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Review Article

Comparison of self-ligating brackets and conventional brackets in canine retraction during orthodontic treatment: systematic review and meta-analysis

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Abstract: The purpose of this study was to compare the canine retraction performance between orthodontic self-ligating and conventional brackets through a systematic review of the literature. Randomized clinical trials and controlled clinical trials, comparing canine retraction between self-ligating brackets and conventionally brackets, were identified through an electronic search in Medline, Embase, Web of Science, CENTRAL, China National Knowledge Infrastructure (CNKI), China Biology Medicine disc (CBM), and SIGLE, between January 1980 and December 2017. Primary outcomes included velocity of canine retraction and anteroposterior anchorage loss of first molars. Secondary outcomes included distal inclination of canines, mesial inclination of first molars, and canine rotation. Meta-analyses were conducted using Stata version 14.0. Seven studies were included, including six randomized controlled trials and one clinical controlled trial. The present meta-analysis revealed no significant differences regarding velocity of canine retraction (SMD=0.03; 95% CI: -0.59-0.64), anteroposterior anchorage loss of first molars (SMD=-0.47; 95% CI: -1.23-0.30), distal inclination of canines (SMD=0.001; 95% CI: -0.31-0.31), and mesial inclination of first molars (SMD=-0.07; 95% CI: -0.37-0.24) between self-ligating and conventional brackets. However, self-ligating brackets had less canine rotation than conventional brackets (SMD=-0.31; 95% CI: -0.60--0.01). Based on present evidence, self-ligating brackets control canine rotation better than conventional brackets in canine retraction.

Keywords: Canine retraction, self-ligating, brackets, systematic review, meta-analysis

Introduction

Orthodontic tooth movement requires overcoming classical friction (FR), an important source of resistance of sliding mechanics. Heavy force will occlude the vascular system in periodontal tissue, resulting in blockage of blood flow, local hypoxic environment, and hyalinization of alveolar bone, further leading to the impediment of tooth movement [1]. Thus, using a proper light force that can overcome FR has been advocated in orthodontic clinical practice in past decades. Reducing the FR within the appliance system, ensuring that teeth are being moved efficiently by a light force, has always been the pursuit of orthodontists.

Self-ligating brackets (SLBs) can engage themselves to archwires without elastomeric ties or ligation wires. They have been reported to produce less FR during tooth movement than conventional brackets (CBs) [2]. Current studies have identified the advantages of SLBs in FR levels, even in different bracket-archwire-angle combinations [3] and different third-order torques [4]. However, whether less FR produced by SLBs can lead to more efficient tooth movement in clinical situations remains controversial.

Two-step retraction, in which canine retraction is followed by incisor retraction, has been widely used in sliding mechanics to close extraction space. Although closing space in two steps has advantages over one step en masse retraction, it takes a longer time [5]. Some complications, including anchorage loss, inclination, and rotation of both canines and molars may occur during canine retraction, resulting in prolonged treatment duration and unsatisfactory clinical outcomes [6]. Prolonged treatment duration may be accompanied by a higher risk of complications, including gingival enlargement and external root resorption [7, 8]. Optimal canine retraction should be performed with fast velocity and minimal complications.

Since FR must be kept at a minimum level to achieve optimal canine retraction [9], it is assumed that the low level of FR produced by SLBs can bring better canine retraction. This issue has been investigated by numerous clinical trials. However, the results have been controversial. Hassan et al. reported that, when using SLBs, the amount and rates of canine retraction were greater, while canine rotation and anchorage loss were less than using CBs [10]. Burrow observed a faster retraction rate with the CBs [11]. Moreover, a recent study found that both brackets showed the same rate of canine retraction and loss of anteroposterior anchorage of the molars, with no changes found between brackets regarding the inclination of canines and first molars [12]. These different results may puzzle clinicians when they choose brackets in clinical situations. A previous study reviewed trials before September 2014, suggesting that both bracket types had the same rate of canine retraction and anchorage loss of the first molars [13]. However, results of this review require caution because of the methodological deficiency, especially the lack of exploring heterogeneity. In the last few years, newly reported RCTs have found some different results. One study even brought forward a new standpoint from the previous trials [10]. This present systematic review aimed to include all new RCTs, and to comprehensively compare the performance between self-ligating brackets and conventional brackets on canine retraction. Aspects regarding the velocity of canine retraction, anteroposterior anchorage loss of first molars, unwanted inclination of canines and first molars, and canine rotation were evaluated.

Material and methods

This systematic review was conducted according to the guidelines of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [14] and the *Cochrane Handbook for Systematic Reviews of Interventions*.

Inclusion criteria for included studies

To be included in this review, trials had to meet these criteria: Study design: Randomized controlled trials (RCTs) and controlled clinical trials (CCTs) Participants: patients (1) treated with SLBs or CBs; (2) with extraction of first premolars in either upper or lower dentition; and (3) with full dentition and no periodontal diseases or systematic diseases before treatment. Intervention: fixed orthodontic treatment with SLBs on canines. Comparison: fixed orthodontic treatment with CBs on canines. Primary outcomes: velocity of canine retraction and anteroposterior anchorage loss of first molars. Secondary outcomes: distal inclination of canines, mesial inclination of first molars, and canine rotation.

Search strategy

An electronic search was undertaken using the following electronic databases: Medline via OVID, Embase via OVID, Web of Science, the Cochrane Central Register of Controlled Trials (CENTRAL), China National Knowledge Infrastructure (CNKI), and China Biology Medicine disc (CBM). The electronic search included all articles published between January 1980 and December 2017, with no language restrictions. System for Information on Grey Literature in Europe (SIGLE) was searched for grey literature. Specific search strategies are presented in **Table 1**. In addition, reference lists of relevant studies were also examined for additional relevant studies. Two review authors conducted the electronic search, independently. Disagreements were resolved by consensus or judged by a third investigator.

Data extraction and analysis

Data extraction was independently performed by two review authors using a custom-designed form. Relevant data, including name of first author, publication year, study design, sample size, participant age, interventions, follow-up periods, measurement methods, and outcomes, were extracted and recorded. Disagreements were resolved by consensus or judged by a third investigator.

Risk of bias evaluation

According to *Cochrane Handbook for Systematic Reviews of Interventions*, risk of bias of all included studies was assessed by two independent reviewer authors. Main items included

Table 1. Search strategy for each database[a]

Step	Medline	EMBASE	Web of Science, CNKI & CBM	CENTRAL	SINGLE
1	exp Orthodontic Appliances/or self-ligat$.mp.or Orthodontic Bracket$.mp.	exp Orthodontic device/or self-ligat*.mp.or Orthodontic Bracket*.mp.	self-ligat* or Orthodontic Bracket*	Orthodontic Appliances [MESH] or self-ligat* or Orthodontic Bracket*.mp.	orthodontic
2	(canine$ adj3 retract$).mp. or two step$.mp. or anchorage.mp.	(canine* adj3 retract*).mp. or two step$.mp. or anchorage.mp.	(canine* NEAR/3 retract*) or two step*or anchorage	(canine* near/3 retract*).mp. or two step*. mp. or anchorage.mp.	self-ligating
3	orthodontic space closure/or (sliding mechanics or sliding technique).mp.or (space adj2 clos*). mp.	orthodontic space closure/or (sliding mechanics or sliding technique).mp. or (space adj2 clos*).mp.	(sliding mechanics or sliding technique) or (space NEAR/2 clos*)	orthodontic space closure [MESH] or sliding mechanics or sliding technique or space near/2 clos*	1 and 2
4	1 and 2 and 3	1 and 2 and 3	1 and 2 and 3	1 and 2 and 3	
5	(randomized controlled trial or controlled clinical trial).pt.	(randomized controlled trial or controlled clinical trial).pt.	randomized controlled trial or controlled clinical trial		
6	(Randomized or Placebo or Randomly or Trial or Groups).ab.	(Randomized or Placebo or Randomly or Trial or Groups).ab.	Randomized or Placebo or Randomly or Trial or Groups		
7	drug therapy.fs.	drug therapy.fs.	drug therapy		
8	5 or 6 or 7	5 or 6 or 7	5 or 6 or 7		
9	exp animals/not humans.sh.	exp animals/not humans.sh.	animals		
10	8 not 9	8 not 9	8 not 9		
11	4 and 10	4 and 10	4 and 10		

[a]Limits: pulication date from January 1990 to December 2017.

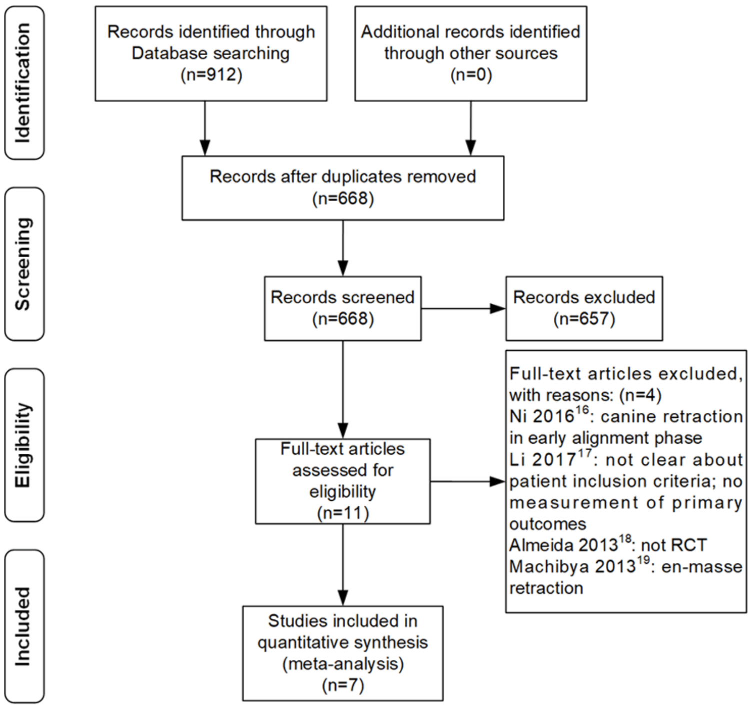

Figure 1. PRISMA flow diagram for systematic search and selection.

sequence generation, allocation concealment, blinding, incomplete outcome data, selective outcome reporting, and other apparent risks of bias. Disagreements were resolved by consensus or judged by a third investigator.

Statistical analysis

Meta-analyses were performed using the metan command in Stata version 14.0 (StataCorp, College Station, Tex). For continuous data, standardized mean differences (SMD) and 95% confidence intervals (CI) were used. For dichotomous data, risk ratios (RR) and 95% CIs were calculated. Appropriate data conversions were applied when necessary. Primary authors of the studies were contacted for missing data. Heterogeneity among recruited studies was assessed using Chi-squared test and I^2 statistic. An I^2 statistic greater than 50% indicated substantial heterogeneity. In that case, a random-effects model was adopted for the meta-analysis. Meta-regression or subgroup analysis would be employed to explore heterogeneity. Otherwise, a fixed-effect models was used. Factors related to bracket-archwire couples were selected a priori for subgroup analysis to assess their influence on outcomes. Sensitivity analysis was performed to test the robustness of pooled results. Publication bias was evaluated according to recommendations of the *Cochrane Handbook.*

Results

Description of included studies

The flow diagram in **Figure 1** illustrates the PRISMA process. Cohen's Kappa coefficient showed that inter-examiner bias was low regarding article screening (kappa=0.89) [15]. This study identified 912 potential articles (258 from Medline, 246 from Embase, 226 from Web of Science, 143 from CENTRAL, 105 from CNKI, 103 from CBM, and 2 from SINGLE). After duplicate articles were removed, a total of 668 remained. Titles and abstracts of these articles were screened. Irrelevant studies were excluded. The remaining 11 articles were fully read. Four [16-19] were excluded for not meeting all of the eligibility criteria. Finally, seven studies were included in this systematic review, including six RCTs and one CCT.

Table 2 summarizes the characteristics of enrolled studies. One of the studies was in Chinese [20], the others were in English [6, 10-12, 21, 22]. Patients in each study received split-mouth design, dividing their dental arches into the left and the right side. The canine on one random side was bonded with SLBs, while the contralateral canine was bonded with CBs. The remaining teeth received CBs. After alignment and leveling, canines were retracted with nickel-titanium closed coil springs or elastomeric chains. All studies compared canine retraction velocity with SLBs and CBs. Five studies reported anchorage loss of first molars, three assessed distal inclination of canines and mesial inclination of first molars, and two reported canine rotation.

Quality of included studies

Of the seven enrolled studies, four were assessed to be of high quality, two of medium quality, and one with a high risk of bias. The overall quality of included studies was consid-

Table 2. Characteristics of included studies

Author (Year)	Study design	Study location	Patient[a]			Intervention[a]								Outcomes		
			Sample size	Age (year)	Gender (F/M)	Tested SLBs	Tested CBs	Upper/lower arch	Arch wire	Auxiliary devices	Loading appliance	Force (g)	I/C[b]	Measurement method	Follow-up	Variables measured[c]
Monini et al. (2014) [22]	RCT	Brazil	25	23.32±5.08, range: 17.66-35.49	16/9	In-Ovation, R	In-Ovation	upper	0.020-inch round SS wire	no	nickel-titanium closed coil springs	100	25/25	oblique cephalometric radiogragh	after total canine retraction	1, 2, 3 & 4
Monini et al. (2017) [12]	RCT	Brazil	25	23.32±5.08, range: 17.66-35.49	16/9	In-Ovation, R	In-Ovation	lower	0.020-inch round SS wire	no	nickel titanium closed-coil springs	100	25/25	oblique cephalometric radiogragh	after total canine retraction	1, 2, 3 & 4
Lin et al. (2014) [20]	RCT	China	40	-	-	Quick	Victory	upper	0.018-inch round SS wire	no	nickel titanium tension springs	150	40/40	-	after total canine retraction	1
Burrow (2010) [11]	RCT	USA	43	14.8±6.24, range: 11.3-27.6	19/24	Damon3 & SmartClip	Victory	upper	0.018-inch round SS wire	transpalatal arch	sentalloy retraction springs	150	43/43	measured intra-orally by a flexible ruler	when space was closed on one side	1
Hassan et al. (2016) [10]	RCT	Syria	15	20.99±2.36, range: 18.33-24.42	11/4	Damon Q	Mini Master Series	upper	0.019×0.025-inch rectangular SS wire	0.9 mm SS transpalatal bars	nickel titanium close-coil springs	150	15/15	study models and model photocopies	12 weeks	1, 2 & 5
Mezomo et al. (2011) [6]	RCT	Brazil	15	18.00, range: 12-26	10/5	SmartClip	Gemini	upper	0.018-inch round SS wire	no	elastomeric chains	150	15/15	dental casts and a digital caliper	12 weeks	1, 2 & 5
Oz et al. (2012) [21]	CCT	Turkey	19	13.60, range: 12.7-15.3	5/14	SmartClip	Mini Uni-Twin	upper & lower	0.019×0.025-inch rectangular SS wire	mini-implant screws; transpalatal and lingual arches	nickel-titanium closed-coil springs	200	32/32	lateral cephalometric radiograph	8 weeks	1, 2, 3 & 4

[a]F: female; M: male; SS: stainless steel; [b]I/C: the number of canines in intervention group versus the number in control group; [c]1: velocity of canine retraction; 2: anteroposterior anchorage loss of first molars; 3: distal inclination of canines; 4: mesial inclination of first molars; 5: canine rotation.

Table 3. Quality assessment of included studies

Study	Adequate Sequence Generation	Allocation Concealment	Blinding	Incomplete Outcome Data Addressed	Absence of Selective Reporting	Absence of Other Apparent Bias	Score[a]	Quality
Monini et al. (2014)	low	unclear	low	low	low	unclear	10	high
Monini et al. (2017)	low	unclear	low	low	low	unclear	10	high
Lin et al. (2014)	low	unclear	unclear	high	high	high	4	low
Burrow (2010)	low	unclear	high	low	high	unclear	6	medium
Hassan et al. (2016)	low	unclear	low	low	low	unclear	10	high
Mezomo et al. (2011)	low	unclear	unclear	low	low	unclear	9	high
Oz et al. (2012)	high	high	unclear	low	low	unclear	6	medium

[a]Scoring rules: "Low" for 2 scores, "Unclear" for 1 score, and "High" for a score of 0. Quality was categorized as low (score 1-4), medium (score 5-8), or high (score 9-12).

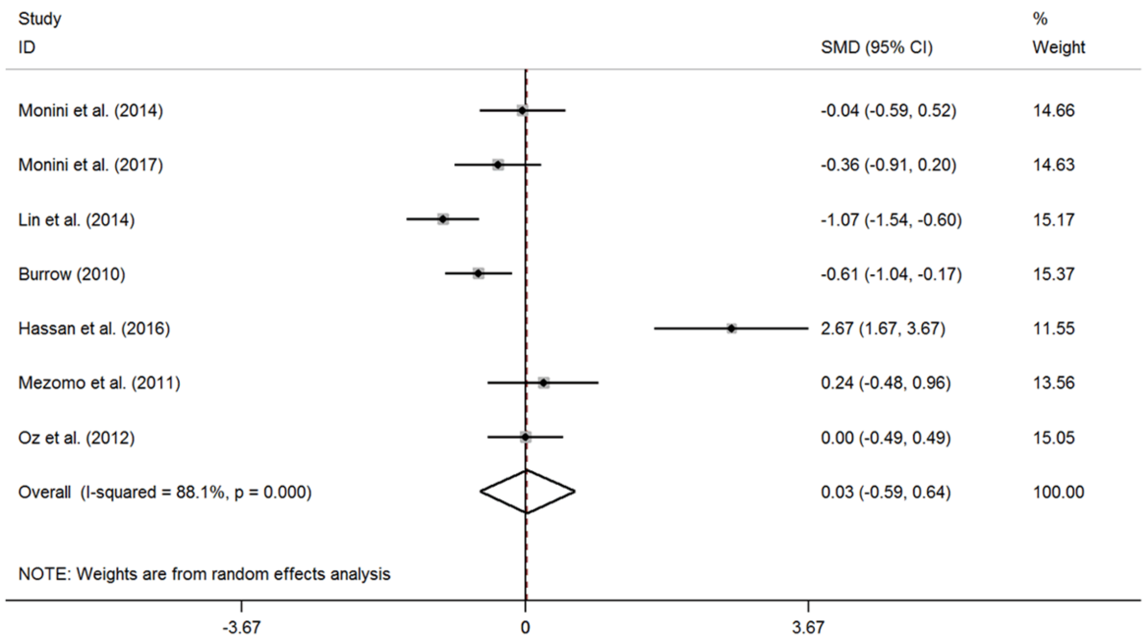

Figure 2. Forest plot of canine retraction velocity comparing SLBs with CBs.

ered adequate. Detailed results regarding quality assessment are shown in **Table 3**.

Velocity of canine retraction

Seven studies investigated this outcome. Monini et al., Mezomo et al., and Oz et al. [6, 12, 21, 22] reported no significant differences between SLBs and CBs. Hassan et al. [10] reported greater canine retraction velocity when using SLBs, while Lin et al. and Burrow [11, 20] found that canines moved faster when bonding CBs. Data from all seven studies were statistically pooled using a continuous model. Overall, the meta-analysis showed that no significant differences were detected regarding canine retraction rates between SLBs and CBs (SMD= 0.03; 95% CI: -0.59-0.64) (**Figure 2**).

Anteroposterior anchorage loss of first molars

Five studies reported this outcome. Three studies [6, 12, 22] carried out trials without auxiliary devices, while Hassan et al. [10] used transpalatal bars and Oz et al. [21] used transpalatal and lingual arches. Mini-screws were also applied as anchorage points during canine retraction in the latter study. Auxiliary devices, including mini-screws [23, 24], trans-palatal [25], and lingual arches [26], were deemed to reduce anchorage loss. This may explain why the anchorage loss of molars in this study were

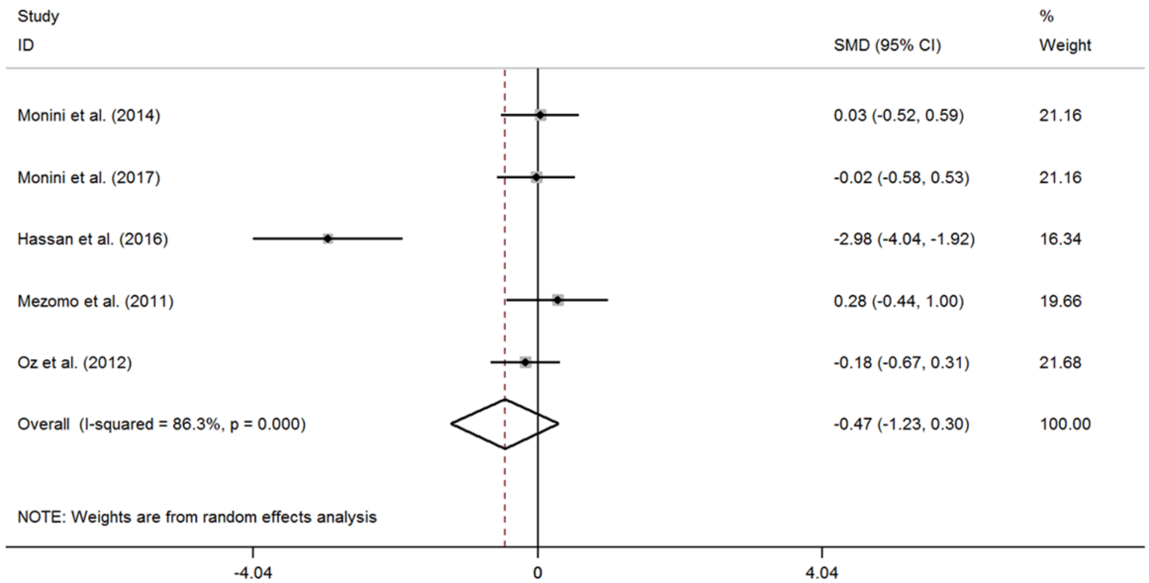

Figure 3. Forest plot of anteroposterior anchorage loss of first molars comparing SLBs with CBs.

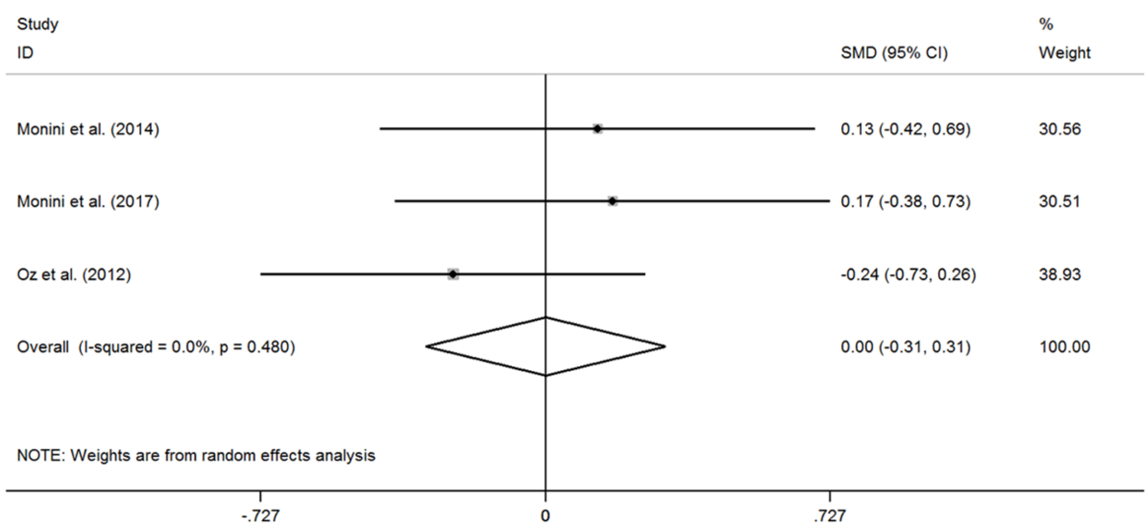

Figure 4. Forest plot of distal inclination of canines comparing SLBs with CBs.

much smaller than those in others. Data from the studies were statistically pooled in this meta-analysis, with results showing no significant difference regarding anteroposterior anchorage loss of first molars between SLBs and CBs (SMD=-0.47; 95% CI: -1.23-0.30) (**Figure 3**).

Distal inclination of canines

Three studies [12, 21, 22] assessed this outcome, showing no heterogeneity (I^2=0%). Meta-analysis results found no significant differences regarding distal inclination of canines between SLBs and CBs (SMD=0.001; 95% CI: -0.31-0.31) (**Figure 4**).

Mesial inclination of first molars

The aforementioned three studies [12, 21, 22] measured the mesial inclination of first molars. Data from these studies were statistically pooled, with results showing no significant differences regarding mesial inclination of first molars between SLBs and CBs (SMD=-0.07; 95% CI: -0.37-0.24) (**Figure 5**).

Canine rotation

Two studies reported this outcome with low heterogeneity (I^2=23.9%). Hassan et al. [10]

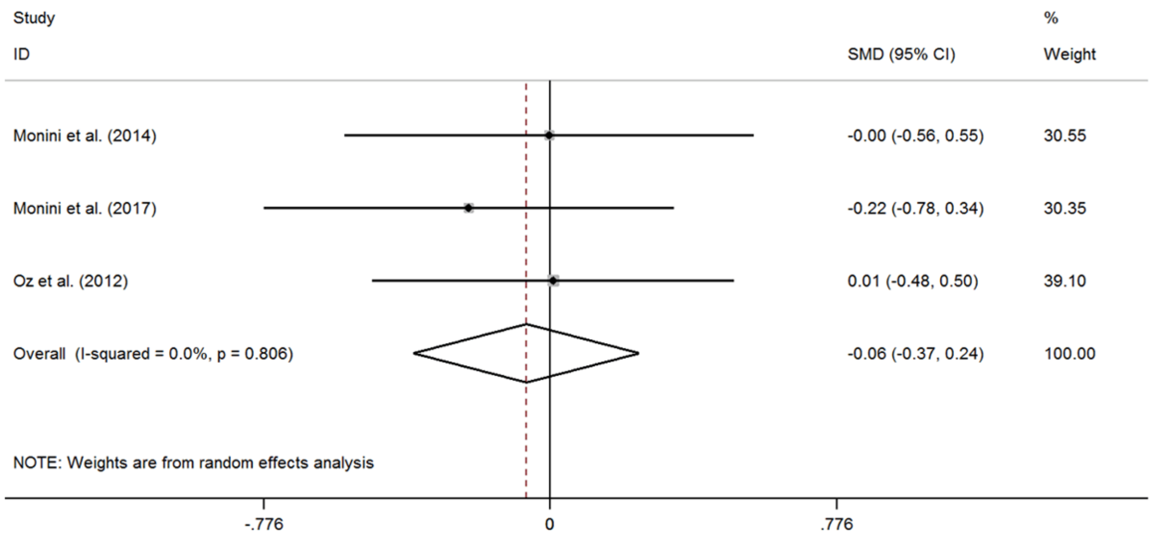

Figure 5. Forest plot of mesial inclination of first molars comparing SLBs with CBs.

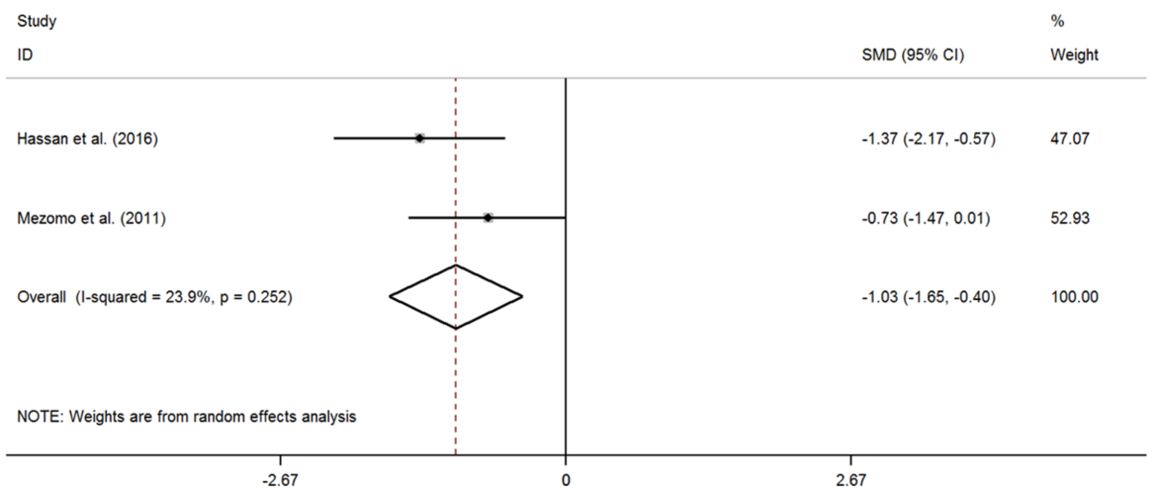

Figure 6. Forest plot of canine rotation comparing SLBs with CBs.

and Mezomo et al. [6] found that rotation of the upper canines during sliding mechanics was smaller with SBs than CBs. The meta-analysis demonstrated consistent results and conclusions (SMD=-1.03; 95% CI: -1.65-0.41) (**Figure 6**).

Subgroup analysis

Heterogeneity was substantial among studies assessing the two primary outcomes, with I^2 statistics of 88.1% and 86.3% for canine retraction velocity and anchorage loss of first molars, respectively. Due to the limited number of enrolled studies (less than 10), subgroup analysis was used to explore heterogeneity. Subgroup analysis was performed based on the type of bracket-archwire couples. Since all enrolled studies adopted 0.22×0.28 slot brackets, subgroup analysis concerning canine retraction velocity and anchorage loss of first molars was performed based on the size of working archwires. Subgroup analysis found no significant differences for the two foregoing outcomes, serving as an indicator of the robustness of this meta-analysis (**Table 4**).

Sensitivity analysis

To examine the stability of results regarding velocity of canine retraction and anchorage loss of first molars, sensitivity analysis was performed by omitting each of the included studies in turn. No significant changes were observed, indicating that the meta-analysis was reliable (**Table 5**). It is noteworthy that the study conducted by Lin et al. [20] was assessed to be of low quality (**Table 3**). Moreover, the SLBs used in this study were active SLBs, while the other studies used passive SLBs. Active SLBs actively press against the archwire by spring clips, resulting in less friction than passive SLBs or conventional brackets [27, 28]. Sensitivity analysis, excluding Lin et al., found no significant changes, suggesting that pooled results were stable (**Table 5**).

In the study conducted by Oz et al. [21], the sides chosen for SLBs or CBs bonding were alternated with each consecutive patient, indicating a semi-random controlled trial. The auxiliary devices used in this trial had biomechanical effects on some of the outcomes. Thus, further sensitivity analysis was performed by excluding Oz et al. [21]. Results showed consistency (**Table 5**).

Publication bias

The current study did not test publication bias. A small number of studies were included in the meta-analysis and approaches to detect publication bias would exhibit limited efficacy, according to guidelines of the *Cochrane Handbook*.

Discussion

Overall results of the current meta-analysis provide evidence suggesting that SLBs may control canine rotation better in canine distal movement. With respect to canine retraction velocity, anchorage loss of first molars, and unfavored inclination of teeth, SLBs and CBs had similar performances. Subgroup analysis found no significant differences between SLBs and CBs when using different types of archwires. Sensitivity analysis indicated the robustness of meta-analysis results.

Although SLBs have less FR, canine retraction velocity and anchorage loss with SLBs seem to be in accord with CBs. It was speculated that this is associated with the role of elastic binding (BI). BI is also a component of resistance to sliding, which consists of FR, BI, and physical notching (NO) [29]. BI comes into being when the wire contacts the edges of the bracket slot during tooth movement. When the bracket-archwire second-order angulation is slightly greater than the critical contact angle for binding (θc), the FR component is greater than the BI. When angulation continues to increase, the BI component overwhelms FR and the overall effects of the ligation type and method decrease [30, 31]. During canine retraction on the same archwire, narrower brackets induce greater bracket-archwire second-order angulation, thus leading to larger BI [31]. Almost all SLBs in the enrolled studies had smaller widths than CBs, which may explain the similar performance between them.

Inclination and rotation of teeth occur when the exerted force does not pass through the center of resistance of teeth and there exists clearance between the archwire and bracket slot [32]. If unfavored tooth movement becomes critical, taking canine rotations more than 10° for an example, archwire sequencing may become hard [6]. Present results suggested that SLBs had less rotation of canines in sliding mechanics. However, this should be treated with caution since only two studies [6, 10] were included in the meta-analysis.

Limitations of this analysis were as follows. Firstly, although most of the studies included were evaluated to be at low to medium risk of bias, the lack of high-quality studies was a limitation of this systematic review. Secondly, small sample sizes and relatively short follow-up periods of a few studies might have affected overall estimates. Thirdly, heterogeneity among enrolled studies may have influenced conclusion credibility. Although consistent outcomes of subgroup analysis and sensitivity analysis indicated the robustness of present meta-analysis results, heterogeneity sources were hard to clarify because some confounding factors could not be quantitatively assessed. There is insufficient scientific evidence from currently available studies to recommend a specific bracket type for canine retraction in sliding mechanics. More well-designed RCTs of larger sample sizes are required to obtain more reliable conclusions.

In conclusion, the available limited evidence suggests that SLBs control canine rotation better in canine retraction than CBs. No differences were found between SLBs and CBs regard-

Table 4. Summary of subgroup analysis results

Outcome	Number of trials included	Overall		0.020-inch round SS wire		0.018-inch round SS wire		0.019×0.025-inch rectangular SS wire	
		SMD	95% confidence interval	SMD	95% confidence interval	SMD	95% confidence interval	SMD	95% confidence interval
Velocity of canine retraction [6, 10-12, 20-22]	7	0.028	-0.59, 0.64	-0.20	-0.59, 0.20	-0.53	-1.17, 0.11	1.30	-1.32, 3.92
Anchorage loss of first molars [6, 10, 12, 21, 22]	5	-0.47	-1.23, 0.30	0.01	-0.39, 0.40	0.28	-0.44, 1.00	-1.54	-4.28, 1.20

Table 5. Results of sensitivity analysis (SMD and 95% CI)

Item	Original Estimates	Monini et al. (2014) omitted	Monini et al. (2017) omitted	Lin et al. (2014) omitted	Burrow (2010) omitted	Hassan et al. (2016) omitted	Mezomo et al. (2011) omitted
Velocity of canine retraction	0.03 (-0.59, 0.64)	0.054 (-0.67, 0.78)	0.11 (-0.62, 0.84)	0.22 (-0.43, 0.86)	0.16 (-0.58, 0.90)	-0.34 (-0.72, 0.04)	0.00 (-0.69, 0.69)
Anchorage loss of first molars	-0.47 (-1.23, 0.30)	-0.63 (-1.65, 0.38)	-0.62 (-1.64, 0.40)	-	-	-0.01 (-0.30, 0.27)	-0.67 (-1.60, 0.26)
Distal inclination of canines	0.00 (-0.31, 0.31)	-	-	-	-	-	-
Mesial inclination of first molars	-0.07 (-0.37, 0.24)	-	-	-	-	-	-

ing the velocity of canine retraction, anteroposterior anchorage loss of first molars, unfavored inclination of canines and first molars.

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Disclosure of conflict of interest

None.

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