Evaluation of space closure rate during canine retraction with nickel titanium closed coil spring and elastomeric chain.

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الخلاصة

الهدف:تهدف الدراسة الى تقييم تأثير استخدام السلسلة المطاطية والنابض الحلزوني على معد ل إغلاق المسافة عند سحبه على القوس السلكي باستخدام مثيل الأسنان التشابهي. **المواد وطرائق العمل:**أثبتت المقاييس المعيارية ان كل الأسنان واقفة في مثيل الأسنان التشابهي وانها مغطاة ومثبتة بواسطة العضة الاكريلية عدا الناب ،السلسلة المطاطية او النابض الحلزوني يجب ان يسلط قوة على الناب مقدارها (180)غم المسافة المتاحة يجب ان تكون (5,13) ملم مقاسه بالمسطرة الرقمية. **النتائج:**لقد أظهرت نتائج هذه الدراسة ان انزلاق الناب على القوس السلكي المستطيل (0,025×0,019) انج أعطى تناقص معنوي في معدل إغلاق المسافة مقارنة باستخدام القوس السلكي الدائري (0,018)انج والقوس السلكي المستطيل (0,018 ×0,022) انج وقد أظهرت الدراسة نتائج أخرى مثل سحب الناب باستخدام السلسلة المطاطية أعطى تناقصا معنويا في معدل إغلاق المسافة مقارنة بالنابض الحلزوني وعند سحبه باستخدام الحاصرة التقويمية المصنوعة من السيراميك اعطى تناقصا معنويا في معدل إغلاق المسافة مقارنة باستخدام الحاصرة التقويمية المصنوعة من الفولاذ. **الاستنتاجات:**نستنتج من ذلك ان عملية انزلاق الناب باستخدام السلسلة المطاطية على القوس السلكي المستطيل قياس (0,0025×0,019) انج للحاصرة التقويمية المصنوعة من مادة السيراميك قياس(0,022) انج أعطى مقدار قليل في معدل اغلاق المسافة والعكس صحيح بالنسبة لسحب الناب باستخدام النابض الحلزوني على القوس السلكي الدائري قياس (0,018) انج والحاصرة التقويمية المصنوعة من الفولاذ أعطى مقدار عالي في معدل إغلاق المسافة .

ABSTRACT

Aims: . To investigate the rates of space closure achieved by elastomeric chain and nickel titanium coil springs with the evaluation of the effects of using different bracket types on the rate of space closure during its retraction along different sizes of orthodontic arch wires using typodont simulation system (Ormco). **Materials and Methods**: The standardization criteria were all typodont teeth situated in well aligned position, covered and immobilized by the acrylic bite except canine, elastic chain and nickel – titanium closed coil spring exerting 180 gm of force on canine measured carefully by tension gauge. The available space was 13.5mm (the rate of space closure). **Results**: The present study showed that when using elastic chain as a method of canine retraction gave rise to a a significant decrease in the rate of space closure as compared with nickel – titanium closed coil spring also sliding the canine using ceramic brackets gave rise significant reduction in the rate of space closure than when using stainless steel brackets. Another finding of the present study showed that sliding the canine on large rectangular arch wire (0.019x0.025 inch) gave rise to a significant reduction in the rate of space closure when compared with 0.018 inch and 0.018x0.022 inch arch wires were used. **Conclusions**: It was concluded that the canine retraction with 0.018 inch wire on Roth stainless steel bracket by closed coil spring gave rise a large amount of space closure rate. While the opposite is true for canine retraction with 0.019x0.025 inch wire on standard ceramic bracket by elastic chain retraction method.

Key words: space closure rate, sliding mechanics, canine retraction.

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INTRODUCTION

Reducing the duration of orthodontic treatment is of great interest to orthodontists.[1] Several bracket types and methods have previously been reported to efficiently move teeth. [2-6]The most time-consuming stage of premolar extraction-based orthodontic treatment is canine retraction. Any procedure which reduces the time required to perform this stage will also serve to shorten overall treatment time. [7]

Space closure via sliding mechanics can be done via various methods, but the appropriate force is applied via elastic chain or coil springs [8]. However , the potential disadvantage of elastic chain is the significant force decay over time. [9-11] As a result .NiTi springs are an alternative in wide spread use .NiTi springs have reported advantage of giving significantly quicker and more constant rate of space closure, [2,11-12] but are relatively expensive to use. [13]

The objectives of this study were*:* (1) To investigate the difference in the space closure rate between the elastic chain and NiTi closed coil spring during canine retraction . (2) To evaluate and compare the rate of space closure, during canine retraction with sliding mechanics in different bracket types (standard and Roth for both stainless steel and ceramic brackets). (3) To evaluate and compare the rate of space closure among different sizes of orthodontic arch wires, during canine retraction with sliding mechanics.

MATERIALS AND METHODS

The sample of this study consisted of 24 set of orthodontic brackets (only lower incisors, canines and second premolars) divided into different types (standard and Roth for both stainless steel and ceramic), 240 stainless steel arch wires divided into three sizes(0.018 inch, 0.018x0.022 inch and 0.019x0.025 inch), 120 closed coil nickel titanium spring and600 elastic chain ring .all the study was conducted using two typodont models.Retraction of canine by sliding mechanics was done by using one possibility of the 24 different combinations (four different brackets and three different arch wires and two methods of retraction) 24 brackets/arch wire/ method of retraction combination were tested 10 times for each variable (space closure rate, degree of tipping, degree of rotation and vertical assessment of canine) leading to a total of 240 trials for every variable. Two typodonts were prepared; one for standard edgewise bracket system and the other for Roth system. The brackets were fixed on metallic teeth using epoxy steel adhesive which is supplied into two tubes (Hardener and resin).Each bracket is positioned in its proper position by the aid of bracket positioning gauge to ensure greater vertical accuracy [14]

This study was conducted using class III typodont wax form, so alignment of the teeth was required to obtain a well aligned teeth, according to other studies .[15-18] This was done by placing the arch wires in the lower arch that were progressively upgraded through leveling and aligning, and finally to a 0.019 X 0.025" inch stainless steel wire, after immersing the typodont in a water bath for 5 minutes. The arch wire was ligated to the bracket by using elastomeric ligature because the high variability of tying ligatures makes the use of elastic ligatures the most consisted and reproducible .[19] Both the nickel titanium close coil spring and the elastomeric power chain were stretched to deliver 180 gm, using tesion gauge.[20] 1. Elastic chain was stretched between the hook on the buccal surface of the molar band and canine bracket where the elastic chain attachment can be circumferential around the four tie wings .[3]

2. A NiTi closed – coil spring was engaged between the first molar band hook and the power arm of canine bracket .[21]

Before starting movement of canine (left canine only) into first premolar site, criteria of the following important points should be established:1)All typodont teeth situated in well aligned position and covered by the acrylic bite plane (except canines).2)The distance between the distal wing of canines bracket and the mesial wing of second premolar's bracket was (13.5 mm). This distance considered as the available space and measured by digital vernia . [13]

Rate of space closure was measured after each method of canine movement where again the distance between the distal wing of canine's bracket and the mesial wing of second premolar's bracket is measured [11] by using digital vernia. This distance is considered as the remaining space, therefore;

Rate of space closure = available space – remaining space

The data was analyzed by using Statistical Package for Soft ware System (SPSS version 11.0 Inc., Chicago) Program was used.

1)Descriptive statistics: To show minimum and maximum values, meam and standard deviation for each variable and in each method of measurements. 2)Analysis of Variance (ANOVA): data achieved from previous measurements were initially analyzed by using the three way ANOVA test. 3)Duncan's Multiple Range test: These data were then analyzed by Duncan's Multiple Range test to determine the significant differences among the groups. 4)Student's t – test: to compare the mean value between the elastic chain and closed coil spring.

RESULTS

The descriptive statistics that include mean, standard deviations, minimum and maximum value of space closure for the 30 experimental groups of this study are listed in Table (1). ANOVA test show significant differences in all variables at $p \leq 0.05$ in Tables (2,3).

Table (1) Descriptive statistics with comparison of the rate of space closure among all 24 groups.

Type of bracket	arch wire	Method of retraction	Mean	SD	Min.	Max.	Duncan group
Standard Stainless steel	0.018 inch	Elastic chain	4.18	0.21	3.81	4.48	I
		Closed coil spring	4.64	0.02	4.61	4.66	J
	0.018 x 0.022 inch	Elastic chain	2.96	0.20	2.75	3.25	F
		Closed coil spring	4.11	0.45	3.35	4.89	H
	0.019 x 0.025 inch	Elastic chain	2.38	0.14	2.22	2.68	CD
		Closed coil spring	2.52	0.05	2.46	2.61	DE
Roth stainless steel	0.018 inch	Elastic chain	4.13	0.36	3.55	4.48	HI
		Closed coil spring	4.83	0.02	4.81	4.86	J
	0.018 x 0.022 inch	Elastic chain	3.37	0.47	2.74	3.84	G
		Closed coil spring	4.35	0.01	4.33	4.37	I
	0.019 x 0.025 inch	Elastic chain	2.52	0.04	2.46	2.58	DE
		Closed coil spring	2.68	0.12	2.43	2.89	E
Standard ceramic	0.018 inch	Elastic chain	3.36	0.38	2.86	3.88	G
		Closed coil spring	4.64	0.01	4.62	4.66	J
	0.018 x 0.022 inch	Elastic chain	2.60	0.42	1.95	3.43	DE
		Closed coil spring	3.29	0.15	2.99	3.47	G
	0.019 x 0.025 inch	Elastic chain	1.45	0.41	1.08	2.05	A
		Closed coil spring	2.03	0.23	1.65	2.21	B
Roth Ceramic	0.018 inch	Elastic chain	3.50	0.19	3.25	3.78	G
		Closed coil spring	4.82	0.01	4.8	4.83	J
	0.018 x 0.022 inch	Elastic chain	2.64	0.10	2.53	2.84	E
		Closed coil spring	3.93	0.04	3.87	3.98	H
	0.019 x 0.025 inch	Elastic chain	1.43	0.26	1.09	2.04	A
		Closed coil spring	2.25	0.19	1.96	2.51	BC

F-value = 150.641.P=0.000 ,Number for each group = 10 Measurements in millimeter

Table (2) Comparison of the space closure rate among different bracket types

Arch wire	Type of bracket	Elastic chain			Closed coil spring		
		Mean	**SD**	**Duncan**	**Mean**	**SD**	**Duncan**
0.018 inch	Standard stainless steel	4.18	0.21	B	4.64	0.02	A
	Roth stainless steel	4.13	0.36	B	4.83	0.02	C
	Standard ceramic	3.36	0.38	A	4.64	0.01	A
	Roth ceramic	3.50	0.19	A	4.82	0.01	B
	F-value		20.174*			488.646*	
0.018 x 0.022 inch	Standard stainless steel	2.96	0.2	B	4.11	0.45	B
	Roth stainless steel	3.37	0.47	C	4.35	0.01	C
	Standard ceramic	2.60	0.42	A	3.29	0.15	A
	Roth ceramic	2.64	0.1	A	3.93	0.04	B
	F-value		11.432*			13.903*	
0.019 x 0.025 inch	Standard stainless steel	2.38	0.14	B	2.52	0.05	C
	Roth stainless steel	2.52	0.04	B	2.68	0.12	D
	Standard ceramic	1.45	0.41	A	2.03	0.23	A
	Roth ceramic	1.43	0.26	A	2.25	0.19	B
	F-value		52.995*			31.031*	

Means with different letters vertically have significant difference at $p \leq 0.05$ according to Duncan test.
Number for each group = 10; Measurements in millimeters; ***** at $p \leq 0.05$

Table (3) Comparison of the space closure rate among three sizes of arch wires and between elastic chain and closed coil spring.

Type of bracket	Arch wire	Elastic chain			Closed coil spring		
		Mean	**SD**	**Duncan**	**Mean**	**SD**	**Duncan**
Standard stainless steel	0.018 inch	4.18	0.21	C	4.64	0.02	D
	0.018 x 0.022 Inch	2.96	0.2	B	4.11	0.45	C
	0.019 x 0.025 Inch	2.38	0.14	A	2.52	0.05	A
	F-value		242.761*			175.013*	
Roth stainless steel	0.018 inch	4.13	0.36	C	4.83	0.02	E
	0.018 x 0.022 Inch	3.37	0.47	B	4.35	0.01	D
	0.019 x 0.025 Inch	2.52	0.04	A	2.68	0.12	A
	F-value		55.928*			2585.877*	
Standard ceramic	0.018 inch	3.36	0.38	D	4.64	0.01	E
	0.018 x 0.022 Inch	2.6	0.42	C	3.29	0.15	D
	0.019 x 0.025 Inch	1.45	0.41	A	2.03	0.23	B
	F-value		57.120*			677.463*	
Roth ceramic	0.018 inch	3.50	0.19	D	4.82	0.01	F
	0.018 x 0.022 Inch	2.64	0.1	C	3.93	0.04	E
	0.019 x 0.025 Inch	1.43	0.26	A	2.25	0.19	B
	F-value		280.159*			1349.278*	

Means with different letters vertically and horizontally in each bracket type have significant difference at $p \leq 0.05$ according to Duncan test. Number for each group = 10; Measuremes in millimeters; ***** at $p \leq 0.05$

Comparison of the Space Closure Rate between Elastic Chain and Closed Coil Spring(Table 4)revealed that in all groups, closed coil spring showed highest mean value for the rate of space closure than elastic chain except on 0.019x0.025 inch wire for both standard stainless steel and Roth stainless steel bracket showed no significant differences in the rate of space closure.

Comparison of the Space Closure Rate among Different Bracket Types as demonstrated in Table(4) showed that in both methods of retraction and for the three types of arch wire, the group that use ceramic standard bracket showed the lowest mean value of space closure rate. However, there was no significant difference between standard and Roth type for ceramic and stainless steel bracket in elastic chain retraction group. While in closed coil spring group, the rate of space closure was greater in the Roth type as compared to the standard type for both ceramic and stainless steel brackets in all types of arch wires.

In both methods of retraction as shown in Table (2), sliding the canine along 0.018 inch wire by using four types of brackets produced the highest mean value of the rate of space closure, on the other hand using 0.019x0.025 inch wire produced the lowest one. While sliding the canine along 0.018x0.022 inch arch wire fell and distributed on a statistical level between the other two arch wires.

Table (4) Comparison of the space closure rate between elastic chain and closed coil spring.

Arch wire	Type of bracket	Elastic chain		Closed coil spring		t-value	P value
		Mean	SD	Mean	SD		
0.018 inch	Standard stainless steel	4.18	0.21	4.64	0.02	-6.919	0.000
	Roth stainless steel	4.13	0.36	4.83	0.02	-6.246	0.000
	Standard ceramic	3.36	0.38	4.64	0.01	-10.714	0.000
	Roth ceramic	3.50	0.19	4.82	0.01	-21.749	0.000
0.018 x 0.022 inch	Standard stainless steel	2.96	0.2	4.11	0.45	-3.998	0.001
	Roth stainless steel	3.37	0.47	4.35	0.01	-6.641	0.000
	Standard ceramic	2.60	0.42	3.29	0.15	-4.901	0.000
	Roth ceramic	2.64	0.1	3.93	0.04	-38.749	0.000
0.019 x 0.025 inch	Standard stainless steel	2.38	0.14	2.52	0.05	-3.089	0.006
	Roth stainless steel	2.52	0.04	2.68	0.12	-4.111	0.001
	Standard ceramic	1.45	0.41	2.03	0.23	-3.914	0.001
	Roth ceramic	1.43	0.26	2.25	0.19	-7.974	0.000

DISCUSSION

The present study showed that the sliding method that include Roth type for both stainless steel and ceramic brackets combined with close coil spring on 0.018 inch stainless steel wire gave rise to the highest mean for the rate of space closure. In contrast attachment of elastic chain on ceramic bracket along 0.019x0.025 inch wire showed the lowest mean for the rate of space closure. Many reasons affect this result:

1**.** *Effect of Bracket Materials and Types:*

Stainless steel bracket in the present study showed the highest mean value for the rate of space closure that may attribute to the low frictional force value of stainless steel bracket.[22] Comparison of frictional forces produced in ceramic and stainless steel brackets when different wires were used, suggested that for most sizes, the wire in ceramic brackets produced significant greater friction [23] which, in turn, demonstrate greater resistance to sliding .[24] Frictional force generated at the bracket archwire interface tends to impede the desired movement [15] , if it is so great it can minimize or prevent tooth movement .[25] The size of wider brackets is the other contributor that produces greater friction than narrower bracket, so the large size of ceramic bracket around which the stretched modules exert a greater normal force .[15] Narrow bracket (stainless steel) result in increased inter bracket distance, increases wire flexibility and decreases the resultant frictional force .[26] Bishara and Fehr [27] stated that ceramic brackets can cause nicks in the arch wire resulting in more friction between the bracket and arch wire. This can decrease the efficiency of tooth movement.The main advantage of straight wire is the simplicity of the system because after the leveling phase all bracket slots lie in the same plane, this because the Roth bracket have contoured bracket base with built in torque, so that the brackets' slots runs parallel to the horizontal plane such that the midpoint of the slot run through the LA point. This configuration permits sliding mechanics or movement of groups of teeth.[28] This is in agreement with the results of the present study that found sliding the canine using Roth brackets with closed coil spring gave rise a higher space closure than standard brackets.

2 .*Arch Wire Shape and Size:*

In the present study, the rate of space closure with round arch wire was greater than rectangular arch wire. This is in agreement with Frank and Nikolai [29] who cited that the distribution of normal force may be a significant factor, where the round wire makes only point contact with a bracket slot edge, while the rectangular wire makes line contact. Also Tecco *et al.* [30] showed that large rectangular arch wires generate higher friction than round small arch wires.

The amount of tooth movement decreases with an increase wire size .[31] This is in agreement with the present result. Increasing the size of the arch wire increases its stiffness .[32] Here more force is required to slide a bracket along a larger arch wire than smaller one .[33] Also Matarese *et al*. [34] showed that wires with larger cross sections increase the impact of binding and notching on resisting sliding during dental alignment.

3. *Methods of Retraction:*

The choice of force system and the optimum force magnitude are the decisive factors for obtaining the desired tooth movement .[35] Since the use of elastomeric chains and closed coil spring to translate canines during retraction is common in clinical circumstances [19] .It was decided to implement the same systems of retraction in this study.

This study showed that rate of space closure is significantly greater with nickel – titanium closed coil spring. These results agreed with other studies .[2,11,18] One possible explanation is that nickel – titanium close coil spring delivers a constant force unlike elastic chain which loses its force rapidly,[37] characterized by an initial exponential decrease reaching 50% because of stress relaxation as reported by Eliades *et al*. , [37] Eliades and Bourauel [17] and Kim *et al*. [38] and these results gained of this study. The other possible explanation is related to the increasing of the temperature of nickel – titanium coil spring leading to increasing load delivered by the coil spring .[10,39-41] While Brooks and Hersheg [42] found that when the elastomeric modules were heated the force decreased approximately 30% of the initial force. Also Nattrass *et al*. (33) confirmed that force decay with elastomeric chains is affected by environment and temperature. Nickel – titanium spring gave the most rapid rate of space closure and may be considered the treatment of choice [13] and more effective in terms of movement .[44]

CONCLUSIONS

1. There was no significance difference in the space closure rate between standard and Roth design for both stainless steel and ceramic bracket in elastic chain retraction group for the three types of arch wire except the rate of space closure on stainless steel bracket along 0.018x0.022 inch.
2. Sliding the canine by using Roth bracket design with closed coil spring gave rise a higher space closure rate than standard design.
3. When using stainless steel bracket, the rate of space closure increase. The opposite is true with ceramic bracket.
4. Canine sliding over arch wire of round cross section significantly increases the rate of space closure .The opposite is true with large size rectangular arch wire.

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