The Effect Of Bracket Ligation Method On Canine Retraction

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ABSTRACT:

Aim: This study aimed to compare different types of ligation methods to obtain maximum tooth movement with the least undesirable rotation.

Methods: Titanium brackets bonded to acrylic canine teeth were ligated to straight stainless steel (SS) archwires using four ligation methods (figure-O and figure-8 elastics, SS ligatures, and Leone Slide ligatures). The teeth with the ligatures in place were stored in a water bath at 37°C for 1 day, 1 week, 2, 4 or 6 weeks before testing. The teeth were retracted through softened wax along the archwire and the amount of tooth movement and degree of rotation were measured.

Results: Slide ligatures showed the highest distance of tooth movement and degree of canine rotation followed by figure-O elastics, while figure-8 elastics showed the least amount of retraction and degree of rotation. SS ligatures showed moderate tooth movement with a minimal degree of rotation.

Conclusions: The study recommends the use of loose SS ligatures for canine retraction in sliding mechanics, while Slide elastic ligatures are best used in leveling and aligning stage of crowded teeth since they showed reduced friction with the archwire.

Keywords: Elastic, ligatures, friction, canine retraction. **(J Bagh Coll Dentistry 2017; 29(3):93-99)**

INTRODUCTION

During orthodontic treatment of extraction cases by sliding the canine along archwire, frictional force is generated at the bracket/ archwire/ ligature interface. To obtain an efficient orthodontic treatment, the applied force should be enough to overcome frictional force and the remaining part of force sufficient to induce a biological response within periodontal ligaments to get the desired tooth movement.

Approaches to avoid or minimize the effect of ligatures on frictional resistance include self-ligating brackets, differential placement of conventional elastomeric ligatures on special brackets or by using lubricated elastomeric modules or loosely tied stainless steel ligatures.

Not only is a pure bodily distal movement of the canine difficult to achieve with so-called sliding mechanics, the canine will also rotate because the force application is not through the center of resistance of the tooth in the labiolingual direction. A moment is necessary to counteract tooth rotation. This moment is exerted by the ligature tying the archwire to the bracket. Because of the risk of friction, the ligature tie cannot be very tight. Also, the ligature will probably yield during the control intervals, resulting in rotation of the canine during its distal movement [(1)].

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Thorstenson and Kusy [(2)] found that ligation with loosely tied stainless steel ligature wires eliminated friction. But, Iwasaki et al. [(3)] reported that consistent ligation forces are difficult to attain with stainless steel ligatures even for a trained operator and loose stainless steel ligation was not associated with lower frictional forces than tight stainless steel ligation.

Elastomeric modules are adversely affected by the oral environment, demonstrate stress relaxation with time, and exhibit great individual variation in properties. Also, size and cross-section of elastomeric ligatures have an effect on friction [(4,5)].

Edwards et al. [(6)] showed that elastomeric ligatures tied in figure-8 pattern gave significantly greater mean static frictional forces than the other ligation techniques, while teflon-coated ligatures produced the lowest mean static frictional forces.

Leone Slide ligature was introduced recently. It is manufactured with a special polyurethane mix by injection molding. Once the ligature is applied on the bracket, the interaction between ligature and slot form a tube-like structure, which allows the archwire to slide freely [(7)].

The aim of the study was to compare between four different types of ligation methods (figure-O elastics, figure-8 elastics, stainless steel ligatures and Leone slide ligatures) regarding the distance of canine retraction and the degree of canine rotation after retraction and to correlate between the distance moved and the rotation obtained for each ligation method.

MATERIALS AND METHODS

A freshly extracted human permanent maxillary canine tooth was used as a replica for fabrication of one hundred similar acrylic teeth for standardization of all teeth dimensions and avoid any surface area differences could affect our results.

Five copper boxes (88 x 48 x 30mm) each with eight brass posts (30 x 8 x 4mm) were used. The posts were fixed at a distance of 10mm from the walls of metal box to have a uniform amount of heat distribution through the wax. The wax used in this study was an equal mixture of Baseplate wax and Utility wax melted and mixed together [8,9]. A molar tube (Titanium, slot .018x.030, Dentaurum) was attached to each post being 7mm under the upper edge of post. This level will keep the apex of the acrylic teeth at a distance of 6 mm from the base of the metal box to avoid friction between the apex of tooth and the base during canine retraction.

A bracket (Titanium, slot .018x.030, Dentaurum) was bonded to each acrylic tooth with cyanoacrylate adhesive material in a standardization manner by the use of a specially fabricated mold.

Then, the acrylic canine teeth were inserted in the copper box by ligating their brackets to a .018x.025 SS archwire passing through the molar tubes by the use of elastic ligature.

The copper box was put on a flat table horizontal to the floor and checked by the pendulum fixed on both sides of the box as shown in figure 1. An equal mixture of baseplate wax and utility wax was prepared in accordance with previous studies [8,9] and poured into the boxes as three successive layers to compensate for cooling shrinkage, so that at the end a flat surface was obtained about 2mm gingival to the cemento-enamel junction of the teeth.

Figure 1: Test apparatus with different bracket ligations.

After cooling, the archwires were changed with .016”x.022” stainless steel (Dentaurum) and was cinched back at both ends wire for stabilization.

Then in each box the four brackets were ligated with different ligature types by using a Mathieu artery forceps making four groups:

Group 1: ligature elastics in figure-O (silver-metallic, Dentaurum).

Group 2: ligature elastics in figure-8 (silver-metallic, Dentaurum).

Group 3: Slide Leone elastic ligatures (Leone Orthodontic Products).

Group 4: preformed short stainless steel ligature wire ties (.010, Dentaurum), twisted 8 turns then untwisted 90 degrees and the excess was cut and tucked behind the archwire [10-13].

The boxes were then immersed in distilled water at a temperature of 37°C in a water bath to simulate the environments of temperature and humidity of oral cavity until testing time. According to the time of storage 5 subgroups were identified (24 hours, one week, two weeks, four weeks, and six weeks). Each subgroup composed of five teeth.

Because the molar tube represented the position of the second premolar, special hooks were custom made to enter in the molar tubes to standardize the distance between the hook and the canine bracket hook at 19mm (12mm for the coil spring length and 7mm for the activation). The hook was custom hand made from .016”x.022” spring hard stainless steel straight wire.

At the end of the storage period the temperature of the water bath was raised to 50°C for mild softening of wax and the boxes were kept in the water bath for one hour to allow temperature to equilibrate inside the wax of the assembly [8].

Then NiTi closed coil spring (12mm Rematitan, Dentaurum) were quickly placed for the 4 types of ligature at the same time as shown in figure 2 to minimize the difference in starting time for them as possible. Springs were replaced after three runs, because it was reported that the springs decayed by the seventh run [9]. The boxes were kept in the water bath at 50°C for 20 minutes and then chilled.

The distance from the molar tube to the bracket was measured using a dental vernier. The difference between the measurements before and after testing was regarded as the amount of tooth movement.

Then a top view image was taken by a digital camera to measure the degree of rotation of each tooth. This image was imported into FotoCanvas Program where a line was drawn along the bracket wings and another one along the archwire. The angle between the two lines was measured as shown in figure 3.

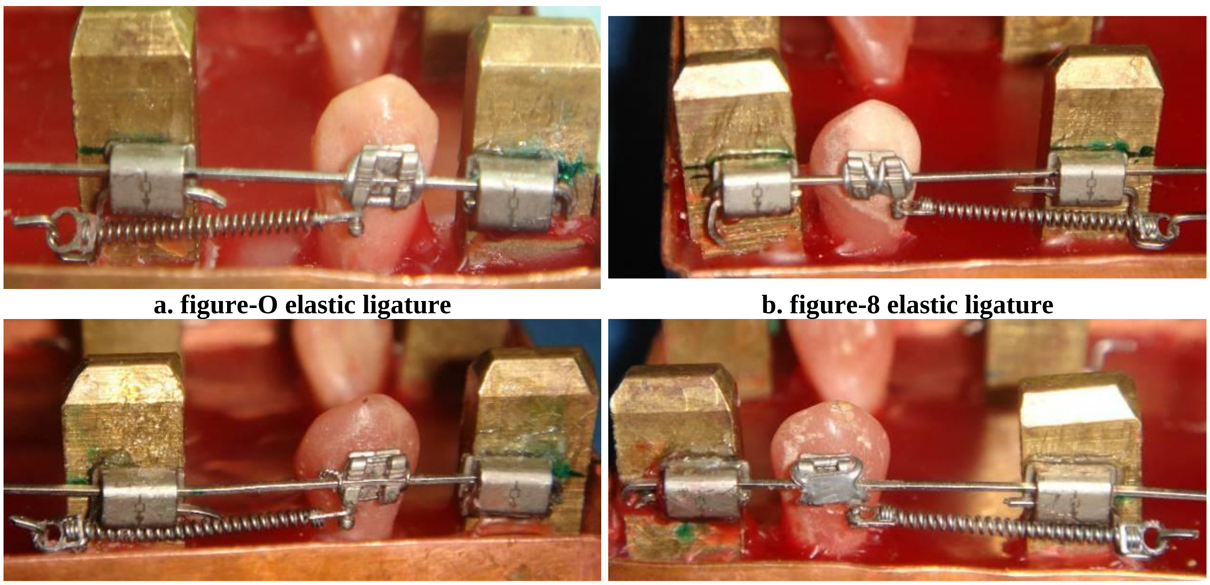
Finally, the copper boxes were cleaned from the wax and the whole procedure was repeated for the other time interval until all five storage times were tested.

It is worth mentioning that practical research steps have been done in orthodontic lab in college of Dentistry/ Baghdad University.

ANOVA test was used to examine any significant difference between more than two groups and LSD test was used to find any statistical significant difference between any two groups.

P values of less than 0.05 were regarded as statistically significant as follows:

$p>0.05$	NS	Non-significant
$0.05\geq p>0.01$	*	Significant
$0.01\geq p>0.001$	**	Highly significant
$p\leq 0.001$	***	Very highly significant



a. figure-O elastic ligature b. figure-8 elastic ligature

c. stainless steel ligature d. Slide elastic ligature

Figure 2: Canine retraction by NiTi closed coil spring for the four groups.

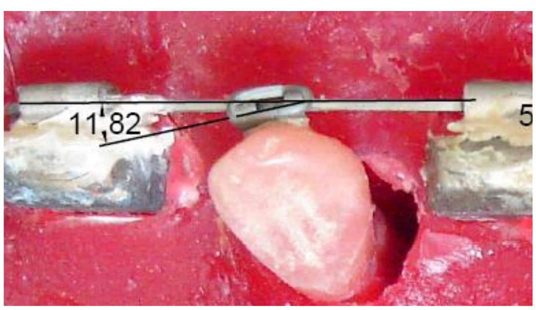


Figure 3: Measuring canine rotation.

RESULTS

Concerning the distance moved by the teeth, after one-day storage of the ligatures the highest amount of tooth movement was with Slide elastics followed by SS ligatures, then figure-O elastics and lastly figure-8 elastics as shown in table 1. After one week the same sequence of ligation methods was found. While, after 2 weeks the sequence changed where Slide elastics remained in the lead, but was followed by figure-O elastics, SS ligatures and lastly figure-8 elastics. This sequence remained the same for the 4 and 6 weeks storage periods. ANOVA test showed highly significant differences between the methods of ligation for each time interval and hence LSD test between each pair of ligation methods was done (Table 2).

Figure-8 elastics showed significantly less tooth movement than all the other 3 ligation methods at all time intervals, except for with SS ligatures at 6 weeks. While, Slide elastics presented significantly higher tooth movement than all the 3 ligation methods at all the 5 time intervals except for a statistically non-significant difference between Slide elastics with SS ligatures at the first day and with figure-O elastics at 2 weeks storage.

On the other hand, figure-O elastics started at the first day in the middle being significantly different from all the other three ligation methods. At the 1 week period the figure-O elastics approximated the reading of SS ligatures being statistically non-significant. At two weeks it increased even more to be non-significantly different from the Slide elastics, but significantly higher than figure-8 elastics and SS ligatures. At 4 and 6 weeks periods, the amount of tooth movement for figure-O elastics dropped to be significantly lower than Slide elastics and significantly more than figure-8 elastics and SS ligatures.

The time of the storage had a statistically significant effect on all types of ligation elastics but not on SS ligatures and that is clear in table 1. ANOVA test showed highly significant differences between the different time intervals for all ligation methods except SS ligatures. LSD test was made to find the differences between each two successive time intervals (Table 1). The differences between one day and one week were generally weak and only significant for figure-O elastics, while the differences between one and two weeks were highly significant for the three elastics. The differences between two and four weeks were significant for figure-O and figure-8 elastics, while between four and six weeks were weak and only significant for figure-8 elastics. LSD test was not computed for SS ligature because the result of ANOVA test was non-significant.

Concerning tooth rotation, the maximum rotation was seen with Slide elastics in all time intervals followed by figure-O elastics, while the least was with figure-8 ligation and SS ligatures (Table 3). ANOVA test were a highly significant difference at each time intervals differences between different methods of ligation and the results. So an LSD test was made to find the difference between each two different ligation methods (Table 4).

Slide and figure-O elastics showed significantly more rotation than figure-8 elastics and SS ligatures for all time intervals. Slide elastics showed more rotation than figure-O elastics at all time intervals. However, this difference was non-significant at 1 day period but statistically significant at 1, 2, 4 and 6 weeks periods. The degree of tooth rotation was statistically non-significant between figure-8 elastics and SS ligatures at all time intervals, where rotation was higher for figure-8 elastics than for SS ligatures except for 1 week period where the readings where comparable.

The effect of storage time on degree of rotation is displayed in figure 1, where there is a tendency to increased rotation with time for figure-O and Slide elastics. However, figure-8 elastics and SS ligatures showed a different picture. ANOVA test showed significant differences in the degree of rotation between the 5 time intervals for figure-O and Slide elastics only, so LSD test was made for them only where only Slide ligatures showed a significant increase in rotation from 1 day to 1 week (Table 3).

DISCUSSION

Slide elastics showed significantly higher tooth movement than all the other ligation methods at all time intervals, which may be attributed to that when the Slide elastics is applied on the bracket, the interaction between the ligature and the slot form a tube-like structure which allows the archwire to slide freely and achieve a large amount of tooth movement [7]; unlike the other three types of ligatures which make a direct contact with the archwire increasing friction.

Figure-8 elastics showed significantly less tooth movement than all the other 3 ligation methods at all time intervals, because of the higher stretching of the elastic making a greater force of ligation which makes an intimate relationship between the bracket slot and the archwire increasing friction. This is in agreement with the findings of previous studies [2,10,12].

After one day, tooth movement with figure-O elastics lower than SS ligatures. This may be attributed to that the elastic ligatures were stretched during placement on the bracket wings creating more ligation force than the loose SS ligatures. This result agrees with Bednar and Gruendeman [12], Iwasaki et al. [3] and Khambay et al. [14] who showed that elastomers induced more friction and archwire seating force than slackened steel ligatures but disagree with Riley et al. [15] and Schumacher et al. [11] who showed that SS ligatures produce more friction than elastomers. This diversity of agreement with previous researches on the difference between figure-O and SS ligatures may be because consistent ligation forces are difficult to obtain with SS ligatures even for a well-trained operator [3].

After one-week period, figure-O elastics approximated the reading of SS ligatures. At 2, 4 and 6 weeks it increased even more, to approximate Slide elastics but significantly higher than SS ligatures. This is attributed to that figure-O elastics are greatly affected by storage in water because elastomeric material undergo swelling and slow hydrolysis and this leads to filling of the voids in the rubber matrix by water where the water act as a plasticizer which facilitates slippage of polymeric chains past each other, eventually force decay occurs as explained by Young and Sandrak [14]. This is in agreement with the results of Andreasen and Bishara [17] and Nikolai [18].

Table 1: Descriptive statistics (Mean ±S.D.) of the distance moved (in mm) with ANOVA and LSD tests for the difference between the time intervals.

Material	1 day	1 week	2 weeks	4 weeks	6 weeks	ANOVA	LSD (difference between time intervals)				
						$F^{\$}$	P level	1d–1w	1w–2w	2w–4w	4w–6w
Figure-O	2.840 ±0.261	3.160 ±0.230	4.340 ±0.207	4.020 ±0.164	4.040 ±0.167	47.283	0.000***	0.025*	0.000***	0.025*	0.881
Figure-8	1.780 ±0.311	2.080 ±0.228	2.940 ±0.261	2.500 ±0.374	2.980 ±0.228	16.949	0.000***	0.113	0.000***	0.025*	0.015*
Slide	3.560 ±0.371	3.840 ±0.391	4.500 ±0.122	4.420 ±0.164	4.560 ±0.230	13.023	0.000***	0.127	0.001**	0.654	0.435
SS ligature	3.380 ±0.327	3.200 ±0.245	3.460 ±0.321	3.360 ±0.167	3.200 ±0.187	1.006	0.428				

$^{\$}$ d.f.=24; d=day; w=week

Table 2: Difference between the distance moved according to the ligation method at the five time intervals by ANOVA and LSD tests.

	ANOVA		LSD (difference between materials)					
	F	P level	O - 8	O - S	O - SS	8 - S	8 - SS	S - SS
1 day	31.278	0.000***	0.000***	0.003**	0.017*	0.000***	0.000***	0.387
1 week	33.501	0.000***	0.000***	0.002**	0.825	0.000***	0.000***	0.002**
2 weeks	47.639	0.000***	0.000***	0.306	0.000***	0.000***	0.003**	0.000***
4 weeks	63.480	0.000***	0.000***	0.016*	0.000***	0.000***	0.000***	0.000***
6 weeks	64.425	0.000***	0.000***	0.001**	0.000***	0.000***	0.109	0.000***

$^{\$}$ d.f.=19; O=Figure-O; 8=Figure-8; S=Slide; SS=SS ligature

Table 3: Descriptive statistics (Mean ±S.D.) of the degree of rotation (in degrees) with ANOVA and LSD tests for the difference between the time intervals.

Material	1 day	1 week	2 weeks	4 weeks	6 weeks	ANOVA	LSD (difference between time intervals)				
						$F^{\$}$	P level	1d–1w	1w–2w	2w–4w	4w–6w
Figure-O	13.566 ±2.074	14.512 ±2.025	16.118 ±1.177	16.580 ±0.692	16.038 ±1.391	3.309	0.031*	0.350	0.120	0.645	0.589
Figure-8	3.792 ±1.626	3.354 ±0.363	3.894 ±0.929	2.852 ±0.630	2.316 ±0.777	2.358	0.088				
Slide	15.546 ±1.423	18.942 ±1.338	18.260 ±2.337	19.088 ±1.198	19.458 ±0.820	5.463	0.004**	0.002**	0.483	0.396	0.702
SS ligature	1.738 ±0.736	3.486 ±0.999	2.838 ±1.581	2.248 ±0.553	2.076 ±0.352	2.668	0.062				

$^{\$}$ d.f.=24; d=day; w=week

Table 4: Difference between the degree of rotation according to the ligation method at the five time intervals by ANOVA and LSD tests.

	ANOVA		LSD (difference between materials)					
	$F^{\$}$	P level	O - 8	O - S	O - SS	8 - S	8 - SS	S - SS
1 day	100.309	0.000***	0.000***	0.059	0.000***	0.000***	0.051	0.000***
1 week	177.504	0.000***	0.000***	0.000***	0.000***	0.000***	0.877	0.000***
2 weeks	126.666	0.000***	0.000***	0.050*	0.000***	0.000***	0.311	0.000***
4 weeks	603.271	0.000***	0.000***	0.000***	0.000***	0.000***	0.255	0.000***
6 weeks	495.006	0.000***	0.000***	0.000***	0.000***	0.000***	0.683	0.000***

$^{\$}$ d.f.=19; O=Figure-O; 8=Figure-8; S=Slide; SS=SS ligature

Storage time significantly affected tooth movement with all types of elastomeric ligatures but not SS ligatures. This may be attributed to that swelling and hydrolysis will occur because of decomposition and leaching of some element from elastic [16] and prolonged contact with water leads to weakening of the intermolecular attraction forces of the chains since it acts as a plasticizer [19,20].

This is especially true for stretched elastic ligatures as found by Al-Faham [19] and Al-Mothaffar and Al-Khafaji [20] who reported a significantly faster breakdown of elastics when stretched compared with non-stretched.

Figure-O elastics significant increased the amount of tooth movement in relation to storage time from one day, one week and two weeks successively. But the difference between 4 weeks and 6 weeks was non-significant because the maximum force decay occurs until four weeks as shown by Hershey and Reynolds [21] who demonstrated that the average force remaining 25-35% of the initial force with simulated tooth movement.

On the other hand, figure-8 elastics showed a non-significant difference only between one day and one week, but showed highly significant differences after one week until six weeks. This is because figure-8 elastics are over-stretched causing full engagement of archwire in bracket slot [10]. After one week, the elastic force drops but is still enough to fully engagement of archwire in bracket slot and hence does not significantly affect the amount of tooth movement.

Slide elastics presented a non-significant difference between the successive time intervals with the exception of a significant difference between one week and two weeks periods. This may be because Slide elastics are not stretched during their placement on the brackets. Hence, they need more time of contact with water to undergo hydrolysis until two weeks storage time. This agrees with Al-Faham [19] who found that the effect of stretching is more than the effect of water sorption on force decay.

Concerning the degree of rotation of the tooth, Slide elastics allowed for more tooth rotation which may be because its design makes it fit on bracket slot without any pressure on archwire (tube like structure); allowing the bracket to rotate.

The same can be seen in figure-O elastics, although they are stretched over the bracket wings and press on the archwire but do not provide enough force to produce the adequate anti-rotation moment. This agrees with Bednar and Gruendeman [12] who stated that during canine rotation, the elastic merely stretch and this prevent the wire from being completely seated in bracket slot.

On the other hand, SS ligatures produced significantly less tooth rotation than figure-O and Slide elastics, because throughout the range of axial rotation the SS ligatures seated the wire tightly in the bracket slot, and this produces enough moment to reduce canine rotation during sliding mechanics which agrees with Bednar and Gruendeman [12] who stated that the SS ligated brackets produce moments approximately 2.5 times than the elastomeric ligated brackets.

Figure-8 elastics showed a similar manner, because it is highly stretched over the bracket causing full engagement of archwire in bracket slot [10] even during canine retraction which produces a large moment to counteract tooth rotation.

The difference between figure-O and Slide elastics was non-significant in the first day because the maximum amount of force decay occur in the first day for the stretched figure-O elastics approximating the properties of the unstretched Slide elastics which need prolonged contact with water to undergo hydrolysis [19]. This difference became statistically significant for the 1, 2, 4 and 6 weeks period when the elasticity of Slide elastics was affected. While the difference between figure-8 elastics and SS ligature was non-significant because they both cause full engagement of archwire in bracket slot which produce large anti-rotation moments that reduce canine rotation.

Storage time affects the degree of rotation through its effect on the force of ligation. Hence, it was found that there is a significant difference for figure-O and Slide elastics with the time intervals because with prolong contact with water and temperature, it undergo more force decay which lead to more tooth rotation [16].

When breaking up the time intervals, figure-O elastics show non-significant increase of tooth rotation between successive time intervals till 4 weeks. This is consistent with our previous finding of increased tooth movement with increased storage time. These findings were small and statistically non-significant may be because elastomeric materials lose about 50-75% of their force in the first day so the degree of rotation in first day was not much different from the other time intervals because only about 10-15% of force will be lost in the other time intervals [16] so there is no much difference in degree of rotation between them.

Slide elastics also showed a tendency to increased canine rotation and tooth movement with increased storage time. The amount of rotation was significantly different between the first day and first week because as explained earlier the Slide elastics being unstretched required prolonged contact with water to undergo hydrolysis and force degradation [19,20].

On the other hand, the effect of storage time on figure-8 elastics and SS ligatures was non-significant because it fully engages the archwire into the bracket slot which minimizes tooth rotation [10].

CONCLUSIONS

1. SS ligatures are preferred for canine retraction with sliding mechanics because they give moderate tooth movement with minimal tooth rotation.
2. The new Leone Slide ligature elastic ligature show the highest amount of tooth movement but with the highest degree of tooth rotation. Hence, it can be used successfully in leveling and aligning stage.

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الملخص

خلفية: هدفت هذه الدراسة إلى مقارنة أنواع مختلفة من طرق الربط للحصول على حركة الاسنان القصوى بأقل دوران غير مرغوب به.

الطريقة: أنياب مصنوعة من الأكريليك رُبِطتْ مباشرة بأسلاك فولاذية من خلال حاصرات تقويمية. ربط السلك بالحاصرات بأستعمال طرق مختلفة (مطاطات على شكلي O و 8 أوأربطة فولاذية أومطاطات ليون سلايد). ثم تم تخزين الأسنان مع الأربطة في حمام مائي بدرجة 37 سيليزية لمدة 24 ساعة، 1 أسبوع، 2 أسابيع، 4 أسابيع أو 6 أسابيع قبل الاختبار. بعدها تم سحبت الأسنان على طول السلك خلال شمع لين بدرجة 50 سيليزية وتم قياس كمية حركة الأسنان ودرجة الدوران.

النتائج: أظهرت مطاطات سلايد أكبر مسافة حركة ودرجة دوران للأنياب ثم تلتها مطاطات شكل O. بينما مطاطات شكل8 أظهرت أقل مسافة سحب ودرجة دوران. أما الأربطة الفولاذية أظهرت حركة معتدلة بدرجة دنيا من الدوران بسبب حصر السلك الفولاذي داخل شق الحاصرة.

الاستنتاجات: توصي الدراسة باستعمال الأربطة الفولاذية المرتخية لسحب الناب بالانزلاق الميكانيكي بينما يتم تفضيل استعمال السلايد المطاطي في مرحلة التسوية والاستواء من علاج الأسنان المزدحمة لأنها تخفض الاحتكاك مع السلك الفولاذي.