Original Article

The clinical and laboratory effects of bracket type during canine distalization with sliding mechanics

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ABSTRACT

Objective: To compare the extent of canine movement with sliding mechanics between a self-ligating (SC) bracket and a modified twin design (MT) bracket. To test the in vitro coefficient of friction (COFs) of these two metal brackets on 0.019- × 0.025-inch, stainless-steel arch wires.

Materials and Methods: For the clinical portion of this study, a split-mouth design was used to bond the brackets of 19 patients. Canine distalization was achieved on a 0.019- × 0.025-inch, stainless-steel arch wire with a nickel-titanium, closed-coil spring strained between a mini-screw and a canine bracket. The linear and angular measurements were performed using lateral cephalometric radiographs taken before and after canine distalization. A tribometer was also used to measure the COFs of the bracket types in vitro. For comparisons, Student's *t*-tests for paired and unpaired samples were used at the 95% confidence level.

Results: The extent of canine movement and the changes in the canine and molar teeth angles were not significantly different between the SC and MT brackets. After 8 weeks, the mean canine movements were 1.83 and 1.89 mm in the maxilla and 1.79 mm and 1.70 mm in the mandible with the SC and MT brackets, respectively. The mean COF of the MT brackets (0.21) was significantly lower than that of the SC brackets (0.37) during in vitro testing.

Conclusion: It is suggested that the rate of canine distalization was not different between the two groups, although in vitro COFs of the SC bracket was higher. (*Angle Orthod.* 2012;82:326–332.)

KEY WORDS: Self-ligation; Canine distalization; Coefficient of friction

INTRODUCTION

Friction is the force that resists motion when objects move tangentially against one another. Tooth leveling and alignment, sliding of the teeth, space closure and, active torque movement produce frictional resistance between the bracket slots and the arch wires.[1–3]

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.[4–7] Reducing friction will result in less applied force than is needed for moving teeth during orthodontic treatment.

Studies have shown that the applied force is lost during sliding mechanics due to the friction between the arch wire, the bracket slot, and the ligation.[8,9] Reducing the static and kinetic friction between the bracket and the arch wire might mitigate the side effects of orthodontic treatment and shorten the treatment period. In recent years, several bracket manufacturers have produced various bracket designs for this purpose. The most frequently claimed advantage of self-ligating brackets is the reduction in the frictional resistance that occurs with conventional brackets. Most of the studies that have investigated the frictional resistance of self-ligating and conventional bracket systems have been performed in vitro with passive configurations between the arch wire and the bracket slots.[7,10–13] However, the oral environment is not passive during orthodontic treatment, and the studies that have measured passive frictional resistance have been unable to fully simulate the oral cavity and tooth movement. In some recent studies, fretting devices have also been used to

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Table 1. Groups of Brackets Used in This Study

	SmartClip (SC)		Mini Uni-Twin (MT)	
	Upper Canine	Lower Canine	Upper Canine	Lower Canine
Slot width	0.022-inch	0.022-inch	0.022-inch	0.022-inch
Torque	0°	-6°	0°	-11°
Angulation	+ 8	+3	+11	+5
In/out	0.30 inch	0.30 inch	0.37 inch	0.37 inch
Manufacturer	3M Unitek, Monrovia, Calif, USA		3M Unitek, Monrovia, Calif, USA	

evaluate the surface properties and coefficients of friction of orthodontic materials.[14,15]

Therefore, the aim of this study is to investigate and compare the tooth movement rates between a self-ligating bracket and a modified twin design bracket with stainless-steel ligations using 0.019- $\times$ 0.025-inch stainless-steel arch wires in vivo. This study also aimed to evaluate the frictional behaviors of the same brackets with the same arch wires in vitro using a fretting machine.

MATERIALS AND METHODS

Clinical Study

Two types of preadjusted canine brackets, a passive self-ligating bracket system (SC) and a modified twin-bracket frame with a centered, single-bracket slot (MT), were used in this study. The specifications of these brackets are given in Table 1.

The subjects for this study were 19 orthodontic patients (5 male, 14 female) with a mean age of 13.6 years (range, 12.7 to 15.3 years) who were selected according to the following criteria: (1) good oral hygiene, (2) an indication for maxillary and/or mandibular premolar extraction and canine distalization, (3) no chronic systemic illnesses, and (4) no regular use of drugs, such as steroids. Upper- and lower-first premolar extraction was planned for 14 patients, while only upper-first premolar extraction was performed in five patients (33 arches total). All of the patients were informed about the aim of the study, and approval was received from the ethics committee (OMU ethics no. 2008/241).

A split-mouth design was proposed for bonding the brackets. The canine was bonded with an SC bracket on one side and MT brackets ligated with stainless-steel ligature wires on the other side. These sides were alternated with each consecutive patient.

After alignment and leveling, 0.019- $\times$ 0.025-inch stainless-steel arch wires were installed and left in place for 4 weeks. Titanium mini-implant screws (Imtec Ortho Implant, 3M Unitek, Monrovia, Calif) were then placed between the roots of the second premolars and the first molars, and these were used as anchorage points during canine distalization. The mini-implants that were used in this study were 1.2 mm in diameter and 8 mm in length. Periapical radiographs were taken to verify the absence of root-implant contact after placement. Orthodontic forces were immediately applied using closed-coil springs (Imtec, 3M Unitek) that were strained between the heads of the mini-screw implants and the hook of the canine brackets (Figure 1). According to the manufacturer, the spring has a force level of 200 g, and the patients were recalled every 4 weeks to check the activation of the springs.

Before taking lateral cephalometric radiographs to evaluate the dental changes, 0.021- $\times$ 0.025-inch, stainless-steel reference wires were inserted into the canine brackets and molar tubes. Wires (with L-shaped bends) were inserted into the right brackets and tubes to distinguish the right and left sides on the lateral cephalometric radiographs. Two sets of lateral cephalometric radiographs were used. The first (T_0) was taken before the start of canine distalization, immediately after implant placement. The second (T_1) was taken 8 weeks after the start of canine distalization.

For the maxillary and mandibular measurements, reference planes were created on the lateral cephalometric radiographs. The horizontal distances from the reference planes to the mesial surfaces of the molars were measured to evaluate the mesial movement of the molars. The horizontal distance between the canine and molar reference wires was also measured on both sides to evaluate the extent of canine movement (Figure 2). The measurements on lateral cephalometric radiographs were repeated by the same investigator at 2-week intervals.

In Vitro Friction Testing

The friction and coefficient of friction between the brackets and the arch wires during the sliding of SC and

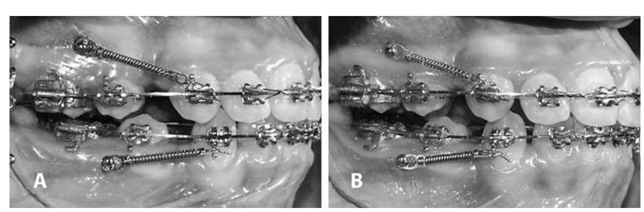

Figure 1. Canine distalization with NiTi closed-coil springs. (A) At the beginning of the study. (B) Eight weeks later.

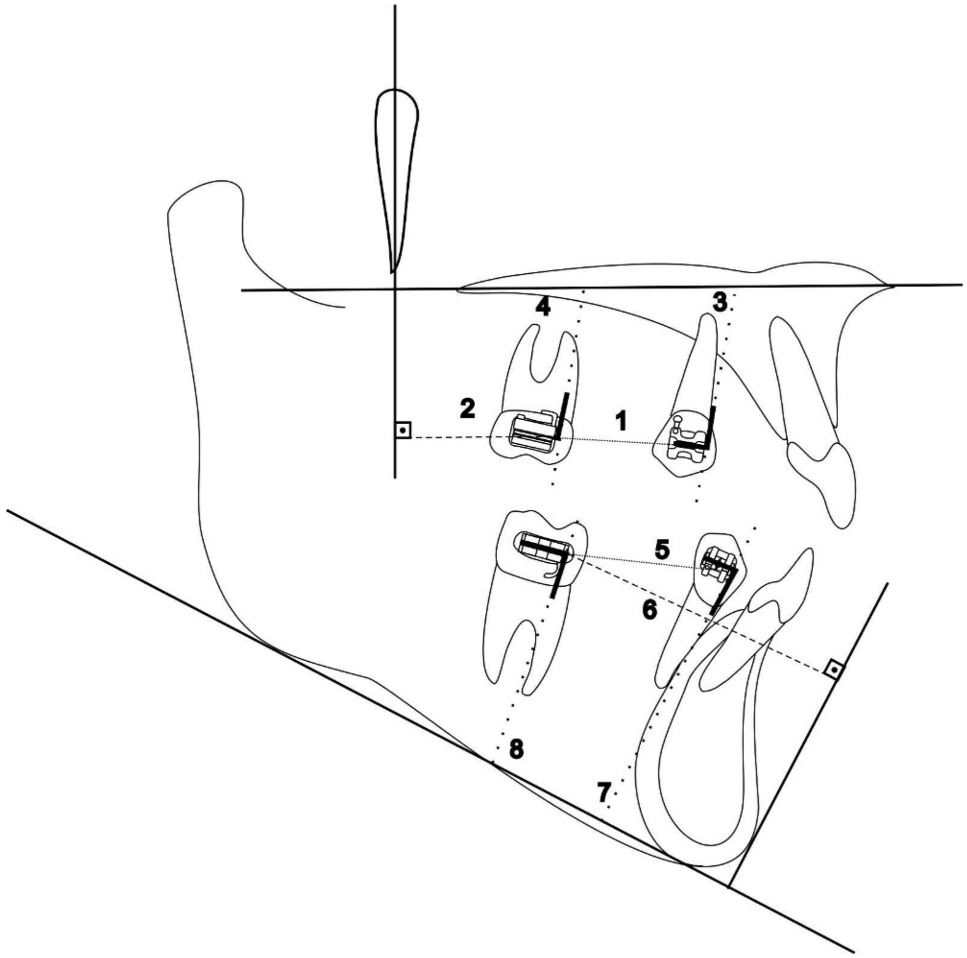

Figure 2. Variables evaluated in the study: (1) Mx3-Mx6 = distance between the upper canine and first molar reference wires, (2) Mx6-Y1 = distance between the upper first molar and posterior reference plane, (3) Mx3-MxP = angle between long axis of the upper canine and MxP; (4) Mx6-MxP = angle between long axis of the upper first molar and MxP; (5) Mn3-Mn6 = distance between the lower canine and first molar reference wires, (6) Mn6-Y2 = distance between the lower first molar and anterior reference plane, (7) Mn3-MnP = angle between long axis of the lower canine and MnP, (5) Mn6-MnP = angle between long axis of the lower first molar and MnP.

MT canine brackets on stainless-steel wires were also investigated in this study. A modified tribometer was used, and the samples were fixed onto a specific holder that was designed for this purpose. The arch wires were attached to the moving portion of the device, and the brackets were bonded onto a marble. A silicon component was also added to the testing apparatus to simulate the binding between the bracket and the arch wire that occurs in clinical situations (Figure 3). Although the wires were not ligated to the brackets during the testing of the MT brackets, a load of 150 g was applied to simulate the ligation force of an elastic module.[16] However, the SC brackets were tested with no load. Stainless-steel wires (0.019 × 0.025 inches), similar to those used in the clinical investigation, were used during the tests. Fifteen new brackets from both groups were tested with 30 new arch wires.

Friction testing took place under "dry" conditions at room temperature at 17 μm/s (~1 mm/min) on the stainless-steel arch wires. The dynamic friction was then measured. Special software was used to record the frictional properties of the samples every second during the sliding tests. The results were converted into graphs and numeral parameters.

Statistical Analysis

The data were analyzed with SPSS (version 12.0.0) for Windows. In the clinical portion of this study, the change from the predistalization period to the postdistalization period (T_0–T_1) was calculated for each variable. The groups were then compared using Student's *t*-test for paired samples at the 95% confidence level. For the in vitro study, Student's *t*-test for independent samples was used

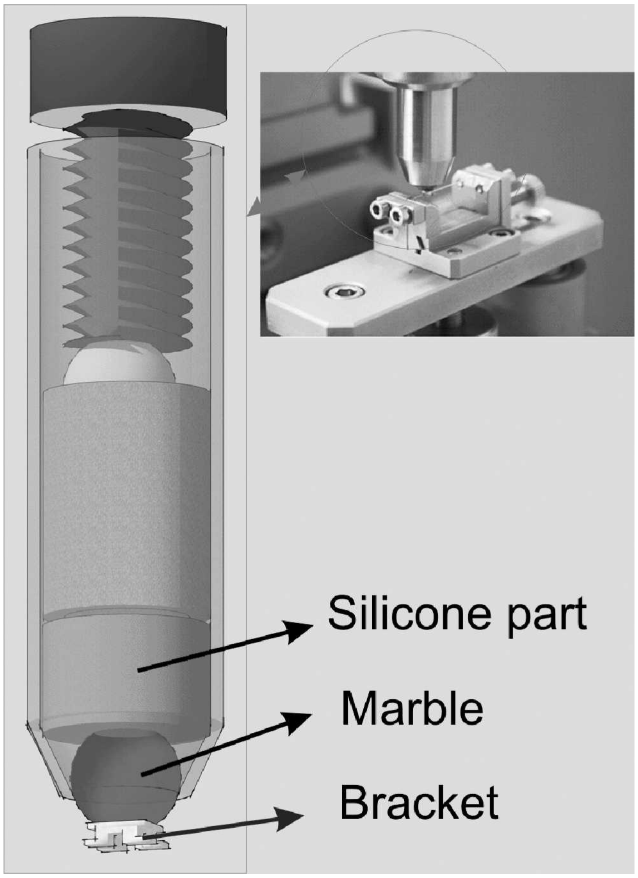

Figure 3. Tribometer and its modified parts used for in vitro evaluation.

to compare the coefficients of friction of the two bracket groups.

RESULTS

The descriptive statistical values of the variables and the significance of the differences between the predistalization and postdistalization measurements are given in Table 2.

Table 3. Comparison of Coefficients of Friction (COFs) of Groups[a]

Group	n	Arch Wire	COF Mean	COF SD	*P*
MT	15	0.019 × 0.025 inch ss	0.21	0.31	.012
SC	15	0.019 × 0.025 inch ss	0.37	0.22	

[a] MT indicates modified twin design; SC, self-ligating.

The mean distal canine movement with the SC brackets was 1.83 mm in the maxilla and 1.77 mm in the mandible. The distal canine movement with the MT brackets was 1.89 mm in the maxilla and 1.70 mm in the mandible. The extent of the canine distalization was not significantly different between the SC and MT groups ($P > .05$) after 8 weeks.

The angular movement of the canines and molars was also evaluated (Table 2). The canine tipped distally in the maxilla by 5.15° and 5.58° with the SC and MT brackets, respectively. In the mandible, the distal tipping of the canine crowns was 3° and 5.07° with the SC and MT brackets, respectively. There was no significant difference between the two bracket groups when the predistalization and postdistalization angles of the canines and molars were compared ($P > .05$).

In vitro testing showed that the modified fretting device generates reproducible results. The mean COF of the SC (0.37) brackets was higher than that of the MT (0.21) brackets (Table 3). Student's *t*-test for independent samples revealed a significant difference between the coefficients of friction of the SC and MT brackets ($P = .012$).

DISCUSSION

In the clinical portion of this prospective investigation, a split-mouth technique was used, and the patients were randomly allocated into two groups. Thus, pseudo-randomization due to the openness of the allocation system was minimized. To eliminate any interexaminer variation, a single professional bonded

Table 2. Descriptive Statistics and Comparisons of Tested Variables

Variable		n[a]	SC (T_0–T_1) Mean	SC (T_0–T_1) SD	MT (T_0–T_1) Mean	MT (T_0–T_1) SD	*P*
Maxillary							
Mx6-Y1	Mm	19	−0.12	0.55	0.04	0.45	.23
Mx3-Mx6	Mm	19	1.83	0.64	1.89	0.63	.77
Mx3-MxP	°	19	5.15	2.96	5.58	3.66	.66
Mx6-MxP	°	19	−0.26	3.47	−0.40	4.01	.89
Mandibular							
Mn6-Y2	Mm	13	−0.14	0.50	−0.13	0.49	.64
Mn3-Mn6	Mm	13	1.77	0.72	1.70	0.60	.81
Mn3-MnP	°	13	3.00	7.63	5.07	3.85	.42
Mn6-MnP	°	13	1.65	3.55	1.35	3.37	.72

[a] In one case, mandibular arch was excluded due to canine bracket loss.

all of the patients and placed all of the mini-screw implants.

This study also has several limitations. First, the time between the two recordings (T_0–T_1) was 8 weeks because, in some cases, the required canine distalization was achieved at the end of this period (2-mm or 2.5-mm distalization). However, this time was sufficient for investigating the canine movement rates associated with the two bracket types. Second, the in vitro friction tests were performed under dry conditions because of the difficulty of simulating the environmental conditions in the oral cavity exactly.

In the literature, there is no true consensus about the optimal force levels for canine distalization. Force systems change depending on the surface area of the canine root and the force magnitude but have been reported to approximately 50–500 g in previous research.[17–19] In this study, a force of approximately 200 g with a low variability of $\pm$25 g was chosen for canine distalization. The initial load that was applied by nickel-titanium closed-coil springs was measured and checked at every visit by a dynamometer. It can also be seen in Table 4 that the mean canine movement rate ranges from 0.7 mm/mo to 1.9 mm/mo in previous studies. All of the canines, as stated above, were successfully moved by 8 weeks in this study, and the canine movement rates were in the range of these values. The canine distalization rate was 0.91 mm/mo in the maxilla and 0.88 mm/mo in the mandible with the SC brackets and 0.94 mm/mo in the maxilla and 0.85 mm/mo in the mandible with the MT brackets.

There has always been a strong desire in orthodontics to move teeth in any direction without detrimental reciprocal forces. This can be achieved when skeletal anchorage is used. Therefore, mini-screw implant anchorage has entered routine clinical use in recent years. Several studies have recommended that at least 2 weeks of tissue cicatrization should elapse between mini-screw placement and load application.[20,21] However, it has been shown that the primary mechanical retention of mini-screw implants enables their immediate loading.[22,23] Therefore, all of 66 mini-screw implants were immediately loaded in this study. A recent study comparing the anchorage losses of mini-screw implants and conventional anchorage systems reported no anchorage loss on the implant side.[24] The extents of the upper- and lower-first molar movements in this study were similar. However, it should be noted that the maximum anchorage was planned during the distal movement of the canines, and thus, in this study, the transpalatal and lingual arches were cemented to the first molars in the maxilla and mandible. In only one patient, the bracket of the lower right canine was found to be debonded before taking the second (T_1) record. Therefore, the lower arch measurement of this case was removed from the study (Table 2). No mini-screw implants were lost during the study period.

Studies on the frictional resistance of orthodontic materials have had variable results due to the test conditions and setups. Many previous studies about the frictional forces of self-ligating brackets were performed in vitro and showed that self-ligating brackets reduced the normal frictional force.[7,10–13,25–27] In contrast, in this study, self-ligating brackets produced significantly higher coefficients of friction than modified twin-design brackets. However, some recent clinical studies have reported that there is no significant difference between self-ligating and conventional brackets.[28,29] Similarly, in this study, the canine movement rates of the self-ligating brackets and the modified twin-design brackets with stainless-steel ligations and 0.019- $\times$ 0.025-inch, stainless-steel arch wires were not significantly different. Furthermore, the angular changes in the long axis of the canines during distalization were not significantly different between the two groups.

In recent years, some reviews and meta-analyses have also been published that analyze the efficiency of self-ligating brackets.[14,15,30,31] Although self-ligating brackets have some advantages compared with conventional brackets, there is insufficient evidence to claim that they produce less friction than conventional brackets in clinical usage. The results of the clinical and in vitro portions of this study also confirm this opinion.

In some recent studies, fretting devices were used to evaluate the surface properties and coefficients of friction of orthodontic materials.[14,15] However, these test apparatuses must be modified to test orthodontic appliances. These types of modifications, including a specific holder and special software, were prepared and used in this study.

CONCLUSIONS

- There was no significant difference in the rate of canine distalization between the SC and MT brackets.
- All of the canines were distalized with a slight distal tipping of the crowns into the extraction spaces when mini-screw implants were used as the only form of anchorage.
- The SC brackets had higher coefficients of friction than MT brackets in vitro. However, the coefficients of friction of these brackets should not be accepted as major contributors to the resistance to sliding during clinical treatment.

Table 4. Summary of Clinical Studies for Distal Canine Movement

Study	Bracket	Ligation	Slot Size, inch	Arch Wire, inch	Force Source	Force Magnitude	Rate of Canine Movement, mm/mo	Anchorage Loss/Type, mm
Ziegler and Ingerval (1989)[32]	Metal	Stainless-steel ligature	0.018		Canine retraction spring	160 g	1.41	0.35
					Elastic chain	380 g		
Hayashi et al (2004)[33]	Edgewise metal	Stainless-steel ligature	0.022		Niti coil springs	100 g	1.41	Mini-screw
					Canine retraction spring		1.91	
Bokas and Woods (2006)[34]	Metal brackets	Stainless-steel ligature	0.018	0.016 × 0.016 ss	Niti coil spring	200 g	1.85	0.46
					Power chain		1.68	0.45
Herman et al (2006)[35]	Metal	Stainless-steel ligature	0.022	0.017 × 0.025 ss	Niti coil springs	150 g	1.3	Mini-screw
Deguchi et al (2007)[36]	Plastic with a metal slot	Clear Snap self-ligation	0.018	0.016 ss	Niti coil springs	50 g 100 g 150 g	Clear Snap ligature 1.6, 1.8, 2	
		Stainless-steel ligature					Stainless-steel ligature 0.7, 1.2, 1.5	
Thiruvenkatachari et al (2008)[24]	Twin metal	Stainless-steel ligature		0.016 × 0.022 ss	Niti coil springs	100 g	Max. 0.93, Man. 0.81 Max. 0.83, Man. 0.76	Mini-screw Molar anch.
Shpack et al (2008)[37]	Tip-Edge Victory Edgewise	Stainless-steel ligature	0.022	0.018 ss	Niti coil springs	50 g or 75 g	Victory Edgewise faster	1.2 mm 1.4 mm
Martins et al (2009)[38]	Metal brackets	Stainless-steel ligature	0.022	0.017 × 0.025-in β-Ti	T-loop spring		Max. 1.6 Man. 1.9	Mini-screw
Burrow (2010)[29]	Conventional metal	Stainless-steel ligature	0.022	0.018 ss	Niti coil spring	150 g	Conventional 1.17	
	SmartClip	Self-ligating					SmartClip 1.10	
	Damon3	Self-ligating					Damon3 0.9	

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