Acta Odontologica Turcica
The official journal of Gazi University Faculty of Dentistry

DOI: https://doi.org/10.17214/gaziaot.1238383

Özgün araştırma makalesi

In vitro comparison of force losses over time of orthodontic nickel-titanium closed springs, elastomeric chains, and active tie-backs

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Abstract

Objective: This study aims to compare the force losses of nickel-titanium closed springs, elastomeric chains, and active tie-backs over time in an *in vitro* environment containing artificial saliva.

Materials and methods: In the study, elastomeric chains, nickel-titanium closed springs, and active tie-backs from 3 different brands were divided into 9 groups. The percentages of force loss in the samples over time were compared in the *in vitro* environment containing artificial saliva. Force values were measured and recorded at initial activation, 1st hour, 24th hour, 7th day, 21st day, and 28th day. Statistical analysis of the data were performed with Kolmogorov-Smirnov, Kruskal Wallis, Mann-Whitney U, and Wilcoxon tests. The significance value was considered as $p<0.05$.

Results: The highest and lowest forces at the initial activation hour were measured in elastomeric chains and nickel-titanium closed springs, respectively ($p<0.05$). There was no significant difference between elastomeric chains, nickel-titanium closed springs, and active tie-backs in the measurements performed at the 24th hour ($p>0.05$). Although significant force losses were measured in all groups on the 28th day, active tie-backs lost significantly less force than elastomeric chains, regardless of brand. On the 28th day, the lowest and highest forces were measured in elastomeric chains and nickel-titanium closed springs, respectively ($p<0.05$).

Conclusions: Among the orthodontic space closure mechanics, nickel-titanium closed springs were the most stable; however, active tie-backs produced a more stable force than elastomeric chains, so the type of force element used was the main indicator of the force loss level.

Keywords: **Closed spring ; elastomerics; orthodontics; orthodontic space closure**

Citation: Aydın E, Çiçek O, Özkalaycı N. *In vitro* comparison of force losses over time of orthodontic nickel-titanium closed springs, elastomeric chains, and active tie-backs. Acta Odontol Turc 2024;41(2):67-74

Editor: Nehir Canıgür Bavbek, Gazi Üniversitesi, Ankara, Türkiye

Funding: None declared.

Conflict of Interest: The authors declare no conflict of interest related to this study.

[Abstract in Turkish is at the end of the manuscript]

Introduction

In the early twentieth century, for his contributions to the field of orthodontics, Edward Angle was known as the 'Father of Modern Orthodontics'.[1] Angle was strongly opposed to orthodontic extraction and paid little attention to aesthetics and facial proportions. Tweed re-evaluated the outcomes of his cases and decided that the facial aesthetics and proportions in the cases were not satisfactory. He re-treated these cases with four premolar extractions and found that the outcomes of the extracted cases were far superior when comparing the two modalities. Tweed's work in the 1940s and 1950s revolutionized the field by making extraction acceptable for orthodontic treatment.[1,2]

Extraction orthodontic treatments have grown in popularity to provide a more stable occlusion with aesthetically satisfying outcomes. For years, orthodontists have sought a force system that can close extraction spaces quickly, accurately, and effectively.[3] Two methods—frictional and frictionless mechanics—can be used to open and/or close a space with orthodontic tooth movement.[4] Because

Received: March 18, 2023; Accepted: August 28, 2023
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of its clinical simplicity and predictability—the archwires control the direction of tooth movement—the frictional method is widely used despite the fact that it considerably reduces force.[5] In space closure with frictional mechanics, force elements such as elastomeric chains, nickel-titanium closed coil springs, active tie-backs, or intraoral elastics are typically used.[6]

The force losses in the nickel-titanium closed spring, elastomeric chain, and active tie-back mechanics used in orthodontic space closure over time were evaluated in this study. When the literature is examined, it was seen that Santos *et al.*[7] evaluated the percentage of force loss in *in vitro* exercises comparing elastomeric chains and Ni-Ti closed springs. Angolkar *et al.*[8] compared the force loss percentages of Ni-Ti closed springs and closed springs produced from different materials. Halimi *et al.*[9] compared the percent force loss in different environments of five different brands of elastomeric chains. Oshagh *et al.*[10] compared the force losses of these three materials in different environmental conditions, one from each brand. In the literature, there is no study evaluating the force losses of the materials of these brands, which are used to close orthodontic gaps, after they are kept in artificial saliva. To that end, in this study, the force losses of the materials kept in artificial saliva were compared at the end of the initial, 1st hour, 24th hour, 7th day, 21st day, and 28th day after force activation.

The first null hypothesis of the study is that there is no statistically significant difference in the force applied at the initial activation between the three different force elements. The second null hypothesis of the study is that there is no significant difference in force losses over time between the three different force elements.

Materials and Method

Ethics committee approval was obtained for the study, dated 06/07/2022 and numbered 2022/13, from Non-Invasive Clinical Research Ethics Committee of Zonguldak Bülent Ecevit University.

In the study, elastomeric chains, Ni-Ti closed springs, and active tie-backs from three different brands (Dentaurum, Ispringen, Germany; American Orthodontics, Washington, USA; G&H Wire Company, Franklin, USA) were included. The sample size calculation was performed in the G*Power 3.1.9.7 program. The effect size was calculated by using the means and standard deviations of the groups. The α error probability was set to 0.05. The power of the study (1-α error prob) was set to 0.95. According to these data, the actual power of the study was calculated as more than 95 %, and the total sample size should have been 18. A total of 45 samples were used, divided into 9 groups with 5 samples from each brand (15 for each brand).

Groups:

Group 1; Continuous, transparent, conventional elastomeric chain (American Orthodontics, Washington, USA)

Group 2; 9 mm (millimeter), 0.010/0.030 inch nickel-titanium (Ni-Ti) closed coil spring (American Orthodontics, Washington, USA)

Group 3; Gray elastic ligature with 3 mm loop diameter with 0.10 inch wire for active tie-back (American Orthodontics, Washington, USA)

Group 4; Continuous, transparent, conventional elastomeric chain (Dentaurum, Ispringen, Germany)

Group 5; 9 mm, 0.010/0.030 inch Ni-Ti closed coil spring (Dentaurum, Ispringen, Germany)

Group 6; Gray elastic ligature with 3 mm loop diameter with 0.10 inch wire for active tie-back (Dentaurum, Ispringen, Germany)

Group 7; Continuous, transparent, conventional elastomeric chain (G&H Wire Company, Franklin, USA)

Group 8; 9 mm, 0.010/0.030 inch Ni-Ti closed coil spring (G&H Wire Company, Franklin, USA)

Group 9; Gray elastic ligature with 3 mm loop diameter with 0.10 inch wire for active tie-back (G&H Wire Company, Franklin, USA)

For force application, fixative nails were placed on 3 auto polymerizing pink acrylic (Vertex, Zeist, Netherlands) blocks with the size of 3 cm x 4 cm x 10 cm (centimeter). Nails were placed in two rows on both sides of the base on each acrylic block, with 2 nails parallel to each other and perpendicular to the base, with a total of 30 nails. The inter-nail distance was 25 mm as suggested by Nattrass.[11]

Elastomeric chains, each loop diameter of 3 mm, were cut into nine loops. Two loops at each end of the nine loops were left out of the working range in order to easily measure the force and to eliminate the possibility of tearing the chains. The remaining five loops were determined as working loops to be stretched between opposing nail heads. The elastomeric chains were stretched and placed between two opposing nails until the distance of 12.5 mm from the beginning of the third loop hole to the end of the seventh loop hole reaches 25 mm (doubling) (Figure 1).[10]

Ni-Ti closed springs were selected in 9 mm size and were stretched between the nails with the help of wire ligature until they reached 18 mm and placed between two opposite nails (Figure 1).[10]

The 3 mm diameter of the elastic ligatures used to apply active tie-back was stretched with the help of a wire ligature until it reached 6 mm and placed between two opposing nails (Figure 1).[10]

The artificial saliva used in the study was prepared in 1000 ml (milliliter) of deionized water with the formula of 0.4 g/l (gram/liter) sodium chloride, 0.4 g/l potassium

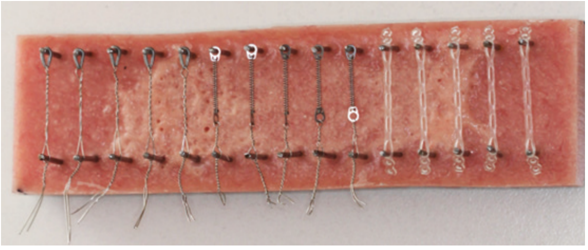

Figure 1. *Placing materials on acrylic block, Black Frame; Active tie-back, Red Frame; Ni-Ti Closed Spring, Yellow Frame; Elastomeric Chain*

Figure 2. *Force gauge (Dentaurum, Correx)*

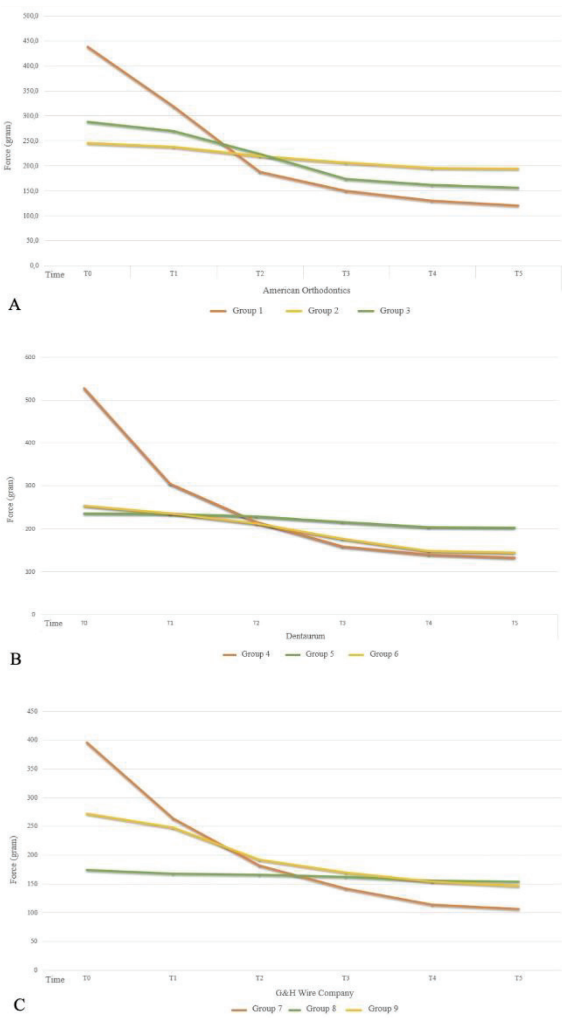

Figure 3. *Force amounts measured over time in American Orthodontics branded groups (A), Force amounts measured over time in Dentaurum branded groups (B), Force amounts measured over time in G&H branded groups (C)*

chloride, 0.8 g/l calcium chloride, 0.78 g/l sodium dihydrogen phosphate, 0.005 g/l sodium sulfite, and 1 g/l urea at a pH of 7.12 In order to simulate the intraoral temperature, the samples were kept in artificial saliva environment and at 37°C in an incubator.

In the study, a manual force gauge (Correx, Dentaurum, Germany) was used to measure force values, which has a measurement range of 0-1000 grams (Figure 2).

Force measurements were performed at initial activation (T0), 1st hour (T1), 24th hour (T2), 7th day (T3), 21st day (T4), and 28th day (T5). Using a force gauge, measurements were performed by stretching the end of the orthodontic material released from the nail on one side to the initial activation position. The measurements were carried out in the same way in all periods by the same researcher (EA), and the values were recorded.

Statistical analysis

Statistical analysis of the data was performed with the IBM SPSS package program (SPSS for Windows, ver 28.0; Chicago, USA). The Kolmogorov-Smirnov test was used for evaluating the normality of data. Kruskal-Wallis and Mann-Whitney U tests were used in the analysis of independent quantitative data, while the Wilcoxon test was used in the analysis of dependent quantitative data. The results were presented in tables and graphs. A value of $p<0.05$ was considered for statistical significance.

Results

Results of force loss percentages measured over time in the groups

The force values of all groups measured over time are shown in Table 1.

In Group 1, the percentages of force loss at the 1st hour, 24th hour, 7th day, 21st day, and 28th day were found to be significantly higher than the initial activation ($p<0.05$). There was no significant difference between the force loss percentages of Group 2 and Group 3 at the 1st hour ($p>0.05$). In Group 2 and 3, the percentages of force loss at the 24th hour, 7th day, 21st day, and 28th day were found to be significantly higher than at initial activation ($p<0.05$) (Table 2 and Figure 3A).

In Group 4 and 6, the percentages of force loss at the 1st hour, 24th hour, 7th day, 21st day, and 28th day were found to be significantly higher than the initial activation ($p<0.05$). In group 5, there was no significant difference in the percentage of force loss measured at the end of the 1st hour and the 24th hour compared to initial activation ($p>0.05$). However, it was seen that the force loss percentages of Group 5 were significantly higher compared to the initial activation when assessed on the 7th, 21st, and 28th days ($p<0.05$) (Table 2 and Figure 3B).

In Group 7, the percentages of force loss at the 1st hour, 24th hour, 7th day, 21st day, and 28th day were found to be significantly higher than the initial activation ($p<0.05$). Force loss percentages of Group 8 and Group 9 at the 1st hour were not significantly different compared to initial activation, ($p>0.05$), but were significantly higher at the 24th hour, 7th day, 21st day, and 28th day ($p<0.05$) (Table 2 and Figure 3C)

Results of forces measured in the groups over time independent of brands

It was found that the forces measured in elastomeric chains at the initial activation and 1st hour were significantly higher than active tie-back and Ni-Ti closed springs ($p<0.05$). The forces measured in active tie-backs at the initial activation and 1st hour were found to be significantly higher than Ni-Ti closed springs ($p<0.05$). The amounts of force measured in the elastomeric chain groups on the 7th day, 21st day and 28th day were found to be significantly lower than the active tie-back and Ni-Ti closed spring groups ($p<0.05$). The 7th day, 21st day and 28th day measurements of active tie-back groups were found to be significantly lower than Ni-Ti closed spring groups ($p<0.05$). There was no significant difference between the force measurements of elastomeric chains, Ni-Ti closed springs, and active tie-backs at 24th hour ($p>0.05$). Results are given in Table 3.

Table 1. *Force values of all groups according to time*

Brands	American Orthodontics			Dentaurum			G&H		
Groups	**Group 1**	**Group 2**	**Group 3**	**Group 4**	**Group 5**	**Group 6**	**Group 7**	**Group 8**	**Group 9**
T0 (Mean ±SD)	438.0 ± 22.8	246.0 ± 11.4	288.0 ± 11.0	528.0 ± 22.8	236.0 ± 5.5	254.0 ± 8.9	396.0 ± 11.4	174.0 ± 5.5	272.0 ± 11.0
T1 (Mean±SD)	318.0 ± 17.9	238.0 ± 4.5	270.0 ± 7.1	304.0 ± 16.7	234.0 ± 5.5	236.0 ± 5.5	264.0 ± 5.5	168.0 ± 8.4	248.0 ± 11.0
T2 (Mean±SD)	188.0 ± 13.0	220.0 ± 7.1	224.0 ± 15.2	216.0 ± 16.7	228.0 ± 8.4	212.0 ± 8.4	182.0 ± 8.4	166.0 ± 5.5	192.0 ± 13.0
T3 (Mean±SD)	150.0 ± 7.1	206.0 ± 5.5	174.0 ± 11.4	158.0 ± 8.4	216.0 ± 11.4	176.0 ± 5.5	142.0 ± 8.4	162.0 ± 4.5	170.0 ± 7.1
T4 (Mean±SD)	130.0 ± 7.1	196.0 ± 5.5	162.0 ± 8.4	140.0 ± 10.0	204.0 ± 5.5	148.0 ± 8.4	114.0 ± 8.9	156.0 ± 5.5	154.0 ± 8.9
T5 (Mean±SD)	120.0 ± 7.1	194.0 ± 5.5	156.0 ± 5.5	132.0 ± 13.0	202.0 ± 4.5	144.0 ± 5.5	106.0 ± 11.4	154.0 ± 5.5	146.0 ± 5.5

For American Orthodontics groups: Group 1; Elastomeric chain, Group 2; Ni-Ti closed spring, Group 3; Active tie-back
For Dentaurum groups: Group 4; Elastomeric chain, Group 5: Ni-Ti closed spring; Group 6: Active tie-back
For G&H groups: Group 7; Elastomeric chain, Group 8; Ni-Ti closed spring, Group 9; Active tie-back
T0; Initial activation, T1; 1st hour, T2; 24th hour, T3; 7th day, T4; 21st day, T; 28th day, SD; Standard Deviation

Table 2. *Statistical results of force loss percentages over time of the all groups*

Brands	American Orthodontics			Dentaurum			G&H		
Groups	**Group 1**	**Group 2**	**Group 3**	**Group 4**	**Group 5**	**Group 6**	**Group 7**	**Group 8**	**Group 9**
T0-T1 (Mean±SD)	0.27 ± 0.07	0.03 ± 0.03	0.06 ± 0.05	0.42 ± 0.04	0.01 ± 0.02	0.07 ± 0.02	0.33 ± 0.02	0.03 ± 0.03	0.09 ± 0.06
p	**0.043***	0.102	0.066	**0.042***	0.317	**0.034***	**0.039***	0.083	0.063
T0-T2 (Mean±SD)	0.57 ± 0.03	0.10 ± 0.03	0.22 ± 0.06	0.59 ± 0.04	0.03 ± 0.03	0.17 ± 0.03	0.54 ± 0.03	0.05 ± 0.03	0.29 ± 0.05
p	**0.042***	**0.039***	**0.042***	**0.042***	0.102	**0.041***	**0.041***	**0.046***	**0.043***
T0-T3 (Mean±SD)	0.66 ± 0.03	0.16 ± 0.04	0.40 ± 0.04	0.70 ± 0.02	0.08 ± 0.04	0.31 ± 0.02	0.64 ± 0.02	0.07 ± 0.02	0.37 ± 0.02
p	**0.039***	**0.041***	**0.042***	**0.042***	**0.041***	**0.041***	**0.041***	**0.034***	**0.041***
T0-T4 (Mean±SD)	0.70 ± 0.03	0.20 ± 0.04	0.44 ± 0.04	0.73 ± 0.02	0.14 ± 0.03	0.42 ± 0.03	0.71 ± 0.02	0.10 ± 0.05	0.43 ± 0.05
p	**0.043***	**0.041***	**0.042***	**0.039***	**0.041***	**0.039***	**0.042***	**0.041***	**0.042***
T0-T5 (Mean±SD)	0.73 ± 0.02	0.21 ± 0.05	0.46 ± 0.03	0.75 ± 0.03	0.14 ± 0.02	0.43 ± 0.03	0.73 ± 0.03	0.11 ± 0.05	0.46 ± 0.03
p	**0.042***	**0.042***	**0.042***	**0.042***	**0.038***	**0.041***	**0.039***	**0.041***	**0.042***

For American Orthodontics groups: Group 1; Elastomeric chain, Group 2; Ni-Ti closed spring, Group 3; Active tie-back
For Dentaurum groups: Group 4; Elastomeric chain, Group 5: Ni-Ti closed spring; Group 6: Active tie-back
For G&H groups: Group 7; Elastomeric chain, Group 8; Ni-Ti closed spring, Group 9; Active tie-back
*T0; Initial activation, T1; 1st hour, T2; 24th hour, T3; 7th day, T4; 21st day, T; 28th day, SD; Standard Deviation, p; significance level, *; p<0.05(Wilcoxon)*

The force losses of the elastomeric chain, active tie-back, and Ni-Ti closed spring groups at the 1st hour, 24th hour, 7th day, 21st day, and 28th day showed a significant increase compared to the initial activation ($p<0.05$) (Table 4).

The amount of force loss in the 1st hour, 24th hour, 7th day, 21st day, and 28th day measurements of the elastomeric chain group was found to be significantly higher than the active tie-back and Ni-Ti closed spring groups ($p<0.05$). The amount of force loss in the st hour, 24th hour, 7th day, 21st day, and 28th day measurements of the active tie-back group was found to be significantly higher than the Ni-Ti closed spring group ($p<0.05$) (Table 4 and Figure 4).

Discussion

In our study, the percentages of force loss over time in the tested materials were found to be statistically significant between the groups. However, although the forces measured in this study at initial were significantly higher in elastomeric chains than in active tie-backs and Ni-Ti closed springs, there was no significant difference at 24th hour between elastomeric chains, Ni-Ti closed springs, and active tie-backs. The result obtained means that the forces of the three materials are close to each other at the end of the 24th hour, indicating that the greatest loss of force is experienced in the chains where a much higher initial force is measured.

Table 3. *Statistical results of forces measured in the groups over time independent of brands*

		Elastomeric Chain[1]	Active Tie-back[2]	Ni-Ti Closed Spring[3]	p
T0	Mean±SD	454.0 ± 59.9	271.3 ± 17.3	218.7 ± 33.8	**0.000***
	Median	440[2,3]	280[3]	230	
T1	Mean±SD	295.3 ± 27.2	251.3 ± 16.4	213.3 ± 33.7	**0.000***
	Median	300[2,3]	240[3]	230	
T2	Mean±SD	195.3 ± 19.6	209.3 ± 17.9	204.7 ± 29.2	0.203
	Median	190	210	220	
T3	Mean±SD	150.0 ± 10.0	173.3 ± 8.2	194.7 ± 25.3	**0.000***
	Median	150[2,3]	170[3]	200	
T4	Mean±SD	128 ± 13.7	154.7 ± 9.9	185.3 ± 22.3	**0.000***
	Median	130[2,3]	160[3]	200	
T5	Mean±SD	119 ± 14.9	148.7 ± 7.4	183.3 ± 22.3	**0.000***
	Median	120[2,3]	150[3]	190	

*T0; Initial activation, T1; 1st hour, T2; 24th hour, T3; 7th day, T4; 21st day, T5; 28th day, SD; Standard Deviation, p; significance level, *; p<0.05 (Kruskal-Wallis), 1,2,3;Numerical notation of those with significantly difference*

Table 4. *Statistical results of the materials' percentages of force loss independent of brands*

	Elastomeric Chain[1]	Active Tie-Back[2]	Ni-Ti Closed Spring[3]	p
T0-T1				
Mean±SD	0.34 ± 0.08	0.07 ± 0.05	0.02 ± 0.03	**0.000*,K**
Median	0.33[2,3]	0.07[3]	0.00	
p	**0.001*,w**	**0.001*,w**	**0.011*,w**	
T0-T2				
Mean±SD	0.57 ± 0.04	0.23 ± 0.07	0.06 ± 0.04	**0.000*,K**
Median	0.56[2,3]	0.21[3]	0.06	
p	**0.001*,w**	**0.001*,w**	**0.002*,w**	
T0-T3				
Mean±SD	0.67 ± 0.03	0.36 ± 0.05	0.10 ± 0.05	**0.000*,K**
Median	0.65[2,3]	0.35[3]	0.09	
p	**0.001*,w**	**0.001*,w**	**0.001*,w**	
T0-T4				
Mean±SD	0.72 ± 0.03	0.43 ± 0.04	0.15 ± 0.06	**0.000*,K**
Median	0.71[2,3]	0.42[3]	0.13	
p	**0.001*,w**	**0.001*,w**	**0.001*,w**	
T0-T5				
Mean±SD	0.74 ± 0.03	0.45 ± 0.03	0.16 ± 0.06	**0.000*,K**
Median	0.73[2,3]	0.46[3]	0.17	
p	**0.001*,w**	**0.001*,w**	**0.001*,w**	

*T0; Initial activation, T1; 1st hour, T2; 24th hour, T3; 7th day, T4; 21st day, T5; 28th day, SD; Standard Deviation, p; significance level, K;Kruskal-Wallis, w; Wilcoxon test, *; p<0.05, 1,2,3;Numerical notation of those with significantly difference*

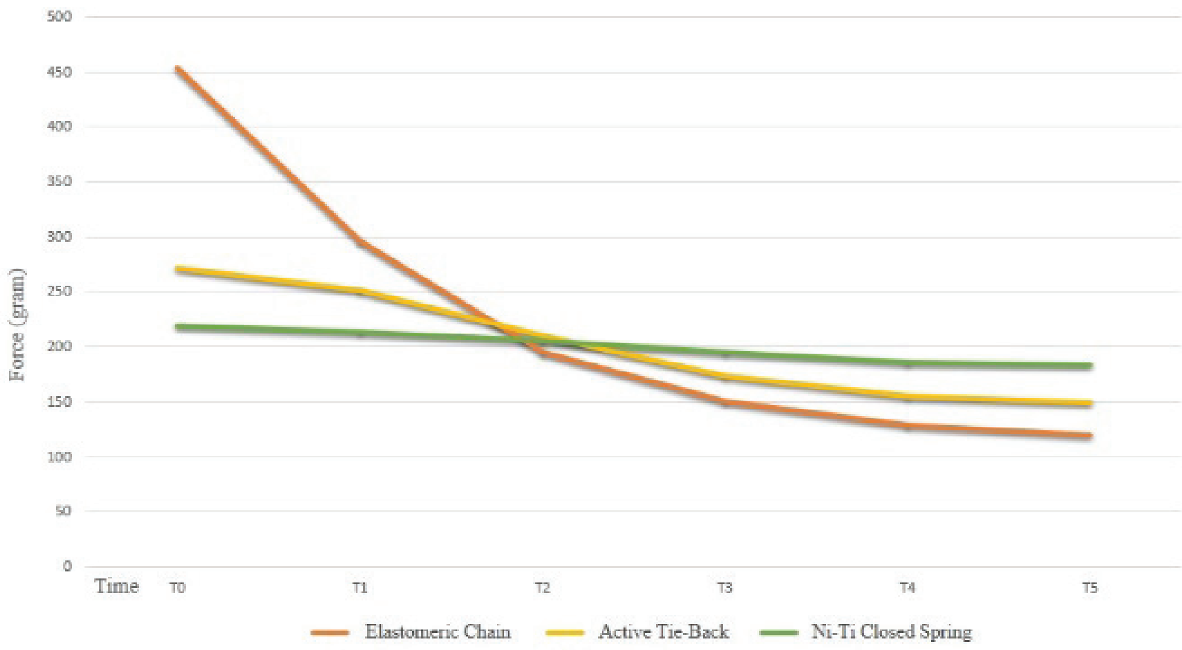

Figure 4. *Changes in the measured forces of materials over time, independent of brands, The sample size for each group is 15.*

The forces exerted by the elastomeric chains have been reported to be unstable and dependent on the dye added to the elastomers, the stretching rate, the pre-stretching effect, the configuration, and the degree of the applied force.[13] Additionally, the forces generated by Ni-Ti coil springs are affected by parameters such as length, gauge, lumen size, coil configuration, production, and exact composition of the springs.[8,14] Because the quality of these commercially available elastomerics and Ni-Ti closed coil springs depends on the production process, periodic researches are required to verify their physical behavior properties.[15]

Previous studies have shown that the elastomeric chains and active tie-backs cannot produce a constant force for a long time.[16-18] With the introduction of nickel-titanium alloys in orthodontics, Ni-Ti closed springs have been used to prevent these rapid force losses in elastomers.[19]

On one hand, it has been reported that the initial (initial activation hour) activation forces of the elastomeric chains and active tie-backs are higher than the optimal force range for retraction.[20] On the other hand, it is seen that the forces at the hour of inital activation of Ni-Ti closed springs are closer to the optimal force range.[21] The first null hypothesis of the study was rejected since there was significant difference between the groups in the initial activation hour force measurements.

Although by different amounts, the observed force losses in the elastomeric chains and the active tie-backs over time are higher than in the Ni-Ti closed springs.[22] Elastomeric chains, in particular, exhibit a rapid loss of force at the beginning, as reported in the study by Menon *et al.*,[23] that showed a 46-49% rapid force loss percentage at 24th hour. However, it has been emphasized that Ni-Ti closed springs produce more constant force and exhibit less force loss.[24] In the study, the force loss percentages were found to be 74% in elastomeric chains, 45% in active tie-backs, and 16% in Ni-Ti closed springs at 28th day measurements. Based on the study results, the second null hypothesis was also rejected, since there was a significant difference between the force loss percentages of three different force elements in the 28th day measurements.

In the study of Oshagh *et al.*[10], in which they compared elastomeric chains, active tie-backs, and Ni-Ti closed springs, the least force loss percentages occurred in active tie-backs at the end of the 21st day. Javanmardi and Salehi.[25] found that the percentage of strength loss of elastomeric chains is higher than Ni-Ti closed springs. In the present study, although significantly force losses percentages occurred in all groups in the 21st day measurements, it was seen that the least force loss percentages was in Ni-Ti closed springs. The results of present study are supported by the study by Javanmardi and Salehi.[25] It is thought that the conflict between the data of Oshagh *et al.*'s[10] study and our study is due to brand differences. It should be also noted that water weakens intermolecular forces and causes chemical degradation.[6]

Santos *et al.*[7] found the force loss percentages of elastomeric chains and Ni-Ti closed springs on the 28th day to be 48.1% and 22.6%, respectively. In our study, we found significant force loss percentages in elastomeric chains and Ni-Ti closed springs at 28th day measurements as 74% and 16%, respectively. The reason for this difference is thought to be due to the measurement technique. In our experiment, the measurements were performed manually, while Santos *et al.*[7] measured with the Instron universal machine.

In their study investigating the force losses of elastomeric chains and active tie-backs, Oshagh and Ajami[26] reported that there were significantly force losses of both elastomeric chains and active tie-backs at the 24th and 48th hour measurements compared to the initial measurements. In addition, when the force loss percentages of both materials were compared at the 24th and 48th hours, it was reported that statistically more force loss was experienced in the elastomeric chains. In this study, although there was no significant difference between the forces of elastomeric chains and active tie-backs measured at 24th hour, a statistically significant difference was found between the percentages of force loss, more in elastomeric chains. The reason for this difference is thought to be caused by the brand.

In their study on chain, Andhare *et al.*[27] found the mean force decay percentages *in vivo* to be 41.9% at 24 hours, 42.6% after 1 week, and 55.0% after 3 weeks. Cox *et al.*,[28] in their study on Ni-Ti closed coil springs, observed a 12% force decay percentage in the 4th week. In the study on chains, the percentage of force loss in the first 24 hours was 57%, the percentage of force loss was found as 65% in the 1st week measurements, and 71% in the 3rd week measurements. In our study, it was found that there was a 17% force decay percentage in the Ni-Ti closed coils in the 4th week measurements.

Although this study was conducted with artificial saliva, limitations of this study were the inability to simulate the oral environment, keeping the distance constant and the potential effect on force loss due to differences in patient oral hygiene.[28] However, the results of the study provided the evaluation of changes in the biomechanical properties of the tested materials over time.

Conclusion

- The highest and lowest forces measured at the initial activation hour were found in elastomeric chains and Ni-Ti closed springs, respectively.
- There was no statistically significant difference between the forces of elastomeric chains, Ni-Ti closed springs, and active tie-backs measured at 24th hour.
- The highest and lowest forces measured on the 28th day were found in Ni-Ti closed springs and elastomeric chains, respectively.
- It was observed that the highest and lowest force losses were in elastomeric chains and Ni-Ti closed springs, respectively.
- Ni-Ti closed coil springs apply more stable force than other materials. In clinical use, Ni-Ti closed coil springs seem to be more advantageous than other materials.

Note: This study was generated from Emine Aydın's specialty dissertation thesis at Zonguldak Bülent Ecevit University, Faculty of Dentistry, Department of Orthodontics. This study was presented as an oral presentation at the International Congress of Multidisciplinary Medical and Health Sciences Studies (ICOMMEH-2023) on 27–28 May 2023, Ankara, Türkiye.

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Ortodontik Nikel-Titanyum Kapalı Yayların, Elastomerik Zincirlerin ve Aktif Tie-Backlerin Zamana Göre Kuvvet Kayıplarının *In Vitro* Karşılaştırılması

Özet

Amaç: Ortodontik kuvvet elemanlarından nikel-titanyum kapalı yayların, elastomerik zincirlerin ve aktif tie-backlerin zamana göre kuvvet kayıplarının yapay tükürük içeren *in vitro* ortamda karşılaştırmaktır.

Gereç ve Yöntem: Çalışmada 3 farklı markadan elastomerik zincirler, Ni-Ti kapalı yaylar ve aktif tie-backler 9 gruba ayrıldı. Örneklerin yapay tükürük içeren *in vitro* ortamda zamana bağlı kuvvet kayıp yüzdeleri karşılaştırıldı. Kuvvet değerleri başlangıçta, 1. saatte, 24. saatte, 7. günde, 21. günde ve 28. günde ölçüldü ve kaydedildi. Elde edilen veriler Kolmogorov-Smirnov, Kruskal Wallis, Mann-Whitney U ve Wilcoxon testleri ile istatistiksel analize tabi tutuldu. Anlamlılık değeri $p<0.05$ olarak kabul edildi.

Bulgular: Başlangıçta en fazla ve en az kuvvetler sırasıyla elastomerik zincirlerde ve nikel-titanyum kapalı yaylarda ölçüldü ($p<0.05$). 24. saatte yapılan ölçümlerde elastomerik zincirler, nikel-titanyum kapalı yaylar ve aktif tie-back'ler arasında anlamlı farklılık bulunmadı ($p>0.05$). 28. günde tüm gruplarda anlamlı kuvvet kayıpları ölçülse de, aktif tie-backlerde elastomerik zincirlere göre markadan bağımsız olarak anlamlı şekilde daha az kuvvet kaybı ölçüldü ($p<0.05$). 28. günde en az ve fazla kuvvetler sırasıyla elastomerik zincirlerde ve Ni-Ti kapalı yaylarda ölçüldü ($p<0.05$).

Sonuç: Ortodontik boşluk kapatma mekaniklerinden, nikel-titanyum kapalı yaylar en stabil olmak üzere, aktif tie-backlerin elastomerik zincirlere göre daha stabil bir kuvvet uyguladığı dolayısıyla kullanılan kuvvet elemanı tipinin kuvvet kaybı düzeyinde temel belirteç olduğu görüldü.

Anahtar Kelimeler: Elastomer; kapalı yay; ortodonti; ortodontik boşluk kapatma