



Comparative evaluation of force decay of elastomeric chains and active tie backs exposed to two different beverages- An *in vitro* study

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Abstract

Objective: To evaluate and compare the force decay of elastomeric chains and active tiebacks immersed in hot tea and in carbonated cold drink over the period of 28 days.

Method: This experimental study was conducted on 60 samples which was further divided into 3 groups containing 10 samples of each elastomeric chains and active tiebacks. This samples were submerged into distilled water (control group) for 24 hours, cold drink ($10^{\circ}\text{C} \pm 1^{\circ}\text{C}$) and hot tea ($70^{\circ}\text{C} \pm 1^{\circ}\text{C}$) for 60 seconds twice a day for total of 28 days. Measurement of force was done on beginning of study, at 24 hours, 7 days, 14 days, 21 days and 28 days, two-way ANOVA with post hoc Bonferroni test was done to compare the force decay of elastomeric chains and active tiebacks among each other in different groups.

Result: Statically significant difference in force decay was found while comparing hot tea group with cold drink group of elastomeric chain as hot tea group showed more overall force decay then cold drink group. However, no statically significant difference in force decay is seen while comparing different groups of active tiebacks. More overall force decay was found in elastomeric group at the end of 28 days then in active tieback group.

Conclusion: The study reveals that elastomeric chains are more susceptible to elevated temperatures, which can accelerate the force decay. In contrast, active tiebacks provide more consistent force retention, regardless of beverage exposure.

Keywords: Force decay, active tieback, elastomeric chain, space closure

Introduction

Orthodontics has developed remarkably over centuries, with advances in materials and methods revolutionizing treatment results. Two of the key instruments in contemporary orthodontics are elastic chains (E-chains) and active tiebacks, which enable accurate tooth movement, particularly in space closure. E-chains and active tie-backs are both commonly used components in orthodontic treatment to help move teeth and align the bite effectively. Though they both serve similar purposes (applying force to move teeth), they differ in their design, function, and specific use in orthodontics. Active tie-backs are designed to provide an active force to help move teeth, particularly when there is a need to move teeth posteriorly (backwards) or correct the bite. They are typically used when more significant forces are needed to affect tooth movement, such as in the treatment of bite issues or to control molar movement.^[1]

Although useful, it is difficult to precisely control the force that elastomeric chains deliver because of such factors as sliding resistance (binding and friction between the bracket and the archwire) and plastic deformation. The evidence indicates that 50% of the force applied can be lost because of these resistances^[2]. Pre-stretching influences force levels, but neither the geometry nor the production process of E-chains does^[3]. Thus, orthodontists must understand these influencing factors to use power chains effectively and ensure appropriate force delivery tailored to each patient's

needs. Studies have been carried out to evaluate force degradation in several conditions related to individual habits and oral cavity, such as the use of alcohol concentration in mouthwashes, and different diet products^[4, 5]. However, the effect of high-temperature on elastomeric chain and active tieback has not been accessed. It is well known that hot beverages are highly appreciated in most of the countries. In this context, it is relevant to investigate if this drinking routine can somehow affect the orthodontic outcome.

According to some authors like David A Balhoff *et al.*^[2] in 2010 conducted a study on elastomeric chains and found out that, the greatest decrease in force delivered by elastomeric chains occurs in the first hour but losses of 33% to 50%¹¹ have been found in the first 24 hours after placement. Other authors like Marc Philipp Dittmer *et al.*^[6] found losses of up to 73% in the same time interval followed by three weeks during which forces delivered were considerably constant. To conduct orthodontic treatments satisfactorily, it is necessary to know the characteristics and properties of orthodontic elastics, as well as to monitor the amount of force delivered at different time intervals.

The primary aim of this study is to evaluate and compare the effect of hot tea and carbonated cold drinks on the force decay of elastomeric chains and active tie backs over a 28-day period. By simulating typical dietary exposures in an orthodontic context, this research will help clarify how these beverages influence the effectiveness of two commonly used orthodontic force delivery methods.

Materials and Method

The study consisted of 3 groups (Distilled water, hot tea and cold drink) which is further divided into 2 sub-groups (e-chain and active tieback) containing 10 samples in each sub groups making total of 60 samples.

Experimental setup

3 Rectangular jigs were prepared to hold the samples and two nails were placed opposite each other on all the slabs, 25 mm apart for the e-chains (3M Unitek, USA) and 27 mm apart for the O rings (3M Unitek, USA). 20 consecutive pins were placed on single rectangular slab and total of 3 slabs were made to hold 60 samples. The e-chains and active tiebacks were arranged such that 10 samples of e-chains and active tiebacks are attached between these pins in one jig. (figure 1). They both were stretched up to 200 grams of initial force which was recorded with the help of force measuring gauge. (figure 2)

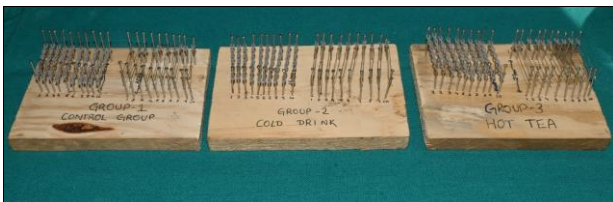


Fig 1: Elastomeric chains and Active tieback are stretched on jigs.



Fig 2: Measuring gauge recording at initial force of 200 grams.

Immersion protocol

All the slabs were kept at a controlled temperature of 37°C ± 1°C in the incubator for 28 days.

- Group 1: The slab was submerged in Distilled water.
- Group 2: The slab was submerged in Hot Tea at a temperature of 70°C ± 1°C (figure 3)



Fig 3: slab submerged in Hot Tea at a temperature of 70°C ± 1°C
Group 3: The slab was submerged in Cold Drink at a temperature of 10°C ± 1°C (figure 4)



Fig 4: slab submerged in Cold Drink at a temperature of 10°C ± 1°C

Group 2 and group 3 were immersed twice a day for 60 seconds at a time. There was a 12-hour interval between immersions to allow the samples to rest and ensure consistent testing conditions.

The force exerted by each sample was measured at the following intervals:

- 24 Hours (Initial Day)
- 7th Day
- 14th Day
- 21st Day
- 28th Day

After each immersion period, the specimens were placed on the digital scale, ensuring they were stretched to the same distance each time (the initial distance of 25mm for e chains or 27mm for O rings).

For each specimen, the force (in grams) required to stretch the e chain or O ring was recorded at each of the time intervals. These measurements helped in assessment of the mechanical behaviour as elasticity or degradation of the materials over time when exposed to the different liquids.

Force was measured in grams with the help of force measuring gauge.

Statistical Analysis

Repeated measures two-way ANOVA was done to compare the force of active tiebacks and elastomeric chains in each group and repeated measures two-way ANOVA with post hoc Bonferroni test was done to compare elastomeric chains among each other in different groups and active tiebacks among each other in different groups.

Results

Comparison of mean force of elastomeric chains among study groups at various time intervals revealed that difference was seen in all 3 groups and there was significant difference between force decay of hot tea compared to cold drink group, whereas there was no significant difference found with control group compare to other groups. Around about 55% of force decay was seen in hot tea group and 50% of force decay was seen in cold drink group at the end of 28 days. (Table 1)

Table 1: Comparative assessment of mean force of elastomeric chains among study groups at various time intervals

Sub Groups	Force (Mean ± SD) (gms)						p value
	Initial	24 hours	7 days	14 days	21 days	28 days	
Control group	200 ± 0.000	144.50 ± 8.31	131.00 ± 8.09	118.00 ± 6.74	105.00 ± 6.23	90.00 ± 6.66	0.000*
Cold drink	200 ± 0.000	144.00 ± 14.29	138.50 ± 8.51	123.50 ± 7.83	108.50 ± 9.44	99.00 ± 7.74	
Hot tea	200 ± 0.000	147.50 ± 10.06	127.00 ± 4.83	110.50 ± 4.37	98.50 ± 4.74	89.00 ± 5.67	
p value	0.003*						

Comparison of mean force of active tie backs among study groups at various time intervals revealed that there is no significant difference in force decay in all the 3 groups.

Around about 40.5% of force decay is seen in all the groups. This can also be seen in the line chart as the lines of each group comes to the same spot at the 28-day mark. (Table 2)

Table 2: Comparative assessment of mean force of active tie backs among study groups at various time intervals

Sub groups	Force (Mean ± SD) (gms)						p value
	Initial	24 hours	7 days	14 days	21 days	28 days	
Control group	200± 0.000	173.50 ± 10.28	162.50 ± 5.89	148.50 ± 9.44	127.50 ± 6.77	117.00 ± 9.18	0.000*
Cold drink	200± 0.000	171.00 ± 11.97	163.50 ± 8.18	152.50 ± 8.89	131.00 ± 8.09	120.00 ± 8.16	
Hot tea	200± 0.000	169.50 ± 6.85	159.50 ± 3.68	148.00 ± 5.37	130.00 ± 7.45	116.00 ± 8.43	
p value	0.904						

Comparison of mean force of elastomeric chains and active tie back among control group at various time intervals showed significant difference in force decay. After 24 hours, the amount of mean force decay of elastomeric

chains was 27.5% of force degradation, compare to active tiebacks which shows force decay of 13.5%. Total amount of force decay seen in elastomeric chain is 55% at the end of 28 days and in active tieback is 41%. (Table 3)

Table 3: Comparative assessment of mean force of elastomeric chains and active tie back among control group at various time intervals

Sub groups	Force (Mean ± SD) (gms)						p value
	Initial	24 hours	7 days	14 days	21 days	28 days	
Elastomeric chains	200 ± 0.000	144.50 ± 8.31	131.00 ± 8.09	118.00 ± 6.74	105.00 ± 6.23	90.00 ± 6.66	0.000*
Activetie backs	200 ± 0.000	173.50 ± 10.28	162.50 ± 5.89	148.50 ± 9.44	127.50 ± 6.77	117.00 ± 9.18	
p value	0.000*						

Comparison of mean force of elastomeric chains and active tie back among cold drink group at various time intervals revealed significant difference in force decay. This time the total force decay at the end of the study period in

elastomeric group was around 100 grams which is 50% of force decay, but in active tieback the total force decay is around 80 grams which is 40% of force decay. (Table 4)

Table 4: Comparative assessment of mean force of elastomeric chains and active tie back among cold drink group at various time intervals

Sub groups	Force (Mean ± SD) (gms)						p value
	Initial	24 hours	7 days	14 days	21 days	28 days	
Elastomeric chains	200 ± 0.000	144.00 ± 14.29	138.50 ± 8.51	123.50 ± 7.83	108.50 ± 9.44	99.00 ± 7.74	0.000*
Active tie backs	200± 0.000	171.00 ± 11.97	163.50 ± 8.18	152.50 ± 8.89	131.00 ± 8.09	120.00 ± 8.16	
p value	0.000*						

Comparison of mean force of elastomeric chains and active tie back among hot tea group at various time intervals showed significant difference in force decay. In this group the total amount of force decay in elastomeric chain was

around 115 grams at the end of our study of 28 days which was 57% whereas the total amount of force decay seen in active tieback was 85 grams at the end which is 42% (table 5)

Table 5: Comparative assessment of mean force of elastomeric chains and active tie back among hot tea group at various time intervals

Sub groups	Force (Mean ± SD) (gms)						p value
	Initial	24 hours	7 days	14 days	21 days	28 days	
Elastomeric chains	200± 0.000	147.50 ± 10.06	127.00 ± 4.83	110.50 ± 4.37	98.50 ± 4.74	89.00 ± 5.67	0.000*
Activetie backs	200 ± 0.000	169.50 ± 6.85	162.50 ± 5.89	148.00 ± 5.37	130.00 ± 7.45	116.00 ± 8.43	
p value	0.000*						

Discussion

Elastomeric chains, which consist of interlinked elastic loops, are extensively employed in orthodontic treatment due to their ease of customization and ability to generate continuous force for tooth movement. However, a well-known limitation of elastomeric chains is their susceptibility to rapid force degradation, particularly under intraoral

conditions such as humidity, temperature fluctuation, and mechanical stress.

To evaluate this force degradation more precisely, the present study utilized custom-fabricated jigs to hold the samples and divided them into three groups: a control group, a cold drink exposure group, and a hot tea exposure group.

Samples were immersed in the respective beverages for one minute every day to simulate real-life exposure, and force measurements were taken at baseline, 24 hours, and at 7, 14, 21, and 28 days.

The findings showed a significant force decay in elastomeric chains across all groups. The control group experienced a 28% force loss within 24 hours, reaching 52% by day 28—findings consistent with Andréa Fonseca *et al.* [7] who reported a 47% decay over a similar time period, thereby validating the reliability of the experimental design. When comparing the thermal groups, elastomeric chains in the hot tea group exhibited the highest force degradation, reaching 55% at 28 days. This aligns with studies by Emanuel Braga *et al.* [8] and Rameez Asif Nachan *et al.* [5], which also demonstrated that elevated temperatures accelerate force decay, likely due to increased molecular mobility and polymer relaxation. Conversely, the cold drink group showed a slightly lower force decay (~50%) over the same period, corroborating findings by Kiran Kumar *et al.* [9], who reported a 40–50% decay under low-temperature conditions. Importantly, no statistically significant difference was found between the cold drink and control groups, suggesting that moderate cold exposure may not exacerbate degradation beyond normal intraoral conditions.

In contrast, active tiebacks demonstrated remarkable thermal stability throughout the study. Regardless of exposure to hot or cold beverages, the average force decay for active tiebacks remained around 41% at 28 days.

This stability may be attributed to their distinct material composition or manufacturing process, which possibly endows them with improved resistance to thermal stress. These results are comparable with the findings of Amir Mohammadi *et al.* [10], who reported a force decay range of 29–63% after four weeks, with the variation likely resulting from differences in material brands or batch properties. Such consistency supports the potential clinical reliability of active tiebacks, especially in cases where predictable long-term force is essential.

Several clinical studies have echoed these findings. For instance, Sanika M. Thakur *et al.* [11], conducted an *in vivo* study over six weeks and found that both elastomeric chains and active tiebacks exhibited similar force decay, suggesting that oral environmental factors—such as saliva enzymes, masticatory forces, and individual patient habits—could contribute to the convergence in force behavior over time. Another study by Tanusha Mahobia *et al.* [12], revealed that while elastomeric chains allowed for faster initial canine retraction, they also underwent higher force degradation than active tiebacks over a four-month period. This highlights a clinical trade-off: although elastomeric chains may be beneficial for quick initial movement, they may not sustain force as consistently over longer durations.

The current study also addressed pH as a potential variable influencing force decay but chose not to control for it, based on existing literature by Amin Khalegh *et al.* [13], AH Mirhashemi *et al.* [14], and Abdelali Halimi *et al.* [15], all of whom concluded that variations in pH had limited impact on the mechanical integrity of elastomeric materials. Therefore, this study focused instead on temperature as a more critical influencing factor.

One of the notable strengths of this study lies in its dual focus—evaluating not just the performance differences between elastomeric chains and active tiebacks, but also the impact of temperature fluctuations, a factor not extensively

explored in existing literature. The controlled laboratory setting allowed for systematic assessment, while comparisons with prior studies validated the methodology and findings. While elastomeric chains continue to be a popular and effective orthodontic tool, their sensitivity to thermal variation could compromise performance in real-world scenarios, especially in patients with high consumption of hot beverages. Active tiebacks, by contrast, offer greater thermal resilience and more predictable force decay patterns, making them a potentially superior choice for long-term space closure treatments. This study adds valuable insight to the limited body of research on active tiebacks and reinforces their clinical utility in environments where thermal exposure is a relevant concern.

However, several limitations must be acknowledged. Being an *in vitro* study, environmental conditions such as salivary flow, bacterial colonization, mastication, and oral hygiene behaviours were not replicated, possibly affecting the external validity of the results. Sample size was another limitation; a larger number of specimens might provide more robust statistical power. Additionally, using only one brand of elastomeric chain and active tieback could limit the generalizability of our findings, as material properties may vary across manufacturers.

Future research should focus on testing different brands and compositions, conducting longer observation periods, and including *in vivo* studies to better approximate clinical conditions. Other variables such as dietary habits, mechanical brushing forces, alcohol consumption, and frequency of temperature exposures should also be considered.

Conclusion

- Elastomeric chains showed significantly greater force decay compared to active tiebacks in all three groups.
- Among elastomeric chains, the highest force degradation occurred in the hot tea group (Group 3), followed by the cold beverage group and the control group.
- Active tiebacks, on the other hand, demonstrated minimal variation in force decay across all temperature conditions, indicating greater stability over time.

These findings suggest that elastomeric chains are more susceptible to environmental influences, particularly elevated temperatures, which accelerate force decay. In contrast, active tiebacks provide more consistent force retention, regardless of beverage exposure. This has important clinical implications, as patients consuming hot beverages frequently may experience diminished orthodontic role in the degradation of elastomeric materials, while active tiebacks remain largely unaffected.

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