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Effect of temperature on tensile force of orthodontics power chain in artificial saliva solution

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Abstract. The objective of this study was to determine the effect of temperature and artificial saliva solution on the tensile force of orthodontic power chains. We studied 56 orthodontic power chain specimens (Ormco, Orange, CA, USA), the closed type, that were stretched at 100% of the initial length (40 mm). Each group was stretched on an acrylic plate immersed in artificial saliva solution and Aqua Dest for 210 minutes. The tensile force was measured using a Correx meter force gauge with units of grams-force (gf) at the initial and final immersion. The temperatures used in this study were 4°C obtained from the refrigerator, 23°C from storage at room temperature, 37°C from storage in an incubator, and 55°C from heating with a hot plate. Our results showed a significantly decreased tensile force ($P < 0.05$) at various immersion temperatures. The effects of the immersion medium (artificial saliva solution and Aquadest) resulted in a significant decline in tensile force at 23°C ($P < 0.05$), but the results at 4°C, 37°C, and 55°C were not significantly different.

1. Introduction

The orthodontic power chain is an elastomer rubber made of polyurethane. It is a long chain with an interconnected hole, and available in various colors. The work mechanism of the power chain is to pull teeth due to its elastic ability. The force given by the elastic is related directly to the amount and the attachment distance of the ring power chain, depending on the orthodontic treatment objective [1].

The advantages of using an elastomer chain are its ease of use, need for little or even no patient cooperation, good biocompatibility, relative hygiene, and low cost. Meanwhile, the disadvantage is that the force produced is irreversible so it must be replaced after some time [2]. This happens due to the many factors that affect it, one of them being oral temperature. Based on previous research, the elastomer chain, like the power chain is highly affected by temperature; as the temperature increases, the force decreases [3].

There is a cultural difference in daily eating and drinking habits. People in South America usually drink cold water when they eat, while those in Europe prefer to drink water at room temperature, and Asian people prefer to drink hot water or tea [4]. Previous research showed that the effect of food temperature during consumption could increase (or decrease) the oral temperature [5]. This would affect the strain force formed by use of the orthodontic power chain, which was studied by Taloumis et al. (1997). Different brands of power chain were tested at room (23°C) and oral (37°C) temperatures. They concluded there was a higher decrease in strain force at the oral temperature [6]. The varied



decrease in the stretching force can complicate the decision of when to replace the power chain to obtain an optimal result [7].

Thus, we attempted to determine the effects of various temperatures produced inside the oral cavity, which can affect the decrease in the orthodontic power chain strain force.

2. Research Method

This laboratory experimental study was conducted at the Dental Materials Laboratory, Faculty of Dentistry, Universitas Indonesia from November to December 2014.

There were 56 continuous-type orthodontic power chain specimens (Generation II, Ormco, USA) (Figure 1) of 20 mm (6 lumen) tested in this study. Stretching was done on an acrylic plate with two rows of stainless steel posts at a distance of 40 mm (100%) from the initial specimen length with seven posts on each row. Two immersion media were used: artificial saliva, manufactured by Fusayama Meyer and Aqua Dest with pH 7. Specimens were divided into eight groups: 4°C, 23°C, 37°C and 55°C artificial saliva, and 4°C, 23°C, 37°C, and 55°C Aqua Dest. Each group consisted of seven specimens.



Figure 1. Orthodontic power chain (Generation II, Ormco, USA)

The specimens were immersed based on the determined temperature, which was 4°C from storage inside the cooling machine, 37°C in the incubator, and 55°C maintained with heating with a hot plate. The immersion time was 210 minutes, assuming food consumption at a stable temperature for five minutes, three times a day, and the power chain was replaced every 14 days.

The tensile force was tested with the Correx meter force gauge before and after immersion. Generally, for the measurement technique, the first power chain lumen tip was placed on an acrylic plate string and the last lumen tip was hooked onto the hook arm of the Correx meter. Continuous stretching was performed until the determined distance of 40 mm or 100% of the initial length and the indicator needle on the dial in the “gram/pond” section indicated the gram-force unit (gf) of the measured unit force. The initially unstretched power chain was measured after the immersion and then after the stretching test to the determined distance (4 mm). After that, the measurement was applied to a determined formula to obtain the mean score of the decrease in power chain tensile strength:

$$\% \text{ Decrease in tensile force} = \frac{\text{The difference of initial force and final force}}{\text{initial force}} \times 100$$

Then, the resulting data were collected and statistical analysis was done using the SPSS 17.0 program (SPSS, Inc., Chicago, IL, USA). The data were presented as mean and standard deviation for

each group. Then, the data were analyzed to check for a normal distribution. One-way analysis of variance (ANOVA) was done to determine the difference in decrease in power chain tensile force due to temperature effect and immersion media, followed by a post hoc Tukey analysis to identify intragroup variables due to the effect of temperature and immersion media.

3. Result

The power chain was measured before and after immersion at various temperatures of 4°C, 23°C, 37°C, and 55°C. The immersion solutions used were artificial saliva and Aqua Dest. On broad outline, deformation occurred in every specimen in the form of elongation from the initial state and decrease in tensile force. The mean percentage power chain tensile force in each treatment groups is noted in Tables 1.

Table 1. Reduction in power chain tensile force after immersion at various temperatures.

Immersion medium	Immersion temperature (°C)	Tensile force		Force reduction (%)
		Before immersion (gf)	After immersion (gf)	
Artificial saliva	4 ± 2	382.86 ± 4.88	357.14 ± 4.88	6.71 ± 1.35
	23 ± 2	384.29 ± 5.34	342.86 ± 4.88	10.77 ± 1.69
	37 ± 2	381.43 ± 6.90	311.43 ± 6.90	18.35 ± 1.40
	55 ± 2	378.57 ± 6.90	240.00 ± 5.77	36.61 ± 0.85
Aquadest	4 ± 2	384.29 ± 5.34	358.57 ± 6.90	6.69 ± 1.38
	23 ± 2	372.86 ± 4.88	317.14 ± 4.88	14.94 ± 1.34
	37 ± 2	378.57 ± 3.78	304.29 ± 9.76	19.64 ± 2.15
	55 ± 2	378.57 ± 3.78	231.43 ± 6.90	38.87 ± 1.86

Table 1 shows the lowest decrease in the power chain tensile force occurred in the 4°C treatment group, and the highest occurred in the 55°C treatment group in both immersion media. Based on the data homogeneity test, the data variation was homogeneous. Therefore, next, analysis was done with the one-way ANOVA, which showed a significant difference ($P < 0.05$) within the temperature treatment groups using the artificial saliva solution. Table 2 shows the results of the post hoc Tukey analysis to compare the power strain tensile force decrease after the temperature treatments in artificial saliva. Based on the post hoc Tukey analysis, the decreasing in the power chain tensile force in all the temperature treatment groups with the artificial saliva solution was significantly different ($P < 0.05$).

Table 2. Result of the post hoc Tukey test in the decrease in the power chain tensile force with artificial saliva at various immersion temperatures.

Temperature (°C)	Artificial saliva			
	4	23	37	55
4		*	*	*
23	*		*	*
37	*	*		*
55	*	*	*	

*($P < 0.05$)

The one-way ANOVA showed a significantly different result ($P < 0.05$) between the immersion media groups at the same temperature. Table 3 shows results from the post hoc Tukey analysis to compare the decreasing tensile forces after immersion in media at various temperatures. The decrease in the power chain tensile force in the artificial saliva and Aqua Dest immersion media was significantly different ($P < 0.05$) only in the 23°C temperature group, while the differences were insignificant in the other temperature groups (4°C, 37°C, and 55°C).

Table 3. Post hoc Tukey analysis of the decreasing power chain tensile force in artificial saliva and Aqua Dest at various immersion temperatures.

		Artificial saliva			
		4	23	37	55
Aqua Dest	4				
	23		*		
	37				
	55				

*($P < 0.05$)

** $P > 0.05$

4. Discussion

The results showed the power chain with an initial tensile force of 381.8 ± 28.2 gf in the artificial saliva solution at different temperatures produced a varied decrease in the tensile force. The final tensile force produced at 4°C, 23°C, 37°C, and 55°C was 357.14 ± 4.88 , 342.86 ± 4.88 , 311.43 ± 6.90 , and 240.00 ± 5.77 gf, respectively, with decreasing tensile strengths of 6.8%, 10.8%, 18.3%, and 36.6%, respectively. The decrease in the tensile strength after treatment was statistically significant ($P < 0.05$).

Stretching of the power chain at certain distances and times causes a decrease in the initial tensile strength. This is because the stretched power chain undergoes shifting and elongation of the component structural bond. The shifting of the structural bond causes a slow and permanent change. Meanwhile, the elongation of the structural bond causes the fast and impermanent change. Both properties cause the power chain to have a stable force, but during a certain time span, the power chain will experience decreasing force and permanent deformation [8]. This is supported by another study by Syaukani in 2011 showing that the largest decrease in several brands of the power chain occurred within the first 24 hours, after which the force would decrease a little bit constantly [9].

The decrease in the power chain tensile strength is affected by temperature, which was proved by the significantly different result ($P < 0.05$) within the groups at different temperature treatments. The lowest decrease in tensile strength occurred in the 4°C temperature group, and the largest decrease occurred in the highest (55°C) temperature group. In 1997, Taloumis et al. stated the decrease in elastomer tensile strength is affected by temperature (53% vs. 68%) in the first 24 hours [6]. In addition, in 1998, Natrass stated the elastomer chain is affected by temperature, so that tensile strength decreases as the temperature increases [3].

The orthodontic power chain is a thermoplastic polymer that is made of polyurethane. The thermoplastic polymer will soften if heated (and finally melt). On the other hand, it will harden when cooled. On a molecular level, when the temperature increases, the secondary bond strength will decrease (with increasing molecule movement) so chain movement, which is relatively near, will be facilitated. This is shown by our result that the higher the temperature received by the power chain, the greater the decreasing force.

In our study, the immersion of the power chain in Aqua Dest at different temperatures produced decrease varied tensile force. The final tensile force produced at temperatures of 4°C, 23°C, 37°C, and 55°C was 358.57 ± 6.90 , 317.14 ± 4.88 , 304.29 ± 9.76 , and 231.43 ± 6.90 gf, respectively, with a decrease in the tensile strength of 6.7%, 14.9%, 19.6%, and 38.9%, respectively. The tensile strength decrease between treatment groups in Aqua Dest was statistically significantly different ($P < 0.05$).

Descriptively, Figure 1 shows that the tensile force after immersion in artificial saliva was not greatly decreased compared to that after immersion in Aqua Dest. However, in the post hoc Tukey analysis, only the 23°C temperature showed a significantly different result ($P < 0.05$) between the artificial saliva and Aqua Dest groups. Meanwhile, the results of testing at other temperatures (4°C, 37°C, 55°C) were not significantly different. This can be due to the withdrawal process of ion H^+ , which has a positive charge from water molecules into the polymer molecule, so that the elastomer chain becomes larger. This causes further the interstructural polymer to be inserted by the water molecule [7]. Thus, the effect of artificial saliva in the decrease in orthodontic power chain tensile force is more likely caused by the temperature rather than the mineral content inside the artificial saliva.

5. Conclusion

The immersion temperature affects the decrease in the orthodontic power chain tensile force. The tensile strength affected by the immersion of the orthodontic power chain in artificial saliva was statistically different compared to that after immersion in Aqua Dest at a temperature of 23°C. However, the differences after immersion at temperatures of 4°C, 37°C, and 55°C were not statistically significant.

6. References

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