determine the time it takes to normally drink a can of soft drink, so the immersion times could be standardize. The mean immersion time determined was 15 minutes.

Tensile tests of the chains were performed at T0- initially, T1- 24 hours, T2- 7days, T3- 14 days, and T4- 21 days using a dial-type dynamometer Correx (Haag-Streit; Berne, Switzerland).[11] The data were statistically analyzed using the Tukey test at a 5% significance level.

Results

Force decay was recorded over the 21 days for both elastomeric chains, Chainette and Sunburst, whether immersed in artificial saliva, Light Coke, phosphoric acid, or citric acid. The greatest force decay occurred in the first 24 hours. The Chainette module had lower force decline than the Sunburst chain, which was statistically significant ($p<0.05$). When the elastomeric chains were assessed in different immersion mediums, the force decay did not vary with the immersion treatment ($p>0.05$) (Tables 1 and 2, Figure 3).

Discussion

Gray medium size elastomeric chain segments of four loops each were used in the present study because it represents orthodontic use in canine retraction into a premolar-extraction space.[5]

There are differences in the force exerted by long and short elastic size segments when stretched over the same distance; the short

Table 2. Mean force value (gf) of elastomeric Sunburst chain according to the immersion treatment and time.

Time	Saliva		Light Coke™		Phosphoric Acid		Citric Acid	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Initial	235.50	9.30	233.50	9.75	228.75	11.57	244.25	6.74
24 hours	136.25	5.35	135.00	9.87	157.75	22.27	142.25	5.95
7 days	95.00	11.81	90.25	6.58	89.75	9.10	93.00	5.48
14 days	71.75	3.35	78.25	4.94	76.75	5.45	78.25	4.06
21 days	65.50	5.36	67.00	6.37	63.25	8.63	67.00	6.37

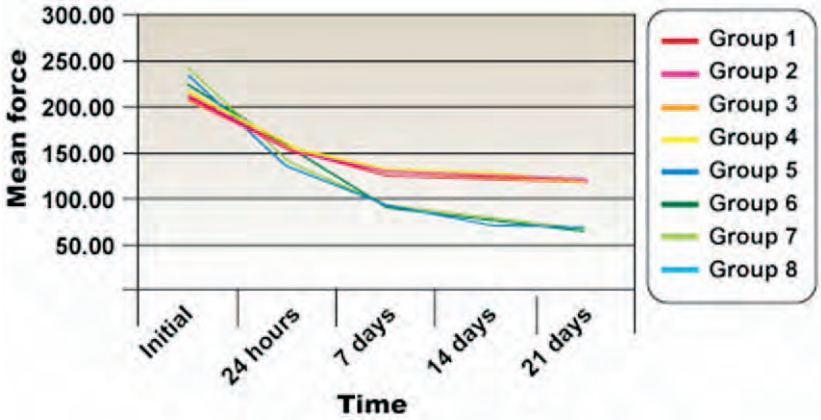

Figure 3. Mean force value of elastomeric chains, Chainette and Sunburst, in accordance with the immersion treatment and time. **Group 1:** Chainette in Light Coke™; **Group 2:** Chainette in Phophoric Acid; **Group 3:** Chainette in Citric Acid; **Group 4:** Chainette in Saliva; **Group 5:** Sunburst in Saliva; **Group 6:** Sunburst in Phosphoric Acid; **Group 7:** Sunburst in Citric Acid; **Group 8:** Sunburst in Light Coke™.

sizes exert higher force values than the long elastic segments.[1] In this study the length of the elastomeric chain modules was standardized and each one stretched to attain an initial force ranging from 210gf to 250gf, which is considered within the force limits for canine retraction.[12]

The experimental elastomeric chain force decay test performed at room temperature and in a dry state, not only is a weak representative of the oral conditions but also provides force values that differ from those generated when chains are stored in water,[5-13] artificial saliva, liquid medium, and distilled water.[1,4,5,14]

In the investigation of the effect of Coke, a drink with a low pH, on tooth enamel surface, specimens were divided into four groups with different immersion frequencies in Coke and control groups were stored in a physiologic medium. The results indicated a reduction in enamel microhardness in the experimental groups when compared to the control group.[15]

To simulate consumption of two cans of Light Coke a day, the devices holding the elastomeric chains were immersed twice a day, in the morning and in the afternoon, followed by storage in artificial saliva, in accordance with the study of Van Eygen et al.[15] It was not necessary to intersperse the 15 minute immersion with artificial saliva immersions, since immediate buffering of the Light Coke's pH does not occur in the oral cavity.

Nattrass[7] tested the effect of three frequent environmental factors in the oral cavity on elastomeric chains: water, Coke, and coloring solutions. After 7 days of immersion in these solutions, the results demonstrated that in the first hour the specimens stored in Coke and coloring solutions had a higher initial force decay than those stored in air and water. In Coke, chains were shown to have greater force decay and at all times the force levels were much lower than the force levels of the specimens stored in water. This fact suggested the difference between the results of the specimens tested in water and in Coke and coloring medium was due to one or more factors present in the solutions, capable of modifying the elastic physical properties. In the experiment with Coke, one of the factors suggested was its acidic pH. This is in contrast with Ferriter,[10] who found less force decay in an acid environment and with Stevenson and Kusy,[16] who found no statistically significant difference in the degradation of elastics associated with an increase in acidity.

In the present study no statistically significant difference was found in the elastomeric chain force decline pattern between the control group and the experimental groups. The difference between these results and those found by Nattrass[7] can be explained by the fact in the earlier study the elastomeric chains were stored in Coke for 7 straight days, which is not representative of normal oral conditions, even in the case of frequent consumption of the soft drink.

The results of the present study also showed a force decay with time which was greater in the first 24 hours, followed by gradual reduction, in accordance with the results of De Genova,[1] Taloumis,[13] and Kim.[4]

The elastic modules in the present study were kept stretched at a fixed length for 21 days, but if tooth movement was to be simulated by reducing the elastic stretching length in 0.5 mm per week, the values of the remaining forces would probably be different.[1]

Bousquet[11] compared two elastomeric chain model brands with different manufacturing methods of the American Orthodontics™ model brands and found no statistically significant differences in the force decay. When the two GAC elastomeric chains were compared, Chainette had lower force decay than Sunburst in agreement with the manufacturer's specifications. Considering the ideal elastic chain for tooth movement should present a continuous force, the Chainette presented the best results in this study.

Conclusion

1. Immersion in Light Coke does not alter the force decay pattern of the Chainette and Sunburst elastomeric chains.
2. The Chainette elastomeric chain had less force decay than the Sunburst chain.
3. In both elastomeric chain modules the greatest force decay occurred in the first 24 hours, followed by a gradual reduction in the subsequent 21 days.

Clinical Significance

Soft drinks such as Light Coke and other liquids with a low pH are very often consumed in the daily diet. As a result, the influence of these beverages on the rate of force-degradation of elastomeric materials could be a reality and of concern with regard to orthodontic biomechanics. However, the findings of this investigation refute this hypothesis. Orthodontists should not restrict the consumption of low pH liquids by patients during the appliance activation period using elastomeric chains. This study provides orthodontists additional information to make choices about the products they use. Between the elastomeric chains evaluated, the Chainette presented a force decay pattern more favorable to the clinical performance of tooth movement.

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