

# EFFECT OF UHT MILK ON FRICTION OF STAINLESS STEEL (SS) AND NICKEL TITANIUM (Ni-Ti) WIRE- AN IN VITRO STUDY

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**Abstract :** Friction in orthodontic treatment were essential factor in biomechanical tooth movement, that infulenced by biological factors such as corrosion can inhibit tooth movement, thereby extending the duration of orthodontic treatment. UHT milk is a nutrient-rich drink that is often consumed by the public and is a weak acid solution. To investigate the effect of UHT milk on stainless steel and nickel-titanium wire friction. A total of 24 ORMCO® SS 0.018 and Ni-Ti 0.018 wires were used in this experimental study. The frictional SS and Ni-Ti wires immersed (8 groups n=3) in the following two solutions were measured: UHT Milk and artificial saliva for 7.5 hours, 10 hours 37°C in incubator, respectively. Static and dynamic frictional forces were measured using Universal Testing Machine. Independent T-test analyses were applied to compare the groups for significant differences (P<0.05). Average value Ni-Ti wire friction is greater than SS wire when immersed with UHT milk even though the analysis results showed no difference significantly. No effect of UHT milk on the friction of stainless steel and nickel-titanium wires.

**Keywords:** *friction, corrosion, UHT milk, stainless steel wire, nickel titanium wire*

## INTRODUCTION

After periodontal disease and tooth cavities, malocclusion is one of the most common issues with oral health and dentistry in Indonesia.<sup>1</sup> Malocclusion is an aberrant occlusion disorder characterized by abnormal tooth position and upper and lower jaw malrelationships.<sup>2</sup> A person's quality of life may be negatively impacted by functional and cosmetic issues brought on by untreated malocclusion.<sup>1,2</sup> Sliding mechanics, which involves moving teeth constantly down an archwire with brackets, is one technique frequently employed to move teeth during orthodontic treatment.<sup>3,5</sup> Friction between brackets and wires prevents teeth from moving during orthodontic treatment.<sup>4</sup>

Friction can be caused by a wide range of variables, including biological and mechanical ones. In contrast to biological considerations, which include corrosion, saliva, and the buildup of dirt and plaque, mechanical factors include the properties of the wire, bracket, ligation technique, and spacing between brackets.<sup>3-5</sup> Food and drink consumption can cause changes in pH and temperature in the oral cavity, which can lead to corrosion of orthodontic wires.<sup>6</sup>

The two types of wires that are most frequently used in orthodontic treatment are stainless steel and nickel-titanium.<sup>2</sup> Milk is one beverage that tends to be acidic or can lower pH. The pH range of milk is 6.0 to 6.7. According to previous research, immersing stainless steel in simulated milk solution for four to forty-eight hours resulted in pitting corrosion, increased surface roughness, and the release of metal ions.<sup>7,8</sup>

## **METHODS**

Ormco® brand round cross-section stainless steel and nickel-titanium (NiTi) orthodontic wire with a 0.018-inch diameter and a 10-centimeter length were employed as the experimental specimens in this investigation. After that, it was steeped in UHT milk solution and artificial saliva solution before a friction test was conducted. The Chemical Engineering Laboratory at Sriwijaya State Polytechnic in Palembang is where the artificial saliva solution was created. At the University of Indonesia's Faculty of Engineering, Manufacturing Research Center Laboratory, friction testing was then done on stainless steel and nickel-titanium wires.

This study employed a laboratory experimental and post-test design with a control group (post-test only control group design), which measures test outcomes following the implementation of an intervention in conjunction with a control group. After dividing the samples into test groups, a minimum sample value of 3 is determined, yielding a total of 24 samples. The test groups were split up as follows: For 7.5 hours, Group A (control)'s stainless steel wire was soaked in artificial saliva, and Group B's stainless-steel wire was steeped in UHT milk. 7.5 hours, Group C (control), 10 hours of artificial saliva solution soaking stainless steel wire, Group D, 10 hours of UHT milk solution soaking stainless steel wire, Group E (control), 7.5 hours of artificial saliva solution soaking nickel-titanium wire, Group F, 7.5 hours of UHT milk soaking nickel-titanium wire, Group G (control), 10 hours of artificial saliva solution soaking nickel-titanium wire, and Group H, 10 hours of stainless-steel wire soaking in UHT milk.

## **RESULT**

The average and standard deviation of the wire friction values following immersion in UHT milk drink and artificial saliva revealed that the group soaking in UHT milk drink had higher wire friction values than the group submerged in artificial saliva. The nickel-titanium wire group had the greatest mean value and standard deviation at 7.5 hours of immersion ( $2.070 \pm 0.649$ ), followed by the

stainless-steel wire group ( $1.429 \pm 0.219$ ). The NiTi wire group had the highest value ( $2.549 \pm 0.613$ ) in the 10-hour immersion group, followed by the SS wire group ( $1.794 \pm 0.496$ ). This was also observed in that group.

**Table 1.** Mean and standard deviation of friction after immersing the wire in artificial saliva and UHT milk

group	Friction (Mean±SD)			
	NiTi		SS	
	7,5 hours	10 hours	7,5 hours	10 hours
artificial saliva	1.887±0.459	2.021±0.586	1.369±0.189	1.367±0.241
UHT milk	2.070±0.649	2.549±0.613	1.429±0.219	1.794±0.496

The data for the two sets of wires were found to have a normal ( $p>0.05$ ) and homogenous ( $p>0.05$ ) distribution based on the findings of the Shapiro-Wilk normality test and Levene's homogeneity test. The Independent T-test was then used to examine the data and assess the relevance of UHT milk drink influence on SS and NiTi wire friction.

As compared to the control group after soaking for 7.5 hours ( $p=0.739$ ) and 10 hours ( $p=0.251$ ), the friction value in the SS wire group after immersion in UHT milk did not exhibit a significant difference ( $p>0.05$ ), according to the findings of the Independent T-test statistical test in Table 2. Similar findings were also seen in Table 3, which indicates that after immersion in UHT milk, the friction value in the NiTi wire group did not differ significantly ( $p>0.05$ ) from the control group at 7.5 hours ( $p= 0.709$ ) and 10 hours ( $p= 0.350$ ).

**Table 2.** Average friction of SS wire after immersion in UHT milk

soaking solution	Duration	n	Friction Mean ±SD (N)	<i>p-value</i>
artificial saliva	7.5 hours	3	1.369±0.189	0,739
UHT milk	7.5 hours	3	1.429±0.219	
artificial saliva	10 hours	3	1.366±0.241	0,251
UHT milk	10 hours	3	1.749±0.495	

**Table 3.** Average friction of NiTi wire after immersion in UHT milk

soaking solution	Duration	n	Friction Mean ±SD (N)	<i>p-value</i>
artificial saliva	7.5 hours	3	1.887±0.459	0.709
UHT milk	7.5 hours	3	2.070±0.649	
artificial saliva	10 hours	3	2.021±0.586	0.350
UHT milk	10 hours	3	2.539±0.613	

Subsequently, an additional independent T-test analysis was conducted to ascertain the relevance of variations in friction force values between SS and NiTi wire types over a single immersion duration. With a value of  $p=0.844$  ( $p>0.05$ ), the study findings in Table 4 demonstrate that there is no discernible difference between the friction values of SS and NiTi wires after a 7.5-hour immersion. The 10-hour immersion group likewise discovered the same thing: with a value of  $p=0.899$

( $p > 0.05$ ), there was no discernible difference between the friction values of SS and NiTi wire.

**Table 4.** Average friction between types of wire after immersion in UHT milk for one soaking time

wire	Durasi	n	Friction Mean $\pm$ SD (N)	<i>p-value</i>
SS wire	7,5 hours	3	0.059 $\pm$ 0.042	0.844
NiTi wire	7,5 hours	3	0.184 $\pm$ 1.030	
SS wire	10 hours	3	0.427 $\pm$ 0.611	0.899
NiTi wire	10 hours	3	0.518 $\pm$ 0.982	

The significance of the variation in friction values during 7.5 and 10 hours of immersion in UHT milk drinks in the SS and NiTi wire groups was next ascertained using an independent T-test analysis. Table 5's analysis results indicate that there is no discernible difference between the two wire groups' friction values between 7.5 and 10 hours of immersion ( $p = 0.705$ ;  $p > 0.05$ ) for the NiTi wire and SS wire groups, and  $p = 0.357$  ( $p > 0.05$ ) for the other wire group).

**Table 5.** Difference in the average value of wire friction after soaking for 7.5 hours to 10 hours in UHT milk

wire	Durasi	n	Friction Mean $\pm$ SD (N)	<i>p-value</i>
SS wire	7.5 hours	3	0.059 $\pm$ 0.042	0.357
	10 hours	3	0.427 $\pm$ 0.611	
NiTi wire	7.5 hours	3	0.184 $\pm$ 1.030	0.705
	10 hours	3	0.518 $\pm$ 0.982	

## DISCUSSION

The amount of orthodontic force that will give the teeth and periodontium tissue a mechanical stimulus to allow the teeth to move will determine how effective sliding mechanics will be in treating orthodontic patients.<sup>10, 11, 13, 14</sup> Elevated friction between the wire and bracket surfaces will intensify the orthodontic force required to shift teeth, thereby prolonging the orthodontic treatment's duration.<sup>15</sup> Wire friction is influenced by a number of factors, including mechanical factors (wire surface characteristics) and biological factors (corrosion).<sup>13</sup>

Static friction, or the maximum force needed to start a wire moving from rest over a distance of 5 mm, is the basis for the friction measurement used in this study. In sliding mechanics, static friction is more important than mechanical friction because orthodontic tooth movement doesn't happen all at once. When teeth move in an orthodontic manner, they will initially tilt, and then the alveolar bone and periodontium tissue will react biologically, causing the teeth to straighten and the surrounding bone to remodel at the same time.<sup>14</sup> This tooth movement cycle is characterized by tiny, repetitive movements rather than a continuous motion.<sup>10, 11, 13, 14</sup>

The friction values of SS and NiTi wire increased following immersion in UHT milk, according to the research's findings (Table 1). With a pH of 5.9, the UHT milk used in this study is a weak acid solution that contains corrosive agents that can lead to corrosion.<sup>19</sup> Chloride, which is present in UHT milk, diffuses throughout the milk by combining with cations.<sup>20</sup> According to a study, metal ions on the surface of the protective layer of stainless-steel wire can react with chloride ions to form metal chloride compounds, which can lead to pitting corrosion.<sup>21</sup> The protective titanium oxide layer on NiTi wire can be weakened by chloride ions, according to similar results that have also been reported.<sup>22</sup>

Lactose processing during the UHT milk production process and the interaction of lactose with acid-producing bacteria during the UHT milk storage process result in the formation of other corrosive agents in the form of organic acids found in milk, specifically lactic acid and formic acid.<sup>16,17</sup> According to a study, immersing titanium in lactic acid solutions at different concentrations causes the metal to corrode more quickly. This occurs as a result of the chelating agent properties of lactic acid, which enable it to bind to metal ions and form compounds ([Ti(OH)<sub>3</sub>].L). This substance will hasten the deterioration of titanium oxide's (TiO<sub>2</sub>) barrier, causing titanium to corrode.<sup>23</sup> A study that found that formic acid could cause corrosion in 316L stainless steel in which noted a similar phenomenon in stainless steel.<sup>24</sup> Furthermore, a study found that fatty acids like stearic acid, lauric acid, and palmitic acid found in milk triglycerides are also corrosive to stainless steel.<sup>18</sup> Corrosion will happen when the protective layer of the wire is compromised by the presence of a corrosive agent, dissolving the metal ions on the wire's surface.<sup>9</sup>

On orthodontic wires, corrosion typically results in higher friction values and increased surface roughness.<sup>25</sup> The orthodontic force needed to move teeth increases with the friction force on the wire. This has the effect of decreasing sliding mechanics' effectiveness, which lengthens the orthodontic treatment's duration.<sup>10,12-15</sup> The type of bracket, the size of the bracket slot, the dimensions of the wire, and the ligation technique are additional factors that affect friction. Since this study is an experimental laboratory study, additional variables such as brackets and ligation techniques are applied consistently to every sample. Therefore, it is reasonable to assume that this variable has no bearing on how much the wire friction force is.

Table 1 presents research findings indicating that, when soaked in UHT milk, NiTi wire exhibits an average friction value greater than SS wire; however, Table 4's analysis results do not reveal a statistically significant difference. This is because the NiTi wire's surface morphology was initially rougher than that of SS wire, resulting in a higher friction coefficient for the former.<sup>9,26</sup> Surface imperfections such as tiny cracks and a rough surface can appear on NiTi wire due to its high nickel content, which ranges from 47 to 50%.<sup>9,27</sup> Furthermore, NiTi wire's corrosion resistance attributes are also influenced by the initial state of the wire surface morphology.<sup>9</sup> Corrosive substances like lactic acid, formic acid, and

hydrochloric ions can pierce the protective layer (TiO<sub>2</sub>) in acidic environments, leading to pitting corrosion.<sup>9</sup> Small surface fissures on the NiTi wire then hasten the protective layer's (TiO<sub>2</sub>) deterioration, hastening the corrosion process on the wire. According to previous research, surface morphology of SS and NiTi wires was observed after immersion in low pH (pH 5 and pH 3), and it was found that surface defects on NiTi wires resulting from pitting corrosion were more severe than those on SS wires.

The analysis's findings demonstrate that, in this investigation, there was no discernible difference between the friction values of the SS and NiTi wires after immersion in UHT milk and those of the control group. As a solution's pH drops, the rate of wire corrosion is directly correlated with the hydrogen ion concentration.<sup>9</sup> The pH of the UHT milk used in this investigation was 5.9, which is not sufficiently acidic to encourage additional corrosion in this state. The same observation was made in a prior study that looked at the corrosion rate of SS and NiTi wire in low pH solutions (pH 3 and pH 5) for 30 days. The corrosion rate at pH 5 was lower than at pH 3 because the protection of the SS and NiTi wire was still present. steady even thirty days later.<sup>9</sup> Formic acid and lactic acid are examples of corrosive agents that can cause corrosion on stainless steel and NiTi wire; however, the effect will be mitigated if the pH of the solution is not high enough to erode the protective layers of Cr<sub>2</sub>O<sub>3</sub> and TiO<sub>2</sub>.<sup>9</sup>

Temperature is another factor that affects the corrosion rate in addition to pH. Because the re-formation of the protective layer (repassivation) on the surface of the SS and NiTi wire is disrupted, the rate of corrosion increases with temperature. sixty Within the range of room temperature and body temperature, temperature has very little effect on the rate of corrosion. The sixty samples used in this investigation were soaked in an incubator set to 37°C, which is the ideal temperature for the oral cavity. Furthermore, it takes little time to change UHT milk at room temperature outside the incubator and doesn't result in drastic temperature fluctuations. Because of this, the temperature variable in this study is controlled and has no bearing on how quickly SS and NiTi wire corrodes.

The variety of corrosion properties found in an alloy with the same chemical composition but produced using different methods can also have an impact on the rate at which corrosion occurs on wires. The microstructure, alloy distribution, and metallurgical characteristics of wire are influenced by a range of manufacturing processes, including heat treatment, aging, and cold working, used by different wire manufacturers. These factors can directly affect the corrosion resistance properties of the wire.<sup>9,28</sup>

Due to its high nutritional content and predicted annual consumption growth due to population growth and lifestyle changes, UHT milk is a food item that is frequently consumed by the general public. The friction of nickel-titanium and stainless steel was not affected by the consumption of UHT milk in this study, indicating that in clinical applications, UHT milk consumption has no appreciable effect on friction

and does not negatively impact the clinical performance of wires in orthodontic treatment.

## CONCLUSION

The investigation's findings support the notion that UHT milk have no effect on the friction between nickel-titanium and stainless-steel wires.

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