Original Article

Force and amount of resin composite paste used in direct and indirect bonding

Takeshi Muguruma[a]; Yoshitaka Yasuda[b]; Masahiro Iijima[c]; Naohisa Kohda[a]; Itaru Mizoguchi[d]

ABSTRACT

Objective: To investigate the relationship between the forces applied by the operator and the amount of adhesive used in the direct and indirect bonding methods.

Materials and Methods: A system for measuring the force applied by operator was used to test specimens prepared by 12 orthodontic specialists. To determine the proper amount of adhesive, metal brackets were bonded to transparent resin teeth using composite resin paste and different forces (100, 200, and 300 g); the area of the composite resin paste was then measured using image-analysis software. The mean forces applied in direct and indirect bonding were compared by Student's *t*-test.

Results: Various values for force were obtained for the direct bonding (53–940 g) and indirect bonding (150–870 g) techniques. Although in all cases the area of composite resin paste after the application of constant force was greater than the area of the metal brackets, an insufficient amount of composite resin paste on the bracket base was observed with forces of 100 and 200 g.

Conclusions: A force of greater than 200 g might be preferable for obtaining a thin composite resin layer and for achieving sufficient spreading of the composite resin paste. (*Angle Orthod.* 2010;80:1089–1094.)

KEY WORDS: Direct bonding; Indirect bonding; Composite resin paste

INTRODUCTION

The direct bonding of a fixed appliance has been widely used in clinical orthodontics over the past half century. On the other hand, an indirect bonding technique, which was first described in detail in 1972 by Silverman and Cohen,[1] has been developed over the last 38 years.[2–4] Theoretically, indirect bonding should permit more accurate bracket positioning, although laboratory studies[5–9] have shown various results. Clinical trials have compared the bond-failure rates of the direct and indirect bonding techniques, and mixed results have been reported.[10,11] Previous studies[12–14] on the bond strength of orthodontic adhesives have shown that the adhesive thickness affected the bond strength, but this depends on the type of bonding material and the bonding test used (tensile vs shear bond strength test). Although the force applied by the operator and the amount of adhesive affect accurate bracket positioning and the bond strength for both the direct and indirect bonding techniques, optimal operator force for clinical use in both techniques is unknown. Because a thick layer of adhesive might cause inaccurate bracket positioning, a thin layer might be preferable for the bracket bonding. In addition, insufficient or excess adhesive might cause demineralization of the enamel around the brackets.

The purposes of this study were to measure the force applied by the operator in both the direct and indirect bonding techniques and to investigate the relationship between this force and the amount of adhesive used.

[a] Instructor, Division of Orthodontics and Dentofacial Orthopedics, Department of Oral Growth and Development, School of Dentistry, Health Sciences University of Hokkaido, Hokkaido, Japan.

[b] Private practice, Nishinomiya, Japan.

[c] Associate Professor, Division of Orthodontics and Dentofacial Orthopedics, Department of Oral Growth and Development, School of Dentistry, Health Sciences University of Hokkaido, Hokkaido, Japan.

[d] Professor, Division of Orthodontics and Dentofacial Orthopedics, Department of Oral Growth and Development, School of Dentistry, Health Sciences University of Hokkaido, Hokkaido, Japan.

Corresponding author: Masahiro Iijima, DDS, PhD, Division of Orthodontics and Dentofacial Orthopedics, Department of Oral Growth and Development, School of Dentistry, Health Sciences University of Hokkaido, Hokkaido, Japan
(e-mail: iijima@hoku-iryo-u.ac.jp)

Accepted: April 2010. Submitted: March 2010.

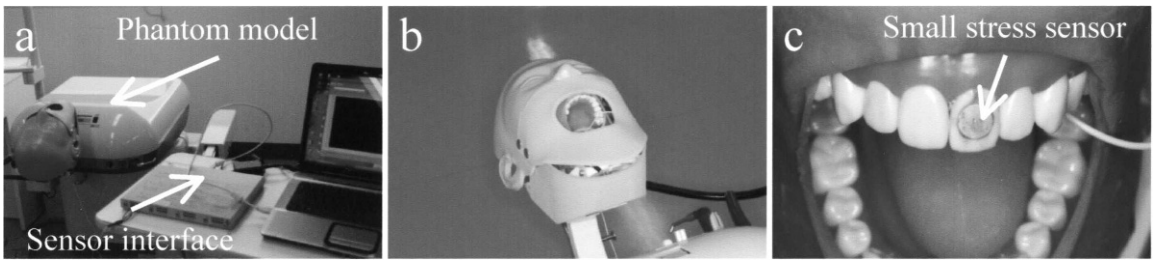

Figure 1. System for the measurement of force used in the present study. (a) Force-measuring system; (b) phantom model; and (c) custom-made epoxy model.

MATERIALS AND METHODS

System for Measuring Force and the Selection of Operators

The force-measuring system in this study consisted of a custom-made epoxy model with a small force sensor (PS-20KC, Kyowa, Tokyo, Japan) at the left maxillary central incisor, a phantom model (DR-11, Morita, Kyoto, Japan), and a sensor interface (PCD-300A, Kyowa) connected to a PC with analysis software (PCD-30A, Kyowa) (Figure 1). The stress sensor was calibrated before the force was measured. Twelve experienced orthodontic specialists (nine males, three females) with a mean of 11 years of experience (range, 4–23 years) participated in this study. They were asked to bond preadjusted straight-wire brackets (PRECI bracket, Shofu, Kyoto, Japan) to the buccal surface of the left maxillary central incisor using both the direct and indirect bonding techniques at room temperature.

Direct Bonding Technique

The composite resin paste used in this study did not contain a polymerization initiator (camphorquinone) and was made by Shofu. Seven milligrams of composite resin paste (Beauty Ortho Bond Paste, Shofu) was placed on the bracket base. The bracket was positioned on the epoxy model and then pressed with an explorer for 10 seconds; the force was measured during this procedure (Figure 2). This procedure was repeated 10 times for all orthodontists. Since the force was stable within a half second after application of the force, the force after 3 seconds was considered in this study ($n = 10$).

Indirect Bonding Technique—Laboratory Stage

A transfer tray (Shirasuka method[15]) was composed of three layers: incisal (occlusal) stopper, primary core, and secondary core (Figure 3).

- An impression of the maxillary anterior region was taken using a silicone rubber impression material (DENT SILICON-V, Shofu). The casts were poured immediately with a vacuum spatulator and high-quality stone and were allowed to dry overnight (Figure 3a). The stone model was ground so that it was no higher than 2 cm in order to allow easy use of the vacuum-forming apparatus. The cast was painted with liquid foil and allowed to dry completely.
- An incisal stopper composed of thermoplastic resin (Occlusal stopper, Shofu) was made to prevent vertical deflection of the tray during the bonding procedure (Figure 3b).
- A small amount of composite resin paste was placed on the bracket base (PRECI bracket, Shofu), and the bracket was placed in its correct position. The bracket was then firmly pressed against the tooth surface, and any excess composite resin paste was removed with an explorer. The paste was allowed to light-cure for 20 seconds (10 seconds from each proximal side) (Figure 3c).
- The primary core was made with a highly elastic silicone material (Emiluma, Shofu; Ultradent, South Jordan, Utah) (Figure 3d).
- A sheet of mouth-guard material measuring 2 mm thick (Mouth-guard material, Shofu) was softened with a thermo-forming vacuum machine to fabricate the secondary core (Figure 3e).

Figure 2. The direct bonding technique.

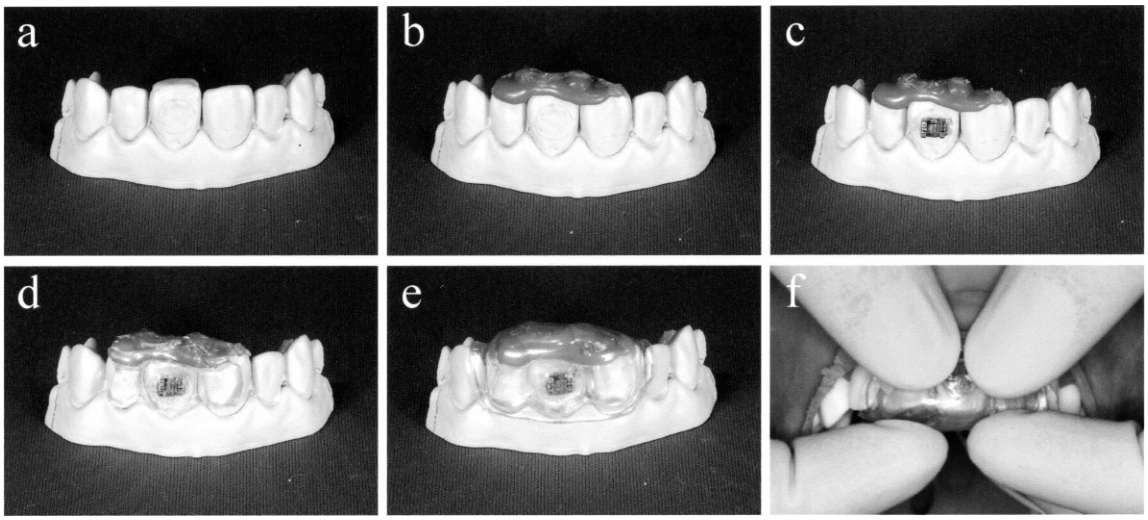

Figure 3. The indirect bonding technique. (a) The high-quality stone model. (b) Incisal (occlusal) stopper. (c) The bracket placed at the correct position. (d) Primary core. (e) Secondary core. (f) The tray was seated against the tooth surface.

Indirect Bonding Technique—Clinical Stage

Seven milligrams of composite resin paste was placed on the bracket bases of an indirect bonding tray. The tray was seated against the tooth surfaces and was not only held in place with the fingers but was also subjected to light pressure on its labial surface for 10 seconds (Figure 3f). The force used during this procedure was measured, and this measurement was repeated 10 times for each of the orthodontists. Since the force was stable within a half second of application of the force, the force after 3 seconds was considered in this study (n = 10).

Measurement of Insufficient and Excess Composite Resin Paste Under a Constant Force

Metal brackets (PRECI bracket, Shofu) were bonded to transparent teeth (upper central incisor, upper lateral incisor, and upper canine) made with epoxy resin (Epofix, Struers, Copenhagen, Denmark) using a custom-made jig that could be used to apply constant forces to the buccal surface of a tooth (Figure 4). The amount of composite resin paste (Beauty Ortho Bond Paste, Shofu) used for the bonding brackets was 5–7 mg for the central incisor, 4–6 mg for the lateral incisor, and 7–9 mg for the canine, as measured with a precision digital balance (ER-182A, A&D, Tokyo, Japan). Forces of 100, 200, and 300 g were used for bracket bonding (n = 5). The transparent teeth were then observed from the opposite side with a stereoscopic microscope to measure the area of the composite resin paste using image-analysis software (Win ROOF, Mitani, Tokyo, Japan).

Statistical Analysis

Statistical analysis was performed using the Statistical Package for Social Science (version 16.0J for Windows, SPSS Inc, Chicago, Ill). The mean forces associated with the direct and indirect bonding techniques were compared by Student's *t*-test.

RESULTS

Forces with the Direct and Indirect Bonding Techniques

The forces in the direct and indirect bonding techniques for the 12 orthodontists are shown in

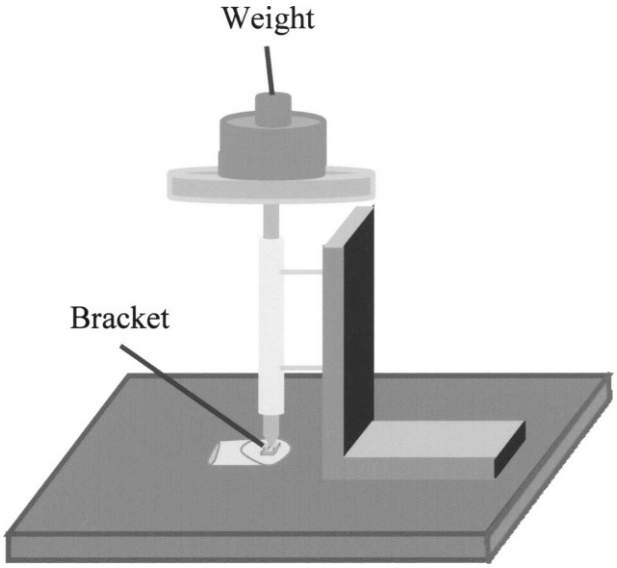

Figure 4. A custom-made jig to apply constant force to the buccal surface of the teeth.

Table 1. Mean Bonding Force Obtained from 12 Experienced Orthodontic Specialists (A–L)[a]

	Direct Bonding		Indirect Bonding	
	Mean	SD	Mean	SD
A	452.31	71.42	684.22	87.03
B	225.59	22.58	229.44	49.65
C	812.17	92.93	265.99	37.02
D	186.15	23.52	256.38	18.53
E	733.29	64.15	626.5	85.43
F	82.97	18.33	518.52	122.88
G	223.67	23.78	382.88	61.56
H	364.6	27	599.57	106.07
I	431.22	38.9	595	119.35
J	263.11	61.86	206.83	31.79
K	174.61	29.96	367.49	22.92
L	120.97	18	293.41	47.28
Mean	339.22	25.04	418.85	37.25

[a] The mean forces in the direct and indirect bonding technique were compared by Student's *t*-test; $t(238) = -2.98$, $P = .003$. SD indicates standard deviation.

Table 1. Various values for the force were obtained using both techniques. The average force for the indirect bonding technique (420 g) was significantly greater than that for the direct bonding technique (340 g) ($P = .003$).

Measurement of the Area of the Composite Resin Paste After the Application of Force

The surface areas of the metal brackets used in this study were 12.6 mm^2 for the central incisor, 10.0 mm^2 for the lateral incisor, and 13.3 mm^2 for the canine. The mean areas of the composite resin paste after the application of force are shown in Table 2, and the number of specimens for which insufficient composite resin paste was observed at the edge of the bracket base is shown in Table 3. In all cases, the surface area of the composite resin paste after the application of force had a greater value than did the areas of the metal brackets (Table 2). However, an insufficient amount of paste to fill the entire bracket base area was observed for some combinations of amount of composite resin paste and force (Table 3).

DISCUSSION

In this study, various force values obtained with the direct bonding (53–940 g) and indirect bonding (150–870 g) techniques and the average values of the 12 orthodontists were 340 g and 420 g respectively. Although this study used a limited number of orthodontists, no difference in force was seen between gender or the years of experience as an orthodontist. The average values for the force were higher than we expected. The median values were 245 g for direct bonding and 360 g for indirect bonding. Accordingly, we used forces of 100, 200, and 300 g to measure the area of composite resin paste. During the indirect bonding procedure in the present study, light pressure was applied to the labial surface of the tray. To generate sufficient force, it may be necessary to apply pressure from the labial side as an indirect bonding technique. In addition, an indirect bonding tray might be preferable to divide into an incisor and canine region and a molar region to achieve appropriate force.

The clear transfer tray has been popular for the indirect bonding technique because it enables the use of light-cured composite adhesives. The clear transfer tray used in this study (Shirasuka method[15]) consisted of the dual-layered structure: clear soft inner and clear hard outer combination. The soft inner facilitates the removal of the tray from the brackets. On the other hand, other materials, such as clear impression compound and polyvinylsiloxane, are also popular for the clear tray for the indirect bonding technique. Since these materials might have a greater degree of hardness and elastic modulus than Emiluma, a different level of force might be obtained for the indirect bonding. Further study comparing different materials for the transfer tray is required.

Table 2. Mean Area of Composite Resin Paste after the Application of Force (mm^2)[a]

	Amount of Composite Resin, mg	Force					
		100 g		200 g		300 g	
		Mean	SD	Mean	SD	Mean	SD
Central incisor	5	12.92	0.63	13.96	0.32	14.48	0.91
	6	14.76	1.3	16.11	1.51	16.32	1.19
	7	16.39	1.33	17.88	0.94	18.51	0.95
Lateral incisor	4	11.22	1.9	12.22	1.9	12.71	1.71
	5	13.21	1.41	14.06	1.07	14.45	0.79
	6	13.09	0.79	14.24	0.8	14.83	0.69
Canine	7	15.23	0.4	15.75	0.73	16.08	0.67
	8	16.6	1.43	17.78	1.07	18.3	1.05
	9	16.92	0.29	18.53	0.22	18.83	0.57

[a] SD indicates standard deviation.

Table 3. Number of Specimens that Showed Insufficient Composite Resin Paste at the Edge of the Bracket Base

	Amount of Composite Resin, mg	Force		
		100 g	200 g	300 g
Central incisor	5	4	3	3
	6	3	0	0
	7	0	0	0
Lateral incisor	4	4	3	2
	5	1	0	0
	6	0	0	0
Canine	7	4	2	1
	8	3	0	0
	9	0	0	0

The appropriate force and the amount of adhesive might vary according to the adhesive product used as a result of differences in flow properties. The flow of a composite resin adhesive paste should be mainly influenced by the properties of the fillers, such as the amount, grain size, and shape. In addition, the temperature of the environment (of the room or oral temperature) influences the flow property. A recent study[16] showed that Beauty Ortho Bond paste contained a variety of irregular particles ranging from approximately 0.5 μm to 10 μm in size, with some larger (10–15 μm) irregular particles. Enlight Cure adhesive (Ormco) and Kurasper F Light Cure adhesive paste (Kuraray Medical) had similar features. In addition, Beauty Ortho Bond paste had a filler content of 70%, which was comparable to the values of other composite resin adhesive products. Where a composite paste is placed before the application of force is also an important consideration. In the present study, the composite paste was placed at the center of the bracket base. Cooper et al.[17] described the benefits of the precoated brackets, such as the consistency of coating, ease of clean up, and elimination of waste, associated with indirect bonding. The use of precoated brackets might be worthwhile in the case of the indirect bonding technique to avoid problems caused by an improper amount of composite resin paste.

Previous studies[12–14] that compared the bond strength of orthodontic adhesives have shown that the adhesive thickness affected the bond strength. A thick layer of adhesive might cause inaccurate bracket positioning. In addition, since either an insufficient amount or an excess amount of adhesive might cause demineralization around orthodontic brackets,[18] the amount of bonding adhesive is an important factor in clinical orthodontics. Although in this study in all cases the area of composite resin paste after the application of force was greater than the area of the metal bracket (Table 2), an insufficient amount of composite resin paste on the bracket base was observed with forces of 100 g and 200 g (Table 3). The results clearly demonstrate that a force greater than 200 g might be preferable for achieving a thin composite resin layer and for avoiding an insufficient amount of composite resin paste on the bracket base.

CONCLUSIONS

- Based on the results with 12 orthodontists and an in vitro model, various values of force were obtained with the direct bonding (53–940 g) and indirect bonding (150–870 g) techniques.
- A force of greater than 200 g might be preferable for achieving a thin composite resin layer and for avoiding insufficient composite resin paste on the bracket base.

ACKNOWLEDGMENT

The authors thank Dr Naoki Shirasuka for expert technical assistance with the indirect bonding technique.

REFERENCES

1. Silverman E, Cohen M. A universal direct bonding system for both metal and plastic bracket. *Am J Orthod*. 1972;62: 236–244.
2. Thomas R. Indirect bonding: simplicity in action. *J Clin Orthod*. 1979;13:93–106.
3. Kalange JT, Thomas RG. Indirect bonding: a comprehensive review of the literature. *Semin Orthod*. 2007;13:3–10.
4. Thompson MA, Drummond JL, BeGole EA. Bond strength analysis of custom base variables in indirect bonding techniques. *Am J Orthod Dentofacial Orthop*. 2008;133: 9.e15–e20.
5. Aguirre MJ, King GJ, Waldron JM. Assessment of bracket placement and bond strength when comparing direct bonding to indirect bonding techniques. *Am J Orthod*. 1982;82:269–276.
6. Read MJ, O'Brien KD. A clinical trial of an indirect bonding technique with a visible light-cured adhesive. *Am J Orthod Dentofacial Orthop*. 1990;98:259–262.
7. Koo BC, Chung CH, Vanarsdall RL. Comparison of the accuracy of bracket placement between direct and indirect bonding techniques. *Am J Orthod Dentofacial Orthop*. 1999; 116:346–351.
8. Rossouw PE, Bruwer HC, Stander IA. The rationale behind a viable alternative to direct bonding of orthodontic attachments. Indirect bonding. *Ont Dent*. 1995;72:19–25.
9. Polat O, Karaman AL, Buyukyilmaz T. In vitro evaluation of shear bond strengths and in vivo analysis of bond survival of indirect-bonding resins. *Angle Orthod*. 2004;74:405–409.
10. Zachrisson BU, Brobakken BO. Clinical comparison of direct versus indirect bonding with different bracket types and adhesives. *Am J Orthod*. 1978;74:62–78.
11. Thiyagarajah S, Spary DJ, Rock WP. A clinical comparison of bracket bond failures in association with direct and indirect bonding. *J Orthod*. 2006;33:198–204.
12. Schechter G, Caputo AA, Chaconas SJ. The effect of adhesive layer thickness on retention of direct bonded brackets. *J Dent Res*. 1980;59:285.
13. Evans L, Powers JM. Factors affecting in vitro bond strength of no-mix orthodontic cements. *Am J Orthod*. 1985;87: 508–513.

14. Arici S, Caniklioglu MC, Arici N, Ozer M, Oguz B. Adhesive thickness effects on the bond strength of light-cured resin-modified glass ionomer cement. *Angle Orthod*. 2005;75: 254–259.
15. Yasuda YT, Shirasuka N, Yasuda YH, eds. *Indirect Bonding System* [in Japanese]. Tokyo, Japan: Tokyo Clinical Publication, Inc; 2007:33–72.
16. Iijima M, Muguruma T, Brantley WA, Yuasa T, Uechi J, Mizoguchi I. The effect of filler on the grindability of composite resin adhesive. *Am J Orthod Dentofacial Orthop*. In press.
17. Cooper RB, Goss M, Hamula W. Direct bonding with light-cured adhesive precoated brackets. *J Clin Orthod*. 1992;8: 477–479.
18. Sudjalim TR, Woods MG, Manton DJ, Reynolds EC. Prevention of demineralization around orthodontic brackets in vitro. *Am J Orthod Dentofacial Orthop*. 2007;131: 705e1–e9.