Original Article

A comparative anchorage control study between conventional and self-ligating bracket systems using differential moments

Marcio Rodrigues de Almeida[a]; Francisco Herrero[b]; Amine Fattal[c]; Amirparviz R. Davoody[d]; Ravindra Nanda[e]; Flavio Uribe[f]

ABSTRACT

Objective: To compare the efficiency in anchorage preservation of conventional and self-ligating brackets after the extraction of first maxillary premolars using differential moment mechanics.

Materials and Methods: Thirty-eight patients requiring extraction of maxillary first premolars and maximum anchorage during space closure were evaluated based on bracket type. Group 1, comprising 23 patients, was bonded with preadjusted conventional brackets (CBs) with a slot of 0.022-inch $\times$ 0.030-inch. Group 2 comprised 15 patients who were bonded with 0.022 inch preadjusted self-ligating brackets (SLBs). Patients in both groups received a nickel titanium (NiTi) intrusion arch and a 150 g NiTi closing coil spring for separate canine retraction, followed by a continuous mushroom loop archwire to retract the incisors. Lateral cephalograms were available at the start of treatment (T1) and at the completion of space closure (T2). Statistical comparisons were performed with paired and unpaired Student's *t*-tests.

Results: No significant differences were found between the groups in maxillary molars anchorage loss (3.87 ± 1.35 mm and 3.65 ± 1.73 mm for the CB and SLB groups, respectively). Only the mean vertical movement of the tip of the incisor was significantly different between the groups (CB $= -0.92 \pm 1.46$ mm; SLB $= 0.56 \pm 1.65$ mm).

Conclusion: There were no significant differences in the amount of anchorage loss of the maxillary first molars between SLB and CB systems during space closure using differential moments. (*Angle Orthod.* 2013;83:937–942.)

KEY WORDS: Extraction; Anchorage control; Differential moments

[a] Full Professor, Department of Orthodontics, University of North Parana, Londrina, PR, Brazil.

[b] Former Research Fellow, University of Connecticut School of Dental Medicine, Farmington, Conn, currently a First Year Resident, School of Orthodontics, Jacksonville University, Jacksonville, Florida.

[c] Former Research Fellow, University of Connecticut School of Dental Medicine, Farmington, Conn, currently in private practice in Beirut, Lebanon.

[d] Clinical Instructor, Division of Orthodontics, Department of Craniofacial Sciences, University of Connecticut School of Dental Medicine, Farmington, Conn.

[e] University of Connecticut Orthodontic Alumni Endowed Chair and Professor, Department of Craniofacial Sciences, University of Connecticut School of Dental Medicine, Farmington, Conn.

[f] Associate Professor and Program Director, Division of Orthodontics, Department of Craniofacial Sciences, University of Connecticut School of Dental Medicine, Farmington, Conn.

Corresponding author: Dr Flavio Uribe, Department of Craniofacial Sciences, Division of Orthodontics, University of Connecticut Health Center, 263 Farmington Ave, Farmington, CT 06030
(e-mail: furibe@uchc.edu)

INTRODUCTION

Orthodontic treatment often includes extraction of the first premolars and subsequent retraction of anterior teeth to improve anterior overjet in Class II malocclusions and to reduce lip procumbency in bimaxillary protrusion.[1] Anchorage control is critical in such patients if maximum anterior tooth retraction is desired. Extraoral appliances such as headgears have been effective in molar anchorage control; however, their effectiveness depends on patient compliance.[2–4]

Burstone[5] developed a noncompliant intraoral anchorage preservation technique limited to archwires. The basis of this approach is a differential moment strategy between the anchor and active units. By altering the position, materials, and cross-section of a

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T loop, the anchor unit can remain stationary while displacing the active unit. This concept of differential moments was later applied to a continuous straight wire to control posterior anchorage during canine retraction with minimal anchorage loss.[6–8]

Friction in sliding mechanics has drawn a lot of attention, especially as it pertains to effectiveness and efficiency in orthodontic tooth movement. Studies have explored various factors that can affect friction during sliding mechanics in an in vitro setting.[5] These factors include bracket slot width, bracket composition, wire size, wire shape, wire composition, wire-to-slot ligation method, bracket/wire surface conditions, interbracket distance, saliva, and relative interface motion between bracket and archwire.[9,10]

Recently, numerous researchers have claimed that self-ligating brackets may reduce friction during orthodontic treatment.[11,12] As friction is decreased during canine retraction, molar anchorage loss is also reduced as a result of the smaller load on the anchor unit.[13,14] Although this concept is conceivable, clinical evidence is lacking to support the claim as the vast majority of the literature is based on in vitro studies with contradictory findings.

In fact, although some studies have reported reduced friction with self-ligating brackets (SLBs),[15–17] others have found that SLBs have similar or higher friction compared with conventional brackets (CBs).[18,19] Few studies have compared the effectiveness of anchorage control in SLBs and CBs during space closure. Recently, Mezomo et al.[20] and Machibya et al.[21] showed similar amounts of anchorage loss among orthodontic patients treated by SLBs and CBs. The aim of this study was to compare the effectiveness in anchorage preservation between CBs and SLBs after extraction of first maxillary premolars using differential moment mechanics for space closure. The null hypothesis was that there is no difference in molar anchorage loss between SLBs and CBs in space closure using differential moments.

MATERIALS AND METHODS

This retrospective study was conducted after obtaining approval from the Human Subject Protection Office of the University of Connecticut Health Center (IRB 12-134-1). A convenience sample (N = 38) from two groups of patients recruited from 2007 to 2011 was used. The first group (CB) consisted of 23 patients (18 females and 5 males) with an initial mean age of 15.36 years (SD = 5.59 years), who were consecutively treated at the private practice of one of the investigators MRA in Bauru, São Paulo, Brazil. This cohort of patients was treated using a differential moment technique for two-phase retraction of anterior teeth (separate canine retraction) after extraction of the first premolars with conventional brackets.

The other group (SLB) comprised 15 consecutive patients (10 females and 5 males) with an initial mean age of 17.63 years (SD = 8.93 years) who were previously treated at the orthodontic clinic at the Department of Craniofacial Sciences, University of Connecticut School of Dental Medicine using the same mechanics. The only difference from the CB group was that the SLB group was bonded with SLBs. Both samples were collected based on a treatment plan that required extraction of the maxillary first premolar and maximum anchorage control. To be included in the study the patients had to have an angle Class II molar and canine relationship or angle Class I malocclusion with bialveolar dental protrusion, all permanent teeth erupted (except second and third molars), and good oral hygiene. The exclusion criteria were missing permanent teeth (except third molars), periodontal bone loss, and any medical condition or medication taken that could affect tooth movement. The CB group had 9 patients with Class I malocclusion and 14 with Class II malocclusion. The SLB group had 6 patients with Class I malocclusion and 9 with Class II malocclusion.

Space Closure Guidelines

In the CB group, patients were bonded with conventional preadjusted brackets with a 0.022-inch slot (3M Unitek, Monrovia, Calif). Patients in the SLB group were bonded with a Carriere 0.022-inch preadjusted self-ligating appliance (ClassOne Orthodontics Co, Carlsbad, Calif). In both groups, nickel titanium (NiTi) wires for leveling and aligning were used with the same sequence of archwires beginning with the 0.014-inch and 0.016-inch until a 0.016-inch × 0.022-inch base archwire was inserted.

The following differential moments mechanics were used in both groups for space closure, according to Davoody et al.[6] Briefly, a prefabricated 0.017 × 0.025-inch NiTi intrusion arch was tied over the 0.016-inch × .0.022-inch base stainless steel archwire in the maxillary arch. The intrusion arch was tied mesial to the lateral incisors, delivering a tip-back moment on the molars and an intrusive force to the anterior teeth. Canines were retracted separately by means of NiTi coil springs (150 g of force) from the first molars (Figure 1a). Force levels delivered by the springs were checked at initial placement.

Once full canine retraction was obtained on the maxillary arch, the intrusion arch was removed and a prefabricated CNA Mushroom Loop (Ortho Organizers, Carlsbad, Calif) archwire was placed (Figure 1b). The loop was preactivated with 45° gable bends and

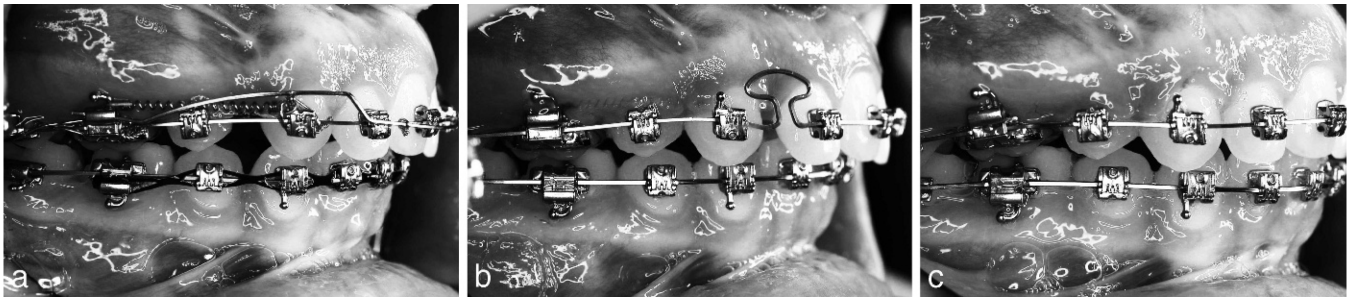

Figure 1. Differential moment approach to space closure. (a) Base archwire with NiTi intrusion arch tied anteriorly mesial to the lateral incisors and NiTi retraction coil spring from first molar to the canine. (b) Mushroom loop used to close space mesial to the canine. (c) Completed space closure at T2.

activated initially by separating the legs 4 mm. The loop was reactivated as needed, preventing excessive lingual tipping of the incisors, until the premolar space was closed (Figure 1c).

Lateral Cephalogram Analysis

Lateral cephalometric radiographs were taken for all patients before starting treatment (T1) and when space closure was completed (T2). Lateral cephalograms of the groups were standardized to a 7% magnification factor. The T1 and T2 lateral cephalograms for all patients were traced separately by two investigators. Any discrepancies in landmark location and measurements were resolved by mutual agreement.

The cephalograms were manually traced and superimposed on the maxilla. Maxillary bone, upper first molar, upper central incisor, and pterygomaxillary fissure were traced on both cephalometric radiographs. Two references axes were constructed, and nine variables were identified (Table 2). The first axis, or X axis, connected the anterior nasal spine to the posterior nasal spine. The second axis (Y axis) was perpendicular to the X axis and tangent to the posterior border of the pterygomaxillary fissure, creating an X-Y coordinate system that was transferred for reference to the T2 tracing. The T1 and T2 superimposition was done over the incisive canal and posterior palatal plane.[22] The U6 landmark represented the mesial contact point of the maxillary first molar. The other variables represented self-defined distances or angles to the coordinate system.

Statistical Analysis

To verify a normal distribution of the data, a Shapiro-Wilk test was used. Results of this test demonstrated that all cephalometric variables presented a normal distribution (for initial and final values, as well as for the changes). Therefore, paired and unpaired *t*-tests were used to compare intra- and intergroup changes. The results were regarded as significant at $P < .05$. All of the statistical analyses were performed with SPSS software for Windows version 17.0 (SPSS Inc, Chicago, Ill).

Two different examiners retraced all the radiographs and obtained double measurements for all the radiographic measurements at two different time points. Interexaminer reliability was assessed with the intraclass correlation coefficient. The intraclass correlation coefficient ranged from 0.88 to 0.98, showing good to excellent reliability between raters. Random error averaged less than 1.2 mm and 1° for linear and angular measurements, respectively.

RESULTS

There were no significant differences between the groups at T1 in gender, mean age, and malocclusion type (Table 1). Also, no significant differences were found between groups for any of the cephalometric variables evaluated (Table 2).

Table 3, shows that no significant differences were found between the groups for most variables. Maxillary molars moved mesially by 3.87 ± 1.35 mm and 3.65 ± 1.73 mm for CB and SLB, respectively. When measuring anchorage loss at the furcation of the maxillary molars, a similar trend was observed: CB = 3.29 ± 1.73 mm; SLB = 2.61 ± 1.72 mm. In the

Table 1. Descriptive Statistics of Group Samples and Comparison of Gender, Age, and Malocclusion Type Between Groups at T1[a]

	CB (n = 23)	SLB (n = 15)	Significance
Gender			NS*
Male	5	5	
Female	18	10	
Mean age (years)	15.36 (5.59)	17.63 (8.93)	NS**
Malocclusion type			NS*
Class I	9	6	
Class II	14	9	

[a] CB indicates conventional bracket; SLB, self-ligating bracket; NS, not significant.
* Chi-square test.
** Unpaired *t*-test.

Table 2. Mean Cephalometric Differences Between Groups at T1[a]

Variable	CB (n = 23), Mean (SD)	SLB (n = 15), Mean (SD)	Mean Difference (SD)	CI (95%)	*t*	*P* Value
U6 to Y (mm)	23.07 (2.81)	23.10 (3.43)	0.32 (1.01)	−2.09 to 2.03	1.01	.974
U6 to X (mm)	21.13 (1.29)	21.77 (2.42)	0.63 (0.91)	−2.50 to 1.22	0.91	.492
U6 angulation to X (°)	80.13 (5.08)	79.73 (5.55)	0.39 (1.74)	−3.15 to 3.94	1.74	.822
U1 tip to Y (mm)	52.21 (366)	51.70 (3.89)	0.50 (1.24)	−2.02 to 3.03	1.24	.688
U1 tip to X (mm)	27.30 (3.28)	28.22 (2.85)	0.92 (1.03)	−3.02 to 1.17	1.03	.379
U1 angulation to X (°)	116.63 (8.10)	117.60 (8.73)	0.96 (2.77)	−6.59 to 4.65	2.77	.729
U1 apex to Y (mm)	41.30 (3.74)	41.22 (3.83)	0.07 (1.25)	−2.46 to 2.62	1.25	.952
U1 apex to X (mm)	5.26 (2.48)	6.18 (2.31)	0.91 (0.80)	−2.54 to 0.71	0.80	.261
U6 furcation to Y (mm)	19.85 (2.49)	20.30 (2.77)	0.45 (0.86)	−2.20 to 1.29	0.86	.603

[a] SD indicates standard deviation; CI, confidence interval.
* $P < .05$.

vertical plane, maxillary molars extruded 0.94 ± 1.29 mm in the CB group and 0.68 ± 0.97 mm in the SLB group, respectively. The amount of mesial molar angulation was slightly different between the groups (CB = 2.22 ± 4.03°; SLB = 5.01 ± 5.04°), but with no statistical significant difference.

Horizontal movement of the incisor tip showed less incisor retraction (−3.80 ± 2.33 mm) in the CB group than in the SLB group (−4.90 ± 2.49 mm), but the difference was not significant. The incisor tip vertical movement was the only variable that was considered statistically significant. The mean vertical movement of the tip of the incisor was −0.92 ± 1.46 mm for the CB group and 0.56 ± 1.65 mm for the SLB group (P = .006). Thus, the upper incisors intruded slightly in the CB group and slight extrusion was observed for SLB group. However, the measurement of the apex of the incisors to the horizontal line showed that both groups had minimal intrusion (CB = −0.85 ± 1.13 mm; SLB = −0.13 ± 1.75 mm).

As for the angulation of the incisors, both groups had a controlled tipping reflected by a minimal anteroposterior movement of the incisor apex (CB = −0.81± 2.00 mm distally; SLB = 0.48 ± 2.53 mm mesially) and an angular change of the longitudinal axis of −3.25° for the CB group and −8.49° for the SLB group.

DISCUSSION

A premolar extraction in orthodontics is a treatment alternative geared primarily to resolve moderate to severe crowding and anterior tooth protrusion. Often the goal of space closure is to retract the maxillary anterior teeth while maintaining anchorage in the posterior teeth. Separate canine retraction (two-step) and en masse retraction are the two most common space-closure techniques after premolar extractions. Separate canine retraction has been described as a method for better anchorage preservation than en masse retraction as a periodontal root surface differential during the retraction phases may prevent anterior molar movement in the two-step retraction method. However, two recent studies found no significant difference in molar anchorage loss between these two methods of space closure.[23,24]

The method of separate canine retraction used in this study varied from the one used in the studies mentioned earlier.[23,24] Differential moments were used to enhance anchorage during both phases. On average, anchorage loss was 3.87 mm for the CB group and 3.65 mm for the SLB group, which is comparable to the results achieved in other studies using two-step or en masse space closure without differential moments. It is important to highlight that the

Table 3. Mean Cephalometric Changes From T1 to T2 Between Groups[a]

Variable	CB (n = 23), Mean (SD)	SLB (n = 15), Mean (SD)	Mean Difference (SD)	CI (95%)	*t*	*P* Value
U6 to Y (mm)	3.87 (1.35)	3.65 (1.73)	0.22 (0.50)	−0.79 to 1.24	0.44	.661
U6 to X (mm)	0.94 (1.29)	0.68 (0.97)	0.26 (0.39)	−0.52 to 1.06	0.68	.497
U6 angulation to X (°)	2.22 (4.03)	5.01 (5.04)	−2.79 (1.47)	−5.79 to 0.20	−1.89	.067
U1 tip to Y (mm)	−3.80 (2.33)	−4.90 (2.49)	1.10 (0.79)	−0.51 to 2.71	1.38	.175
U1 tip to X (mm)	−0.92 (1.46)	0.56 (1.65)	−1.48 (0.51)	−2.52 to −0.45	−2.90	.006*
U1 angulation to X (°)	−3.25 (7.71)	−8.49 (10.31)	5.24 (2.92)	−0.69 to 11.17	1.79	.082
U1 apex to Y (mm)	−0.81 (2.00)	0.48 (2.53)	−1.29 (0.73)	−2.79 to 0.20	−1.75	.087
U1 apex to X (mm)	−0.85 (1.13)	−0.13 (1.75)	−0.72 (0.46)	−1.67 to 0.22	−1.54	.131
U6 furcation to Y (mm)	3.29 (1.73)	2.61 (1.72)	0.67 (0.57)	−0.48 to 1.84	1.17	.246

[a] SD indicates standard deviation; CI, confidence interval.
* $P < .05$.

amount of variation reported in different studies for molar anchorage loss is quite large and ranges from 1.8 to 5.6 mm.[21,23–25] Ultimately, this large variation could be explained by the amount of space present after alignment for retraction of the anterior teeth.

To accurately measure the amount of anchorage loss, studies should report the amount of anchorage loss after the alignment phase has completed, just before the space-closure phase. Most studies report on the initial and final molar position based on the lateral cephalometric radiographs taken at those points in treatment. Davoody et al.[6] measured exactly the molar anchorage loss with differential moments after alignment and completion of space closure, finding, on average, 2.55 mm of maxillary mesial molar movement. Based on this finding one could presume that about 1 mm of molar anchorage loss may be expected during the alignment phase. Further studies evaluating this initial phase could answer this question.

SLBs have been introduced to allow for efficient sliding mechanics by reducing friction.[11,12] This study did not find a difference in molar anchorage loss between the CB and SLB groups. This result is in accordance with the findings of two recent studies.[20,21] In a randomized clinical trial, Mezomo et al.[20] found 2.68 mm of anchorage loss during the first 3 months of canine retraction for SLBs, while anchorage loss for CBs was 2.53 mm. On the other hand, Machibya et al.[21] found a mean 5.68 mm anchorage loss in the upper permanent molar for the SLB group compared to a mean loss of 5.33 mm in the CB group using en masse retraction for space closure.

It is not surprising that no difference in molar anchorage loss was found between both bracket types. Overall, the type of ligation should have little influence over friction in space closure. Space closure may be more dependent on the second order wire-to-bracket interface than on the first order, where design differences between brackets are apparent. Furthermore, other characteristics, such as bracket width, wire dimension, saliva, and occlusal forces, may be more important in affecting the frictional forces developed during canine retraction. This is supported by Thorensten and Kusy,[26] who found that binding is not affected by the bracket ligation method once active configuration was reached.

The differential moment technique in sliding mechanics, applied by means of an intrusion arch, could be labeled as a differential friction technique in space closure. The differential moment concept was originally described in frictionless mechanics by means of a loop responsible for the delivery of the different force systems with no sliding involved. By applying an intrusion arch at the molar, a moment is added to this tooth, which would increase the normal forces on the molar bracket and thus increase the frictional force. If the applied force is kept at a low level, the friction on the molar generated by the intrusion arch could have a major contribution to reducing anchorage loss, as was observed in this study.

The effects on the canine as a result of the increased friction on the molar were not measured in this study. However, it could be assumed that the intrusion arch reduces the deflection in the base arch resulting from the moment generated at the canine with the retraction force; therefore, it may be expected that the binding of the canine during sliding may be reduced.

In our study, only one variable was considered statistically different between the groups (incisor tip vertical movement). The mean vertical movement of the tip of the incisor was −0.92 mm for the CB group and 0.56 mm for the SLB group. Thus, the upper incisors showed a small amount of intrusion for the CB group, and an opposite movement was found for the SLB group (extrusion). The most likely reason for this difference was that the CB group needed more intrusion; however, there was no difference in maxillary vertical incisor relationship to the horizontal coordinate axis at T1 between groups. Alternatively, an initial difference in overbite and the initial relationship of the incisal edge to the occlusal plane between the groups could further explain this result. Nonetheless, this difference is of no clinical significance and shows that the intrusion arch during space closure is an adequate method for controlling the vertical position of the incisal edge during space closure. Furthermore, the type of incisor movement can be described as controlled tipping of the incisors for both groups with this mechanics.

The evidence has thus far been unable to prove enhanced performance of SLBs as it relates to efficiency of tooth movement in alignment or space closure.[20,27–29] This study also demonstrates that molar anchorage loss is similar regardless of the bracket system used. Biomechanical adjuncts to space closure, such as intrusion arches or gable bends, may be more important than the type of ligation method in anchorage preservation. However, a clinical trial comparing conventional straight wire space closure with a differential moment approach is needed.

CONCLUSIONS

- Differential moment approach to space closure using a CB system or a SLB system is effective in controlling molar anchorage loss, but mesial molar movement is still significant.
- There were no significant differences in the amount of anchorage loss of the maxillary first molars between SLB and CB systems during space closure.

- A clinically insignificant difference in amount of incisor tip change showed slight intrusion in the CB group compared with slight extrusion in the SLB group.

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