***ISSN:* 1812–1217**

Effect of Bracket's Slot Size on Canine Position and Space Closure Rate (A Typodont Study)

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الخلاصة

الأهداف: تهدف الدراسة إلى تحديد تأثيرآت حجم فتحة الحاصرة التقويمية (٠،٠٢٠ انج) المطور حديثا على موقع الناب ونسبة إغلاق الفضاء في الفك السفلي، **المواد و طرائق العمل** : تشمل الدراسة ست مجموعات وفقا لأحجام فتحة الحاصرة التقويمية (٠.٠١٨، ٠.٠٢٠ و ٠،٠٢٢)، وطرائق سحب الناب المستخدمة (سلسلة الطاقة المرنة و النوابض المغلقة اللولبية)، تم استخدام (٢٠٠) غرام من قوة السحب على سلك تقويم قياس (٠.٠١٧ × ٠.٠٢٥ من نوع أسلاك الفولاذ المقاوم للصدأ ربطت على ألأقواس التقويمية بواسطة أربطة مطاطية على طول مسافة (١٣) مم. تم تثبيت امتداد عارضة مستوى العضة (BPB) وامتداد عارضة الناب (CB)لقياس درجتي الميلان والدوران للناب. بعد غمس مثيل الأسنان في حمام الماء بدرجة (٥٠–٥٥) درجة سيليزية لمدة خمس دقائق، يتم قياس معدل إغلاق المسافة باستخدام المسطرة الرقمية (بين الأجنحة الوحشية للحاصرة المثبتة على الناب المنزلق إلى الأجنحة الإنسية للحاصرة المثبتة على الضاحك الثاني العلوي الأيمن). ويتم قياس درجة الميلان ودرجة الدوران للناب بعد اخذ صورة للمثيل السني باستخدام الكاميرا الرقمية وبإسقاط جانبي (لقياس درجة الميلان)، وإسقاط عامودي باتجاه الإطباق (لقياس درجة الدوران) للجهة اليمنى مباشرة باتجاه الناب، بعد ذلك يتم قياس الزاوية بين(BPB) و(CB)باستخدام المنقلة.**النتائج**: أظهرت النتائج أن فتحة القوس التقويمي(٠.٠٢٢) ولديها أعلى معدل كمية من إغلاق الفراغ والميلان و الدوران، في حين كانت فتحة الأقواس التقويمية (٠.٠٢٠) لديها غلق للفراغ أكثر من مجموعة الأقواس (٠،٠١٨) انج .**الاستنتاجات**: نستنتج من هذا البحث إن فتحة الأقواس التقويمية (٠.٠٢٠) انج لديها أعلى معدل من غلق الفراغ مع سيطرة على الميلان و الدوران شبيه أو أفضل من فتحة الأقواس التقويمية (٠.٠١٨) انج.

ABSTRACT

Aims: This study aimed to determine the effect of newly introduced 0.020" slot size brackets on dimensional positions and space closure ratio of mandibular canine. **Material and Methods:** The study includes six groups according to slot sizes (0.018", 0.020" and 0.022") and materials of canine retraction (elastomeric power chain and closed coil spring). A 200 gm of retraction force was used on 0.017" X 0.025" stainless steel wire ligated to brackets by elastomeric ligatures along 13 mm available space. After immersion of the typodont in water bath with (50-55) C for 5 minutes, the rate of space closure were measured in millimeter using vernier (from the distal wings of canine bracket and the mesial wings of the second premolar), In both vertical and horizontal directions, digital images were taken by camera and the angle between canine extension bar)C B) and bite plane extension bar (BPB) was measured by protractor to determine tipping and rotation.
Results: The results showed that 0.022" slot bracket groups had highest amount of rate of space closure tipping and rotation, while 0.020" slot brackets groups had higher space closure rate than 0.018" slot brackets groups. **Conclusions:** bracket slot 0.022" groups showed higher tipping, rotation and space closure rate, while 0.020" slot brackets groups had higher rate of space closure with same or better rotation and tipping control in comparison with 0.018" slot bracket groups.
Key Words: sliding, biomechanics, typodont , bracket's slot sizes.

Al-Jumaili KA, Ali AI, Shindala HM. Effect of Bracket's Slot Size on Canine Position and Space Closure Rate (A Typodont Study). *Al–Rafidain Dent J*. 2014; 14(1):60-69.
Received: 12/8/2012 ***Sent to Referees:*** 13/8/2012 ***Accepted for Publication:*** 26/11/2012

INTRODUCTION

Orthodontic tooth movement during space closure is achieved through two types of mechanics; segmental or sectional mechanics (non-frictional system) and sliding mechanics (frictional system) that involve either moving the brackets along an arch wire or sliding arch wire through brackets and tubes. [1] One of main differences between two mechanics is the friction, since sectional mechanics do not involve friction; while friction plays a significant role in sliding space closure. (2) Friction is the resistance to motion when an object moves tangentially against another. (3,4) During orthodontic space closure with sliding mechanics, frictional force is generated at the bracket arch wire interface and has a tendency to inhibit the desired tooth movement. (5) Tooth movement ceases when there is balance of the retraction force with the resistance force, frictional force and wire resiliency this is called ”frictional lock”. (6)

In orthodontic mechanics, friction is affected by the type of arch wire and bracket material, the design of the bracket and bracket slots, the ligation method, the inter bracket distance, and the oral environment. Reducing friction will result in less applied force than is needed for moving teeth during orthodontic treatment. (7)

After extensive experimentation with the edgewise appliance, Angle adopted the dimensions of 0.022 inch as his slot size because it allowed better control of crown and root position in all three planes of space using the precious metal arch wires available to him at the time, In the 1930s, stiffer, less expensive stainless steel arch wires were introduced, replacing the softer precious metal arch wires. These advances in metallurgy allowed orthodontists to provide similar clinical forces with smaller arch wires. This change in materials made it feasible to downsize from the traditional 0.022 inch bracket slot to the smaller 0.018 inch slot. (8,9)

Another factor in determining clinical outcome of an orthodontic case is treatment time. Although arch wires of the same size and material have been shown in studies to align the mandibular anterior teeth faster using the 0.022 inch brackets than the 0.018 inch brackets, total treatment time with 0.022 inch brackets is longer compared with 0.018 inch brackets. However, none of these studies measured the quality of the outcomes of any of the completed cases. (9)

The pre adjusted appliance seems to perform best in the 0.022” slot form, the larger slot allow more freedom of movement and helps to keep forces light, with the 0.018” slot the main working wires are normally more flexible than those used in 0.022” slots and hence show greater deflection and binding during space closure.(10)

The ideal in the use of sliding mechanics would find the best combination of arch wire size, slot size, and force which would translate a tooth along an arch wire with minimal friction without excessive tipping and without unduly disturbing anchorage. (11)

Aims of the study:

To evaluate the effect of different bracket’s slot width and type of retraction force(elastics and springs) on the rate of space closure, tipping and rotation of canine after sliding.

MATERIALES AND METHODS

The samples of this study divided into six groups (10 samples for each group), with a different slot sizes brackets (either 0.022”, 0.020” or 0.018” slot size, two sets of brackets of each slot size) and methods of force application (elastomeric power chain and nickel titanium closed coil spring, 30 pieces of each). The retraction of right mandibular canine was done by using either a short continuous elastomeric power chain (six rings) or nickel titanium closed coil spring (9 mm in length) which were attached posteriorly to the molar’s band hook and anteriorly to the canine’s bracket hook along (0.017” × 0.025”) stainless steel arch wire(6 pieces) and across an 13mm extraction space, and arch wire was ligated to orthodontic bracket by using elastomeric ligature.

The six groups are:

Group 1: (E22), 0.022” slot bracket and eastomeric chain for retraction.

Group 2: (S22), 0.022” slot bracket and nickel titanium coil spring for retraction.

Group 3: (E20), 0.020” slot bracket and eastomeric chain for retraction.

Group 4: (S20), 0.020” slot bracket and nickel titanium coil spring for retraction.

Group 5: (E18), 0.018” slot bracket and eastomeric chain for retraction.

Group 6: (S18), 0.018” slot bracket and nickel titanium coil spring for retraction.

Each one of these groups will undergo three measurements which are : tipping, rotation and rate of space closure.

The force applied was adjusted to be about 200 gm (measured by using a tension gauge) according to manufactures instruction (Ormco). The typodont was immersed in a water bath (HAAKE – England) with (50-55) 0C for 5 minutes then removed and immersed directly in a tap water. [12]

The typodont used in this study was prepared according to manufacturer's instructions (Ormco). The preadjusted Roth stainless steel brackets (either 0.022", 0.020" or 0.018" slot sizes brackets, Dentos, South Korea) were fixed on the metallic typodont teeth by using epoxy steel adhesive. [13] The vertical position of brackets were checked by using the bracket positioning gauge, [14] the Roth stainless steel molar bands were also fixed to the metallic first molar tooth by using Zinc polycarboxylate orthodontic cement. A class II typodont wax form was used, so aligment of the teeth was done by using arch wires started from 0.014"NiTi and gradually upgraded till we reach 0.017"X0.025" Stainless steel archwire.[15]

The first premolar was removed from the typodont to allow a space for canine sliding. Acrylic bite plane was constructed by taking a primary alginate impression for the aligned teeth then pouring by plaster materials then a special tray were made and a final impression taken with alginate to construct a master cast, then wax materials was applied in a way that cover the occlusal, incisal, palatal, labial and lingual surface of the teeth (except the canine and the first premolar extraction space), then the wax replaced by hot cure acrylic resin.[11]

A special two stainless steel bars (rods) were constructed, the first was a bite plane extension bar (BPB) and the other was canine extension bar (CB), as shown in (Figure1).

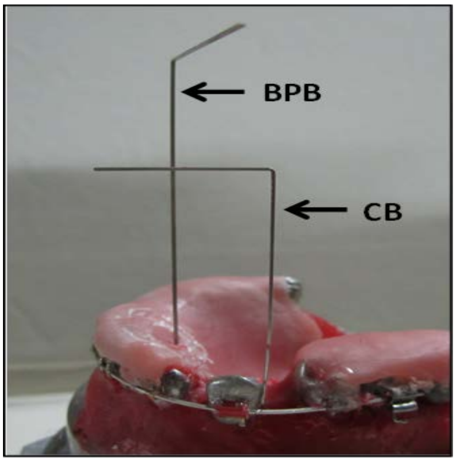

Figure (1): Canine extension bar (CB) and bite plane extension bar (BPB)

The BPB is a L-shape bar made from 0.018" X0.025" stainless steel rectangular wire, the short arm is inserted in the lingual midline of the acrylic bite plane, this bar emerges upward for 10 mm then it bends (90 degree) and extends facially 20 mm to make right angle with CB [11] , the CB were also constructed from a from 0.018" X 0.025" stainless steel rectangular wire in a form of L-shape, the short arm is welded to the distal aspect of the right canine (the tooth intented to be slides). This arm extended upward incisally 10 mm then it bends at right angle and extended anteriorly 20 mm and 5 mm over the tip of canine cusp and under the BPB by about 5 mm. such two bars are used as a guide to determine the position of canine after each sliding procedure regarding the degree of tipping and rotation, this method is a modification of Huffman and Way procedure [16].

A wooden table was constructed with two metallic bases, one to fix the digital camera (vertically for rotational measurements and horizontally for tipping measurements), and the other to fix the typodont in a way to allow a standard position for taking images before and after each sliding.

Canine position measurements:

Before starting sliding of canine into first premolar space, the following were checked:

First: all the teeth were situated in well aligned position.

Second: the distance between the distal wings of canine bracket and the mesial wings of the second premolar bracket was measured in millimeter by using digital vernier before each sliding (initial space before retraction) which found be equal to 14 mm.

Third: the angle between BPB and CB should be 90^0 from both horizontal and vertical direction. This angle is considered as CB original angle (zero tipping and rotation before retraction).

Sliding was performed by immersion of loaded typodont (power chain or coil spring attached between canine and molar) in water bath at temp. 50 – 55 degree for 5 min. so wax will soften as a reaction to heating permitting canine retraction to occurs, subsequently, typodont will remove and immediately immersed in tap water for other 5 minute for wax hardening and enhance teeth stability to occur for measurement.

After sliding, the distance between the distal wings of canine bracket and the mesial wings of the second premolar were again measured by using digital vernier after each sliding (remaining space after retraction), then the rate of space closure was measured (by subtraction of the remaining space from the initial space).

The canine's tipping degree after retraction was measured by taking an image to the typodont using digital camera, with transvers projection from right side (directly toward the right canine) where the angle between BPB and CB is exposed and then can be measured directly on the image using Protractor. This angle is considered as CB inclination angle, then the canine's tipping was measured by subtraction of the CB inclination angle from the CB original angle.

The canine's rotation degree after movement was measured by taking a photograph to the typodont using digital camera, with vertical projection from occlusal side (directly toward the right canine) where the angle between BPB and CB is exposed and then can be measured directly on the photograph using Protractor, this angle is considered as CB rotation angle, then the canine's rotation was measured by subtraction of the CB rotation angle from the CB original angle.

Statistical methods used include: descriptive statistics, analysis of variance (ANOVA) and Duncan multiple range testes.

RESULTS

The descriptive statistics (mean, standard deviations, standard error, minimum and maximum values) for the degree of tipping, rotation and rate of space closure of the three groups are listed in the Table (1).

Table (1): Descriptive analysis (mean, standard deviations, standard error, minimum and maximum values) for the tipping, rotation and rate of space closure of all six groups

		N	Mean	SD	SE	Min	Max
Tipping	E22	10	12.0000	1.63299	.51640	9.00	14.00
	S22	10	12.5000	1.64992	.52175	9.00	15.00
	E20	10	6.6000	1.50555	.47610	4.00	9.00
	S20	10	6.0000	1.15470	.36515	4.00	8.00
	E18	10	6.3000	1.41814	.44845	4.00	9.00
	S18	10	6.5000	1.35401	.42817	5.00	9.00
Rotation	E22	10	30.4000	2.63312	.83267	25.00	34.00
	S22	10	32.3000	1.88856	.59722	29.00	35.00
	E20	10	22.1000	2.60128	.82260	18.00	25.00
	S20	10	20.9000	2.37814	.75203	17.00	24.00
	E18	10	21.7000	3.05687	.96667	17.00	26.00
	S18	10	23.4000	2.50333	.79162	20.00	27.00
Rate of space closure	E22	10	6.4500	.51478	.16279	5.50	7.20
	S22	10	7.7400	.79610	.25175	6.20	9.10
	E20	10	4.7800	.90774	.28705	3.50	6.90
	S20	10	5.0000	.73030	.23094	3.90	6.00
	E18	10	3.8100	.77381	.24470	2.70	5.10
	S18	10	3.7400	.70742	.22371	2.90	4.90

*mean measurements for tipping and rotation are in degree.
** mean measurements of rate of space closure are in millimeters.

Tipping:

The ANOVA test for the tipping showed that there is a significant difference among the six groups at $p \leq 0.001$ as shown in the Table 2. The Duncan Multiple Analysis Range Test showed that (S22) group had the highest amount of tipping with a significant difference from other groups (except E22) at $p \leq 0.001$, while (S20) group had the lowest level of tipping with a non significant difference from E18, S18 and E20 groups at $p \leq 0.001$ as shown in the Table 3.

Table (2): One way ANOVA analysis for tipping measurements.

	Sum of Squares	df	Mean Square	*F*	Sig.
Between Groups	467.483	5	93.497	43.713	.000
Within Groups	115.500	54	2.139		
Total	582.983	59			

Table (3): Duncan's test for comparing the tipping for all six methods of canine retraction

Method	Mean*± SE	Duncan groups**
S22	12.5 ± 0.521	A
E22	12 ± 0.516	A
E20	6.6 ± 0.476	B
S18	6.5 ± 0.428	B
E18	6.3 ± 0.44	B
S20	6.00 ± 0.365	B

*The mean in degree measurement.
**different letters mean significant different at $p \leq 0.05$.
E22 : 0.022" slot bracket and elastomeric chain for retraction.
S22 : 0.022" slot bracket and nickel titanium coil spring for retraction.
E20 : 0.020" slot bracket and elastomeric chain for retraction.
S20 : 0.020" slot bracket and nickel titanium coil spring for retraction.
E18 : 0.018" slot bracket and elastomeric chain for retraction.
S18 : 0.018" slot bracket and nickel titanium coil spring for retraction.

Rotation:

The ANOVA test for the rotation showed that there is a significant difference between the six groups at $p \leq 0.001$ as shown in the table 4. The Duncan Multiple Analysis Range Test showed that (S22) group had the highest amount of rotation with a significant difference from other groups except (E22) group at $p \leq 0.001$, while (S20) group had the lowest amount of rotation with a significant difference from other groups except E20 and E18 at $p \leq 0.001$ as shown in the Table 5.

Table (4): One way ANOVA analysis for rotation measurement.

	Sum of Squares	df	Mean Square	*F*	Sig.
Between Groups	1210.133	5	242.027	37.686	.000
Within Groups	346.800	54	6.422		
Total	1556.933	59			

Table (5): Duncan's test for comparing the rotation measurement for all six methods of canine retraction.

Method	Mean*± SE	Duncan groups**
S22	32.3 ± 0.597	A
E22	30.4 ± 0.832	A
S18	23.4 ± 0.791	B
E20	22.1 ± 0.822	BC
E18	21.7 ± 0.966	BC
S20	20.9 ± 0.752	C

*The mean in degree measurement.
**different letters mean significant different at $p \leq 0.05$.
E22 : 0.022" slot bracket and elastomeric chain for retraction.
S22 : 0.022" slot bracket and nickel titanium coil spring for retraction.
E20 : 0.020" slot bracket and elastomeric chain for retraction.
S20 : 0.020" slot bracket and nickel titanium coil spring for retraction.
E18 : 0.018" slot bracket and elastomeric chain for retraction.
S18 : 0.018" slot bracket and nickel titanium coil spring for retraction.

Rate of space closure:

The ANOVA test for the rate of space closure showed that there is a significant difference between the six groups at $p \leq 0.001$ as shown in the Table 6. The Duncan Multiple Analysis Range Test showed that (S22) group had the highest level of rate of space closure with a significant difference from other groups at $p \leq 0.001$, while (S18) group had the lowest level with a significant differences from other group except (E18) group at $p \leq 0.001$. the remaining groups are distributed between the highest and lowest groups with a significant differences at $p \leq 0.001$ as shown in the table 7.

Table (6): One way ANOVA analysis for rate of space closure measurements.

	Sum of Squares	df	Mean Square	*F*	Sig.
Between Groups	122.771	5	24.554	43.908	.000
Within Groups	30.198	54	.559		
Total	152.969	59			

Table (7): Duncan's test comparing the space closure rate for all six methods of canine retraction.

Method	Mean*± SE	Duncan groups**
S22	7.74 ± 0.251	A
E22	6.45 ± 0.162	B
S20	5.00 ± 0.23	C
E20	4.78 ± 0.287	C
E18	3.81 ± 0.244	D
S18	3.74 ± 0.223	D

*The mean in millimeters measurement.

**different letters mean significant different at $p \leq 0.05$.

E22 : 0.022" slot bracket and elastomeric chain for retraction.

S22 : 0.022" slot bracket and nickel titanium coil spring for retraction.

E20 : 0.020" slot bracket and elastomeric chain for retraction.

S20 : 0.020" slot bracket and nickel titanium coil spring for retraction.

E18 : 0.018" slot bracket and elastomeric chain for retraction.

S18 : 0.018" slot bracket and nickel titanium coil spring for retraction.

DISCUSSION

Regarding tipping, (S22 and E22) groups reflect highest amount of tipping from other groups, this is may be due to larger space between bracket slot and archwire from other groups lead to poor wire control on tooth position during sliding, this agree with Ehsania *et al* [17] who mentioned that the tipping is a constant phenomenon during sliding and it always occurs when orthodontic force is applied to the tooth. The highest degree of tipping that associated with 0.022" brackets groups may be attributed to high rotational degree present in the same groups that makes part of the arch wire out of the slot at the distoocclusal and distogingival wings. Huffman *et al*, [11] mentioned that as wires decrease in size relative to bracket slot size creating more clearance between the arch wires and bracket slots there will be considerably more tipping.

Elastomeric ligatures that used in ligation were polyurethane based polymers, and studies have verified that these materials undergo stress relaxation and slow hydrolytic decomposition overtime [18] may lead to weaker ligation force.

No significance difference was found in this study between the effect elastomeric power chain and nickel titanium close coil spring on tipping .

The remaining groups (E20, S18, E18 and S20) reflect lower tipping magnitude than (S22 and E22) with non significant difference between them, this may be due to more close contact between arch wire and slot walls lead to better control over tooth position, in same time no significant difference in tipping was found between 0.018” slot and 0.020” slot bracket that may mean there was a small difference in controlling force of arch wire on tooth position in both slot dimensions. Also no distinctive effect on tipping was found between elastic chain and closed coil spring.

Regarding rotation, (S22 and E22) showed highest amount of rotation after sliding, retraction of the canine with a force labial to its center of resistance will cause a tendency for the tooth to rotate distopalatally, [19] a moment is necessary to counteract tooth rotation, this moment is exerted by the ligature tying the arch wire to the bracket, but the ligature will probably yield during the control intervals, resulting in rotation of the canine during its distal movement, [20] arch wire tend to escape from wide bracket slot and partial failure of elastic ligature to keep arch wire inside slot lead to this remarkable rotation.

In the same time (S20) group reflect smaller amount of rotation between all groups, smaller slot size than 0.022” groups lead to more friction between slot walls and wire surfaces, this friction may help in keeping wire inside slot and decrease rotation. Rotational play depend on the length of the rotational lever arm and the quality of the ligation technique to keep the archwire seated in the bottom of the slot. [21] No significant difference was found between (E20 and E18) on the effect of rotation during sliding.

Regarding space closure, both (S22 and E22) groups have highest space closure rates among all groups with a significant difference between them, minimal friction between arch wire and bracket lead to easy tooth sliding along arch wire these small friction come from wider bracket slots and relatively weak ligation force exerted by elastic ligature . Anderson *et al* 1970, suggested that friction can be reduced by having more freedom of movement between wire and bracket slot but these condition allow more tipping.

This study found significant difference between elastomeric power chain and nickel titanium closed coil spring on rate of space closure on 0.022” slot size bracket, coil spring obviously have larger space closure rate than elastomeric chain, this may be due to more constant continuous force of coil spring in comparison to rapid dropping of force in elastomeric chain, also heat have deteriorative effect on elastomeric chain lead to force relaxation phenomenon. [23]

In the same time, (E18 and S18) had minimal space closure rate due to high friction between bracket and arch wire that try to prevent sliding of tooth along arch wire, these greater friction resulted actually from the closer the fit between bracket and arch wire [24], the reduction of the clearance between arch wire and the bracket slot frictional resistance increases.[11]

Ligature elastic either placed around the bracket in a figure-O pattern or in a figure-8 pattern, this ligation method will increase the friction by pressing the arch wire against the bracket slot. [25]

In other hand (S20 and E20) had significantly intermediate space closure rate between 0.022” slot bracket and 0.018” slot bracket with a non significant difference between coil spring and elastomeric chain.

The results of this study have clinical value that using 0.020” slot brackets will significantly reduce tipping and rotation more than 0.022” and 0.018” slot brackets and in same time produce rate of space closure significantly more than 0.018” slot brackets does.

CONCLUSIONS

- Brackets with a slot gauge 0.022” have highest degree of rotation and tipping and largest space closure rate.
- Brackets with a slot gauge 0.020” have similar or better rotation and tipping control from 0.018 slot brackets.
- Rate of space closure in 0.020 slot bracket are larger than 0.018 slot bracket.
- As regard to the variables tested in this study, using 0.020 brackets are more beneficial than using 0.018 ones.

REERENCES

1. Gjessing P. Biomechanical design and clinical evaluation of a new canine-

retraction spring. *Am J Orthod Dentofac Orthop*. 1985; 87: 353-62.
2. Tecco S, Festa F, Caputi S, Traini T, Di Iorio D, D'Attilio M. Friction of conventional and self-ligating brackets using a 10 bracket model. *Angle Orthod* 2005;75:1041-5.
3. Cicciafesta V, Sfondini MF, Ricciardi A, Scribante A, Klersy C, Auricchio F. Evaluation of friction of stainless steel and esthetic self-ligating brackets in various bracket-archwire combinations. *Am J Orthod Dentofac Orthop*. 2003; 124(4): 395-402.
4. Cash A, Curtis R, Garrigia-Majo D, McDonald F. A comparative study of the static and kinetic frictional resistance of titanium molybdenum alloy archwires in stainless steel brackets. *Eur J Orthod* 2004;26:105-11.
5. Angolkar PD, Kapila S, Duncanson MG Jr, Nanda RS. Evaluation of friction between ceramic brackets and orthodontic wires of four alloys. *Am J Orthod DentofacialOrthop*. 1990; 98:499–506.
6. Yamaguchi K, Nanda R, Morimoto N, Oda Y : A study of force application , amount of retarding force and bracket width in sliding mechanics, *Am J Orthod Dentofacial Orthop*. 1996; 50-56.
7. Alper A, Arici N, and Arici S : The clinical and laboratory effects of bracket type during canine distalization with sliding mechanics, *Angle orthod*.2012 82(2).
8. Cash AC, Good SA, Curtis RV, McDonald F : an evaluation of slot size in orthodontic brackets – are standards as expected? , angle orth. Vol 74 no 4 2004.
9. Detterline DA, Isikbay SC, Brizendine EJ, Kula KS, clinical outcomes of 0.018- inch and 0.022- inch bracket slot using the ABO objective grading system. *Angle orthod*. 2010, 80 (3).
10. Mclaughlin RP, Bennett JC, Trevesi HJ, systemized orthodontic treatment mechanics , mosby 2001,
11. Huffman DJ , Way DC: A clinical evaluation of tooth movement along arch wires of two different sizes. *Am J OrthodDentofacialOrthop*.1983, 83(6): 453-459.
12. Baccetti T, Franchi L: Friction produced by types of elastomeric ligatures in treatment mechanics with the preadjusted appliance. *Angle Orthod*. 2006; 76(1): 211-6.
13. MuLaughlin RP, Bannett JC: Bracket placement with the preadjusted appliance. *J. Clin. Orthod*; 1995, 29(5): 302-311.
14. Elsheikh MM, Godfreg K, Manosudprasit M, Viwattanatipa N : A forsusdistalizer : A pilot typodont study; *Am J Orthod Dentofacial Orthop.* 2004, 7(2): 107-116.
15. Eliades T , Boourauel C: Intraoral aging of orthodontic materials: the picture we miss and its clinical relevance. *Am J Orthod Dentofacial Orthop*. 2005, 127(4): 403-412.
16. Hain M, Dhopatkar A, Rock P. The effect of ligation method on friction in sliding mechanics. *Am J Orthod Dentofacial Orthop*. 2003; 123(4):416- 22.
17. Ehsania S, Mandichb MA, El-Bialyc TH, Mirc CF. Frictional resistance in self-ligating orthodontic brackets and conventionally ligated brackets. *Angle Orthod*. 2009: 79(3): 592-601.
18. Thomas S, Sherriff M, Birnie D: A comparative in vitro study of the frictional charachteristics of two types of self ligating brackets and two types of pre-adjusted edgewise brackets tied with elastomeric ligatures, *Eur. J Orthod*. 1998,20,589-596.
19. Shpack N, Davidovich M, Sarne O, Panayi N, Vardimon AD, Duration and anchorage management of canine retraction with bodily versus tipping mechanics, *Angle Orthod*, 2008,78 (1).
20. Ziegler P, Ingervall B, A clinical study of maxillary canine retraction with a retraction spring and with sliding mechanics, *Am J Orthod Dentofacial, Orthop*,1989 (99-106).
21. Creekmore TD, Kunik RL,: Straight wire : The next generation, *Am J Orthod,Dento facial, Orthop,* 1993,104(5): 8-20.
22. GF Andreasen , FR Quevedo, Evaluation of frictional forces in the 0.022 × 0.028 edgewise bracket in vitro. *J Biomech*, 1970,3:151-160.
23. Baty D, Storie D, von Fraunhofer J, synthetic elastomeric chain: a literature

review, *Am J Orthod,Dento facial, Orthop*,1994 (536- 542).

24. Waters NE, Houston WJ, Stephens C, The charachterization of arch wires for the initial alignment of irregular teeth, *Am J Orthod,Dento facial, Orthop*,1981, 79(4): 373-389.
25. Ogura M, Yamagata K, Kubota S, Kim JH, Kuroe K, Ito G : Comparison of tooth movements using Friction-Free and preadjusted edgewise bracket systems. *J. Clin. Orthod*. 1996; 30(6): 325-330.