Original Article

Bracket Placement in Lingual vs Labial Systems and Direct vs Indirect Bonding

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ABSTRACT

Objective: To examine the ultimate accuracy of bracket placement in labial vs lingual systems and in direct vs indirect bonding techniques.

Materials and Methods: Forty pretreatment dental casts of 20 subjects were selected. For each dental cast, four types of bracket placement were compared: labial direct (LbD), labial indirect (LbI), lingual direct (LgD), and lingual indirect (LgI). Direct bonding was performed with the casts held in a mannequin head. Labial brackets were oriented with a Boone gauge, and lingual brackets were oriented with the Lingual-Bracket-Jig System. Torque error (TqE) and rotation deviation (RotD) were measured with a torque geometric triangle and a toolmaker's microscope, respectively. Both torque and rotational measurements were evaluated statistically as algebraic and absolute numeric values, using analysis of variance with repeated measures.

Results: Absolute TqE and RotD were significantly ($P < .001$) higher in direct than in indirect bonding techniques higher in both the labial and lingual bracket systems by twofold and threefold, respectively (LbD = 7.26°, 1.06 mm; vs LbI = 3.02°, 0.75 mm; LgD = 8.42°, 1.13 mm; vs LgI = 3.18°, 0.55 mm). No statistically significant difference was found between labial and lingual systems for the same bonding technique. Maxillary incisors demonstrated the largest RotD angle (eg, right lateral: 12.04°). A distal off-center RotD was predominant in the mandibular dentition.

Conclusions: Labial and lingual systems have the same level of inaccuracy. For both systems, indirect bonding significantly reduces absolute TqE and RotD. The TqE found can cause transverse discrepancy (scissors or crossbite) combined with disclusion with antagonist teeth. The RotD found can result in irregular interproximal contact points.

KEY WORDS: Bracket placement; Lingual brackets; Labial brackets; Torque; Rotation

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INTRODUCTION

The straight-wire appliance (SWA) is based on the concept that ideal bracket placement will correct tooth positions in all three planes of space during treatment.[1–9] The SWA was designed for labial/buccal appliance placement. Lingual application of the SWA philosophy has been reported previously,[10–17] including topographic contour mapping of lingual dental anatomy.[10] Cephalometrically, no significant differences in incisor inclination have been reported between labial and lingual treatment techniques.[18]

Misplacement of a bracket in the SWA can cause deviations in rotation, tipping, in/out, extrusion/intrusion, and torque.[19,20] In lingual orthodontics, limited access and visibility, greater variation in lingual surface morphology (especially of the maxillary anterior teeth), shorter lingual crown height, a wide range of labiolingual crown thicknesses, slopped lingual surfaces, smaller interbracket distance, and tongue interference can all contribute to inaccurate bracket placement.[21]
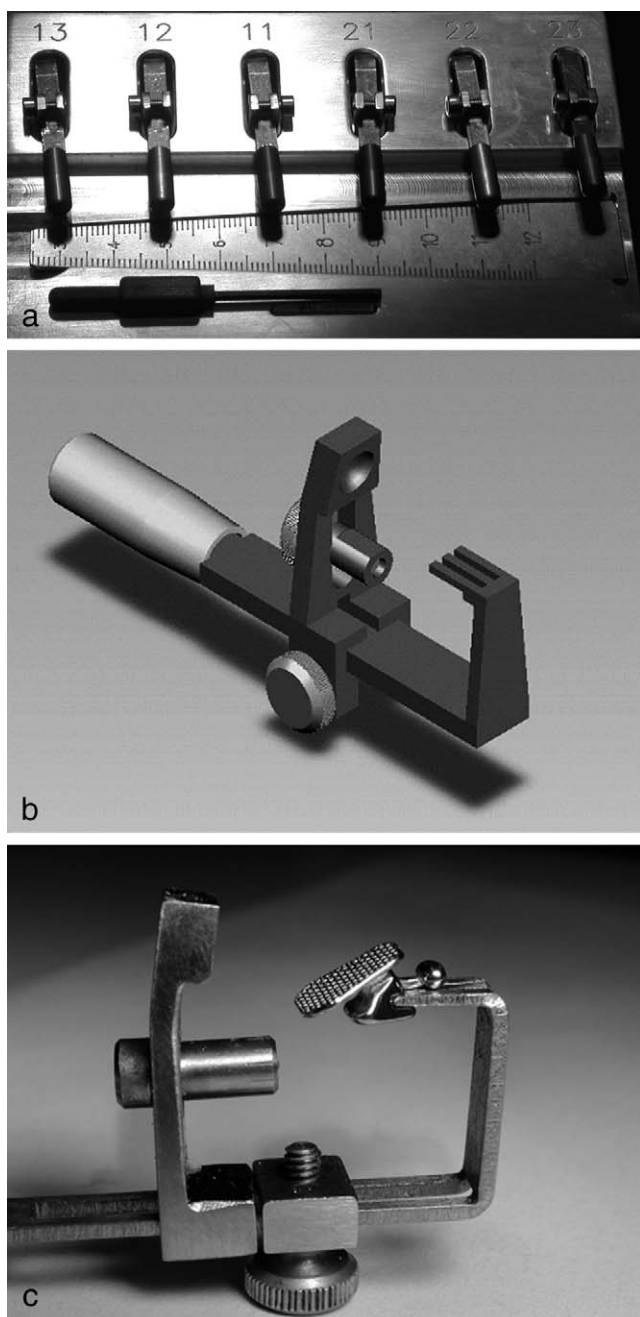
Figure 1. (A) The Lingual-Bracket-Jig (LBJ) consists of a set of six jigs for the maxillary anterior teeth (canine to canine), which present the most morphologic variations on the lingual side, a millimeter ruler (0.1-mm accuracy), and a wrench for in-out adjustments. The ruler is used to measure the in-out bracket position, compensating for differences in thickness. The LBJ was used in both direct and indirect bonding techniques. (B) High magnification of a jig. (C) A lingual bracket attached to a jig.

Brackets can be bonded directly or indirectly. The direct bonding technique was initially described by Newman[22] and has been modified.[23–25] For the lingual direct bonding technique, the Lingual-Bracket-Jig System (LBJ) (ZAD Shlomi, Israel) is a bracket positioning

**Figure 2.** A setup model is placed in a toolmaker's microscope for measuring RotD in millimeters.

device that copies the labial bracket slot prescription and translates it to the lingual surface. The LBJ was introduced to overcome the aforementioned difficulties[21] (Figure 1).

In the indirect bonding technique, orthodontic brackets are initially placed on a dental cast and later transferred, affixed to a tray, to the patient's mouth.[26] This has been proposed as the preferable bracket placement technique for both lingual and labial orthodontics.[27–29] The indirect lingual bracket setup has been described using either the TARG System,[30,31] the Creekmore slot machine, the CLASS System,[30,31] or the Hiro technique.[30,31]

The objectives of the present study were to compare torque error (TqE) and rotation deviation (RotD) between labial and lingual bracket systems for both direct and indirect bonding techniques.

MATERIALS AND METHODS

Pretreatment study models of 20 orthodontic subjects who presented for treatment at the International Postgraduate Orthodontic Program at Tel Aviv University with differing types of malocclusions were randomly selected (n = 5 Class I, n = 11 Class II division 1, n = 1 Class II division 2, and n = 3 Class III). Subjects were divided into four groups according to the location of the bonded orthodontic appliance (labial/lingual) and technique of bonding (direct/indirect): labial direct
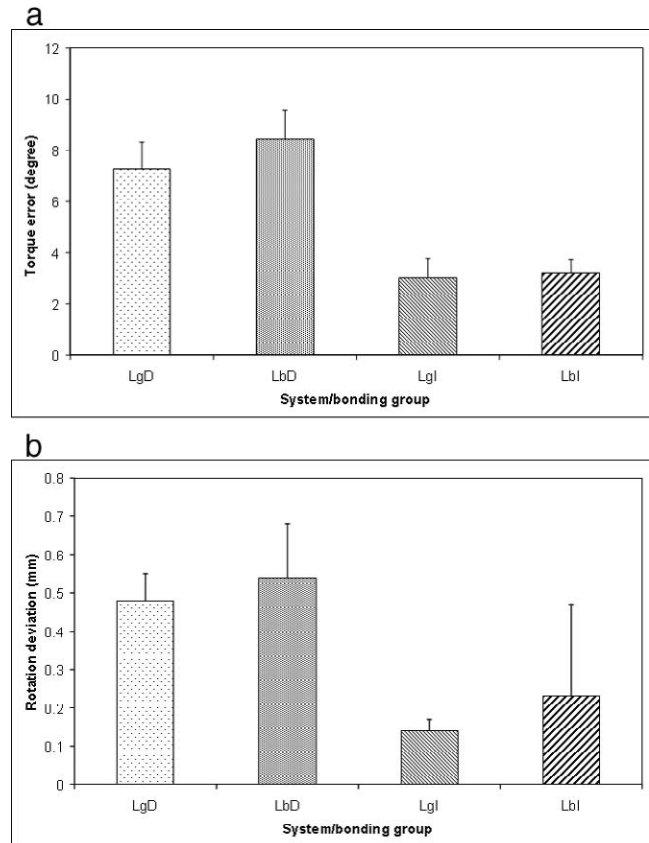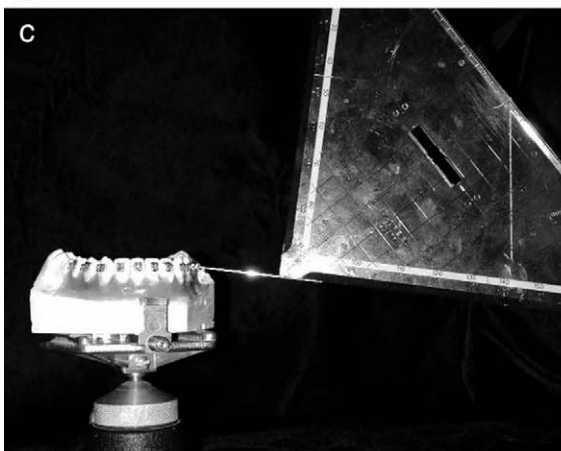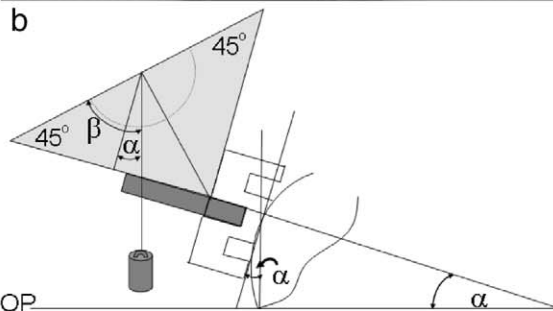
Figure 4. (A) TqE absolute means and SDs for the four groups. (B) RotD absolute means and SDs for the four groups. Groups are designated as labial direct (LbD), labial indirect (LbI), lingual direct (LgD), and lingual indirect (LgI).

(LbD) = brackets bonded directly on the labial tooth surface; labial indirect (LbI) = brackets bonded indirectly on the labial tooth surface; lingual direct (LgD) = brackets bonded directly on the lingual tooth surface; lingual indirect (LgI) = brackets bonded indirectly on the lingual tooth surface.

Orthos brackets (Ormco, Orange, Calif) with a preadjusted 0.022×0.028-inch slot were placed on the subjects in the LbD and LbI groups. Lingual Generation 7 brackets (Ormco) with a 0.018×0.025-inch slot (from canine to canine) and a 0.022×0.028-inch slot (premolars) were placed on the LgD and LgI groups. Transbond XT (3M, Unitec, Monrovia, Calif) was used for both direct and indirect bonding.

←

Figure 3. (A) A level occlusal plane was established by setting up the model with an isosceles triangle in a parallelometer. (B) The torque angle (α) is calculated by subtracting the measured angle (β) from 45° ($\alpha = 45° - \beta$). (C) The abscissa of the geometric triangle is aligned with the projection of the metal jig (0.022×0.028-inch or 0.018×0.025-inch), and the plumb line emerging from the vertex of the protractor shows the angle β.

a

$$x = R \sin \alpha$$

$$y = 2R \sin^2 \frac{\alpha}{2}$$

b

$$x = R \sin \alpha$$

$$y = 2R \sin^2 \frac{\alpha}{2}$$
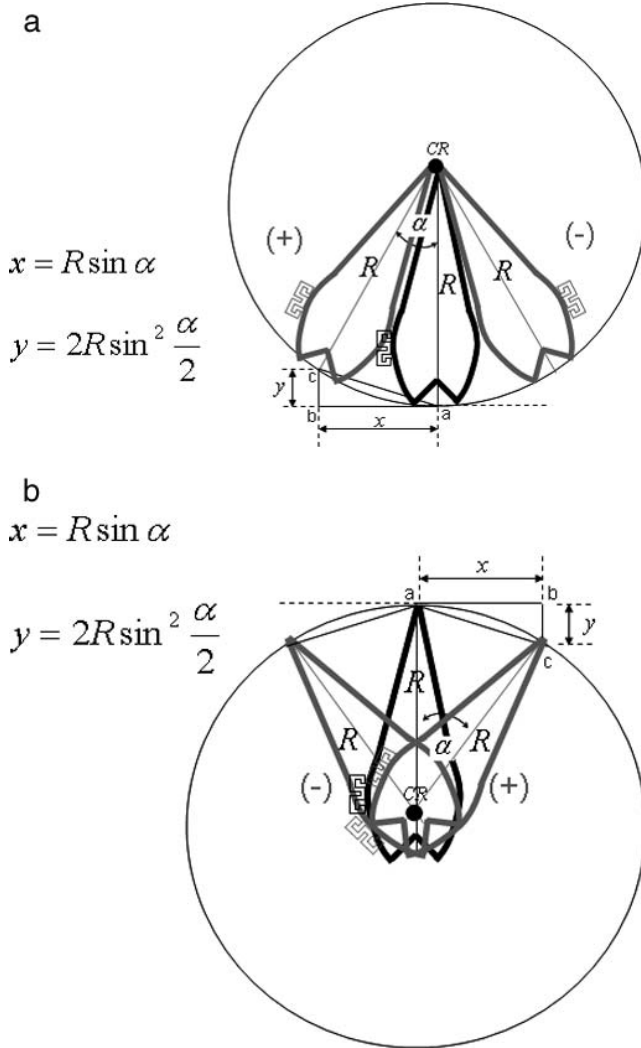
Figure 5. Conversion of TqE ($\alpha°$) into horizontal (X) and vertical (Y) displacement (mm). (A) The center of rotation (CR) is located around the apex, producing tip movements. (B) The center of rotation (CR) is located around the midcrown, producing torque movements. Note the change in the vertical position of the tooth in both types of movement.

Models of the directly bonded groups were mounted on a mannequin head to simulate clinical conditions. For bracket positioning, the LBJ was used in both lingual groups (Figure 1) and a Boone gauge (Ormco) was used in both labial groups. After bracket placement, the bonded teeth were cut from the dental cast using a handheld jigsaw passed gingivo-occlusally through the interproximal contact points. These were then held in wax according to Andrews keys.[3] TqE and RotD were measured on the resulting setup norm-occlusion. RotD was measured with an optic toolmaker's microscope (Mitutoyo Kawasaki, Japan) (Figure 2). The horizontal divergence between the tooth's long axis and that of the bracket was measured to the nearest hundredth of a millimeter (mesial bracket deviation

= positive values, distal bracket deviation = negative values). The RotD in millimeters was converted into degrees (α) according to the equation:

$$\alpha = \tan^{-1}\left(\frac{RotD_{mm}}{\text{half crown thickness}_{mm}}\right)$$

RotD measurement error of repeated measures was 0.025 mm.

Each setup was placed on a surveyor's parallelometer (Dentalform, Torino, Italy) (Figure 3A). Under ideal conditions of tooth morphology and bracket placement, there should be zero torque angle in the norm-occlusion setup model. Any torque angle that was not equal to zero was considered as TqE. Furthermore, variations of crown shape, size, and contour could result in error in the torque angle, even in norm-occlusion setup models.[32] However, in this study these factors did not affect the statistical comparison since the same teeth were compared between all four groups. The TqE is the angle between the occlusal plane and the long axis of each bracket slot (Figure 3B). TqE was measured with a torque angle gauge constructed of a geometric triangle (Aristo 1650, TZ-Dreieck, Innsbruck, Austria) and a plumb line emerging from the vertex of the protractor (Figures 3B,C).[32] A custom-made metal jig was fully engaged in the corresponding bracket slot (Figure 3C). A positive TqE refers to lingual root torque error and a negative TqE indicates buccal root torque error. The measurement error of repeated measurements was 0.80° for the maxillary right central incisor and 1.22° for the mandibular left first molar.

TqE and RotD were evaluated as algebraic and absolute numeric values. Absolute numeric values were used to show the magnitude of the deviation, since coexisting positive and negative values within an algebraic calculation tend to negate each other, leading to a deceptive result of minute value when a mean is calculated. Algebraic numeric values were used to show the direction of the error (buccal/lingual TqE, mesial/distal RotD). Analysis of variance with repeated measures compared, by tooth, the amount of torque and rotation error within and between groups (LbD vs LbI, LgD vs LgI, LbD vs LgD, LbI vs LgI).

RESULTS

Torque

The largest absolute TqE occurred at the mandibular right lateral incisor (10.2° ± 3.1°) in the LgD group and the maxillary left second premolar (9.6° ± 8.8°) in the LbD group (Table 1A). Significant absolute TqE differences ($P < .001$) were found between the direct and indirect techniques within and between the labial and lingual systems. No significant absolute TqE dif-

Table 1A. Absolute Mean TqE for Each Tooth in All Groups* for Both Sides

| | Torque, Deg | | | | | | | |
| | Right | | | | Left | | | |
	LbD	LbI	LgD	LgI	LbD	LbI	LgD	LgI
Maxilla								
Central	6.2 ± 2.8	2.3 ± 1.8	6.0 ± 2.5	2.1 ± 1.6	6.5 ± 2.6	3.0 ± 1.8	7.8 ± 3.4	3.7 ± 2.4
Lateral	5.2 ± 1.9	2.5 ± 1.4	6.6 ± 3.4	2.4 ± 1.5	6.3 ± 2.4	2.0 ± 1.4	8.0 ± 2.4	3.6 ± 1.8
Canine	7.8 ± 2.8	4.6 ± 2.5	8.0 ± 3.2	3.2 ± 2.3	6.8 ± 3.0	2.7 ± 2.3	8.3 ± 4.0	4.0 ± 2.2
First premolar	5.9 ± 2.8	3.1 ± 2.0	8.1 ± 2.8	3.3 ± 2.3	6.3 ± 2.3	2.2 ± 2.0	7.7 ± 3.5	2.4 ± 1.8
Second pre-molar	8.0 ± 3.1	3.0 ± 2.3	8.6 ± 4.7	3.1 ± 1.6	9.6 ± 8.8	3.0 ± 2.0	9.0 ± 2.9	3.2 ± 2.9
Mandible								
Central	8.6 ± 3.6	4.0 ± 2.9	9.9 ± 4.0	4.0 ± 2.5	9.5 ± 3.0	4.2 ± 1.9	10.2 ± 2.8	3.1 ± 2.0
Lateral	8.1 ± 3.5	3.9 ± 2.6	10.2 ± 3.1	4.6 ± 2.5	7.9 ± 2.5	3.5 ± 1.8	9.5 ± 3.3	3.3 ± 1.8
Canine	7.3 ± 1.9	3.2 ± 2.0	8.4 ± 2.9	3.1 ± 2.2	8.3 ± 3.0	3.3 ± 1.8	8.7 ± 3.3	2.8 ± 2.1
First premolar	6.3 ± 2.7	2.3 ± 1.9	7.6 ± 3.1	2.2 ± 1.6	6.9 ± 2.0	2.5 ± 1.5	9.7 ± 3.5	2.5 ± 1.5
Second pre-molar	6.7 ± 3.5	2.2 ± 1.4	7.7 ± 2.7	2.8 ± 2.0	6.4 ± 2.3	2.2 ± 1.4	8.0 ± 3.2	3.2 ± 2.9

* LbD, labial direct; LbI, labial indirect; LgD, lingual direct; LgI, lingual indirect.

ferences were found between the LbD and LgD groups, or between the LbI and LgI groups (Table 1B). The mean absolute TqE declined in the following order: LgD > LbD > LgI > LbI (Figure 4A).

In the labial groups, more positive algebraic TqE (lingual root torque) was generally found than negative TqE (labial root torque) (Table 2).

Rotation

The greatest absolute RotD in each technique occurred at the maxillary left canine (0.72 ± 0.45 mm) in the LgD group and maxillary left first premolar (0.62 ± 0.24 mm) in the LbD group (Table 3A). For RotD in degrees, the most severely affected tooth was the maxillary right lateral incisor in all four groups (LgD: 12.04° ± 6.08°) (Table 3B).

Significant absolute RotD differences ($P < .001$) were found between the direct and indirect techniques within and between the labial and lingual systems. No significant differences were found between the LbD and LgD groups and between the LbI and LgI groups (Table 3C). Absolute RotD declined in the following order: LgD > LbD > LgI > LbI (Figure 4B).

In both lingual and labial systems, more negative algebraic RotD values (distally positioned bracket) than positive algebraic RotD values (mesially positioned bracket) were found. The maxillary canines in all groups showed the highest number of cases with distal algebraic RotD (Table 4).

DISCUSSION

Direct vs Indirect Method

Absolute TqE and RotD were significantly ($P < .001$) more accurate in direct than in indirect bonding

techniques in both bracket systems (twofold and threefold, respectively). This contradicts other reports, which concluded that no differences were found between the bonding techniques[33,34] or that any differences were limited to the canines.[34] It has been reported that fewer bracket failures and less total time accompany the direct bonding technique.[25,35] However, recent developments in indirect bonding have reduced bracket failure rates to 3.5%.[36]

Labial vs Lingual Method

When comparing labial vs lingual for each bonding method, no significant differences in TqE and RotD were found. This finding contradicts the prevailing notion that lingual bracket placement is less accurate than labial placement.[12,30,37,38] Most likely, the nonsignificant bracket positioning error on the lingual side was achieved because of the LBJ, which helps the clinician control in-out bracket positioning and achieve lingual bracket placement based on the ideal labial bracket positions.[21]

Tooth Categories

When comparing direct vs indirect bonding methods for each technique (LgD vs LgI and LbD vs LbI), the greatest inaccuracy was mainly observed with the direct bonding technique, which showed TqE in the maxillary second premolars (8.8°) and mandibular central and lateral incisors (9.6°, 8.9°). These teeth were probably more affected because of the posterior position of the second premolar and the initial crowded and malinclined position of the mandibular incisors. The excessive RotD of the maxillary central (11.2°) and lateral (9.7°) incisors is linked to the (narrow) crown thickness in relation to the millimetric RotD.

Table 1B. Level of Significance: Absolute TqE Values* for All Groups†

	P Right				*P* Left			
	LbD-LbI	LbD-LgD	LgD-LgI	LbI-LgI	LbD-LbI	LbD-LgD	LgD-LgI	LbI-LgI
Maxilla								
Central	<.001	.840	<.001	.605	<.001	.244	<.001	.131
Lateral	<.001	.090	<.001	.742	<.001	.028	<.001	.003
Canine	<.001	.887	<.001	.021	<.001	.193	.006	.131
First premolar	<.001	.001	<.001	.678	<.001	.033	<.001	.760
Second premolar	<.001	.519	<.001	.861	<.001	.806	<.001	.792
Mandible								
Central	<.001	.267	<.001	.960	<.001	.409	<.001	.173
Lateral	<.001	.007	<.001	.337	<.001	.065	<.001	.733
Canine	<.001	.324	<.001	.824	<.001	.365	<.001	.414
First premolar	<.001	.230	<.001	.750	<.001	.005	<.001	.923
Second premolar	<.001	.232	<.001	.512	<.001	.036	<.001	.240

* Comparison between different bonding techniques within the same system (LbD vs LbI and LgD vs LgI) and between different systems within the same bonding techniques (LbD vs LgD, and LbI vs LgI) per tooth for each side.
† LbD, labial direct; LbI, labial indirect; LgD, lingual direct; LgI, lingual indirect.

Table 2. No. of Cases,* by Tooth, with Malpositioned Lingual Root Torque (+TqE) and Labial Root Torque (−TqE), by Group†

	Right and Left							
	LbD		LbI		LgD		LgI	
	+TqE	−TqE	+TqE	−TqE	+TqE	−TqE	+TqE	−TqE
Maxilla								
Central	17	22	6	28	7	33	10	25
Lateral	20	18	17	16	15	23	12	21
Canine	31	8	31	4	15	15	17	10
First premolar	24	15	25	10	23	17	23	12
Second premolar	28	9	23	9	26	12	21	13
Mandible								
Central	35	3	33	2	6	31	12	22
Lateral	32	8	34	5	11	28	7	30
Canine	37	3	33	6	14	20	17	13
First premolar	26	13	17	15	19	15	15	15
Second premolar	28	10	21	13	14	25	13	21

* Total number of cases in each tooth category does not equal 40, as some brackets were placed in ideal position.
† LbD, labial direct; LbI, labial indirect; LgD, lingual direct; LgI, lingual indirect.

Direction of Error

Torque. In the labial system, more teeth had algebraic lingual TqE; in the lingual system the opposite occurred, suggesting a similar error pattern. That is, during bonding, the incisal edge of the bracket acquires a firmer contact with the tooth surface than the gingival edge. This produces lingual root torque when the brackets are placed labially and labial root torque when placed lingually.

Rotation. In the maxilla, only a slight distal error direction was established for both labial and lingual systems, in contrast to an exclusive distal off-center error in the mandibular dentition. Teeth were more mal-

aligned in a mesial rotation.[39] However, in the untreated population, the prevalence of tooth rotation is 2.1% to 5.1%.[40] Thus, the shift toward a distal off-center rotation cannot be entirely explained by pre-existing rotation. A plausible explanation is a perspective optical illusion, where the distal portion of the tooth surface is stretched more than the mesial (Ponzo illusion).[41]

Clinical Significance

Torque. The extent of torque error is difficult to understand when judged on an angular scale. To assess the inaccuracy, degrees need to be converted to millimeters. For example, in the LbD, the maxillary sec-

Table 3A. Absolute Mean RotD, in Millimeters, for Each Tooth in All Groups* for Both Sides

	Rotation Deviation, mm							
	Right				Left			
	LbD	LbI	LgD	LgI	LbD	LbI	LgD	LgI
Maxilla								
Central	0.52 ± 0.19	0.14 ± 0.17	0.62 ± 0.30	0.15 ± 0.01	0.52 ± 0.19	0.15 ± 0.10	0.70 ± 0.31	0.19 ± 0.12
Lateral	0.55 ± 0.25	0.17 ± 0.12	0.64 ± 0.32	0.18 ± 0.16	0.57 ± 0.23	0.15 ± 0.13	0.61 ± 0.26	0.19 ± 0.17
Canine	0.58 ± 0.25	0.15 ± 0.12	0.67 ± 0.48	0.21 ± 0.14	0.51 ± 0.22	0.17 ± 0.11	0.72 ± 0.45	0.25 ± 0.19
First premolar	0.50 ± 0.17	0.13 ± 0.10	0.56 ± 0.26	0.21 ± 0.16	0.62 ± 0.24	0.17 ± 0.01	0.60 ± 0.27	0.19 ± 0.10
Second premolar	0.54 ± 0.29	0.17 ± 0.15	0.59 ± 0.26	0.22 ± 0.15	0.51 ± 0.16	0.17 ± 0.12	0.53 ± 0.27	0.19 ± 0.14
Mandible								
Central	0.38 ± 0.17	0.11 ± 0.01	0.39 ± 0.19	0.16 ± 0.01	0.39 ± 0.15	0.13 ± 0.01	0.45 ± 0.20	0.14 ± 0.01
Lateral	0.35 ± 0.10	0.01 ± 0.01	0.42 ± 0.15	0.15 ± 0.01	0.35 ± 0.10	0.13 ± 0.01	0.39 ± 0.13	0.15 ± 0.10
Canine	0.59 ± 0.31	0.12 ± 0.01	0.62 ± 0.31	0.16 ± 0.10	0.45 ± 0.18	0.14 ± 0.01	0.46 ± 0.24	0.01 ± 0.01
Firstpremolar	0.49 ± 0.20	0.11 ± 0.01	0.49 ± 0.20	0.17 ± 0.11	0.41 ± 0.15	0.11 ± 0.01	0.49 ± 0.19	0.18 ± 0.01
Second premolar	0.33 ± 0.01	0.11 ± 0.01	0.46 ± 0.18	0.14 ± 0.11	0.47 ± 0.23	0.16 ± 0.11	0.45 ± 0.26	0.20 ± 0.01

* LbD, labial direct; LbI, labial indirect; LgD, lingual direct; LgI, lingual indirect.

Table 3B. Absolute Mean RotD, in Degrees, for Each Tooth in All Groups* for Both Sides

	Rotation Deviation, Deg							
	Right				Left			
	LbD	LbI	LgD	LgI	LbD	LbI	LgD	LgI
Maxilla								
Central	8.45 ± 3.10	2.29 ± 2.78	10.04 ± 4.89	2.45 ± 0.14	8.45 ± 3.10	2.45 ± 1.63	11.30 ± 5.06	3.10 ± 1.96
Lateral	10.38 ± 4.76	3.24 ± 2.29	12.04 ± 6.08	3.43 ± 3.05	10.75 ± 4.38	2.86 ± 2.48	11.49 ± 4.95	3.62 ± 3.24
Canine	8.25 ± 3.57	1.90 ± 1.71	9.50 ± 1.71	3.00 ± 2.00	7.26 ± 3.14	2.24 ± 1.57	10.20 ± 6.41	3.57 ± 2.71
First premolar	6.33 ± 2.16	1.65 ± 1.27	7.09 ± 3.30	2.67 ± 2.03	7.84 ± 3.05	2.16 ± 0.11	7.59 ± 3.43	2.71 ± 1.43
Second premolar	6.84 ± 3.68	2.16 ± 1.90	7.46 ± 3.30	2.79 ± 1.90	6.46 ± 2.03	2.16 ± 1.52	6.71 ± 3.43	2.71 ± 2.00
Mandible								
Central	7.21 ± 3.24	0.21 ± 0.001	7.40 ± 3.62	3.05 ± 0.001	7.40 ± 2.86	2.48 ± 0.03	8.50 ± 3.81	2.67 ± 0.17
Lateral	6.14 ± 1.76	0.01 ± 0.01	7.36 ± 2.64	2.64 ± 0.12	6.14 ± 1.76	2.29 ± 0.12	6.84 ± 2.29	2.64 ± 1.76
Canine	8.94 ± 4.72	1.83 ± 0.12	9.38 ± 4.72	2.44 ± 0.10	6.84 ± 2.74	2.13 ± 0.10	6.99 ± 3.66	0.12 ± 0.10
First premolar	7.44 ± 3.05	1.68 ± 0.09	7.44 ± 3.05	2.59 ± 1.68	6.23 ± 2.29	1.68 ± 0.10	7.44 ± 2.90	2.74 ± 0.12
Second premolar	4.71 ± 0.12	1.57 ± 0.81	6.56 ± 2.57	2.00 ± 1.57	6.70 ± 3.29	2.29 ± 1.57	6.41 ± 3.71	2.86 ± 0.11

* LbD, labial direct; LbI, labial indirect; LgD, lingual direct; LgI, lingual indirect.

ond premolar showed TqE of about 8° (α). If the distance from the root tip to the bracket is about 25 mm (R) and the TqE is pure tipping with the center of rotation around the apex, the horizontal error (X) would be 3.44 mm ($X = 2R \sin(\alpha/2) \cos(\alpha/2) = R \sin \alpha$) (Figure 5A). This width displacement can create almost a full scissors bite ($-$TqE) or crossbite ($+$TqE) with the antagonist tooth. However, if the torque error is pure torque and the tooth rotates around the midcrown, then the displacement is expressed as inaccurate root position (Figure 5B). Most likely, a combination of tip and torque occurs, which if equally distributed reduces the horizontal displacement to 1.72 mm. Nevertheless, this still has a detrimental effect on intercuspation. The

vertical error ($Y = 2R \sin^2(\alpha/2)$) in this case is 0.24 mm (Figure 5). It is always gingival, leading to disclusion with the antagonist tooth.

Another aspect to consider is the play between the archwire and the slot. That is, although maximal archwires were used as jigs for the different slot sizes (0.022 × 0.028-inch and 0.018 × 0.025-inch), ±2° freedom remained because of an oversized slot or undersized archwire.[8,42] However, torque play affected all teeth equally in all four groups.

Rotation. Clinically, an off-center mistake in bracket placement can affect the integrity of the interproximal contact points, which is related to poor esthetics and posttreatment relapse. The increased RotD in degrees

Table 3C. Level of Significance: Absolute RotD Values* for All Groups†

	P Right				P Left			
	LbD-LbI	LbD-LgD	LgD-LgI	LbI-LgI	LbD-LbI	LbD-LgD	LgD-LgI	LbI-LgI
Maxilla								
Central	<.001	.099	<.001	.894	<.001	.015	<.001	.170
Lateral	<.001	.159	<.001	.706	<.001	.595	<.001	.709
Canine	<.001	.555	.001	.064	<.001	.070	.006	.064
First premolar	<.001	.219	<.001	.022	<.001	.533	<.001	.357
Second premolar	<.001	.556	<.001	.078	<.001	.614	<.001	.466
Mandible								
Central	<.001	.643	<.001	.104	<.001	.278	<.001	.902
Lateral	<.001	.098	<.001	.003	<.001	.085	<.001	.591
Canine	<.001	.637	<.001	.355	<.001	.980	<.001	.029
First premolar	<.001	.746	<.001	.067	<.001	.290	<.001	.037
Second premolar	<.001	.012	<.001	.321	<.001	.731	.001	.092

* Comparison between different bonding techniques within the same system (LbD vs LbI and LgD vs LgI) and between different systems within the same bonding techniques (LbD vs LgD, and LbI vs LgI) per tooth for each side.
† LbD, labial direct; LbI, labial indirect; LgD, lingual direct; LgI, lingual indirect.

Table 4. No. of Cases,* by Tooth, with Bracket Placement More Mesial Than Ideal (+RotD) or More Distal Than Ideal (−RotD), by Group†

	Right and Left							
	LbD		LbI		LgD		LgI	
	+RotD	−RotD	+RotD	−RotD	+RotD	−RotD	+RotD	−RotD
Maxilla								
Central	20	19	17	22	17	23	20	19
Lateral	14	24	15	22	19	19	17	20
Canine	12	27	9	30	6	29	9	20
First premolar	22	17	23	16	19	21	23	17
Second premolar	21	16	16	19	21	17	22	16
Mandible								
Central	17	21	17	21	15	22	17	20
Lateral	13	27	18	22	10	27	13	26
Canine	16	24	22	18	6	28	11	21
First premolar	21	18	18	20	8	26	10	24
Second premolar	14	24	18	19	16	23	19	19

* Total number of cases in each tooth category does not equal 40, as some brackets were placed in ideal position.
† LbD, labial direct; LbI, labial indirect; LgD, lingual direct; LgI, lingual indirect.

of the maxillary incisors may be explained by the narrow labiopalatal dimension of these teeth. A RotD of 0.5 mm will cause a 9.4° rotation of the maxillary lateral incisor with a mean thickness of (buccolingual dimension) 6 mm and a rotation of 6.3° in a premolar tooth with thickness of 9 mm. The thinner the crown thickness, the more vulnerable the tooth is to rotation.

CONCLUSIONS

a. The indirect bonding technique was significantly (twofold) more accurate than the direct technique for all teeth in both labial and lingual orthodontics. This is valid for both TqE and RotD.
b. In both TqE and RotD, no statistical difference was found between the labial and lingual systems for each direct and indirect technique. This suggests that the LBJ is a reliable method for lingual bracket placement.
c. The distal off-center RotD in the mandible is most likely caused by the Ponzo visualization illusion.

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