



Original Article

Effects of plastic bracket primer on the shear bond strengths of orthodontic brackets



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KEYWORDS

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Adhesive remnant index;
Metal bracket;
Ceramic bracket

Abstract *Background/purpose:* To assess the usefulness of plastic bracket primer (PBP) for improving the bond strength of plastic brackets (PBs) using three types of orthodontic brackets, including PBs, metal brackets (MBs), and ceramic brackets (CBs).

Materials and methods: A total of 162 premolars were gathered and divided equally into six groups of 27. Three groups were tested with the application of PBP (PB+, MB+, and CB+), and three groups were tested without primer (groups PB-, MB-, and CB-). All the groups were bonded using BeautiOrtho Bond II self-etching adhesive. The shear bond strength (SBS) was measured and the bond failure mode was evaluated using the adhesive remnant index after debonding.

Results: There were significant differences in the mean SBS between groups PB-, MB and CB-, between PB+ and CB+, and between MB+ and CB+. Group PB + had a significantly higher mean SBS than group PB-. The occurrence of bond failure at the enamel and adhesive interface was more frequent in groups PB+ and CB- than in group PB-; and in groups PB+ and CB + than in group MB+.

Conclusion: Plastic bracket primer can increase the bond strength of PBs to the level of metal brackets, but not to the level of ceramic brackets.

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Introduction

Most metal brackets (MBs) are made from stainless steel and are commonly used for orthodontic treatment owing to their superior durability and operability.¹ With an increased awareness of esthetic dentistry within the community, relatively invisible esthetic brackets, such as ceramic and plastic brackets (CBs and PBs), have come into vogue.² Most CBs are made of mono- or polycrystalline alumina or zirconia, and are chemically inert to oral fluids.³ Drawbacks of CBs are their propensity to fracture and their abrasiveness towards tooth enamel.⁴ Currently available PBs are composed of polycarbonate, a thermoplastic polymer with linear and branched chains that is soluble in organic solvents.⁵ Disadvantages of PBs include discoloration,¹ wear,⁶ distort,⁶ and poor dimensional stability;⁷ however, they do not cause enamel abrasion.⁸ Alteration of PB design, such as metal slot and mechanical undercuts of the bracket base, have alleviated deformation and low bond strength.⁹ With the increasing esthetic requests of orthodontic patients, CBs are widely used in many patients, and PBs reinforced with ceramic or fibreglass fillers and/or metal slots are also becoming increasingly popular.¹⁰

It is difficult to perform successful orthodontic treatment using orthodontic brackets with a low bond strength; however, the highest possible bond strength causes enamel to fracture or crack at debonding.¹¹ Some researchers have reported that the bond strength of MBs was significantly higher than that of CBs,^{12,13} while others have reported that it was comparable¹⁴ or lower.^{14,15} Some studies showed no significant difference in bond strength between PBs and MBs.^{16,17} Other studies found that PBs exhibit a significantly lower bond strength than MBs^{6,7,9,16} and CBs² because of the lack of strength and stiffness in the PB structure.¹

One study verified that plastic bracket primers (PBP) can improve the low bond strength of PBs,¹⁷ while another study demonstrated no significant difference in the bond strength of PBs with and without the application of PBP.⁹ Still another study raised questions about the usefulness of PBP for increasing the low bond strength of PBs.¹⁶ These evidence has reflected that there is no consistent finding as to whether PBP is useful for improving the bond strength of PBs. Moreover, these studies have all used two types of PB and MB, and not CBs, to assess the usefulness of PBP. Therefore, further investigation is necessary to clarify the interaction between PBP and PBs.

The purpose of this study was to assess the usefulness of PBP for improving the bond strength of PBs using three types of orthodontic bracket: PBs, MBs, and CBs.

Materials and methods

The protocol was approved by the Ethics Committee of The Nippon Dental University School of Life Dentistry at Niigata (ECNG-R-303). Sample size was calculated based on a priori power analysis using G*Power software (version 3.1, Heinrich Heine University, Dusseldorf, Germany) for a two-way analysis of variance (ANOVA) at an effect size of 0.25 (Cohen's medium effect size), an alpha error probability of 0.05, a power of 0.8, and six groups. The analysis showed that a total of 162 teeth was required, and hence it was decided that the sample size in each group would be 27 teeth.

A total of 162 human premolars extracted for orthodontic reasons within 1 month were collected and stored in 0.1% (weight/volume) thymol at 4 °C to prevent bacterial growth and dehydration until used in this study. The selection criteria for teeth included intact buccal enamel without cracks incidental to extraction, no pretreatment with chemical agents such as hydrogen peroxide or fluoride, and no caries.

The buccal surfaces of all teeth were cleaned and polished with fluoride-free pumice in a rubber cup for 10 s. Each tooth was then rinsed with a water spray for 10 s and dried with an oil-free air drier. All teeth were divided equally into six groups of 27 teeth each. Three groups were tested with the application of PBP (PB+, MB+, and CB+), and three groups were tested without this primer (groups PB-, MB-, and CB-).

Our study included three types of premolar standard edgewise brackets: PBs, MBs and CBs (Table 1).

The adhesive and light-curing unit used in this study are listed in Table 2. In all six groups, BeautiOrtho Bond II self-etching primer (Shofu, Kyoto, Japan) was rubbed on the buccal enamel surface for 10 s and gently dried with an oil-free air drier for 2 s. In groups PB+, MB+ and CB+, two thin uniform layers of PBP were applied to the bracket base and then dried for 10 s. In groups PB-, MB- and CB-, PBP were not applied to the bracket base. In all six groups, BeautiOrtho Bond II paste was applied to the bracket base. The bracket was then placed on the buccal surface of the tooth and pressed firmly into place to squeeze paste from the rim of the bracket base. Excess paste was removed with an explorer before curing. Specimens in groups PB and CB and in groups MB were light-cured towards the bracket surface for 20 s and from the mesial and distal direction for 10s each (total curing time; 20 s),¹⁸ respectively, with a high-power LED curing light (PenCure 2000, Morita, Tokyo, Japan) to sufficiently polymerize the paste.

Each tooth bonded to the bracket separated into the crown and the root using a diamond point. The separated

Table 1 Orthodontic brackets used in this study.

Bracket	Labeling	Composition	Manufacture	Lot no.	Mean bracket base area (mm ²)
Plastic bracket (PB)	Clear Bracket	Polycarbonate stainless steel slot	Dentsply, Tokyo, Japan	00010940	11.55
Metal bracket (MB)	Victory series	Stainless Steel	3 M Unitek, CA, USA	H12QT	10.23
Ceramic bracket (CB)	Crystalline 7	Polycrystalline alumina	Tomy, Tokyo, Japan	A2X5	13.69

Table 2 Orthodontic adhesive and light-curing unit used in this study.

Material	Components	Composition	Lot no.	Manufacture
BeautiOrtho Bond II®	Self-etching primer	Acetone, Water, Bis- GMA, Carboxylic acid monomer, Phosphoric acid monomer etc.	081705	Shofu, Kyoto, Japan
	Paste Viscos	Bis- GMA, TEGDMA, S - PRG filler, etc.	101401	
	Plastic bracket primer	MMA, Bis-GMA, etc.	081702	
PenCure 2000®	Light-cure	High-power LED	AF0051	Morita, Tokyo, Japan

tooth crown was embedded in a specimen holder ring with chemically activated acrylic resin and so that the buccal surface of the teeth was projecting, and parallel to above, the brim of the cylindrical specimen holder ring. All specimen holder rings with the embedded teeth were stored in distilled water at 37 °C for 24 h according to International Standards Organization 11405 (ISO TS11405).¹⁹

The shear bond strength (SBS) was measured on a universal testing machine (EZ Test, Shimadzu, Kyoto, Japan). The specimen holder rings were arranged in the machine so that the load was applied to the bracket wings with the direction of force parallel to the buccal enamel surface and the bracket base (Fig. 1). The force required to shear off the bracket was recorded in Newton at a crosshead speed of 1.0 mm/min (ISO TS11405).¹⁹ The SBS (MPa) was then calculated by dividing the shear force by the bracket base area.

After the SBS of each tooth was measured, the enamel surface was then photographed using a stereomicroscope and a scanning electron microscope (SEM, JSM-IT300LA, JEOL Ltd., Tokyo, Japan) at 10x and 22x magnifications, respectively. Before SEM observation, enamel surfaces in

each group were etched with 37% phosphoric acid gel, sputter-coated with gold-palladium. The stereomicroscope and SEM photographs were coded for each specimen by a person not directly involved in this study, and the enamel surface was examined by an investigator (HS) to evaluate the bond failure with the adhesive remnant index (ARI)²⁰ (Table 3, Fig. 2). One month later, the ARI scores were reexamined independently by the same investigator (HS) and another investigator, who not directly related to this study. To avoid any examination bias, the investigators examined the coded photographs blindly to group. Intra- and inter-examiner kappa values were 0.94 and 0.85, respectively, thus demonstrating almost perfect intra- and inter-examiner agreement.²¹

Statistical analysis

Statistical analysis was performed using BellCurve for Excel (version 2.15, Social Survey Research Information, Tokyo, Japan). Means, standard deviations, and ranges of SBS were calculated for each of the groups. Two-way ANOVA was used to analyze the effects of the bracket type and the PBP on the SBS after testing the normality of the distribution and homogeneity of the variance. If the two-way ANOVA showed a significant interaction between these two factors, simple main effects and Bonferroni tests were used to compare the SBS between the application and nonapplication of PBP in each bracket type, and between the bracket types for the application and nonapplication of PBP. Mann–Whitney U tests, Kruskal–Wallis and Steel–Dwass tests were performed to compare the distribution of ARI scores between the application and nonapplication of PBP and between the bracket types. All statistical tests were performed at a significance level of 0.05.

Results

D'Agostino–Person test confirmed the normality of the distribution for the SBS, but the Levene test did not show the



Figure 1 The universal testing machine with the specimen holder ring.

Table 3 Evaluation of adhesive remnant index.

Score	Description
0	No adhesive remaining
1	Less than half of the adhesive remaining
2	More than half of the adhesive remaining
3	All adhesive remaining

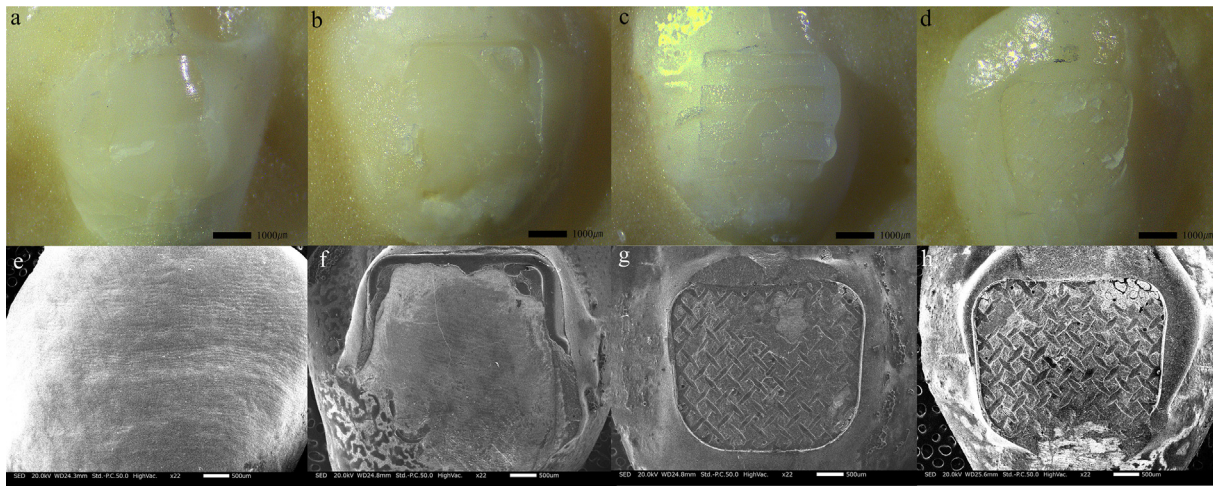


Figure 2 Stereomicroscope photographs (a-d, x 10) and Scanning electron microscope photographs (e-h, x 22) of the enamel surface showing typical ARI scores of 0–3; a, e the ARI score 0, no adhesive remaining; b, f the ARI score 1, less than half of the adhesive remaining; c, g the ARI score 2, more than half of the adhesive remaining; d, h the ARI score 3, all adhesive remaining.

homogeneity of the variance. Two-way ANOVA indicated significant the interaction between two factors of the bracket type and the PBP on SBS ($p < .01$).

There was a significant difference in the mean SBS between groups PB- and PB+, and no significant differences between groups MB- and MB+ or between groups CB- and CB+ (Table 4, Fig. 3). There were significant differences in the mean SBS between groups PB- and MB-, between groups PB- and CB-, and between groups MB- and CB-; significant differences between groups PB+ and CB+ and between groups MB+ and CB+; and no significant differences between groups PB+ and MB+ (Table 4, Fig. 3). In group PB-, the mean SBS (5.5 MPa) and the SBS of 18 out of 27 specimens (66.7%) did not reach 6 MPa, which is considered the minimum requirement for clinical use.²² In group PB+, the mean SBS reached 6 MPa and the SBS of 4 out of 27 specimens (14.8%) was below 6 MPa.

As shown in Table 5, there were a significant difference in the distribution of ARI scores between groups PB- and PB+, between groups PB- and CB-, between groups PB+ and MB+, and between groups MB+ and CB+. These results exhibited that the occurrence of bond failure at the enamel and adhesive interface was more frequent in groups PB+ and CB- than in group PB-; and in groups PB+ and CB+ than in group MB+.

Discussion

Our results showing that PBs had a significantly lower mean SBS than MBs and CBs without the application of PBP were consistent with those of several studies.^{2,6,9,16} However, previous studies have demonstrated that the mean SBS of PBs was comparable with that of MBs^{16,17} and higher than that of CBs.⁷ Some studies reported that the mean SBS was significantly lower in MBs than in CBs,^{14,15} as evidenced by this study, whereas others reported that the reverse was true.^{7,12,13} Still others showed no significant differences in the mean SBS between MBs and CBs.^{14,23,24} Reported variations in the significant differences in bond strength among the three types of brackets might be attributed to discrepancies in the tooth type (human or animal teeth, and anterior or posterior teeth),¹³ the adhesive system (acid etching or self-etching, and self-curing, light-curing or dual-curing),^{2,4,6,7,9,12,13,16,17,23} the adhesives used (resin cement or glass ionomer resin),^{9,13,14,23,24} and aging of the adhesives (with or without thermocycling and short- or long-term water storage).^{9,13,23} In this study, all specimens were stored in distilled water at 37 °C for 24 h before SBS measurements followed guidelines in ISO/TS 11405¹⁹ and previous orthodontic literatures.²⁵ These selected conditions were determined because the temperature of 37 °C simulated

Table 4 Shear bond strength (MPa).

	Plastic bracket primer					
	Nonapplication (-)			Application (+)		
	Mean	SD	Range	Mean	SD	Range
Plastic bracket (PB)	5.53	1.80	3.27–8.82	8.75	2.46	4.77–13.20
Metal bracket (MB)	9.44	2.37	6.07–14.07	8.87	1.82	6.09–13.87
Ceramic bracket (CB)	12.63	2.70	8.56–18.15	13.78	3.08	7.93–18.56

SD indicates standard deviation.

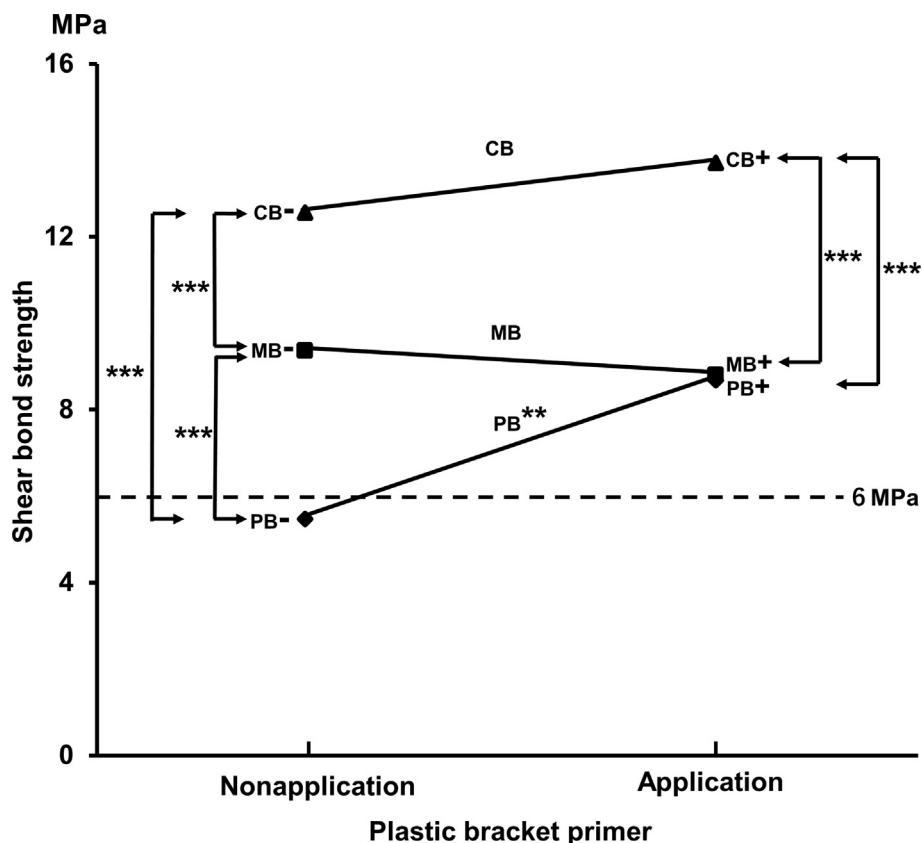


Figure 3 Shear bond strength (MPa). PB, MB, and CB indicate plastic, metal, and ceramic brackets, respectively; PB-, MB-, and CB- indicate plastic, metal, and ceramic brackets without the application of plastic bracket primer, respectively; PB+, MB+, and CB+ indicate plastic, metal, and ceramic brackets with the application of the plastic bracket primer, respectively. ** $p < .01$, *** $p < .001$.

oral conditions, and polymerization is expected to be complete at the end of 24 h.²⁶ Moreover, these conditions were used in most bond strength studies and allowed comparison with other studies.²⁷

In this study, CB (13.69 mm²) had the highest mean area of bracket base, followed by PB (11.55 mm²), and MB (10.23 mm², CB > PB > MB, Table 1), whereas CB- had the highest mean SBS, followed by MB-, and PB- (CB- > MB-

> PB-, Table 3), thus showing that there was no relationship between the bracket base area and SBS. This finding was supported by MacColl et al.,²⁸ who demonstrated that there was no significant differences in SBS for bracket base area in excess of 6.82 mm².

In this study, the SBS for 18/27 PB specimens without primer application (66.7%) and 4/27 PB specimens with primer application (14.8%) did not reach 6 MPa,

Table 5 Distribution of adhesive remnant index (ARI) scores.

	ARI scores								Comparison between application and nonapplication Mann–Whitney U test
	Nonapplication (-)				Application (+)				
	0	1	2	3	0	1	2	3	
Plastic bracket (PB)	3	7	17	0	4	18	5	0	<0.01
Metal bracket (MB)	3	10	14	0	2	10	15	0	NS
Ceramic bracket (CB)	3	18	6	0	4	21	2	0	NS
	Comparison between brackets types								
Kruskal–Wallis test	<0.05				<0.01				
Steel–Dwass test	PB- vs MB-		NS		PB+ vs MB+		<0.05		
	PB- vs CB-		<0.05		PB+ vs CB+		NS		
	MB- vs CB-		NS		MB+ vs CB+		<0.01		

NS indicates not significant.

demonstrating that PBP induced a decrease in the failure rate of PB. Moreover, after the application of PBP, the mean SBS significantly increased for PBs, but not for MBs and CBs. These results were partially supported by Akin-Nergiz et al.¹⁶ and Piton et al.,¹⁷ who reported that their plastic primers, including Dentacolor Connector (Kulzer, Wehrheim, Germany) and Ortho Primer (Morelli, Sorocaba, Brazil), significantly increased the bond strength of the PBs. It can be speculated that the discrepancy in the changes in SBS after the application of PBP according to the bracket type is caused by differences in the structure of the brackets. PBs are composed of polycarbonate, which is a thermoplastic polymer with linear and branched chains, and is soluble in organic solvents such as PBP.⁵ PBP mainly consists of methyl methacrylate and bisphenol-A glycidyl methacrylate. Because these polymer chains of PBs are separate and discrete,²⁹ the methyl methacrylates of the PBP easily penetrate into the polymers of the polycarbonate, diffuse, and polymerize, thus increasing the mechanical bond strength of the PB. MBs and CBs are chemically inert to the PBP;³ therefore, no significant change in the SBS is induced by the application or non-application of PBP.

Egan et al.³⁰ used PBP on MBs, which was developed to improve SBS of PBs, to compare the SBS between application and nonapplication of PBP. Piton et al.¹⁷ applied PBP to MBs as well as PBs. Kilponen et al.³¹ used silane primer on not only CBs but also MBs, although this primer was designed to enhance bond strength of the ceramic.³² In these studies, PBP and silane primer were used for the purpose other than the original ones. Therefore, PBP was applied to MBs and CBs as well as PBs in our study.

Our results demonstrated that after the application of PBP, the mean SBS of PB was comparable with that of MB, but not as high as that of CB, as shown in Table 4 and Fig. 3. Moreover, one-way ANOVA and the Tukey test verified that the mean SBS of PB with PBP was comparable with that of MB without PBP, and significantly lower than that of CB without PBP. These results suggesting that the PBP increased the mean SBS of PB to the level of MB, but not to the level of CB, can be explained by differences in the structure of the three bracket types, as previously mentioned.

In this study, the distribution of the ARI scores showed that bond failure at the enamel and adhesive interface occurred more frequently in groups PB+, CB- and CB+, and the occurrence of bond failure at the bracket and adhesive interface was more frequent in groups PB- and MB+. The most interesting finding was that the group PB + exhibited increases in occurrence of bond failure at the enamel–adhesive interface as well as the SBS relative to group PB-, while similar bond failure modes occurred together with no significant differences in SBS between groups MB- and MB+, and between groups CB- and CB+. This finding was supported by Odgaard and Segner.³³ and Klocke et al.,³⁴ showed that when bond strength was high, bond failure more often occurred at the enamel–adhesive interface.

In conclusion, shear bond strength of plastic bracket with plastic bracket primer was comparable with that of metal bracket without this primer, and significantly lower than that of ceramic bracket without this primer.

Declaration of Competing Interest

Shofu Inc provided the BeautiOrtho Bond II to carry out this study. However, this company had no role in the study design, conduct of this study, date interpretation or preparation of this article.

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