Resilience differences between TMA and stainless steel archwire after immersion in apple cider

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Abstract

Objective: This research aimed to determine the differences in resilience between TMA and stainless steel archwires after immersion in artificial saliva and apple cider, and resilience between TMA and stainless steel archwires after immersion in apple cider.

Material and Method: The samples were divided into two control groups of TMA and stainless steel archwires immersed in artificial saliva and two treatment groups of TMA and stainless steel archwires immersed in apple cider. Each group consisted of 7 samples, with a diameter of 0.016 x 0.022 inches and a length of 11.6 cm. All samples were incubated, and resilience measurements were taken using a Tensilon RTF-1350 universal testing machine.

Results: The resilience of TMA and stainless steel archwires immersed in apple cider was greater than in artificial saliva. However, apple cider significantly affects the change of resilience of TMA and stainless archwires.

Conclusion: A significant difference was found between the resilience of the TMA and stainless steel archwires after immersion in apple cider.

Keywords: Archwires, Resilience, Stainless steel, TMA
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Introduction

Malocclusion is a deviation from ideal occlusion that can be aesthetically or functionally disturbing. According to the World Health Organization (WHO), it shows that malocclusion is known as the third most important problem of oral health after periodontal and caries disease. The highest prevalence was in Africa (81%) and Europe (72%), then America (53%) and Asia (48%)

Stainless steel archwires are used because of their excellent mechanical properties, such as low friction force, corrosion resistance, and ease of form. TMA archwire is an alternative to stainless steel archwire because it has no nickel and is safe for patients with hypersensitivity to nickel. TMA archwire with TiO2-based coating on the wire surface provides biocompatibility, this wire also has low stiffness, good formability, and direct welding. These two wires have excellent strength and ductility.

Resilience is claimed as the wire’s ability to return to the initial condition when the wire is deflected in the pursuit direction. In the early stage of orthodontic treatment, resilience is an important mechanical characteristic of wire, which is influenced by the cross-section and ductility of the wire material. The relatively high resilience is the advantage of TMA and stainless-steel wire. Interestingly, orthodontic archwires give remarkable resilience and send energy back after being absorbed in the deflection phase, efficiently aligning teeth. Other environmental factors such as pH levels, temperature, and duration of exposure to a substance can also affect changes in the value of resilience. The immersion of TMA archwire can influence the loss of metal ions’ stability from the wire’s surface layer in the form of titanium oxide (TiO2) and the release of ions such as zinc and zirconia. In contrast, the immersion of the stainless steel archwire can affect the formation of a protective layer on the wire surface and the release of...
Ni and Cr ions. Foods and beverages with low pH, such as apples, are one factor that can have an impact on archwire resilience. The benefits of an apple (Malus domestica) are to reduce the risk of stroke, lower cholesterol and diabetes, lower blood pressure, inhibit cancer cell proliferation, and for diet programs. The pH of an apple is 3.5 – 4.5, which includes an acidic pH. The study intended to compare the resilience of TMA and stainless steel archwires after being exposed to fake saliva and apple cider, as well as to compare their resilience after being immersed in apple cider.

**Material and Methods**

This type of research was conducted in an experimental laboratory, where a post-test-only control group design was applied. This study had permission from the Research Ethics Committee of Universitas Sumatra Utara Number 597/KEP/USU/2022. The sample of the study was 28 orthodontic archwires consisting of 14 TMA orthodontic archwires (American Orthodontics) and 14 stainless steel orthodontic archwires (American Orthodontics) having a diameter of 0.016 x 0.022 inches and also 11.6 cm for length. The samples are categorized into two control groups, each was immersed in 15 mL of artificial saliva, and two treatment groups, each was immersed in 15 mL of apple cider, which consisted of 7 samples for each group: Group TMA-K: TMA archwire immersed in artificial saliva; Group SS-K: archwire of stainless steel immersed in artificial saliva; Group TMA-SA: TMA archwire immersed in apple cider; Group SS-SA: archwire of stainless steel immersed in apple cider.

The apple cider was made with 100% concentration, and no sweets or water were added. The pH of the apple cider was determined using a digital pH meter, and the samples were kept in an incubator at 37°C for 26 hours. After 26 hours, samples were removed from the incubator and isolated from the fluid. The sample was placed in a desiccator for 24 hours to eliminate excess water, maintain moisture, and prevent oxidation from the environment. Subsequently, the fluid was tested once more using a digital pH meter.

The wire samples were tested for resilience using a universal testing machine (Tensilon RTF-1350, Dynatech, Japan) equipped with a three-point bending fixture consisting of two supporting pins and one loading pin. The tests were conducted at the IFRC Laboratory of the Department of Mechanical Engineering, University of Sumatera Utara. The bending load was applied at a 1 mm/min rate to determine the loading force and then drawn back to the original position to get the unloading force, which was utilized in this investigation.

Statistical analysis was conducted using the SPSS 17.0 version (Chicago and a Shapiro-Wilk normality test was used because the sample size was less than 50. Suppose the test results indicate a normal distribution or p>0.05. The data is statistically examined using a paired T-test to compare the resilience difference between the control and treatment groups. The investigation used a T-independent test to compare the resilience difference.

**Results**

This research revealed that the average resilience in the control group divided into group TMA-K was 15.278 ± 1.819 N and group SS-K was 18.814 ± 0.865 N. The average amount of resilience in the treatment group, divided into group TMA-SA, was 39.871 ± 3.963 N, and group SS-SA was 51.804 ± 7.161 N. The Shapiro-Wilk normality test findings indicated that the data exhibited a normal distribution for the resilience assessments of stainless-steel TMA and orthodontic archwires in all groups. The results revealed that the average resilience of the treatment group (immersed in apple cider) was greater than the control group. The highest average of resilience was found in group SS-SA, a stainless steel archwire immersed in apple cider. A paired T-test was carried out, and the results showed that there was a significant difference between the resilience of TMA orthodontic archwire after immersion in artificial saliva and apple cider (p=0.001; p<0.05) and there was found a significant difference in the resilience of

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**Table 1. The differences in resilience between TMA and archwires of stainless steel after immersion in artificial saliva and apple cider.**

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean±SD</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>TMA-K</td>
<td>15.278±1.819</td>
<td>0.001</td>
</tr>
<tr>
<td>TMA-SA</td>
<td>39.871±3.963</td>
<td></td>
</tr>
<tr>
<td>SS-K</td>
<td>18.814±0.865</td>
<td></td>
</tr>
<tr>
<td>SS-SA</td>
<td>51.804±7.161</td>
<td></td>
</tr>
</tbody>
</table>

**Table 2. The differences in resilience between TMA and stainless steel archwires after immersion in apple cider.**

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean±SD</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>TMA-SA</td>
<td>39.871±3.963</td>
<td>0.002</td>
</tr>
<tr>
<td>SS-SA</td>
<td>51.804±7.161</td>
<td></td>
</tr>
</tbody>
</table>
Discussion

TMA and stainless steel archwires immersed in apple cider showed greater resilience than archwires immersed in artificial saliva or in other words there was an effect on immersion. This study found the highest resilience in an archwire of stainless steel immersed in apple cider. Pratomo et al. have recently shown that there were significant differences in the loading and unloading force of TMA and stainless steel archwires, where the loading and also unloading force of stainless steel archwire is higher than TMA archwire, followed by Ni-Ti archwire with CuNiTi archwire. Research conducted by Saragih et al. indicated that there was an increase in the resilience of stainless steel archwire after being immersed in a probiotic drink for 0, 4, and 8 days, where the longer the archwire was in contact with acidic pH, the greater the value of the resilience of the wire. In addition, some beverages that might impact the corrosion rate of stainless steel orthodontic wires include jasmine tea, fruit-flavored tea, green packaged tea, and arabica packaged coffee should also be considered. These significantly impact the acceleration of the corrosion rate of stainless steel orthodontic wires.

In this study, TMA and stainless steel archwires were immersed in apple cider (pH = 4.5) and artificial saliva (pH = 6.8). The pH level of the solution can affect the resilience of the wire by causing loss of metal ion stabilization. Resilience is the wire's ability to return to its initial position when deflected in a purposed direction; in orthodontic treatment, resilience is very necessary because it can provide a force during tooth movement. The required movement of the teeth is a light but persistent force. In tooth movement, the wire, an elastic material, receives a certain amount of force (loading), and then the wire will return its shape to its initial state (unloading). The movement of the tooth process in orthodontic treatment can be defined as two stages: loading force, which is a force on purpose to help deform an archwire inserted into a misaligned slot of the bracket, and unloading force that becomes the force by the archwire on a misaligned bracket while reverting to the original shape or the ability of the wire to get back into the first condition before having deflected. The force applied on the wire when it is attached to the bracket is the loading force, while the force applied when the tooth was moved during the orthodontic treatment stage is the unloading force. The value of the resilience that is used in this study is the unloading force, as this force describes the pressure that will be applied to the teeth after the wire is activated.

Apples consumed daily contain malic acid (C4H6O5) which has relatively high H+ particles and an acidic pH which within a long time in the oral cavity can cause changes in the characteristics of orthodontic wires. Changes in the resilience of TMA and stainless steel orthodontic archwires immersed in apple cider for 26 hours showed an increase in the resilience of the wire. The increase in the pH value of apple cider (3.8 to 4.5) at the time of immersion caused an increase in resilience and a decrease in the corrosion rate of the wire so that the wire became more resistant to corrosion. This is caused by the loss of metal ion stabilization in the TMA and stainless steel archwires. TMA archwire has corrosion resistance by forming a passive layer of titanium oxide (TiO2) as the initial wire defense reaction of chromium with oxygen, which serves to form a thin surface of a self-repairing protective layer so that if the wire is damaged due to scratches, the protective layer rich in chromium can be quickly re-coated. Another factor that can also affect the corrosion rate is time limitations, meaning the longer the wire is exposed to an environment with a low pH, the more it affects the occurrence of corrosion. The study's result is in accordance with Utari et al. who stated that there was an increase in the resilience of the wire because the cold temperature applied to
the metal would cause the corrosion rate of the metal to decrease so that the stainless steel archwire would become more resistant to corrosion.11

This study also presents a significant difference in resilience between TMA and stainless steel archwires immersed in apple cider. This happens because the stainless steel archwire has an elastic limit, spring back, and bending moment higher than the TMA archwire. Another factor affecting the difference in resilience between TMA and stainless steel archwires is that stainless steel archwire will form a thin surface of a self-repairing protective layer that comes from chromium, which will spontaneously protect the wire from corrosion. Wires with higher resilience are more effective in the uprighting phase. Stainless steel archwire has a high value of resilience and unloading force, so that it is widely applied in the treatment at its final stages which works to protect teeth from external factors, which is limitations that come from factors outside of doctor treatments such as the patient’s condition and environmental conditions, and to prevent relapse.7,16,24

Conclusion
TMA and stainless steel archwires immersed in apple cider were more resilient than in artificial saliva. The resilience of the stainless steel archwire was greater than that of the TMA archwire, and a significant difference was found between the resilience of TMA and stainless steel archwires after immersion in apple cider. However, apple cider has a significant effect on the change in resilience of TMA and stainless archwires.

Acknowledgment
None.

Conflict of Interest
The authors report no conflict of interest.

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