Access this article online
Quick Response Code:
Website:
www.jorthodsci.org
DOI:
10.4103/jos.JOS_73_18

Comparative evaluation of the maxillary canine retraction rate and anchorage loss between two types of self-ligating brackets using sliding mechanics

Ramadan Abu-Shahba[1] and Ahmed Alassiry

Abstract:

OBJECTIVE: To evaluate the maxillary canine retraction rate and anchorage loss with active and passive self-ligating brackets (SLBs).

MATERIALS AND METHODS: The study was conducted on 10 patients whose age ranged from 14–20 years. The patients had minimal to no crowding with a dental protrusion of maxillary incisor that required the extraction of maxillary first premolars and retraction of canines. The maxillary canines had to be in a good alignment and level before treatment to ensure that canine retraction had started from the same point bilaterally. A cone beam computed tomography (CBCT) had been taken for each patient's maxilla before treatment initiation and after complete canine retraction. Using nickel titanium, close-coil spring canine retraction on both sides and the rate of canine movement was measured.

RESULTS: The patients were checked every 2 weeks to measure the retraction rate and ensure that a constant force (150 g) was being delivered to both canines. The pre- and post-canine retractions CBCT were superimposed to evaluate the pattern and rate of canine movement and anchorage loss. The result of this study showed no statistically significant difference between the two groups.

CONCLUSION: The type of SLB, either active or passive, does not affect the rate or type of canine movement during its retraction in the orthodontic extraction cases, and the anchorage loss of the upper molars was nearly the same in both type.

Keywords:

Anchorage, canine retraction, self ligate

Department of Preventive Dental Sciences, Faculty of Dentistry, Najran University, Saudi Arabia, [1]Department of Orthodontics, Faculty of Dental Medicine, Boys, Cairo, Al-Azhar University, Egypt

Address for correspondence:
Dr. Ahmed Alassiry, Department of Preventive Dental Sciences, Faculty of Dentistry, Najran University, Saudi Arabia.
E-mail: ahmedassiry@hotmail.com

Introduction

Although space closure is a routine procedure in orthodontics, researchers have always tried to find efficient methods for canine retraction.[1]

Canine retraction is the most common clinical situation where sliding mechanics are used to move a tooth over a relatively long distance. The position of the canine after retraction has been recognized to be of paramount importance for function, stability, and esthetics.[2]

Canines can be retracted by two ways: Frictional (sliding) mechanics and Non-frictional (non sliding) mechanics. Frictional mechanics are the sliding of a tooth along an archwire by application of force.[3]

Non-frictional mechanics use loops for tooth movement (non sliding). Both techniques depend on the type of malocclusion and operators' skill and preference. Sliding

How to cite this article: Abu-Shahba R, Alassiry A. Comparative evaluation of the maxillary canine retraction rate and anchorage loss between two types of self-ligating brackets using sliding mechanics. J Orthodont Sci 2019;8:3.

mechanics produce friction at the bracket wire-ligature interface. Self-ligating brackets (SLBs) were first introduced in orthodontics in the 1930s. Because of the use of archwire ligation, these appliances have decreased chair time while increasing clinical efficiency.[4]

SLBs do not require an elastic or wire ligature but have an inbuilt mechanism that can be opened and closed to secure the archwire. In the absence of wire or elastomeric ties, frictional resistance is dramatically reduced and tooth movement occurs at a greater velocity.[5]

SLBs have actually been around since the 1930s but began to become somewhat popular in the 1980s. Since then, they have really taken off within the past few years. This is because of a number of reasons such as less chair time and fewer visits to the orthodontist. They can cause less friction and discomfort and can be potentially easier on teeth. The claim of reduced friction with SLBs is often cited as a primary advantage over conventional ligating brackets.

The aim of this randomized clinical trial was to evaluate the rate of canine retraction and anchorage loss in two different bracket types (self-ligating smart clip brackets and conventional MBT (design of McLaughlin Bennett and Trevisi) pre-adjusted edgewise brackets).

Materials and Methods

Ten orthodontic patients were randomly selected from a large pool of patients who were seeking orthodontic treatment at the outpatient clinic (Orthodontic Department, Faculty of Dental Medicine (Boys), Al-Azhar University, Cairo). Sample size calculation was from a statistical power analysis as follows: for an alpha error of 0.05 and power of 95%, the required sample size was estimated to be 20 canines, or ten patients.

Participants were selected to meet the following inclusion criteria: age range from 14–20 years old, all permanent teeth are erupted (3rd molar not included), all cases require orthodontic treatment with fixed orthodontic appliance, treatment plan should include upper first premolar extraction, the canines and first premolars are nearly in good alignment, good oral health, and compliance, no previous or current periodontal disease, no systemic disease or medication that could interfere with orthodontic tooth movement, no history of trauma, bruxism or para-functions, and no previous orthodontic treatment.

The research objectives were explained to the patients and/or their parents in detail, and an informed consent was signed by all of the patients and/or their parents before starting treatment.

Twenty upper canine teeth were divided randomly into two groups (right and left). The process of randomization and group allocation was undertaken.

Group A consisted of 10 canines receiving 0.022 × 0.028-inch slot metal passive SLBs[1*]. Group B consisted of 10 canines receiving 0.022 × 0.028-inch slot metal active SLBs.**

The patients followed up regularly according to the treatment protocol to assess the rate of canine retraction and the integrity of anchorage unit. Pre- and post-treatment upper canine retraction cone beam computed tomographs (CBCTs) were taken for each patient. All CBCT*** images were taken by the same machine and analyzed by the same operators.

Bracket bonding and leveling

According to random allocation, the patients of each group received 0.022 × 0.028-inch slot SLB, active (Prodigy) in one side and passive (Damon Q) on the other side. The active SLB was bonded to half of the maxillary dental arch, and the passive SLB was bonded to the other half, according to random allocation. The extractions of upper first premolars were made immediately before starting canine retraction. The bonding adhesive used in this study was light-cured orthodontic adhesive, bonded with direct technique and all molars banded.

The initial phase of leveling started after bracket bonding using 0.014-inch nickel titanium (NiTi) archwire[2****] for 4 weeks, then 0.016-inch NiTi for another 4 weeks, followed by 0.016 × 0.022-inch NiTi for 2 weeks.

After complete leveling and alignment, the extraction of bilateral maxillary first premolars was made immediately before insertion of the 0.016 × 0.022-inch Stainless. Steel (St.St) archwire.

Prior to canine retraction, the extraction space (between the cusp tip of canine and mesiobuccal cusp tip of first molar) on both sides was measured with a poly gauge caliper.

Canine retraction

After leveling phase, 0.016 × 0.022-inch St. St archwire was placed. The maxillary canines were retracted on both sides using a closed NiTi coil spring[3**] [Figure 1] size 9 mm exerting150 g of constant force as confirmed by force gauge.[6] The closed-coil spring was attached between the hook of the first molar to the hook of the canine bracket and checked every 2 weeks. If force

1*(Damon Q Oramcocor.orange., USA)
**(Prodigy SL OrmcoCor, orange, USA)
***Planmeca, Helsinki, Finland.
2****NiTi Memory wires, American Orthodontics, USA
3**Oromco, Spain

Figure 1: The maxillary canines were retracted on both sides using a closed NiTi coil spring

decayed (less than 150 g), reactivation was performed. Extraction spaces were measured every 2 weeks to calculate the rate of canine retraction.[7]

After both canines have been retracted completely into the extraction site (the distal surface of the canine reached the mesial surface of the second premolar), all post-retraction records were taken, analyzed, and compared to pre-treatment records.

Cone beam computed tomography

Certain reference planes were assigned, according to which measurements would be taken. After completion of superimposition, the two scans (preoperative and postoperative) were one unit and moved in the same sequence. To assign the maxillary plane, three points were identified at the level of the hard palate: Anterior nasal spine (ANS) anteriorly and the right and left posterior maxillary points (PMPr and PMPl).[8] The coronal line was adjusted to pass through the PMPr and PMP1, and the sagittal line passed through the anterior nasal spine (ANS) and Posterior nasal spine (PNS).[8]

At this orientation, the following views were obtained;

a. Axial view representing the maxillary plane (ANS, PMPr, and PMPl)
b. Sagittal view representing the mid-sagittal plane and perpendicular to the maxillary plane
c. Coronal view representing a plane passing through the PMPr and PMPl and perpendicular to the maxillary plane and mid-sagittal plane.

The following points, lines and planes were identified on each CBCT image:

A- The points

1. Right and left posterior maxillary points (PMPr-PMPl): the point of maximum concavity of posterior border of the palatine bone in the horizontal plane at both sides
2. Anterior nasal spine (ANS): the most anterior midpoint of the ANS of the maxilla
3. PNS: the most posterior midpoint of the PNS of the palatine bone
4. $UCCT_r$–$UCCT_l$: the cusp tip of the maxillary canine, right and left
5. $UCRA_r$–$UCRA_l$: the midpoint on the maxillary canine root apex, right and left
6. $U6MBCT_r$–$U6MBCT_l$: the cusp tip of the mesio-buccal cusp of maxillary first molar, right and left
7. $U6MBRA_r$–$U6MBRA_l$: the midpoint on the apex of the mesio-buccal root apex of maxillary first molar, right and left.

B- The lines

1. Canine long axis: the line connecting UCCT and UCRA
2. Molar long axis: the line connecting U6MBCT and U6MBRA.

C- The planes

1. Maxillary plane (MxP): a plane that passes ANS and both PMPr-PMPl
2. Coronal plane (CP): a plane that passes both PMPr-PMPl.

Linear measurements

1. The distance between the cusp tip of the maxillary canine ($UCCT_r$-$UCCT_l$) and CP in the sagittal section
2. The distance between the midpoint on the maxillary canine root apex (UCRAr-$UCRA_l$) and CP in the sagittal section
3. The distance between the cusp tip of the mesio-buccal cusp of the maxillary first molar ($U6MBCT_r$-$U6MBCT_l$) and CP in the sagittal section
4. The distance between the midpoint on the apex of the mesio-buccal root of the maxillary first molar ($U6MBRA_r$-$U6MBRA_l$) and CP in the sagittal section.

Angular measurements

1. Maxillary canine mesio-distal angulation: the angle between the long axis of the right or left maxillary canine and maxillary plane in the sagittal section
2. Maxillary canine bucco-lingual inclination: the angle between the long axis of the right or left maxillary canine and maxillary plane in the coronal section
3. Maxillary first molar mesio-distal angulation: the angle between the long axis of the right or left maxillary first molar and maxillary plane in the sagittal section
4. Maxillary first molar bucco-lingual inclination: the angle between the long axis of the right or left maxillary first molar and maxillary plane in the coronal section. [Figures 2 and 3].

Results

The intra-examiner reliability of the measurements was determined using double assessments of each parameter taken with the time interval of at least 3 weeks between the measurements. The intra-examiner reliability test showed no statistically significant difference between the two separate readings.

Comparison of treatment changes results between both groups

A paired *t* test was performed for the means of the measured variables, pre- and post-canine retraction, within each group. Highly significant increases were found on all canine and molar measurements, except for the UCRA in PSLBs group, as they showed no significant difference [Table 1].

A paired *t* test was performed to compare the mean changes between active and passive self-ligating groups, as they showed no significant difference between the two groups. [Table 2]

Rate of canine retraction

To compare the upper canine retraction rate at every 2 weeks along the total retraction time, and because the data showed a parametric distribution, a repeated-measures of analysis of variance (ANOVA) was used. The ANOVA revealed no statistically significant difference between the rates of canine retraction every 2 weeks in either the ASLB group or PSLB group [Table 3].

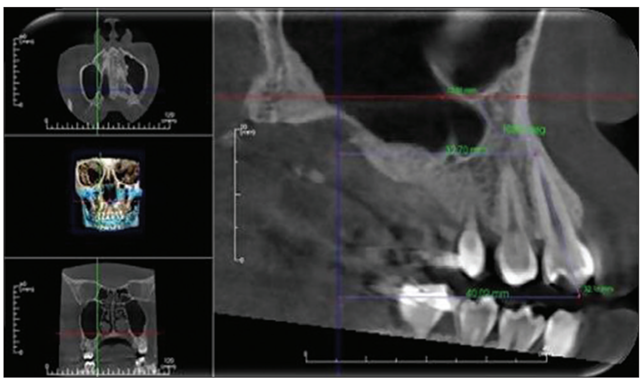

Figure 2: CBCT showing the angle between the long axis of the maxillary canine and maxillary plane in the sagittal section (mesio-distal angulation)

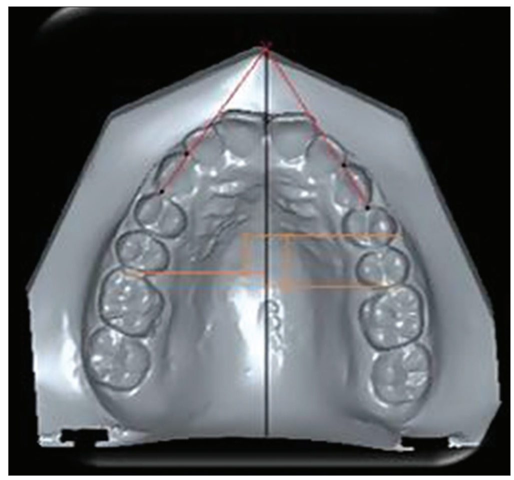

Figure 3: CBCT showing the angle between the long axis of the maxillary first molar and maxillary plane in the coronal section (bucco-lingual inclination)

Table 1: Comparison of treatment change results between both groups

Variable	Group	Mean change	SD	Confidence intervals		*P*
				Lower	Upper	
UCANG	ASLBs	−12.2 (11.39%)	2.46	−14.5	−9.87	0.205^{NS}
PSLBs	−10.55 (9.8%)	1.64	−12.18	−8.92		
UCINCL	ASLBs	6.39 (6.21%)	1.406	4.925	7.855	0.449^{NS}
PSLBs	7.25 (7.08%)	1.75	5.186	9.314		
UCCT	ASLBs	−5.11 (13.09%)	0.5276	−6.17	−5.34	0.557^{NS}
PSLBs	−5.60 (13.3%)	0.7284	−6.35	−4.85		
UCRA	ASLBs	−5.11 (11.6%)	0.5852	−196	−0.912	0.557^{NS}
PSLBs	−1.07 (2.99%)	1.236	−2.35	0.21		
MANG	ASLBs	2.5 (2.85%)	0.64	1.839	3.161	0.1514^{NS}
PSLBS	3.44 (3.93%)	1.2	2.184	4.692		
MINCL	ASLBs	3.02 (3.61%)	1.237	0.223	5.817	0.172^{NS}
PSLBs	1.18 (1.37%)	0.382	0.316	2.044		
MALCT	ASLBs	1.874 (8.66%)	0.5228	1.367	2.381	0.2000^{NS}
PSLBs	1.447 (6.66%)	0.5424	0.927	1.967		
MALRA	ASLBs	0.862 (4.19%)	0.374	0.507	1.217	0.459^{NS}
PSLBs	0.716 (2.29%)	0.272	0.461	0.971		
CCR	ASLBs	6.39 (6.21%)	1.406	4.93	7.86	0.200^{NS}
PSLBs	7.25 (7.07%)	1.75	5.19	9.3		
CMAL	ASLBs	1.874 (8.66%)	0.5228	1.367	2.381	0.200^{NS}
PSLBs	1.447 (6.66%)	0.5424	0.927	1.967		

NS – Non-significant, SD – Standard deviation, *P* – Probability level

Table 2: Descriptive statistics and test of significance for comparison between the rates of canine retraction between both groups at different succeeding time intervals

Time intervals	Group	Mean	SD	Mean difference	CI		*t* test *P*
					Lower	Upper	
T1-T0	*Active*	−0.482	0.298624	−0.080	−0.4074	0.2474	*t*=0.5133
	Passive	−0.562	0.359744				*P*=0.614[NS]
T2-T1	*Active*	−0.47	0.300533	0.1670	−0.2208	0.5548	*t*=0.9047
	Passive	−0.303	0.465103				*P*=0.3776[NS]
T3-T2	*Active*	−0.604	0.026907	0.0290	−0.0185	0.0765	*t*=1.281
	Passive	−0.575	0.06233				*P*=0.2163[NS]
T4-T3	*Active*	−0.477	0.208377	−0.1230	−0.2721	0.0261	*t*=1.733
	Passive	−0.6	0.043818				*P*=0.1002[NS]
T5-T4	*Active*	−0.659	0.169319	0.0480	−0.0748	0.1708	*t*=0.8213
	Passive	−0.611	0.045486				*P*=0.4222[NS]
T6-T5	*Active*	−0.584	0.081756	−0.0620	−0.1392	0.01519	*t*=1.688
	Passive	−0.646	0.073919				*P*=0.1087[NS]
T7-T6	*Active*	−0.558	0.031241	0.0350	−0.0257	0.0957	*t*=1.211
	Passive	−0.523	0.080876				*P*=0.2415[NS]
T8-T7	*Active*	−0.574	0.028705	−0.0740	−0.3251	0.1771	*t*=0.6192
	Passive	−0.648	0.357402				*P*=0.5436[NS]
T9-T8	*Active*	−0.614	0.029732	0.1020	−0.1484	0.3524	*t*=0.8558
	Passive	−0.512	0.356337				*P*=0.4034[NS]
T10-T9	*Active*	−0.632	0.173251	−0.0830	−0.2608	0.0948	*t*=1.001
	Passive	−0.715	0.100457				*P*=0.3337[NS]

NS – Non-significant, SD – Standard deviation, CI – Confidence intervals, *P* – Probability level

Table 3: Comparison of upper canine change results between both groups- Crown tip

		Mean	SD	Confidence intervals		Paired *t* test
				Lower	Upper	
Group	Active self	−1.1514	0.10552	−1.234	−1.068	*P*-value
	Passive self	−1.1206	0.14568	−1.27	−0.97	0.0959[NS]

NS – Non-significant, SD – Standard deviation, *P* – Probability level

When comparing the canine retraction rate every 2 weeks against the total retraction time between the two groups, the paired *t* test revealed no statistically significant difference between the two groups (*P* value 0.0959).

Discussion

Reducing the duration of orthodontic treatment is of great interest to both orthodontists and patients. Canine retraction is considered the longest phase in overall treatment time. Reducing frictional resistance between the archwire and brackets has been proven to lower the rate of tooth movement in sliding mechanics.[6,9] The use of SLBs provides a host of advantages, particularly those relating to reduced frictional resistance.[10,11]

Passive (Damon Q) and active (Prodigy) self-ligating appliances with self-ligating spring clips were introduced to presumably allow for efficient sliding mechanics. It has been documented that SLBs reduce both the static and kinetic friction during orthodontic teeth movement, which is reflected in the reduced degree of anchorage loss and total treatment time.[12,13]

Unfortunately, there are minimal studies that have investigated the effects of the two types of SLBs on the maxillary canine retraction rate and anchorage loss. Few studies performed on canine retraction have compared the self-ligating systems and conventional bracket appliance.[14-16]

The current study was conducted using 10 randomly allocated patients, ages 14–20 years, with the mean age of 15.5 years. The age range was selected to decrease the gap in the age between patients to ensure more or less the same biological response in all evaluated patients.[17,18]

Previous studies have reported that the space resulting from premolar extraction could be closed with different devices. The choice of NiTi closing coil springs used in the current study was on the basis of the fact that they do not exhibit rapid force decay such as that seen with elastic chain or modules, nor do they display the extremes in space closing forces of stainless steel closing loops. The low constant force of NiTi springs may be more biologically compatible than the intermittent high forces delivered by elastic chain, which has been found to degrade over time.[19-21]

The force employed in the present study (150 g) followed recommendations of many investigators who applied forces between 100 g and 200 g for canine retraction. Boster and Johnston concluded that the 150 g force level gave the highest canine retraction rate (1.3 mm/months) when compared to 60, 240, and 350 g that gave 0.8, 0.8, and 1 mm/month, respectively. The 150 g force used was considered optimal as it could result in rapid tooth movement with minor discomfort, avoiding or minimizing rare resorption.[22]

In this study, CBCT, which is a three-dimensional tool, was utilized in an attempt to overcome the limitation of the traditional two-dimensional projections. Many researchers have concluded that the 2-D cephalometric and panoramic projections were not reliable tools for assessing mesio-distal and bucco-lingual tooth angulation, particularly in premolar and canine regions, while CBCT images are considered an accurate alternative.[23,24]

The result shows that the canine retraction rate for the entire period showed no significant difference between passive SLBs (Damon, 1.15 mm/month) and active SLBs (Prodigy, 1.12 mm/month). The rate that was recorded every 2 weeks was not significantly different than any other 2 weeks in the same group or the other group. This is reflected on the total rate of canine retraction.

However, the rate of the canine movement in the current study with ASLB and PSLB was in agreement with the study of werecompared ASLBs, PSLBs, and conventional brackets concerning the rate of extraction space closure. Other studies have reported no difference in the rate of space closure between passive self-ligating and conventional brackets.[25-27]

The reported movement of the retracted canines was mainly uncontrolled tipping as indicated by the reduction in the upper canine angulation after retraction and the reduction in the distance between the upper canine cusp tip and the posterior maxillary point (PNS) (the point of maximum concavity of posterior border of the palatine bone in the horizontal plane at both right and left). There was also a reduction in the distance between the upper canine root apex and the posterior maxillary point, but with a lesser value, indicating retraction with uncontrolled tipping. These findings were observed in both groups without significant differences between them. These findings may be related to the distance between the point of force application and the center of resistance with moment creation. This dynamic is mainly because of the presence of even a minor space between the archwire and the bracket slot walls because the retraction archwire was a rectangular 0.016 × 0.022 inch St. St arch wire, in a 0.022 bracket slot. This was in accordance with the findings of other studies.[28]

Concerning the canine inclination, this study revealed a significant increase in buccal canine inclination in both groups after complete canine retraction. This finding may be related to the movement of canines toward a slightly wider arch. In addition, both SLBs that were used in this study are of standard torque (PSLB torque = +15 and ASLB torque = +12). However, this was in agreement with the findings of other studies. The sagittal molar movement was also similar to canine movement but in the opposite direction, indicating anchorage loss in mesial direction by tipping with an increase in molar buccal inclination.[29]

Conclusion

From the results of this randomized clinical study, we conclude the following:
1. The type of SLB, either active or passive, does not affect the rate or type of canine movement during its retraction in orthodontic extraction cases
2. Anchorage loss of the upper molars was nearly the same with the use of either active or passive SLBs.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

References

1. Hayashi K, Uechi J, Murata M, Mizoguchi I. Comparison of maxillary canine retraction with sliding mechanics and a retraction spring: A three-dimensional analysis based on a midpalatal orthodontic implant. Eur J Orthod 2004;26:585-9.
2. Gjessing P. Controlled retraction of maxillary incisors. Am J Orthod Dentofacial Orthop 1992;101:120-31.
3. Nishio C, da Motta AF, Elias CN, Mucha JN. *In vitro* evaluation of frictional forces between arch wires and ceramic brackets. Am J Orthod Dentofacial Orthop 2004;125:56-64.
4. Stolzenberg J. The Russel attachment and its improved advantages. Int J Orthod Dent Children 1935;21:799-904.
5. Edward GD, Davies EH, Jones SP. The *ex vivo* effect of ligation technique on the static frictional resistance of stainless steel brackets and arch wires. Br J Orthod 1995;22:145-53.
6. 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.

7. Swennen GRJ, Schutyser F, Hausamen JE. Three-Dimensional Cephalometry·- A Color Atlas and Manual. Springer-Verlag; 2006. p. 113-234.
8. Moreira CR, Sales MA, Lopes PM, Cavalcanti MG. Assessment of linear and angular measurements on three-dimensional cone-beam computed tomographic images. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2009;108:430-6.
9. Franchi L, Baccetti T, Camporesi M, Barbato E. Forces released during sliding mechanics with passive self-ligating brackets or nonconventional elastomeric ligatures. Am J Orthod Dentofacial Orthoped 2008;133:87-90.
10. Krishnan M, Kalathil S, Abraham KM. Comparative evaluation of frictional forces in active and passive self-ligating brackets with various archwire alloys. Am J Orthod Dentofacial Orthop 2009;136:675-82.
11. Shivapuja PK, Berger J. A comparative study of conventional ligation and self-ligation bracket systems. Am J Orthod Dentofacial Orthop 1994;106:472-80.
12. Anand M, Turpin DL, Jumani KS, Spiekerman CF, Huang GJ. Retrospective investigation of the effects and efficiency of self-ligating and conventional brackets. Am J Orthod Dentofacial Orthop 2015;148:67-75.
13. Miles PG. Self-ligating versus conventional twin brackets during en-masse space closure with sliding mechanics. Am J Orthod Dentofacial Orthop 2007;132:223-5.
14. Agrawal V. "A Comparative Evaluation of Canine retraction and Anchorage loss using Self-ligating and conventional MDT Pre-adjusted edgewise bracket systems-A Clinical Study. Aust Orthod J 2002;29:31-6.
15. Deguchi T, Imai M, Sugawara Y, Ando R, Kushima K, Takano-Yamamoto T. Clinical evaluation of a low-friction attachment device during canine retraction. Angle Orthod 2007;77:968-72.
16. Boester CH, Johnston LE. A clinical investigation of the concepts of differential and optimal force in canine retraction. Angle Orthod 1974;44:113-9.
17. Samuels RH, Orth M, Rudge SJ, Mair LH. A comparison of the rate of space closure using a nickel-titanium spring and an elastic module: A clinical study. Am J Orthod Dentofacial Orthop 1993;103:464-7.
18. Nightingale C, Jones SP. A clinical investigation of force delivery systems for orthodontic space closure. J Orthod 2003;30:229-36.
19. Von Fraunhofer JA, Bonds PW, Johnson BE. Force generation by orthodontic coil springs. Angle Orthod 1993;63:145-8.
20. Lotzof LP, Fine HA, Cisneros GJ. Canine retraction: A comparison of two preadjusted bracket systems. Am J Ortho Dento Facial Orthop 1996;110:191-6.
21. Bennett JC, McLaughlin RP. Controlled space closure with a pre adjusted appliance system. J Clin Orthod 1990;24:251-60.
22. Mckee IW, Williamson PC, Lam EW, Heo G, Glover KE, Major PW. The accuracy of 4 panoramic units in the projection of mesiodistal tooth angulations. Am J Orthod Dentofacial Orthop 2002;121:166-75.
23. Garcia-Figueroa MA, Raboud DW, Lam EW, Heo G, Major PW. Effect of buccolingual root angulation on the mesiodistal angulation shown on panoramic radiographs. Am J Orthod Dentofacial Orthop 2008;134:93-9.
24. Songra G, Clover M, Atack NE, Ewings P, Sherriff M, Sandy JR, *et al*. Comparative assessment of alignment efficiency and space closure of active and passive self-ligating vs conventional appliances in adolescents: A single-center randomized controlled trial. Am J Orthod Dentofacial Orthop 2014;145:569-78.
25. Echols PM. Elastic ligatures: Binding forces and anchorage taxation. Am J Orthod Dentofacial Orthop 1975;67:219-20.
26. Ireland AJ, Sherriff M, McDonald F. Effect of bracket and wire composition on frictional forces. Eur J Orthod 1991;13:322-8.
27. Cash AC, Good SA, Curtis RV, McDonald F. An evaluation of slot size in orthodontic brackets—are standards as expected? Angle Orthod 2004;74:450-3.
28. Al Thomali Y, Mohamed RN, Basha S. Torque expression in self-ligating orthodontic brackets and conventionally ligated brackets: A systematic review. J Clin Exp Dent 2017;9:123-8.
29. Kojima Y, Fukui H. Numerical simulation of canine retraction by sliding mechanics. Am J Orthod Dentofacial Orthop 2005;127:542-51.