Original Article

Shear Bond Strength of Orthodontic Brackets Bonded to Provisional Crown Materials Utilizing Two Different Adhesives

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ABSTRACT

Objective: To test the hypothesis that there is no difference in the shear bond strength of brackets bonded to provisional crown materials (PCMs) using two adhesive agents.

Materials and Methods: Four PCMs were tested: Integrity, Jet, Protemp, and Snap. Forty cylindrical specimens of 10 mm diameter × 5 mm were prepared for each PCM. Ten specimens from each group were bonded to one of the two brackets, Clarity or Victory, using one of the two adhesives, Fuji Ortho LC or Ortho Bracket Adhesive. The brackets were debonded in shear at a cross-head speed of 5 mm/min, and the shear bond strength (SBS) was calculated. The type of failure was visually determined. The numeric data were analyzed using three-way analysis of variance and Tukey multiple range test at $\alpha = .05$.

Results: The mean SBSs ranged from 2.81 MPa to 9.65 MPa. There was a significant difference between Snap and the other three materials ($P < .0001$). There was no significant difference between the two brackets or the two adhesives ($P > .05$). The bond failure for all the specimens was of the adhesive type between the PCM and the adhesive resin.

Conclusions: The PCM Snap yielded a significantly lower mean SBS value compared to the other three materials. No significant differences were found between the brackets or the adhesives. The bond failure was of the adhesive type. (*Angle Orthod.* 2009;79:784–789.)

KEY WORDS: Provisional crown materials; Shear bond strength; Orthodontic brackets; Adhesives

INTRODUCTION

Esthetic, biologic, and restorative problems associated with dentition may occur as a result of fracture or a gross carious lesion extending subgingivally and impinging on the biologic width of teeth. The treatment options depend on the relationship of the remaining tooth structure to the alveolar crest, the crown-root ratio, and the esthetic requirements of the patient. One of the treatment options may include forced orthodontic root eruption, first described in 1973 by Heithersay[1] and further reported by others.[2–9]

Most often, a post and core is used for an endodontically treated tooth with substantial loss of coronal tooth structure, and a provisional crown is needed prior to orthodontic root extrusion. The purpose of a provisional crown is to provide interim protection, stabilization, and function of the tooth, as well as to determine the esthetic result of the final restoration.[10] In such a clinical situation, an orthodontic bracket is bonded to the provisional crown material (PCM). Chemically activated resins are the popular materials in the market for fabrication of provisional crowns. Although these resins are used for the same purpose, their chemical, physical, and clinical properties differ. Bis-acryl-composite resins, as compared to poly methylmethacrylate or poly ethylmethacrylate, show low exothermic reaction during setting, better strength, adequate margin adaptation, and superior color stability.[10]

The range of force required for translatory movement of teeth is reported to be 70–120 g; for extrusion, 35–60 g.[11,12] Comparing such forces, Reynolds[13] has suggested that a minimum tensile bonding strength of

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Table 1. Materials Used in the Study

Item and Brand Name	Manufacturer
Provisional Crown Materials	
Integrity	Dentsply-Caulk, Milford, Del
Jet	Lang, Wheeling, Ill
Protemp	3M ESPE, St Paul, Minn
Snap	Parkell, Edgewood, NY
Brackets	
Clarity Twin	3M-Unitek, Monrovia, Calif
Victory Twin	
Adhesives	
Fuji Ortho LC	GC America, Alsip, NY
Ortho Adhesive	Henry Schein, Melville, NY

6 MPa to 8 MPa between orthodontic brackets and teeth would be adequate for clinical orthodontic tooth movement. Several investigations have evaluated bracket-natural dentition bond strengths through the agency of resin composite or glass ionomer–type adhesives.[14–19] Information related to the bond strength of brackets with various other restorative and experimental materials is also available[20–23]; however, information specifically related to PCMs is rather limited.[21]

The objective of this in vitro study was to compare the shear bond strength (SBS) between four widely and commonly used PCMs and two different types of orthodontic brackets, using two separate adhesive agents. Based on the results of this study and earlier studies with the natural dentition, it may be possible to make suggestions for the clinical selection of PCMs for teeth requiring orthodontic root extrusion.

MATERIALS AND METHODS

The four PCMs, two orthodontic brackets, and two adhesive systems used in the study are listed in Table 1. Their major ingredients, as obtained from the respective manufacturers, are listed in Table 2. Among the PCMs, the base pastes and the catalyst pastes of Integrity and Protemp were supplied in automix cartridges, whereas the powders and liquids of Jet and Snap were supplied in separate vials. The Clarity brackets were a ceramic type with metallic slots, and

Table 2. Composition of the Materials Used in the Study

Item	Brand Name	Description	Major Ingredients
Provisional Crown Materials	Integrity	Paste (automix cartridge)	Glycol methacrylate Multifunctional methacrylates Malonyl urea derivative Barium glass fillers Fumed silica fillers
	Jet	Powder Liquid	Plasticized methacrylate polymer Methylmethacrylate monomer
	Protemp	Paste (automix cartridge)	BisGMA Dimethacrylate polymer Silane-treated ceramic fillers Synthetic amorphous fumed silica fillers
	Snap	Powder Liquid	Polyethylmethacrylate Isobutyl methacrylate monomer Ethylene glycol dimethacrylate monomer
Brackets	Clarity Twin	Maxillary bicuspid	Ceramic with metal slot
	Victory Twin	Maxillary bicuspid	Stainless steel
Adhesives	Fuji Ortho LC	Powder Liquid	Aluminosilicate glass Polyacrylic acid 2-Hydroxyethyl methacrylate 2,2,4-Trimethylhexamethylene dicarbonate Trimethyleneglycol dimethacrylate
	Ortho Bracket Adhesive	Base paste	Aromatic/aliphatic dimethacrylate monomers Tirtiary amine Silica
		Catalyst paste	Aromatic/aliphatic dimethacrylate monomers Benzoyl peroxide Silica
		Sealant liquid—Base	Aromatic/aliphatic dimethacrylate monomers Tirtiary amine
		Sealant liquid—Catalyst	Aromatic/aliphatic dimethacrylate monomers Benzoyl peroxide
		Etchant	∼38% Phosphoric acid

the Victory brackets were the stainless steel type. The areas of the pads were 11.29 mm^2 and 9.03 mm^2 for Clarity and Victory, respectively.

A 25-mm-diameter clear acrylic rod (American Plastic, Arlington, Tex) was cut into 20-mm-long sections. A 10 $\times$ 5-mm well was bored in the center of each section. The PCMs were mixed according to the respective manufacturer's recommendations and filled into the well. A sheet of thermoplastic material was placed on the surface of the specimen to simulate the clinical/laboratory conditions, in which such sheets are used to form a mold from which the provisional crown is fabricated. The material was allowed to set, and the surface of the specimen was polished with pumice (Medium grit #03492; Whip Mix Corporation, Louisville, Ky) for 15 seconds using a felt wheel mounted on a laboratory lathe. Forty such specimens were prepared for each of the four PCMs and were divided into four groups of 10 each to allow testing of two orthodontic bracket types and two orthodontic adhesives. In total, 160 specimens were tested.

The powder and liquid of Fuji Ortho LC were supplied in premeasured capsules. The base paste and the catalyst paste of the Ortho Bracket Adhesive were in separate jars accompanied by a liquid sealant in two separate bottles. The brackets were bonded to the PCM samples by mixing and using the adhesive components according to the respective manufacturer's instructions. For the specimens using Ortho Bracket Adhesive, a 38% phosphoric acid etching solution and the bonding agent were employed. Excess adhesive beyond the periphery of the pads of the brackets was removed prior to setting. Each group of the PCM samples received a combination of one of the two brackets and one of the two adhesives. The bonded specimens were stored in distilled water at room temperature for 24 hours before testing SBS. The acrylic rod holding the specimen of the PCM sample and bonded bracket was mounted on the Instron universal testing machine (Instron Corp, Canton, Mass; Figure 1). The brackets were subjected to a shear load at a cross-head speed of 5 mm/min until debonding occurred. The peak loads at debonding and the projected areas of the bracket pads opposing the PCM samples were used to calculate SBS. The standard equation SBS = (load/area) was employed to obtain SBS values in terms of megapascals. The debonded surfaces of the brackets and the PCM samples were examined visually to determine whether the failure was adhesive, cohesive, or a combination of the two. The data were analyzed using three-way analysis of variance and compared with Tukey multiple range test at $\alpha = .05$.

RESULTS

As shown in Table 3, the SBS ranged from a minimum of 1.41 MPa for Snap with stainless steel Victory brackets and Fuji Ortho LC adhesive to a maximum of 18.20 MPa for Integrity with Victory brackets and Ortho Bracket Adhesive. The highest mean SBS (9.65 MPa) was observed for Protemp with Clarity brackets and Ortho Bracket Adhesive, whereas the lowest such value (2.81 MPa) was for Snap with Victory brackets and Fuji Ortho LC adhesive. There was a significant difference between the mean bond strength of Snap and that of Jet, Protemp, or Integrity ($P < .0001$). There was no statistically significant difference between the SBSs of Jet, Protemp, and Integrity ($P > .05$) or between the two adhesives, Fuji Ortho LC and Ortho Bracket Adhesive ($P > .05$). There was a highly significant interaction between the provisional materials and adhesives ($P < .001$). There was no significant interaction between the brackets and the adhesives ($P > .05$). It was also noted that the bond failure for all the specimens was of the adhesive type occurring between the provisional material and the adhesive resin, with most of the adhesive layer remaining on the bracket pads.

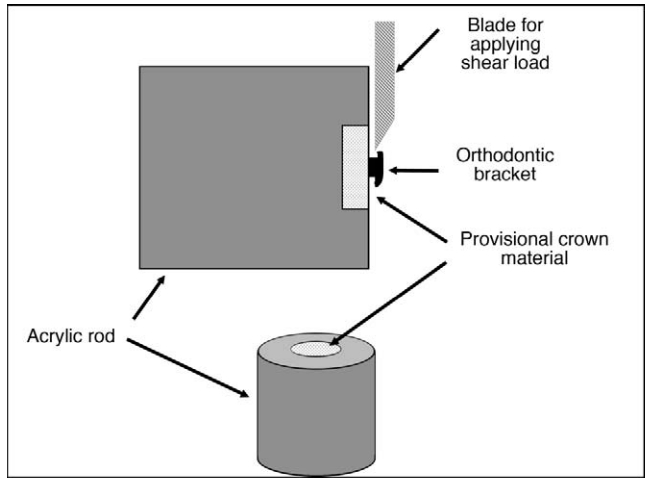

Figure 1. Diagrammatic representation of specimen prepared for testing on the Instron Machine.

DISCUSSION

When a tooth with a fracture or a carious lesion extends subgingivally and impinges on the biologic width needed for restoration, depending on the specific clinical situation the tooth may need surgical crown lengthening or forced orthodontic root eruption or both. The disadvantage of crown lengthening is that it may alter the gingival level of the tooth as compared to that of the adjacent and contralateral teeth, which can lead to esthetic problems for the patient. The advantage of orthodontic extrusion combined with fiberotomy and root planing is that it enables the clinician to maintain the gingival level of the tooth relative to the adjacent/contralateral teeth.[24]

Table 3. Mean Shear Bond Strengths for Orthodontic Brackets on Provisional Crown Materials and Summary of Statistical Results*

			Shear Bond Strength, MPa				
PCM[a]	Bracket	Adhesive	Mean	Std Dev	CV, %	Minimum	Maximum
Integrity	Clarity (Ceramic)	Fuji Ortho LC	8.25	2.45	29.67	5.63	13.75
		Ortho Adhesive	7.10	1.50	21.13	3.39	8.64
	Victory (SS)	Fuji Ortho LC	8.31	1.43	17.16	5.56	10.74
		Ortho Adhesive	7.78	4.44	56.99	1.87	18.20
Jet	Clarity (Ceramic)	Fuji Ortho LC	9.32	2.53	27.18	4.78	11.64
		Ortho Adhesive	8.27	2.08	25.17	6.47	13.56
	Victory (SS)	Fuji Ortho LC	8.52	2.24	26.31	6.39	12.12
		Ortho Adhesive	6.62	2.81	42.40	4.22	14.14
Protemp	Clarity (Ceramic)	Fuji Ortho LC	7.42	1.73	23.33	5.18	10.27
		Ortho Adhesive	9.65	2.35	24.31	6.97	14.23
	Victory (SS)	Fuji Ortho LC	9.33	2.02	21.68	5.01	11.89
		Ortho Adhesive	8.37	2.12	25.36	5.51	13.40
Snap	Clarity (Ceramic)	Fuji Ortho LC	5.40	2.18	40.29	3.64	11.21
		Ortho Adhesive	7.83	1.80	22.99	5.35	10.76
	Victory (SS)	Fuji Ortho LC	2.81	1.33	47.53	1.41	5.06
		Ortho Adhesive	5.08	1.49	29.41	2.48	7.37

* PCMs: Snap had a significantly smaller SBS than Protemp, Integrity, and Jet ($P < .0001$); no significant difference among Protemp, Integrity, and Jet ($P > .05$). Brackets: Clarity [ceramic] had a significantly greater SBS than Victory [stainless steel] ($P < .001$). Adhesives: no significant difference between the adhesives ($P > .05$). Interactions: significant, material-bracket ($P < .046$) and material-adhesive ($P < .001$); not significant, bracket-adhesive ($P = .193$).

[a] PCM indicates provisional crown material; SS, stainless steel; Std Dev, standard deviation; CV, coefficient of variation.

Prior to orthodontic extrusion, however, multidisciplinary treatment procedures are required. These may include endodontic therapy to devitalize the tooth and render it free of pain and infection, restoration of the lost coronal tooth structure with a core retained by a post, and a provisional restoration. In such a clinical situation, there are multiple interfaces between the remaining tooth structure and the orthodontic wire that ultimately exerts the force on the tooth in order to appropriately reposition it. These interfaces include, among others, dentin-luting (bonding) agent-PCM and PCM-adhesive-bracket.

The mechanical characteristics of the interface between dentin and luting agents have been extensively studied,[25–30] and the mean SBS values in this respect have reached in excess of 35 MPa. The SBS values for orthodontic brackets attached to tooth enamel with resin composites or glass ionomer–type adhesives have been reported to be in the range of 4–26 MPa.[14–19]

The selection of the premolar brackets instead of maxillary central incisor brackets was based upon ready availability of the former. The curvature of the bracket against the flat surface of the PCM probably resulted in SBS values that were lower than those that would have resulted if central incisor brackets with smaller curvature were used as reported previously.[31] However, in this study, excess thickness of the adhesive due to the curvature of the bracket does not appear to have any influence on the bond strength, as there were no cohesive failures observed within the adhesive layer.

Because the samples of PCMs were prepared against a constant surface and finished using the same protocol, the degree of surface roughness is expected to be the same for all the materials. Minor differences between the surfaces, if present, are not expected to influence the debonding load values. The etching solution used with Ortho Bracket Adhesive is not expected to create microporosities in the PCMs as it would when used on enamel or dentin. However, it does serve to cleanse the surface of the resin and possibly increase its wettability, allowing the adhesive to be in intimate contact with the resin, a condition that is a primary requirement for satisfactory bonding.

The basic components in all PCMs are based on methacrylate chemistry. As such, the bonding is likely to be influenced by the number of available reactive sites on the polymerized provisional materials. The presence of BisGMA in Protemp and glycol methacrylate in Integrity may account for higher SBS values compared to those for Snap. Similarly, the presence of fillers in Integrity and Protemp may also have some effect on the bond strength.[32]

With the exception of the Victory Stainless steel brackets bonded to Snap with Fuji Ortho LC, the mean SBS values obtained in the present investigation generally exceeded the expected stress values during orthodontic treatment.[12,13] The SBS values obtained for Protemp are smaller than those reported in another investigation,[21] perhaps because of a different adhesive used in that study. In general, the SBS values are smaller than those reported for brackets attached to microfilled resin composite material.[20] This may be due to the differences in the chemical affinities of the two substrates (PCMs and microfilled resin composite) for the orthodontic adhesives. In addition, the roughening of the resin composite samples prior to bonding of the brackets, as well as the differences in cross-head speeds used for debonding the brackets (1 mm/min vs 5 mm/min), may account for these results.

In comparing the brackets, their material type and/or the retentive features appear to significantly affect the SBS. Between the adhesives, Glass ionomer containing Fuji Ortho LC as well as BisGMA containing Ortho Adhesive produced similar SBS values, indicating their equally effective bonding with the PCMs.

Relatively large values of coefficient of variation are common to many studies dealing with bond strengths. Particularly high values were observed for Ortho Bracket Adhesive with Victory brackets in the case of Integrity (56.99%) and Jet (42.40%), and for Fuji Ortho LC adhesive with Snap in the case of Victory (47.43%) and Clarity (40.29%) brackets. Apart from the variability arising from the interactions between the materials, such high coefficient of variation values cannot be explained at present. In this context, it is worth emphasizing the complex nature of testing bond strengths between orthodontic brackets and teeth or restorative materials.[33] In addition, it should be noted that shear or tensile bond strengths are reported in the literature regarding orthodontic brackets and adhesives. A direct comparison between these strengths is, obviously, not valid. However, in general, the shear strength of many dental materials and the SBS reported for limited examples appear to be greater than such strengths in tension.[19]

The bond strength between the bracket and the PCM, as well as that between the provisional crown and the prepared tooth, could be the potential weak links. The present study tested and verified the adequacy of the SBS of the bond between the orthodontic brackets and PCMs. Further studies are needed to test the interfaces between PCMs, luting agents, and tooth structure.

CONCLUSIONS

- SBS for Snap was significantly lower than the other three PCMs (Jet, Protemp, and Integrity).
- There was a significant difference between the SBSs obtained for the two orthodontic brackets.
- There was no significant difference between SBS values for the two orthodontic adhesive agents, Fuji Ortho LC and Ortho Bracket Adhesive.
- The interactions between the materials and brackets as well as between materials and adhesives were significant.

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