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ORIGINAL ARTICLE

Comparative study of 3 methods of crimping in orthodontic hooks with two different types of applied force (elastomeric chains and tie-backs) – in vitro study.

Estudio comparativo de 3 métodos de engarzado en ganchos de ortodoncia con dos tipos diferentes de fuerza aplicada (cadenas elastoméricas y amarres) – estudio in vitro

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ABSTRACT

Introduction: To compare 3 methods of crimping orthodontic hooks with 2 different types of force using tiebacks or elastomeric chains.
Methods: 100 crimped hooks, 100 dotted hooks and 100 hooks with a V stop bending on the archwire, divided into 6 groups were put to detachment test in a universal machine SHIMADZU 5000 applying force by means of tiebacks and elastomeric chains, for the use of the machine an accessory base and arm was designed to keep the test stable and standardized. Data were analyzed using GraphPad Prims 8 for Windows. Significance was predetermined at α =0.05. The Shapiro–Wilk test was used to test the data for normality. The data were not normally distributed and therefore the Kruskal Wallis test was used to determine differences between groups, followed by Dunn's multiple comparisons test.
Results: The maximum forces obtained for the detachment of an orthodontic hook was up to 2.87kg which was recorded by the group of dotted hooks and with force applied with elastomeric chain and the one with the lowest force was 0.87kg with hooks only crimped. The tie backs showed a more controlled force in all groups and the groups with a "V stop" bend also showed the most stable tests and none displacement of the hook but more eviction and break of the hooks.
Conclusions: In the study it was determined that the crimping method is not sufficient for the stability of the hook so pointing it or performing a V stop bend on the wire increases its stability before the maximum force of detachment and clinically gives advantages in the dental movement although it increases the consultation or laboratory time for its realization.

KEYWORDS
Orthodontics; Materials Testing; In Vitro Techniques.

CLINICAL RELEVANCE

Improvement of orthodontic treatments: The results of this study could help orthodontists select the most effective and safe crimping method for their patients, which could improve treatment outcomes. Reduction of complications: If a crimping method is safer or reduces the risk of complications (such as hook detachment), this could improve the patient experience and reduce the need for unplanned follow-up appointments. Treatment efficiency: If a crimping method proves to be more effective at resisting applied forces, it could lead to more efficient treatments, possibly reducing the total treatment time. Treatment personalization: By understanding how different crimping methods respond to different types of forces, orthodontists may be better able to personalize treatments to each patient's individual needs.

INTRODUCTION

Dentoskeletal discrepancies are of great importance considering a high percentage of the population suffers from some form of malocclusion. Malocclusion is the third priorityfor oral decease according to the World Health Organization.[1]There are different treatment options for the wide variety of malocclusions that may occur. These options include conventional orthodontic treatment,[2] orthodontic treatment with extractions,[3]or surgical orthodontic treatment.[4]

When the surgical treatment option is selected, surgical crimpable hooks are used for the stabilization archwire that completely fills the bracket slot, which can be a .019x.025" or .021x .025" archwire in a .022” slot. These hooks help the surgeon as accessories to be able to fix the maxillary in their new position after orthognathic surgery.[4] Additionally, hooks are also important in orthodontic treatment when extractions are required. It is useful for the closure biomechanics after the dental extraction. The hooks are placed distally to the lateral teeth with a stable archwire of .019x.024" as suggested by Mclaughlin and Bennet’s (MBT) principles for fixed orthodontic appliances.[5] Subsequently, the closure of extraction spaces is closed according to the orthodontist treatment, which can be done by using an elastomeric chain, close-coils or tie-backs.[5,6] Orthodontic hooks could be considered an accessory device, it is a fundamental tool for different biomechanics in orthodontic treatment. There are different crimpable hooks depending on the purpose for which they can be applied such as: short hooks, long hooks, surgical hooks, spiral, curves with head to the right or left and multifunctional.[7] Some of the methods to apply active or retraction forces to the archwire are with use of tie backs or elastomeric chains on prefabricated hooks dotted to the archwire, and prefabricated hooks crimped to the archwire.[5] Additionally, welded hooks can be locally manufactured, but these require more laboratory time.[6] If the forces used on the hook are excessive, they can apply flexion to the archwire in an undesirable way, as well as excessive forces on the teeth and cause detachments of the hooks.[8]

Throughout the history of orthodontics, different types of hooks have been created and improved along the way, making them increasingly easy to use for orthodontists and they also have countless of uses depending to the specific needs of the patient. The easiest way to place this accessory in the archwire, is in a crimped approach, by pressing the base of the hook on to the archwire, using the force that is applied by a special plier (Figure 1,3) for crimping thus being able to “adhere” the orthodontic hook to the archwire 0.019x0.025” of stainless steel using 3 the methods of hook placement: a) crimped hooks, b) dotted hooks and c) crimped hooks with V stop bending. All three methods will additionally be used with 2 methods of force application, tieback (active backlink) and elastomeric closed chain.

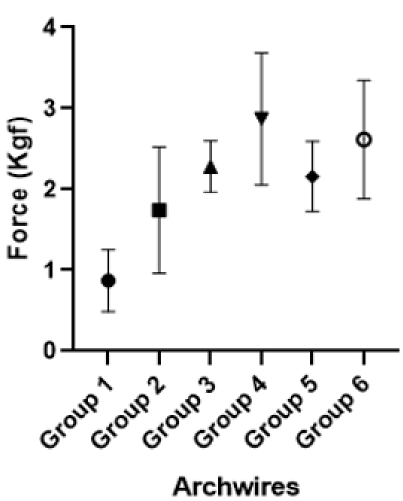

Figure 1. Maximum force (Kgf) required to dislodge hook attachments (mean and standard deviation).

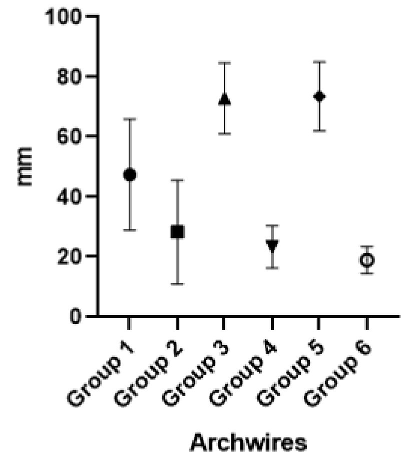

Figure 2. Displacement of the hooks (in mm) during the experiment (mean and standard deviation).

MATERIALS AND METHODS

Three hundred Td Orthodontics ® (Quadra Towers Torre A – 309, Monterrey, N.L., Mexican brand) crimpable hooks were placed in a position suggested by the principles for fixed orthodontic appliances by MBT (Table 1). They were placed with 36-38 mm between hooks on upper steel archwires 0.019x0.025" and 26 mm between hooks for lower steel archwire 0.19x0.025. All hooks from all groups were crimpable per the manufacturer's instructions by the same operator.

The main crimp was performed with TP Orthodontics crimping plier (Image 1, 1-2). The technique of placing the first and second group of stainless-steel archwires were with hooks only crimped to the archwire. In the first group, the archwires and their hooks were subjected to hook displacement tests with the SHIMADZU universal machine (Image 2, 1), the force was applied with the elastomeric closed chain 3M UNITEK simulating the force that is used in a patient to generate a retraction movement when closing spaces, which requires a force of 150 g to generate a translation movement (Table 1).

Table 1. Study groups

Group 1	50 crimpable hooks in 25 arches (1 hook in each hemiarch) 0.019x0.025 steel applying force with closed elastomeric chain.
Group 2	50 crimpable hooks in 25 arches (1 hook in each hemiarch) 0.19x0.025 de steel applying force with tie-backs.
Group 3	Crimped and dotted hooks in 25 steel archwires (0.019x0.025) applying force with closed elastomeric chain.
Group 4	Crimped and dotted hooks in 25 steel archwires (0.19x0.025) applying force with tie-backs.
Group 5	Crimpable hooks with distal V stop in steel archwires (0.019x0.025) applying force with closed elastomeric chain.
Group 6	Crimpable hooks with distal V stop in 25 steel archwires (0.19x0.025) applying force with tie-backs.

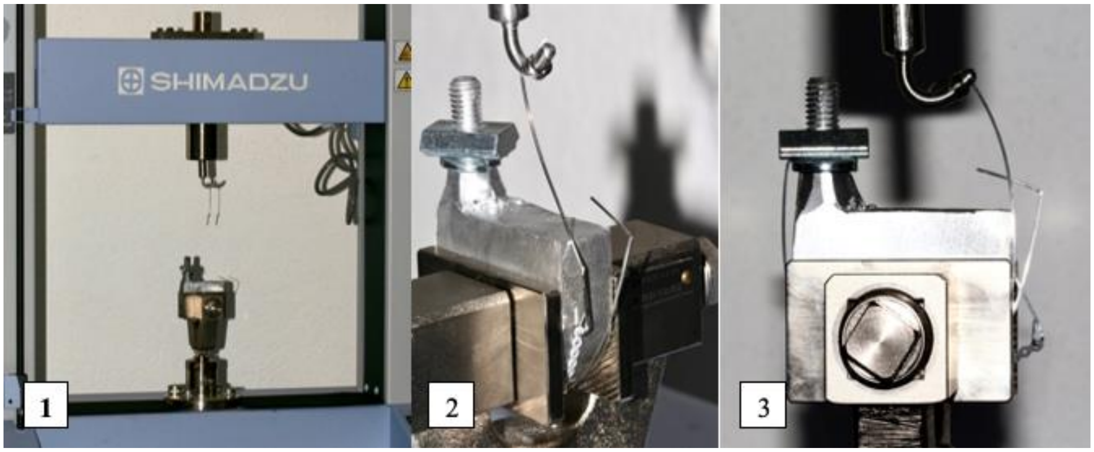

Image 1. Shimadzu universal machine (1), additive designed for tests on universal machine (2), example of how the arch with hook and force attachment was placed on the attachment for the universal machine (3).

Hemiarches of the second group were subjected to hook displacement tests with the SHIMADZU universal machine (Image 2, 1), the force was applied with a tieback with a 3M UNITEK module simulating the force that is applied in the patient for a retraction movement which can be around 150 g. The technique for placing the third and fourth group of stainless-steel archwires was with crimpable hooks dotted with a dotting machine (Table 1). The dotting was performed by the same individual with a grade 4 with two dotting points on each side of the base of the hook previously placed on the archwire. This procedure was done with a dotting machine from Viarden ® (Viarden Lab, LLC 5114 N. La Homa Rd Mission, Tx 78574, Mexican brand). The technique for placing the hooks on the fifth and sixth group of stainless steel archwires was with crimpable hooks and with a "V stop" bending made with a special Hu-friedy plier (Image 1, 3-4). After all hooks were crimpable to the archwires, the 6 groups of archwires were divided by hemiarches to obtain 2 tests due to the hook that will have the archwire on each side (Table 1). In each test, the maximum force and displacement at the moment of dislodgement were recorded, except in the groups with V stop, where due to their characteristics, the maximum force and displacement were recorded at the moment of the deformation of the archwire or hook.

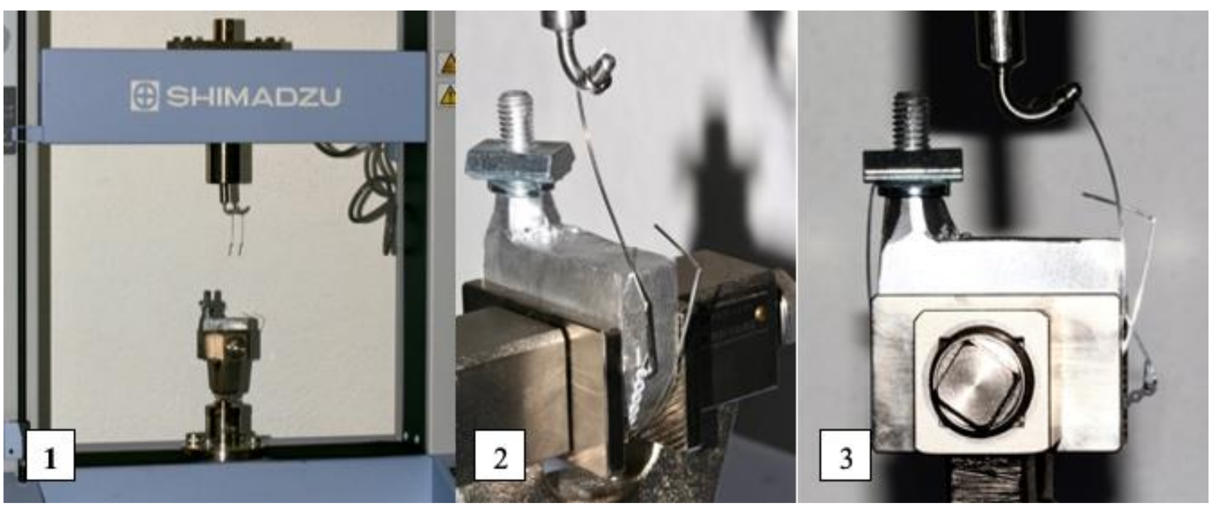

Image 2. Shimadzu universal machine (1), additive designed for tests on universal machine (2), example of how the arch with hook and force attachment was placed on the attachment for the universal machine (3).

The 3M UNITEK elastomeric closed chains were used with a length of 2.5 cm, approximately 8 links, considering that must be activated to twice their size (stretch up to 5 cm) which will produce 150 g of force that is necessary for the total retraction of the anterior dental area. The 5 cm is the approximate distance used in an average patient from the hook to the molar bracket that serves as an anchor to be used in this type of biomechanics. The tiebacks with 3M UNITEK elastic module were also activated until they reached twice the size of the elastic module, which generates a force of 100-150 g, all of these forces were calibrated with a gauge. All the forces applied with both elastomeric chain and tieback was performed up to the maximum force of the hook to any of the materials used (archwire, metallic ligature, elastic module or elastomeric chain). In order to use the SHIMADZU universal machine, a special base (Image 2, 2) had to be designed by a mechanic engineer to place the archwire to stabilize the testing samples, as well as an arm (Image. 2, 3) that generates the necessary force on the hook and be able to slide and activate the applied force (elastomeric chain and tie-backs). The special base had an arch form and the material used was stainlees steel, this due to simulate the human arch and avoid that the archwires lose their original form. All the materials used to applied force to the hooks are too small for the universal machine and none of the original arms of the machine adjusts to our materials, that's why we used a special design for this too. The design was a small long hook with a small head attached to the upper arm of the machine, this arm is the one that displace upwards generating the applied force to the elastomeric chains or tie backs with a speed of 1mm per second. Three hundred tests were performed with the machine and all groups had a uniform sample. All the data was collected for further statistical analysis.

To make sure that the studies prior to ours really showed that the gold standard in elastomeric chains is 3M UNITEK ©, we made 1 wooden board with 20 screws on each side with a distance between them of 5cm, in order to make sure it was 3M UNITEK in did, the gold standard. To be able to place 3M UNITEK elastomeric chain segments of 2.5 cm approximately 8 links of the elastomeric chain and be able to stretch them to their double capacity that both previous studies and the manufacturer suggest that is ideal to generate the necessary and controlled force. The wooden board simulated the use of the elastomeric chain by days, in which we saw the deformation generated through the days and being able to reach 30 days which is what an elastomeric chain is normally left in the mouth. At the end of each test, the elastomeric chain was removed and measured. The initial and final measurement of the elastomeric chain were collected for their analysis (Table 6).

Table 2. Maximun Force (Kgf) required to dislodge hook attachments.

Group	Sample size	Mean	SD	Median	Range
1	50	0.87	0.38	0.8	2.13
2	50	1.74	0.78	1.75	2.75
3	50	2.28	0.31	2.37	1.42
4	50	2.87	0.81	2.91	5.69
5	50	2.16	0.43	2.27	2.08
6	50	2.61	0.73	2.81	3.61

Statistical analysis

Normality test of the distribution of the data was performed through the Shapiro-Wilk test, as well as the homogeneity test of the variances using the Levene's statistical test. Since data was not normally distributed, Kruskal Wallis test and Dunn's test for multiple comparisons was used to observe any statistical differences between the groups. Data were analyzed using GraphPad Prims 8 for Windows. Significance was set at α=0.05. The deformation of the elastomeric chain is reported as a percentage.

RESULTS

The study group that endured the most force before the detachment of the hook was Group 4 (2.87 ± 0.8118 Kgf), followed by group 6 (2.613 ± 0.733 Kgf) and 3 (2.283 ± 0.3146) (Table 2). Statistically significant differences between groups according to the maximum force they can resist can be seen in Table 3. Groups that showed the greatest displacement during the tests were groups 3 (72.94 ± 11.87 mm) and 5 (73.59 ± 11.56 mm). In addition, group 6 is the one with the least displacement (18.94 ± 4.509) followed by group 4 (23.37 ± 7.034) (Table 4). Statistical differences between groups according to displacement can be observed in table 6. At the end of the 30-day test period on the wooden board, the deformation of the elastomeric chain (3M UNITEK ©) was 46.58% (Table 6). This data was not considered for the statistical analysis (Groups 2, 4 and 5).

Table 3. Statistical differences between groups according to maximal force. P-values with an asterisk are statistically significant.

Dunn's multiple comparisons test	Adjusted P Value
Group 1 vs. Group 2	0.0004*
Group 1 vs. Group 3	<0.0001*
Group 1 vs. Group 4	<0.0001*
Group 1 vs. Group 5	<0.0001*
Group 1 vs. Group 6	<0.0001*
Group 2 vs. Group 3	0.1916
Group 2 vs. Group 4	<0.0001*
Group 2 vs. Group 5	>0.9999
Group 2 vs. Group 6	<0.0001*
Group 3 vs. Group 4	0.0002*
Group 3 vs. Group 5	>0.9999
Group 3 vs. Group 6	0.0224*
Group 4 vs. Group 5	<0.0001*
Group 4 vs. Group 6	>0.9999
Group 5 vs. Group 6	0.0001*

Table 4. Displacement of the hooks during the experiment

Group	Sample size	Mean	SD	Median	Range
1	50	47.43	18.49	45.13	115.7
2	50	28.34	17.4	23.33	69
3	50	72.94	11.87	75.32	68
4	50	23.37	7.03	24.99	34.67
5	50	73.59	11.56	76.99	60.33
6	50	18.94	4.509	20.03	21.67

Table 5. Statistical differences between groups according to displacement. P-values with an asterisk are statistically significant.

Dunn's multiple comparisons test	Adjusted P Value
Group 1 vs. Group 2	<0.0001*
Group 1 vs. Group 3	0.0023*
Group 1 vs. Group 4	<0.0001*
Group 1 vs. Group 5	0.0005*
Group 1 vs. Group 6	<0.0001*
Group 2 vs. Group 3	<0.0001*
Group 2 vs. Group 4	>0.9999
Group 2 vs. Group 5	<0.0001*
Group 2 vs. Group 6	0.5528
Group 3 vs. Group 4	<0.0001*
Group 3 vs. Group 5	>0.9999
Group 3 vs. Group 6	<0.0001*
Group 4 vs. Group 5	<0.0001*
Group 4 vs. Group 6	0.8943
Group 5 vs. Group 6	<0.0001*

Table 6. Deformation of elastomeric chain after 30 days and final difference in percentage.

Days	Initial length (cm)	Final length (cm)	Final difference (%)
1	2.5	2.58	3.1
3	2.5	3.16	20.89
6	2.5	3.85	35.06
10	2.5	3.67	31.88
11	2.5	3.84	34.9
12	2.5	3.82	34.55
13	2.5	3.78	33.86
14	2.5	3.91	36.06
15	2.5	4.03	37.97
17	2.5	4.3	41.86
19	2.5	4.3	41.86
20	2.5	4.21	40.62
22	2.5	4.1	39.02
23	2.5	4.26	41.31
25	2.5	4.32	42.13
26	2.5	4.32	42.13
27	2.5	4.39	43.05
28	2.5	4.42	43.44
29	2.5	4.62	45.89
30	2.5	4.68	46.58

DISCUSSION

As hooks are a useful tool used by many orthodontists, research is needed to understand their mechanical limitations. Being a tool of such importance, there have been only few researchers who have shown interest in evaluating its mechanical behavior. Evans and Jones reported that the force applied when crimping the hooks to the wires varies according to the operator. Likewise, they suggest that the force necessary to correctly crimp the hooks is approximately 3 N.[10] In this study, to avoid variation in force at the time of crimping the hooks, the procedure was performed by the same operator. On the other hand, the use of excessive forces on the steel archwire can have a negative effect since this forces can bend the archwires and the orthodontic hooks, in such way, that can cause adverse effects on tooth movement as well as causing the rupture of the archwire itself.[11,12]

Johal et al., evaluated the force necessary to detach orthodontic hooks from the archwires. The authors analyzed two different types of hooks (American Orthodontic and TP Orthodontic). The authors found that the force required for the detachment of the hooks depended on the type of hook and not on the type of archwire used. Therefore, the hooks from the TP Orthodontic brand needed twice as much force (11.7 N or 1.1931 kg) to detach. In our results, the necessary force needed to detach the hooks from the archwires was from 0.873 to 2.87 kg. According to the methodology described by Johal et al., their data was obtained with a force applied to the hooks of approximately 18 kg. In addition, the methodology used by the authors to measure the force applied to the hooks through the universal testing machine and the brands of hooks are different from the ones we used in this study and this could explain the difference in results.[12] In 2006, O'bannon et al., analyzed the force required to dislodge three types of surgical hooks (two types of split crimpable surgical hooks and one type of soldered brass surgical hooks). The authors reported that the soldered brass surgical hook required the greatest amount of force to dislodge (51.3 ± 5.2 N) compared to the other two types of hooks (49.9 ± 6.6 N and 31.3 ± 5.4 N). The results of these authors also seem to support the theory that the type of hook is one of the main factors influencing its detachment. As in the study by Johal et al., the main factors that seem to explain the difference in results with those of our study are the methodology and the type of hook used in the study.[11]

The universal testing machine is made for mechanical engineering tests and generally does not adapt itself to devices as small as the hooks we used (that measure less than 5mm). Therefore, in the present study, a special adaptation had to be made that would allow to keep the archwire stable and be able to apply the desired force to the hooks with different accessories such as tieback or elastomeric chain. This differs from the methodology used in previous studies, for example, Gomes et al., compared different hooks brands to determine which was the most stable when applying force. However, their sample size, was small, having only 10 hooks of each brand with a total of 90 hooks. The authors concluded that the ones that endured the greatest force were those of American Orthodontics welding hooks (8.1415 gf) and TP Orthodontic welding hooks (8.04967 gf). The maximum forces that the authors reported are much lower than those obtained in this study, but we also can conclude due to our maximum force was 2kg for the displacement, eviction or even the breaking of the hook, so if this happens it is because the clinician is generating excesive force (close to 2kg) with the materials used and this can be counterproductive for the effectiveness of our treatment and the oral health of the pacients. This may be due to the different types of hooks used. The aforementioned authors also carried out the tests with a universal testing machine without specifying if any special device had to be adapted in order to apply the force to the hooks and whether the applied force was generated with a common attachment in orthodontics like tiebacks or elastomeric chains.[13]

In another study, Griffind and Ferracane evaluated the use of adhesives and sandblasting on ball hooks crimped to rectangular archwires. The authors reported that the force required for hook detachment increased 10-fold for both methods. This can be a clinical disadvantage during patient care by increasing time of the appointment, however, different methods have also been proposed to speed up this type of technique. This technique shows an advantage by showing less percentage of displacement of the orthodontic hooks.[14] The results of the Griffind and Ferracane study coincide with ours in the sense that the group 4 hooks (crimped and dotted hooks) were the ones that showed the greatest dislodgment force and least displacement.

According to the results of Table 2, it seems that the tie-backs exert a greater and more controlled force in comparison with the elastomeric chains. This agrees with those reported in previous studies. Oshagh and

Shabnam studied the decay of force between tie-backs and elastomeric chains during gap closure. The authors reported that space closure using tie-backs was the method that exerted the greatest initial force, continued force during treatment, and had the lowest rate of force decay.[15] In another study, the authors compared the decay in strength of the elastomeric chain, tie-back, and coil spring when exposed to alcohol containing different brands of mouthwash. the authors reported that tie-backs have less strength decay when exposed to alcohol present in mouthwashes compared to elastomeric chain.[16]

In order to ensure this study's reliability, we also checked the effectiveness of our closed elastomeric chain of 3M UNITEK, which based on different studies, has been endorsed as the golden standard of chains in orthodontics.[17] As mentioned above, the deformation of the elastomeric chain (3M UNITEK ©) used in our study was 46.58%. this coincides with the percentage of optimal deformation reported in previous studies, for example, Yagura and Eliades reported that this type of elastomeric chain has a deformation of approximately 46% over 30 days and depends on the form of activation of the material, being the most effective activation, only 50% of the original size to ensure that the force is controlled and not excessive.[17,18] Due to its elastic properties, (fatigue and deformation) the elastomeric chain can become a material that when not used correctly, can generate uncontrolled forces and therefore cause unwanted effects on teeth.[19] Furthemore, Eliades et al. observed superior properties of the elastomeric chain 3M UNITEK when compared to the elastomeric chain brand Dentaurum.[17]

CONCLUSIONS

By comparing the 6 groups we could observe that the simple crimping of the hook is not stable and it is not enough for the stability of the hook. Clinically a dotted hook or with a distal reinforcement wich can be a "V stop" bend helps and ensure the stability of the hooks. Also, the use of tie-backs allows better control of applied forces. In addition, this study provides information on the behavior of the combined use of Mexican brands of hooks with American brands of tie-backs and elastomeric chains. This type of combinations is very frequent in our country.

CONFLICT OF INTEREST STATEMENT

The author declare that there is no conflict of interest related to the companies mentioned on this editorial.

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