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Effect of three common hot beverages on the force decay of orthodontic elastomeric chain within a 28-day period: An *in vitro* study

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Objective: This study aimed to assess the effects of commonly consumed hot drinks on the force decay of orthodontic elastomeric chains. **Methods:** This *in vitro* experimental study evaluated 375 pieces of elastomeric chains with six rings placed on a jig. Four rings were stretched by 23.5 mm corresponding to the approximate distance between the canine and the second premolar. Fifteen pieces served as reference samples at time zero, and 360 pieces were randomized into four groups: control, hot water, hot tea, and hot coffee. Each group was further divided into six subgroups (n = 15) according to the different exposure periods. The specimens in the experimental groups were exposed to the respective solutions at 65.5°C four times per day for 90 seconds at 5-second intervals. The control group was exposed to artificial saliva at 37°C. The force decay of the samples was measured at 1, 2, 7, 14, 21, and 28 days using a universal testing machine. Data were analyzed using repeated-measures analysis of variance. **Results:** Maximum force decay occurred on day 1 in all groups. The minimum force was recorded in the control group, followed by the tea, coffee, and hot water groups on day 1. At the other time points, the minimum force was observed in the tea group, followed by the control, coffee, and hot water groups. **Conclusions:** Patients can consume hot drinks without concern about any adverse effect on force decay of the orthodontic elastomeric chains.

Key words: Elastomeric chain, Force decay, Hot beverages, Orthodontics

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INTRODUCTION

Many orthodontic patients require space closure, and several tools, including closing loops, coil springs, elastics, and elastomeric chains, are available for this purpose. Elastomeric chains have been used in orthodontic treatment since 1960. These amorphous polyurethane polymers have extensively replaced latex elastics for orthodontic tooth movement.[1-3] Elastomeric chains are user-friendly, time-saving, versatile, and are available in various colors and lengths. These are widely used for different types of tooth movements, such as space closure and correction of dental midline deviation, rotation, retraction, and protraction.[4-6] Short chair time, minimal patient cooperation, optimal biocompatibility, ease of use, high flexibility, and low cost are among the advantages of orthodontic elastomeric chains. However, they also have shortcomings, such as the enhancement of biofilm retention and subsequent enamel demineralization, dental caries, and gingival inflammation.[7,8]

Force decay is an important undesirable property of elastomeric chains, which indicates the need for their replacement, necessitating dental visits.[9] Knowledge of force decay and appropriate time for replacement of elastomeric chains is imperative, considering the preference of light continuous forces in orthodontics due to biological and mechanical considerations. However, predicting the force decay and stability of elastomeric chains is difficult.[3] Evidence shows that elastomeric chains naturally experience force decay because of their viscoelastic properties, wherein a considerably high force decay occurs on the first day after the placement of the elastomeric chains. Factors, such as time, color, the structure of the chain (closed/open), prestretching, the magnitude of stretching, oral environment, saliva, enzymes, pH alterations, exposure to different agents, foods, or mouthwashes, and physical activities, such as mastication and tooth brushing, can affect the force decay of elastomeric chains.[5,10-16] Ideally, reduction of the chain force should occur gradually over time, causing greater tooth movement and decreasing the required frequency of dental visits.

Thermal stress is another factor to consider with respect to its effects on elastomeric chains. The consumption of tea and coffee is highly popular in many countries worldwide, and some patients frequently consume these as hot drinks daily. These thermal stresses may affect force degradation of orthodontic elastomeric chains.[17,18] A previous study reported that elastomeric chains subjected to thermal cycles experienced force decay less than chains stored at 37°C.[1]

Evidence has shown that materials with different chemical compositions have different effects on the force degradation of orthodontic elastomeric chains.[5,9,13] Accordingly, different drinks may have different effects on the force decay of the chains. Thus, if a particular food or drink adversely affects the force decay of elastomeric chains, clinicians may need to request patients to limit their consumption, especially in the first few days after the activation of the chains. Therefore, this study aimed to assess the effect of commonly consumed hot drinks on the force decay of orthodontic elastomeric chains.

MATERIALS AND METHODS

This *in vitro*, experimental study evaluated 375 pieces of silver closed elastomeric chains with six rings (American Orthodontics, Sheboygan, WI, USA). Twenty-four Teflon jigs containing 15 pairs of stainless-steel rods were also used. Each rod was placed 23.5 mm from its corresponding rod to simulate the approximate distance between the canine and second premolars in patients with extracted first premolars. Each pair of rods was placed 5–7 mm from the adjacent pair (Figure 1). The terminal rings of the chains were free, and the chains were stretched by 23.5 mm from the second to the fifth rings. Fifteen specimens were placed in each jig. All chains were prestretched to twice their length prior to placement on the jig. Of the 375 specimens, 15 were used as reference samples (before exposure and at time zero) and 360 were randomly divided into the following groups:

Group 1: exposure to 65.5°C (150°F) hot water
Group 2: exposure to 65.5°C (150°F) hot tea
Group 3: exposure to 65.5°C (150°F) hot coffee
Group 4 (control): exposure to artificial saliva at 37°C

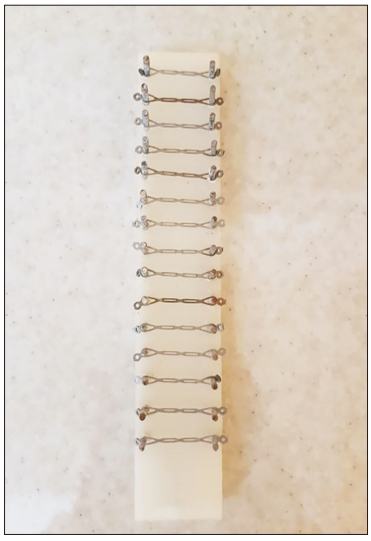

Figure 1. The jig holding 15 pieces of stretched chains.

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All specimens were stored in artificial saliva at 37°C in an incubator (Memmert GmbH, Schwabach, Germany). The artificial saliva was composed of 1.5 mM $CaCl_2$, 0.9 mM NaH_2PO_4, and 0.15 M KCl, at a pH of 7.

Groups 1 to 3 were exposed to the respective hot drinks four times a day, each time for 90 seconds at 5-second intervals, to simulate thermal stresses applied to the elastomeric chains when drinking tea, coffee, or hot water. The temperature of the drinks was regularly checked using a thermometer. The artificial saliva was refreshed twice a week.

Each group was then randomized into six subgroups (n = 15) for exposure times measured at 1, 2, 7, 14, 21, and 28 days. The remaining 15 pieces served as the pre-exposure reference samples at time zero. After completion of the respective exposure periods, the forces of all specimens were measured using a universal testing machine (Zwickroell, Ulm, Germany).

Changes in the force magnitude of the chains were analyzed and compared using repeated-measures analysis of variance (ANOVA) using the PASS software (NCSS LLC, Kaysville, UT, USA), considering the type of drink as a between-subject factor. Statistical significance was set at $P < 0.05$. Tukey HSD post hoc test was used for pairwise comparison.

The study was approved by the ethical committee of the Tehran University of Medical Sciences (no. IR.TUMS.DENTISTRY.REC.1399.125). The informed consent was waived.

Table 1. Amount of force (N) recorded in the four groups at different time points (n = 15) and pairwise comparisons of the groups at each time point

Day	Group	Mean force (N)	Force decay (N)	Force decay (%)	Standard deviation (N)	% at time 0	Tea	Coffee	Hot water
1	Control	0.92	4.81	83.92	0.09	16.07	0.01*	< 0.001***	< 0.001***
	Tea	1.04	4.69	81.88	0.10	18.11		0.39	< 0.001***
	Coffee	1.09	4.64	80.97	0.09	19.02			< 0.001***
	Hot water	1.29	4.44	77.43	0.08	22.56			
2	Control	0.90	4.83	84.25	0.06	15.74	0.19	0.82	0.05
	Tea	0.85	4.88	85.11	0.05	14.88		0.03*	< 0.001***
	Coffee	0.92	4.81	83.87	0.08	16.12			0.31
	Hot water	0.97	4.76	83.13	0.07	16.86			
7	Control	0.90	4.83	84.38	0.09	15.61	0.46	> 0.999	0.69
	Tea	0.84	4.89	85.32	0.09	14.67		0.37	0.06
	Coffee	0.90	4.83	84.27	0.12	15.72			0.78
	Hot water	0.94	4.79	83.66	0.10	16.32			
14	Control	0.85	4.88	85.08	0.08	14.91	0.88	0.89	0.19
	Tea	0.84	4.89	85.42	0.08	14.57		0.47	0.04*
	Coffee	0.87	4.86	84.76	0.07	15.23			0.56
	Hot water	0.91	4.82	84.17	0.06	15.82			
21	Control	0.80	4.93	86.02	0.06	13.97	0.79	0.76	0.24
	Tea	0.78	4.95	86.40	0.07	13.59		0.24	0.03*
	Coffee	0.82	4.91	85.61	0.06	14.38			0.79
	Hot water	0.85	4.88	85.22	0.06	14.77			
28	Control	0.80	4.93	86.12	0.03	13.87	0.18	0.45	0.04*
	Tea	0.77	4.96	86.54	0.03	13.45		< 0.01**	< 0.001***
	Coffee	0.81	4.92	85.82	0.03	14.17			0.59
	Hot water	0.83	4.90	85.56	0.04	14.43			

Tukey HSD Post Hoc.
% at time 0, mean force at each time point × 100/initial force value (5.73).
*$P < 0.05$, **$P < 0.01$, and ***$P < 0.001$.

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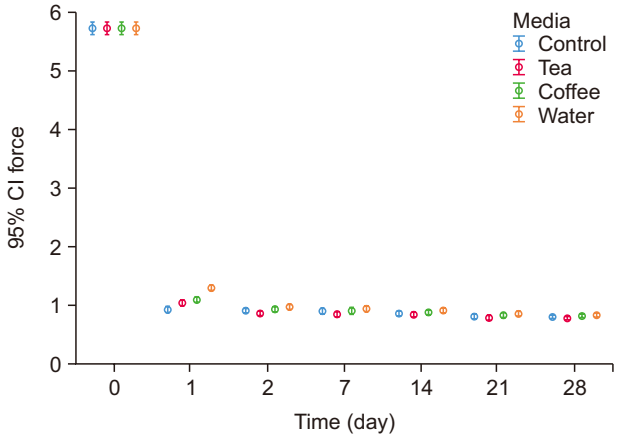

Figure 2. Mean force (N) in the study groups at different time points.
CI, confidence interval.

RESULTS

The mean initial force value at T0 was 5.73 ± 0.20 N. Table 1 and Figure 2 present the mean force values in the four groups at other time points. The results showed significant effects of time and type of drink and their interaction on force decay ($P < 0.001$). ANOVA showed that at all time points, except on day 7 ($P = 0.092$), a significant difference was noted in the force decay of elastomeric chains exposed to the different drinks ($P < 0.05$).

The largest amount of differential force decay occurred on day 1 (4.65 N, 81.06%). The averaged force decay (%) of four groups on days 2, 7, 14, 21, and 28 was 84.09%, 84.41%, 84.86%, 85.81%, and 86.01%, respectively.

Table 2 presents pairwise comparisons of the groups at different time points. On day 1, the order of the mean force from the largest to the smallest was as follows: hot water (1.29 ± 0.08 N), coffee (1.09 ± 0.09 N), tea (1.04 ± 0.10 N), and control (0.92 ± 0.09 N). The control and hot water groups exhibited significant differences from the other groups ($P < 0.05$). The tea and coffee groups were not significantly different ($P = 0.39$). From day 2 to the end of the study period, the order of the mean force from the largest to the smallest was as follows: hot water, coffee, control, and tea. On day 2, the force in the tea group was significantly lower than that in the coffee and hot water groups ($P < 0.05$). The control group showed no significant differences from the other groups ($P > 0.05$). The hot water and coffee groups were not significantly different either ($P > 0.05$). On day 7, no significant differences were observed between groups. On days 14 and 21, only the difference between the tea and hot water groups was significant, such that the mean force was significantly lower in the tea group ($P < 0.05$). On day 28, the tea group had a significantly lower force than the coffee and hot water groups, and the control group had a significantly lower force than

Table 2. Pairwise comparisons of the *P* value of the groups at different time points

Day	Group		*P* value
1	Control	Tea	0.01*
		Coffee	< 0.001***
		Hot water	< 0.001***
	Tea	Hot water	< 0.001***
		Coffee	0.39
	Coffee	Hot water	< 0.001***
2	Control	Tea	0.19
		Coffee	0.82
		Hot water	0.05
	Tea	Hot water	< 0.001***
		Coffee	0.03*
	Coffee	Hot water	0.31
7	Control	Tea	0.46
		Coffee	> 0.999
		Hot water	0.69
	Tea	Hot water	0.06
		Coffee	0.37
	Coffee	Hot water	0.78
14	Control	Tea	0.88
		Coffee	0.89
		Hot water	0.19
	Tea	Hot water	0.04*
		Coffee	0.47
	Coffee	Hot water	0.56
21	Control	Tea	0.79
		Coffee	0.76
		Hot water	0.24
	Tea	Hot water	0.03*
		Coffee	0.24
	Coffee	Hot water	0.79
28	Control	Tea	0.18
		Coffee	0.45
		Hot water	0.04*
	Tea	Hot water	< 0.001***
		Coffee	< 0.01**
	Coffee	Hot water	0.59

Tukey HSD Post Hoc.
*$P < 0.05$, **$P < 0.01$, and ***$P < 0.001$.

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Table 3. Comparison of the *P* value of the mean force decay of elastomeric chains in each group at different time points

Day		Type of beverage			
		Control	Tea	Coffee	Hot water
1	2	> 0.999	< 0.001***	0.001**	< 0.001***
	7	0.99	< 0.001***	< 0.001***	< 0.001***
	14	0.53	< 0.001***	< 0.001***	< 0.001***
	21	0.02*	< 0.001***	< 0.001***	< 0.001***
	28	0.01*	< 0.001***	< 0.001***	< 0.001***
2	7	> 0.999	> 0.999	1.00	0.98
	14	0.84	1.00	0.85	0.65
	21	0.09	0.41	0.15	0.02*
	28	0.06	0.29	0.07	< 0.01**
7	14	0.92	> 0.999	0.99	0.99
	21	0.14	0.62	0.43	0.18
	28	0.10	0.48	0.26	0.05
14	21	0.76	0.73	0.87	0.63
	28	0.66	0.59	0.70	0.30
21	28	> 0.999	> 0.999	> 0.999	> 0.999

Tukey HSD Post Hoc.
Mean force decay, initial force value-force value at each time point.
*$P < 0.05$, ** $P < 0.01$, and ***$P < 0.001$.

the hot water group ($P < 0.05$).

Table 3 compares the force decays at different time points within each group. In all groups, the force gradually decreased from day 0 to 28, and the maximum force decay occurred on day 1.

In the artificial saliva group, the force on day 0 was significantly higher than that at all other time points ($P < 0.05$). Additionally, in the artificial saliva group, the force on day 1 was significantly greater than that on days 21 and 28 ($P < 0.05$). No other significant differences were observed within the artificial saliva group with respect to time ($P > 0.05$).

In the tea and coffee groups, the force on day 0 was significantly higher than those at the other time points ($P < 0.05$). In addition, the force on day 1 was significantly higher than that at the other time points ($P < 0.05$). No significant differences were noted at the other time points ($P > 0.05$).

In the hot water group, the force was significantly higher on day 0 than at the other time points ($P < 0.05$). Furthermore, the force on day 1 was significantly greater than those at the other time points ($P < 0.05$). The force on day 2 was significantly lower than that on days 0 and 1 and significantly higher than those on days 21 and 28 ($P < 0.05$). No other significant differences in force decay of other time points were observed in the hot water group ($P > 0.05$).

DISCUSSION

Force decay is one of the most unfavorable properties of orthodontic elastomeric chains. There are concerns regarding the effect of frequent consumption of hot drinks on the force decay of elastomeric chains. Therefore, this study assessed the effect of commonly consumed hot drinks on the force decay of elastomeric chains.

The present study confirmed the significant effects of temperature and type of drink on the force degradation of elastomeric chains. Considering the impact of heat on most physical and chemical reactions, its effect on the force decay of the chains was in close accordance with expectations. Evidence has shown that different mouthwashes have different effects on the force decay of chains owing to their different compositions; this was also true for different drinks. Therefore, the differences in force decay caused by the different drinks may be attributed to the different ingredients in tea and coffee (caffeine). Differences in the pH of drinks can also affect force decay.

In this study, the effect of hot drinks on the force decay of chains was evaluated over a 28-day period, which was selected because orthodontic visits to replace the chains are often scheduled every 28 days. Nonetheless, the results showed that the majority of the force decay occurred within the first 24 hours (81.06%), which is consistent with the literature. Therefore, the time point of 1 day was clinically more important than the other time points. In addition, it is much more practical and easier to request patients to watch their diet and refrain from the consumption of certain foods or drinks for the first 24 to 48 hours compared with longer periods of time. From the clinical standpoint, a noteworthy issue is that chains are often used several times during the course of orthodontic treatment in order to close the entire space. Thus, the clinical significance of the force decay difference among drinks becomes more prominent when considering the frequency of chain use. According to the results, patients can consume hot drinks during space closure by chains with no concern about possible adverse effects, as they may even have a positive effect. In addition, it would be preferable for patients to drink hot water instead of tea or coffee within the first 24 hours; however, there were no detrimental effects observed when drinking coffee or tea, compared with the control group. Coffee consumption is preferable to tea consumption on day 2, which may be explained by the pH or compositional differences between coffee and tea; however, the effect size is very small and the difference may be clinically irrelevant. One strength

of the present study was the attempt to simulate the consumption of hot drinks in a clinical setting by using 5-second intervals for exposure to drinks instead of immersing the specimens in hot drinks for 30 seconds. The results showed the highest residual force in the hot water group, followed by the coffee, tea, and control groups on day 1. On days 2 to 28, the highest residual force was observed in the hot water group, followed by the coffee, control, and tea groups. Considering the difference in the order of force when comparing day 1 with other time points, the tests were repeated again on day 1 to ensure accuracy, and the same results were obtained.

Several studies have evaluated the elastomeric chain force decay at different time points using various solutions,[1,5,7,9,12-14,17,19,20] commercial brands,[1,11,12,14,19] and temperatures.[1,17,18] Braga et al.[17] evaluated the elastomeric chain force decay following exposure to hot water, green tea, and coffee. In contrast to the present findings, they showed maximum force decay in the first 7 days in the hot water group, whereas the maximum force decay was noted in the tea group in the present study. In addition, they found a significant difference between the groups on day 7, which was not observed in the present findings. These differences may be due to the use of green tea in their study versus black tea in the present study, as well as different methodologies. The samples in that study were immersed in the solutions (twice daily for 30 seconds each), which is different from our methodology. In addition, they did not assess the force decay on day 1 and 28, and they evaluated drinks at 70°C versus 65.5°C in the present study.

Sulaiman et al.[18] evaluated the effects of temperature and artificial saliva on the tensile force of elastomeric chains. The samples were evaluated at 4°C, 23°C, 37°C, and 55°C, by immersing the chains in the solution for 210 minutes. They reported a minimum force decay at 4°C and a maximum reduction at 55°C in both artificial saliva and aquadest groups. Nachan et al.[12] studied the effects of black tea, milk, cola, fluoride mouthwash, and artificial saliva on the force degradation of the Ormco Power Chaib, 3M Unitek Alastik chain, and American Orthodontics of short and long types. The results showed different force degradation rates for different products in different types of solutions. Weissheimer et al.[11] evaluated the force decay of different brands of elastomeric chains: American Orthodontics, Morelli, Ormco, and TP Orthodontics. The force was measured at 1, 3, 5, 7, 9, and 2 hours; and at 7, 14, 21, 28, and 35 days. The results revealed a maximum force decay on day 1, in line with the present findings. Ramachandraiah et al.[14] assessed the effects of mouthwashes (Listerine, Wokadine, 21.6% alcohol, and 8.38% alcohol) on the force decay of 3M Unitek, Ortho Plus, and Ortho Organizer orthodontic chains. In line with the present findings, the maximum force decay was noted on day 1 (39.45–58.35%). In general, the non-prestretched elastomeric chains experienced greater force decay than the prestretched samples did. Based on the results obtained by Ramachandraiah et al.,[14] prestretched chains were used in this study. Brand selection was based on brand availability and reputation.

Despite attempts to simulate the clinical setting as closely as possible, this study used an *in vitro* design that has limitations related to the absence of microbial flora, functional forces, diet, oral habits, and other biological conditions. Therefore, *in vivo* studies and clinical trials are required to obtain reliable results. Further investigations are recommended on the effects of commonly consumed cold drinks, such as milk and fruit juices, on the elastomeric chain force decay.

CONCLUSIONS

Although high variability existed among the different hot drinks at different time points with regard to force decay, the maximum force decay occurred in the first 24 to 48 hours. It appears that after 48 hours, the use or absence of hot drinks did not cause a clinically significant change in the force decay of elastomeric chains. According to the present results, it may not be necessary to refrain from the consumption of hot drinks during space closure by elastomeric chains.

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AUTHOR CONTRIBUTIONS

Conceptualization: SA. Data curation: FS. Formal analysis: MJK. Funding acquisition: SA. Investigation: MN. Methodology: TH. Project administration: AG. Supervision: SA. Writing–original draft: SA. Writing–review & editing: FS.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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