

## 4- and 7-module Elastomeric Chains Undergo Differential Force Decay in Artificial Saliva

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### Abstract

**Objective:** To compare the remaining force between 4- and 7-module memory elastomeric chains (ECs) Dyna-Link (D), Power Chain generation II (P), and Super Chain (S) (D4, P4, and S4 and D7, P7, and S7 groups) and to compare the remaining force between the 4- and 7-module ECs in each brand (D4-D7, P4-P7 and S4-S7 groups) during simulated canine retraction. **Materials and methods:** ECs were divided into six groups (D4, P4, S4, D7, P7, and S7 groups) (n=10). The samples were stretched using a Universal Testing Machine to obtain an approximately 150 grams force and the stretch distance was maintained using pinned blocks which kept in artificial saliva at 37°C. The remaining force in each sample was measured after three and 24 hours, three days, and one, two, three and four weeks. Statistical analysis was performed using the SPSS program. **Results:** Comparing the 4-module groups, the D4 group demonstrated the significantly lowest remaining force at three days. The S4 group had the significantly highest remaining force at one week. The significantly lowest remaining force was seen in the P4 group from 2–4 weeks. When 7-module groups were compared. The S7 group demonstrated the highest remaining force, while the D7 group presented the lowest remaining force from 3 hours - 4 weeks. Comparing the 4- and 7-module groups, the S7 and P7 groups had a significantly higher remaining force compared with the S4 and P4 groups, respectively. **Conclusion:** When an initial force of 150 grams was applied, the S7 group demonstrated the highest remaining force over four weeks. When using ECs for retracting teeth, 7-module chains are preferable compared with 4-module chains.

**Keywords:** Force decay, force relaxation, force degradation, elastomeric chains, memory chains

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## Introduction

Polyurethane ECs have been widely used in orthodontic practice for many decades due to their acceptable elastic properties, ease of use, low cost, various colors, and patient acceptance.<sup>1</sup> These chains are generally used in canine retraction, anterior retraction, and other tooth movements. However, staining, changing properties in the oral environment and force decay are major disadvantages of these ECs.<sup>2</sup> The force decay by ECs results in teeth receiving a heavy initial force when placed or a force below the optimum level after force decay occurs.

Force decay is influenced by the manufacturing process (injection molding or die-cut stamping)<sup>3,4</sup> chain configuration (closed or open),<sup>5-7</sup> coloring,<sup>3,5,8</sup> pre-stretching,<sup>8,11,12</sup> storage media<sup>9,10</sup> and pH level.<sup>10</sup> Furthermore, the mechanics used for retraction also affect force decay.<sup>11</sup> To address the problem of force decay, a new type of ECs known as memory chains was developed. The memory ECs are described as having low force decay. Memory ECs demonstrated significantly less force decay compared with conventional chains.<sup>12-14</sup> The increased memory chain properties may result from the addition of various substances in their composition.<sup>12,15</sup>

Although the memory ECs are claimed to have a reduced force decay rate, there are few studies concerning memory elastomeric chain properties. The aim of the present study was to evaluate the force decay of memory ECs *in vitro* by comparing the percentage of remaining force. The first aim of this study was to compare the amount of percentage of remaining force between three brands of ECs from three companies when simulating

canine retraction *in vitro*. The first null hypothesis was that there is no difference in the percentage of remaining force between these ECs. The second aim was to compare the amount of percentage of remaining force between 4- and 7-module chains in each brand and the second null hypothesis was that there is no difference in the percentage of the remaining force between the 4- and 7-module chains in each brand.

## Materials and Methods

1) Three commercial brands of memory ECs with closed configuration and clear color were divided in three groups (Dyna-link (D), G&H wire, Power chain generation II (P), Ormco, and Super chain (S), Tomy). 2) Twenty chains from each brand (D, P and S group) were divided into two groups (n=10): 4- and 7-module groups. The six groups of ECs were divided as shown in Table 1. The ECs were stretched until an initial force of 150 grams was obtained as measured by a universal Testing Machine (EZ-S 500N Shimadzu) with a 50 N load cell. The six stretched distances for each group were recorded (Table 1). Six acrylic blocks with ten pairs of 0.036-inch stainless steel wire pins were fabricated as previously described.<sup>16</sup> One block was used for each group of ECs (Fig. 1). The distance between the pairs of pins equaled the stretch distance required to generate the 150 grams force for each group. The group names, product brands, companies, distance between pins, mean initial force, and the mean percentage of elongation to obtain 150 grams of initial force are shown in Table 1.

**Table 1** Product names and companies, distance between the pins in the acrylic blocks, and mean initial force of each group.

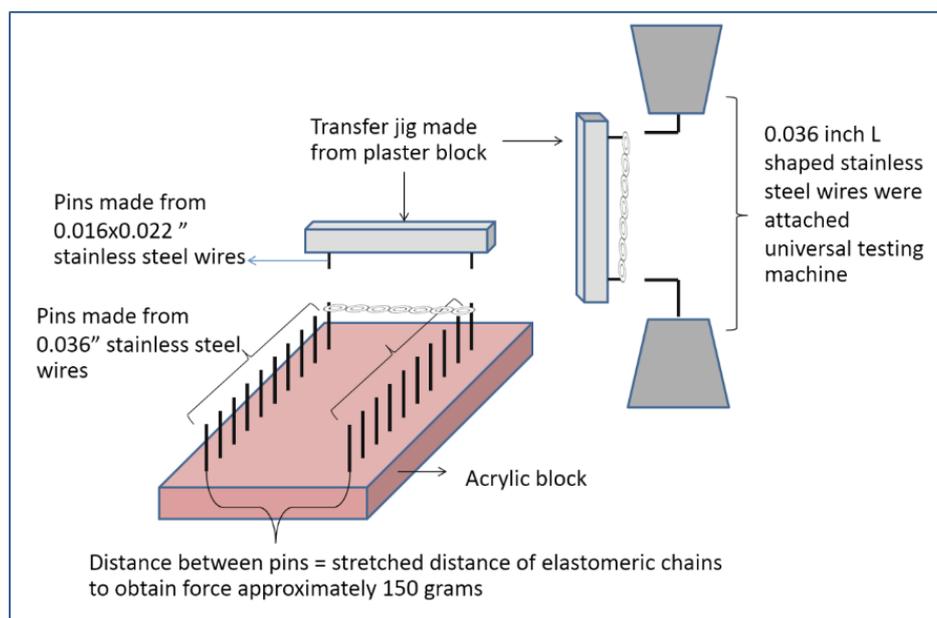
groups	Product brands/companies	Modules	Distance between pins	Initial force (SD)
D4	Dyna-Link/G&H wire	4	13.5 mm	151.41 (3.72)
D7	Dyna-Link/G&H wire	7	23 mm	149.54 (7.33)
P4	Power Chain generation II /Ormco	4	12 mm	155.11 (4.27)
P7	Power Chain generation II /Ormco	7	22 mm	151.21 (4.65)
S4	Super Chain/Tomy	4	12 mm	151.05 (4.54)
S7	Super Chain/Tomy	7	23 mm	150.11 (2.47)

Throughout the study, the acrylic blocks were kept in artificial saliva and stored in an incubator at 37°C (Contherm). The artificial saliva was produced by the Department of Pharmacology, Faculty of Dentistry Chulalongkorn University. The artificial saliva was composed of 0.75 grams potassium chloride, 0.07 grams magnesium chloride, 0.199 grams calcium chloride, 0.965 grams dipotassium hydrogen phosphate, 6 grams sodium caboxy methylcellulose, 0.439 grams potassium dihydrogen phosphate, 0.005 grams sodium fluoride, 36 grams 70 % sorbitol, 18.20 ml paraben, and 1200 ml deionized water.

Two 0.036 in L shaped stainless steel wires were attached to the 50 N load cell of the Universal Testing Machine to measure the initial force and remaining force at 3 and 24 hours, 3 days, and 1, 2, 3, and 4 weeks. Each elastomeric chain was transferred from the acrylic block to the L shape wires using a jig to maintain the length of the elastomeric chain. The jig was made of a plaster block

and a pair of 0.016x0.022 inch stainless steel wires that were set the same distance apart as the pins in each group's respective acrylic block (Fig. 1). The elastomeric chain was stabilized for five seconds on the Universal Testing Machine before recording the force.<sup>7,11</sup> The remaining force was calculated as the percentage of remaining force. (Percentage of remaining force= (remaining force/initial force)x100)

Statistical analysis was performed using the SPSS program. Because the data was not normally distributed in each group, the Kruskal-Wallis H test was used to analyze the differences in initial force and percentage of remaining force between product brands (D4, P4, and S4 and D7, P7, and S7). The Mann-Whitney U test was used for pairwise comparison and analyzing the difference between the 4- and 7-module groups of each brand (D4-D7, P4-P7, and S4-S7). Significant differences were determined at  $p < 0.05$ .



**Figure 1** The acrylic block set with the pins, transfer jig, and L shaped wires attached to the load cell of the Universal testing machine.

## Results

The mean initial force and SD of the groups ranged from 150.11±2.47–155.11±4.27 grams, which were not significantly different (Table 2) ( $p < 0.05$ ). The results of

the remaining force assay indicated that a rapid decrease in remaining force occurred in the D4, P4, and S4 groups over the first 24 hours, with their percentage remaining

forces ranging from approximately 65–52 % (Table 2, Fig. 2A). The percentage of remaining force was the highest in the S4 group, followed by the P4, and D4 groups at three and 24 hours, however, these differences were not significant ( $p>0.05$ ). At three days, the D4 group presented a significantly lower percentage of remaining force ( $42.30\pm 3.42$  %) compared with the P4 and S4 groups ( $p<0.05$ ). The percentage of remaining force in each group continued to decrease in a time-dependent manner, albeit not as precipitously as was seen in the first 24 hours (Table 2, Fig. 2A). After seven days, the S4 group had the significantly highest percentage of remaining force ( $54.89\pm 2.75$ ) ( $p<0.05$ ) among the groups. From 2-4 weeks, the P4 group demonstrated the lowest percentage of remaining force of all the groups, ranging from  $35.05\pm 4.78$ – $31.18\pm 5.37$  % ( $p<0.05$ ).

Evaluating the remaining force between the D7, P7, and S7 groups, the S7 group demonstrated the significantly highest percentage of remaining force (range  $85.78\pm 10.86$ – $77.15\pm 4.05$  %) at all observation points

( $p<0.01$ ) (Table 2, Fig. 2B). Similar to the four module group results, the P7 group had the next highest percentage of remaining force (range  $70.25\pm 2.36$ – $51.58\pm 3.48$  %), with the D7 group presenting the lowest percentage of remaining force (range  $39.44\pm 4.07$ – $36.95\pm 3.59$  %) ( $p<0.01$ ).

Comparing the percentage of remaining force between the 4- and 7-module groups (D4-D7, P4-P7 and S4-S7, Table 2, Fig. 3A-C), the S7 and P7 groups presented significantly higher percentages of remaining force with a range of approximately 20-40 % and 10 % higher, respectively, compared with the S4 and P4 groups at every observation point ( $p<0.01$ ). The D4 and D7 groups only demonstrated a significant difference in percentage of remaining force at 24 hours and four weeks, with the D4 group having a higher percentage of remaining force compared with the D7 group ( $p<0.05$ ) (Table 2, Fig. 3A).

The p values of the pairwise comparisons between 4-and 7-module groups (D4-D7, P4-P7, and S4-S7) are shown in Table 3.

**Table 2** The mean remaining force and percentage in each group at each time point.

group	Dynamlink (remaining force)		Power Chain generation II (remaining force)		Super Chain (remaining force)	
	D4 gram (SD) % (SD)	D7 gram (SD) % (SD)	P4 gram (SD) % (SD)	P7 gram (SD) % (SD)	S4 gram (SD) % (SD)	S7 gram (SD) % (SD)
0	151.41(3.42) 100	149.54(7.34) 100	155.11(4.28) 100	151.21(4.65) 100	151.05(4.55) 100	150.11(2.47) 100
3 hours	93.58(13.25) 61.88(9.20)	87.79(11.43) 58.76(7.38)	96.49(8.38) 62.05(5.65)	106.21(4.45) 70.25(2.36)	98.41(6.38) 65.15(6.39)	128.75(6.44) 85.78(10.86)
24 hours	78.88(5.77) 52.12(3.88)	72.54(5.91) 48.60(4.52)	82.83(6.86) 53.40(4.46)	96.56(4.04) 63.9(3.00)	88.25(12.85) 58.50(8.88)	128.62(6.04) 85.68(3.69)
3 days	64.05(5.53) 42.30(3.42)	65.7(6.13) 44.02(4.64)	71.89(6.85) 46.36(4.46)	89.42(4.28) 59.16(2.76)	75.7(11.97) 50.07(7.42)	127.8(4.56) 85.14(3.05)
1 week	63.08(8.28) 41.65(5.30)	63.9(6.12) 42.81(4.57)	63.67(7.01) 41.08(4.70)	82.97(4.22) 54.89(2.75)	73.52(12.1) 48.64(7.65)	123.7(3.18) 82.42(2.33)
2 week	62.83(5.97) 41.52(4.07)	58.86(5.28) 39.44(4.07)	54.32(7.19) 35.05(4.78)	77.95(4.97) 51.58(3.48)	65.79(13.59) 43.52(8.61)	122.67(3.2) 81.73(2.67)
3 week	56.45(4.73) 39.28(3.15)	56.11(4.93) 37.61(3.99)	54.32(7.19) 35.05(4.78)	72.12(4.38) 47.72(3.13)	65.32(13.98) 43.19(8.89)	121.88(3.96) 81.20(2.67)
4 week	60.04(2.92) 39.67(2.92)	55.12(4.36) 36.95(3.59)	48.34(8.15) 31.18(5.37)	71.61(4.33) 47.39(3.12)	60.01(13.40) 39.71(8.65)	115.77(5.53) 77.15(4.05)

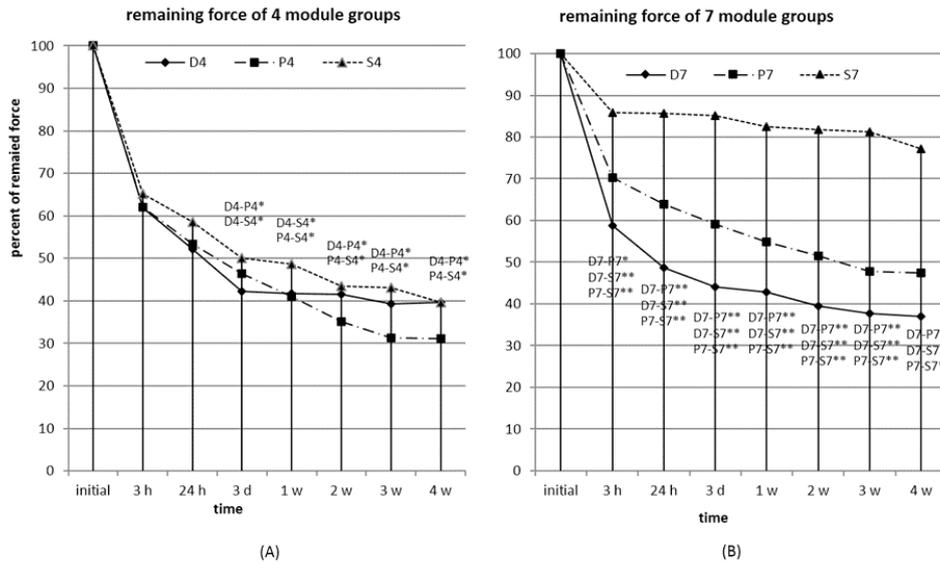


Figure 2 The percentage remaining force at each observation point. A) D4, P4, and S4 groups, and B) D7, P7, and S7 groups. \* indicates a significant difference between the groups at  $p < 0.05$  and \*\* indicates  $p < 0.01$ .

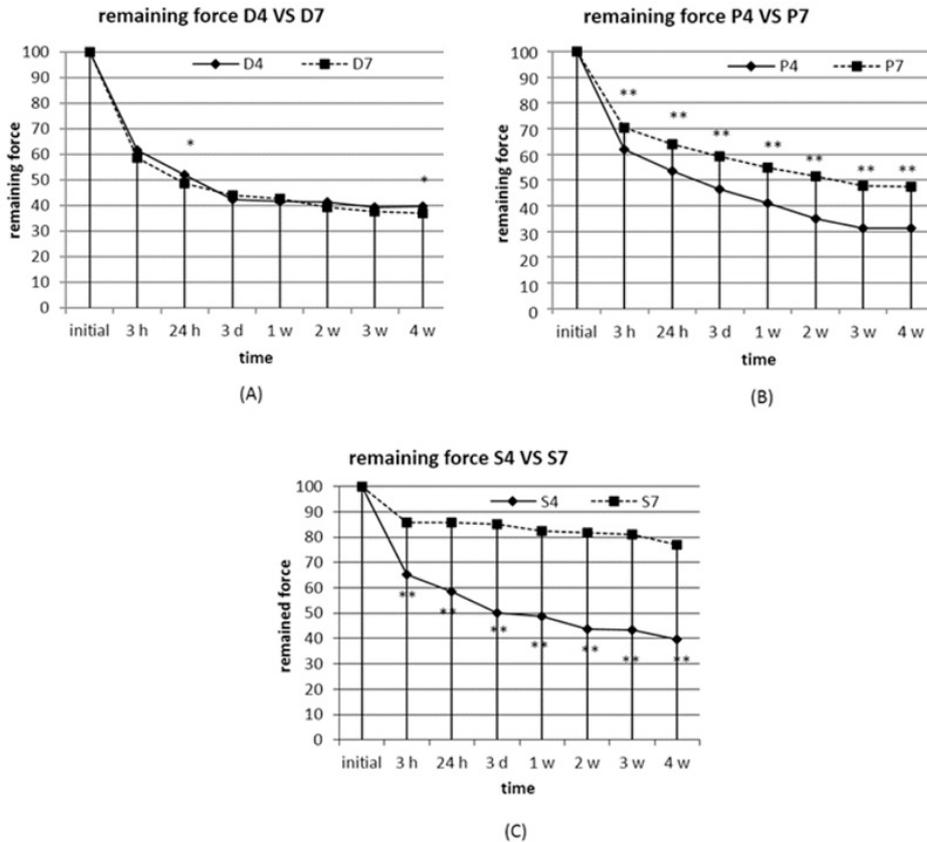


Figure 3 The percentage remaining force at each observation point. A) D4-D7, B) P4-P7, and C) S4-S7 groups. \* indicates a significant difference between the groups at  $p < 0.05$  and \*\* indicates  $p < 0.01$ .

**Table 3** The *p* values of the pairwise comparisons (Mann-Whitney *U* test) between the 4- and 7-module groups.

Observation Period	3 hr	24 hr	3 d	1 w	2 w	3 w	4 w
groups							
D4 VS P4	.650	.821	.041	.880	.010	.049	.003
D4 VS S4	.226	.226	.008	.041	.762	1.000	.364
P4 VS S4	.406	.257	.364	.008	.019	.023	.013
D7 VS P7	.002	.000	.000	.000	.000	.001	.000
D7 VS S7	.000	.000	.000	.000	.000	.000	.000
P7 VS S7	.000	.000	.000	.000	.000	.000	.000
D4 VS D7	.364	.041	.496	.597	.070	.082	.041
P4 VS P7	.002	.000	.000	.000	.000	.000	.000
S4 VS S7	.000	.000	.000	.000	.000	.000	.000

## Discussion

The current study evaluated the force decay of 4- and 7-module Dynalink, Power Chain generation II, and Super Chain memory ECs, which are available in Thailand, over four weeks. There were significant differences found in the percentage of remaining force between brands and also between 4- and 7-module chains. Based on our results, both of the null hypotheses were rejected.

Less force decay of memory chain was discussed in previous studies.<sup>1,12-14,17,18</sup> However, there are few studies of these brands.<sup>1,12,14,18,19</sup> Previous studies have shown that closed configuration chains underwent less force decay compared with open configuration chains.<sup>4,7</sup> Moreover, clear chains experienced less force decay compared with the grey chains in some brands.<sup>4,8</sup> However, one study found that the effect of color within the same brand was minimal.<sup>8</sup> In addition, the storage media and pH affected the force degradation of ECs. ECs demonstrated less force decay in a dry environment compared with in the mouth, 37° water, artificial saliva, and topical fluoride treatment.<sup>4,9,10</sup> Notably, the greatest force decay was found to occur in the oral environment.<sup>9</sup> In our study we used clear ECs<sup>1,12</sup> with closed configuration<sup>11,12,14,16,17,20</sup> in artificial saliva.<sup>6,7,11,14,16,20</sup>

Pre-stretching was not performed<sup>11,12,14,16</sup> in the present study because its effect on force decay is unresolved and there is no standardized pre-stretching method.<sup>4,21-23</sup> Although pre-stretching reduced the force decay in some ECs, the reduction may not be clinically meaningful.<sup>4,21,23</sup> Furthermore, thermocycling was not performed in the present study.<sup>11-14,20,23</sup> However, memory ECs undergoing thermocycling retained significantly higher mean percentages of remaining force compared with those exposed to a constant temperature of 37°C.<sup>6</sup> The improvement was approximately 8-10 % over 21 days.

The present study was designed to simulate canine retraction using 150 grams of force. A systematic review study revealed that the force level that was used to move the upper canine varied from 18–375 grams.<sup>24</sup> The force level of 150 grams used in the present, and previous studies<sup>3,16</sup> was in this range. At the 4-week evaluation point, the force remaining level ranged from 48.34 grams (P4) to 115.77 grams (S7), which is still optimal for canine retraction.

The remaining force over the 4-week period evaluated in the present study ranged from 31.18 % (48.34 grams) to 77.15 % (115.77 grams) in the P4 and S7 groups,

respectively, compared with the 50-67 % remaining force for memory chains observed in previous studies.<sup>1,12-14,17,18</sup> It was found that the S4 and S7 groups demonstrated the highest percentage of force remaining, similar to the results of a previous study.<sup>12</sup> Moreover, the D4 and D7 groups presented a remaining force of approximately 40 %, which corresponded with the results of a clinical study.<sup>19</sup> Although the P4 and P7 groups demonstrated a 30-47 % remaining force that was similar to that of a previous study<sup>18</sup>, this was less than was found in other studies.<sup>1,14</sup> Differences in methods and laboratory environments may account for these differences.

The highest remaining force in the present study was found in the S7 elastomeric chain group. The remaining force in this group was 85.78 % at three hours and 77.15 % at four weeks. This force level corresponded with the mean percentage of force decay of NiTi closed coil springs observed in a previous study.<sup>25</sup> These results suggest that the S7 chains could be used in place of NiTi closed coil springs at a much lower cost.

It was found that the rate of force decay among D4, P4, and S4 groups displayed a similar pattern. Although there were significant differences in the remaining force between the three brands from three days to four weeks, the differences at the same interval were 4.83-11.7 grams, which are not clinically relevant. In contrast, there were significant differences between the D7, P7, and S7 groups as well as between the three brands in every interval evaluated and the differences within the same interval were as high as 35.17-65.77 grams. These higher remaining forces may reduce adverse effect of high initial force. The differences in force decay observed between brands can be attributed to their respective manufacturing processes, such as how they are cut and their raw materials, surface coated materials, or fillers and pigments. However, this information is proprietary. Moreover, different morphologic (ellipsoid or circular) or dimensional characteristics modify the product characteristic.<sup>3,11,13-15,26</sup>

Our results indicated that among the 4- and 7-module groups (D4-D7, P4-P7, and S4-S7), the D group

(Dynalink) demonstrated a consistent level of force decay, however, the S (Super Chain) and P (Power Chain generation II) groups had markedly different levels of force decay. The P7 and S7 groups had a higher remaining force compared with the P4 and S4 groups. These results did not correspond with those of previous studies that found that the difference in the percentages of force remaining within the same brand was less than that found in this study.<sup>11,14</sup> The explanation for this might be that the initial force of 150 grams used in this study was less than was used in other studies, which may account for the lower percentages of elongation (116.46-120 %) in the present study. The higher percentages of elongation of ECs cause permanent deformation of material.<sup>27</sup> A previous study<sup>27</sup> found that using different stretching lengths and stretching cycles during pre-stretching altered the force decay pattern in some brands. The alteration of force decay pattern may be affected by permanent deformation, which would result in a loss of elastic recovery ability.

The distance between the pins in the present study was categorized into two groups. The 12-13.5 mm distances used for the 4-module groups (D4, P4 and S4) are approximately the distance from the second premolar bracket to the canine bracket hook. Moreover, the 22-23 mm distances used for the 7-module groups (D7, P7 and S7) represented ECs that are stretched from the first molar buccal tube hook to the canine bracket hook according to a study of tooth sizes.<sup>28</sup> The results indicate that using Power Chain Generation II or Super Chain for canine retraction by stretching ECs from the first molar to canine is a favorable choice.

A limitation of the present study is that it was performed in vitro, because a previous study found that the force decay was higher in the oral environment<sup>9</sup>, thus further investigation is required.

## Conclusion

The present study used 150 grams of force to simulate canine retraction and compared the percentages

of remaining force between three elastomeric chain products and between 4- and 7-module groups in each product. Based on our results, we conclude:

- In the 4-module groups, the difference among three brands was not evident over 24 hours. The P4 group demonstrated a significantly lower percentage of remaining force from 2-4 weeks compared with the D4 and S4 groups.

- In the 7-module groups, there were marked differences between brands; the S7 group had the significantly highest percentage of remaining force, while the D7 group presented the significantly lowest percentage of remaining force at every interval evaluated.

- Comparing the 4- and 7-module groups within the same brand, the P7 and S7 groups had a significantly higher percentage of remaining force compared with the P4 and S4 groups at every interval evaluated. However, the D4 and D7 groups did not demonstrate significant differences.

- Stretching ECs from the first molar tube to the canine is recommended when Power Chain Generation II and Super Chain chains are used to obtain less force decay.

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