Effect of pH of soft drinks on force decay in orthodontic power chains

M Suprayugo¹, Y K Eriwati¹* and A S Santosa¹

¹Department of Dental Materials, Faculty of Dentistry, Universitas Indonesia, Jakarta, 10430, Indonesia
Email: yosiarianto@gmail.com

Abstract. The aim of this study was to evaluate the effects of Teh Botol, Buavita, Coca-Cola, and distilled water on force decay in orthodontic power chains. Twenty-eight power chains (Ormo; closed type; transparent) were fixed onto acrylic frameworks (inter-hook distance, 40 mm) and immersed in sweet tea, juice, softdrink, and distilled water. Force decay was measured at 1, 24, 42, 72, 168, and 336 h after immersion using a tension gauge. The force levels were decreased after the immersion of power chains in all four solutions. However, acidity did not significantly influence the force decay of the power chains.

1. Introduction
The application of a continuous and optimal force is necessary for ideal orthodontic tooth movement. Interdental gap closure is one of the most commonly encountered orthodontic problems and is treated usually by orthodontic appliances, such as elastomeric chain and modules and nickel titanium coil springs. Elastomeric chain, also known as power chain, is known to undergo force decay with time; however, this characteristic can be modified by controlling the humidity and temperature [1].

Power chains are made up of polyurethane elastomers, which are composed of several repeated subunits called monomers. The intermolecular bonds in a power chain are formed due to the cross-linking of chains through primary and secondary bonds, which are arranged in a spiral from. The power chain undergoes a change when force is applied and reverts to its previous form on removal of the force. This reversion to its pre-stretched form is attributed to the cross-linking of the bonds. However, permanent deformation can occur when a force that surpasses the power chain’s elastic limit is applied [2,3].

Power chains experience substantial force decay within the first 24 h of usage and continually lose force at slow rate until no force is delivered [4,5]. Humidity from water and saliva has been shown to enhance force decay in power chains [6]. Pre-stretching the power chain prior to usage can reduce force decay [7]. Previous studies on force decay in power chains at room temperature and in a dry environment did not accurately represent the clinical conditions of the oral cavity; therefore, several studies simulating oral cavity conditions using artificial saliva and immersion in water at 37°C were conducted [8,9]. In spite of that, those studies did not fully mimic the actual power chain force decay.
within the oral cavity. The force decay of power chains in the oral environment is greater than that found in laboratory tests [10].

Studies on power chain force decay using distilled water, artificial saliva, and fluorides have ever been carried. However, studies on the effect of food and drink consumed by orthodontic patients on force decay in power chains have rarely been conducted. Natras et al. conducted a study to compare force decay in power chains immersed in Coca-Cola, turmeric solution, and distilled water and demonstrated the power chain immersed in Coca-Cola presented with the greatest force decay [11].

Power chains can absorb small molecules such as water resulting in a decrease in intermolecular forces between chains within the polymer. During the process of water absorption, hydrogen ions from water penetrate the polymer owing to the positively charged oxygen atoms in the polymer. Water molecules penetrate the polymers causing the power chain to swell by increasing the distance between the polymer molecules. This reduces the force exerted by the power chain. Moreover, the power chain remains elongated and does not revert to its original pre-stretched form [12,13].

The degradation of power chain forces is influenced by several factors, including raw materials and technique used during manufacture, chemicals added to the power chain (such as dyes), chain configuration (open or closed), pre-stretching of the elastic chain, acidity of oral cavity, and method of storage [13,14].

Power chains from different brands exhibit differences in force decay. This may be attributed to the differences in the manufacturing process, such as the printing system, raw materials, additional chemicals, and shape and size of loops used [13,15]. The differences in power chain force decay were also influenced by the amount of time the power chain was stretched. Kim et al. stated pre-stretched power chains have smaller force decay than those that are unprestretched [7].

Saliva and food debris inside the oral cavity also influence the force decay of power chains. According to Andreasen and Bishara, power chains inside the oral cavity undergo degradation in qualities such as force reduction and unexpected color changes [14].

The aim of this study was to evaluate the effects of Teh Botol (bottled tea), Buavita (orange drink), Coca-Cola, and distilled water on force decay in orthodontic power chains.

2. Methods
Twenty-eight power chains (Ormco, USA) with six loops in each were used in this study. The power chains were of the closed type and transparent because they are known to exhibit stable force. The chains were fixed onto a prepared acrylic framework measuring 7 × 6 cm with an inter-hook distance of 40 mm. The 28 power chain specimens were divided into four groups based on the type of solution they were immersed in: distilled water (n = 7); regular softdrink, Coca-Cola (n = 7); ready-to-drink juice, Buavita, orange flavor (n = 7); and sweet tea, Teh Botol (n = 7). Before the immersion, the force of the power chain was measured using a digital force gauge and the acidity of the solution was measured using a universal pH meter. The power chains were, subsequently, fixed onto an acrylic framework and immersed in the solutions and stored in an incubator at 37°C. The forces of the power chains were measured after 1, 24, 42, 72, 168, and 336 hours of immersion.

Parametric and non-parametric tests were used to determine statistically significant differences in power chain forces between the four groups. Shapiro-Wilk’s normality test was used in this study. The non-parametric Friedman’s and Kruskall Wallis tests were used to find significant differences in power chain force decay before and after immersion in the solutions, and the Mann Whitney test was used to ascertain significant differences in force levels among the four treatment groups. The significance level (p) was set at ≤ 0.05 and 95% confidence level (α) at 0.05.

3. Results
The power chains in all the four treatment groups demonstrated force decay in this study. The force levels and percentages of force decay in the power chains from each group are presented in Table 1.
The data revealed the power chains experienced force decay throughout the immersion period. Maximum force decay occurred during the first 24 h in specimens immersed in distilled water when compared to those in the other three solutions. The amount of force remaining in the power chains from each of treatment group was reduced to approximately 50% after 336 h of immersion. The power chains that were immersed in Coca-Cola experienced maximum force decay from 48 until 336 h of immersion.

Result of Friedman test showed that there was no significant difference in force of power chain before and after immersion in all solutions. The results of Kruskal Wallis and Mann Whitney tests showed that there was no significant difference in force of power chain between immersion in the Teh Botol. Buavita. Coca Cola. and distilled water.

4. Discussion
The current study evaluated the effect of the pH of local soft drinks (Teh Botol. Buavita. and Coca-Cola) on force decay in orthodontic power chains. Friedman’s test demonstrated significant differences in forces between power chains before and after immersion in the soft drinks. Interestingly, the Kruskal Wallis and Mann Whitney tests revealed no significant differences in forces among the power chains immersed in Teh Botol. Coca-Cola. Buavita. and distilled water.

The chemical structure of a power chain is affected easily by its environment owing to factors such as temperature, humidity, and other chemicals (enzymes and saliva). Water is known to reduce the force of a power chain due to the attraction between the hydrogen atoms in water and oxygen atoms in the power chain. This force of attraction results in the absorption of water into the polymer chain. The absorbed water occupies the spaces between the polymer chains and widens the gaps between them [10].

Polymers can absorb water up to a certain extent until it reaches its water peak [12]. After 336 h of immersion, the power chains immersed in distilled water presented with the highest amount of remaining force when compared to those immersed in the other three solutions. Furthermore, the power chains immersed in Coca-Cola had the lowest pH and the least amount of remaining force when compared to the power chains in the other three treatment groups. Lower force decay was demonstrated in specimens immersed in distilled water at 72 h after immersion; 0.44% only of force decay remained when compared to the force recorded at 48 h after immersion. This is most likely because the amount of water absorbed by the power chains might have reached the water peak. The power chains immersed in Buavita experienced force decay but at a more stable rate than those immersed in the other solutions. Buavita has a thicker consistency when compared to the other three

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Table 1. Mean force and percentage of force decay before and after immersion in the solutions

| Time  | Teh Botol | Buavita orange | Coca-Cola | Distilled water |
|-------|-----------|----------------|-----------|-----------------|
|       | Mean (gmf) | Force decay percentage | Mean (gmf) | Force decay percentage | Mean (gmf) | Force decay percentage | Mean (gmf) | Force decay percentage |
| 0 h   | 327.14    | 100.00%         | 328.57    | 100.00%         | 328.57    | 100.00%         | 325.71    | 100.00%         |
| 1 h   | 304.28    | 93.01%          | 298.57    | 90.87%          | 308.57    | 93.91%          | 290       | 89.04%          |
| 24 h  | 264.28    | 80.79%          | 261.42    | 79.57%          | 264.28    | 80.43%          | 262.85    | 80.70%          |
| 48 h  | 242.85    | 74.24%          | 245.71    | 74.78%          | 244.28    | 74.35%          | 245.71    | 75.44%          |
| 72 h  | 232.85    | 71.18%          | 234.28    | 71.30%          | 234.28    | 71.30%          | 244.28    | 75.00%          |
| 168 h | 214.28    | 65.50%          | 205.71    | 62.61%          | 215.71    | 65.65%          | 228.57    | 70.18%          |
| 336 h | 181.42    | 55.46%          | 181.42    | 55.22%          | 172.85    | 52.61%          | 187.14    | 57.46%          |

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solutions due to the presence of fibers from orange pulp. Therefore, only a little amount of citric acid from the orange drink may have reacted with the water resulting in weaker attraction between the acidic Buavita solution and the polymers when compared with Coca-Cola and Teh Botol. Consequently, the power chains might have reached water peak faster with Buavita than with Coca-Cola or Teh Botol (estimated to occur at 168 h after immersion). The force of the power chains immersed in Buavita was lower than that of those immersed in distilled water because Buavita contains several dissolved components such as citric acid, which increases the spaces between chains in the polymer [16].

After 336 h of immersion, the remaining force of the power chains immersed in Coca-Cola was lower than that of the chains in the other three treatment groups (Table 1). This may be attributed to the fact that Coca-Cola contains molecules such as phosphoric acid and sodium benzoate, which can dissociate into ions in water. This results in the transport of these ions by the water that is absorbed into the power chains thereby increasing the spaces between the polymer bonds [10]. This has been demonstrated by the changes in the color of the power chain. Power chains undergo color change depending on the color of the solution it is immersed in, indicating the absorption of certain ions. The power chains that were immersed in Coca-Cola, Teh Botol, and Buavita demonstrated brownish black, brown, and yellowish discolorations, respectively, corresponding with the colors of the solutions. The power chains that were immersed in distilled water had turned white.

The findings of the current study are in accordance with those reported by Nattras et al. where force decay was greater in the power chains that were immersed in Coca-Cola when compared to those that were immersed in distilled water [10]. Furthermore, the authors also demonstrated lower force decay in the power chains that were immersed in Coca-Cola and turmeric solution for 24 h when compared with those that were immersed for more than 24 h [10]. This may be due to the fact that during immersion in distilled water, water is easily absorbed into the power chain resulting in greater force decay; conversely, during the first 24 h of immersion in an acidic solution less water is absorbed by the power chain because of the acidic components, which reacts with the water.

5. Conclusion
In conclusion, force decay of the power chains in the current study was not significantly influenced by the pH of Coca-Cola, Teh Botol, Buavita, or distilled water. Moreover, the force levels of the power chains were not influenced by the duration of the immersion in the four solutions.

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