Resin bonding to primary teeth using three adhesive systems

Nicholas Mazzeo, DDS   Norman W. Ott, DMD   Steven O. Hondrum, DDS, MS

Abstract

In vitro bond strengths of three resin adhesive systems were tested using 111 primary teeth. Ninety-six flat dentin surface specimens were divided into six groups consisting of 16 primed or 16 unprimed samples for each adhesive system. The remaining 15 tooth samples were divided into three groups of five to determine each adhesive system's bond strength to primary etched enamel. Resin buttons were polymerized to all specimens with visible light, thermocycled for 2000 cycles between 5 and 55°C, and shear bond strength was measured with a Instron® Testing Machine (Instron Engineering Corp, Canton, MA). ANOVA and multiple comparison tests showed that Optibond Multi-use Bonding Agent had a statistically greater mean shear bond strength to primary dentin (20.5 ± 3.5 MPa) than Prisma Universal Bond 3 Multi-purpose Bonding System (9.1 ±4.4 MPa), Scotchbond Multi-purpose Dental Adhesive System (7.3 ±3.7 MPa), and primary etched enamel (9.8 ±4.4 MPa) at $P < 0.05$*. This study demonstrated that resin adhesive systems may achieve bond strengths to primary dentin comparable to those of primary enamel, and that these bonds may be as strong as bonds to permanent enamel and dentin. These adhesive systems may allow more confident esthetic restoration of primary anterior teeth. (Pediatr Dent 17:112–15, 1995)*

Dentists treating children often are challenged by the esthetic restoration of anterior primary teeth that are discolored, malformed, or have multisurface carious or traumatic destruction.[1] The rapid spread of decay, enamel thinness, pulpal anatomy, and small tooth size can make restorative treatment of these teeth difficult.[2] An effective bond to primary dentin and etched enamel would reduce marginal microleakage, bacterial penetration that leads to recurrent decay, post-operative sensitivity, and the possibility of pulpal inflammation, and would preserve tooth structure by allowing more conservative cavity preparation.[3]

New-generation dentin bonding systems (DBS) are capable of producing bond strengths comparable to those of resin to etched enamel in permanent teeth.[4] Current DBS typically consist of an acidic dentin conditioner, a hydrophilic resin monomer (primer), and an intermediate unfilled resin adhesive. With some DBS, the primer is an acidic resin monomer that conditions the dentin as well.[5] The dentin conditioner removes, penetrates, or solubilizes the smear layer, and demineralizes the exposed dentin surface.[6] Primer infiltration into the demineralized dentin allows this monomer to polymerize and interlock with the dentin, altering its collagen fiber arrangement, elasticity, and wettability for improved adhesive resin penetration.[7] Van Meerbeck et al. categorized dentin adhesive systems morphologically into three groups. The first removes the smear layer, providing a demineralized dentin surface with a collagen-rich meshwork for monomer diffusion. The second type preserves the smear layer by monomer incorporation and can also have affinity for organic and/or inorganic components of the underlying dentin. The third group partly dissolves/modifies the smear layer to create a thin resin-impregnated dentin layer and a resin-impregnated smear plug.[8]

A smear layer is produced when dentin is cut. This 1- to 5-μ-thick layer is weakly attached to dentin and consists of hydroxyapatite crystals and the underlying dentin's partially denatured collagen.[6] Dentin demineralizing agents that are washed off completely remove the smear layer; those that are not toileted modify or disrupt the smear layer.[9] Davis and coworkers reported no difference in shear bond strength between smear layer conditioning and its complete removal. Prior studies had suggested that the smear layer interfered with dentin adhesion.[10] The penetration of primer into the demineralized dentin subsurface and its subsequent polymerization generate adhesive bonds. These bonds are a function of the penetrability of dentin and the diffusibility of the primer.[11] Monomer impregnation of demineralized superficial dentin creates a hybrid layer. This transitional zone of resin-reinforced dentin, sandwiched between cured resin and unaltered dentin substrate, appears to be the primary site for dentin adhesion.[6, 9] The bond between DBS and dentin is thought to be derived from micromechanical retention of the DBS to intertubular dentin; a chemical interaction of the bonding system to the inorganic/organic components of dentin may also play a role. Two-thirds of the adhesive bond strength results from an interaction between the bonding system and intertubular dentin and only one third from the penetration of resin into the dentinal tubules.[7]

Dentinal tubules, their tissue fluid contents, intertubular dentin, and peritubular dentin are the main structures of dentin.[12] The majority of dentin consists of intertubular dentin. Peritubular dentin is highly mineralized and surrounds the dentinal tubule to almost its entire length.[13] Dentinal sclerosis, or the laying down of more peritubular dentin, decreases the effect of dentin conditioning and thus resin penetration and adaptation.[14] Hirayama et al. found no difference in the calcium or phosphorous content of peritubular and intertubular dentin for permanent and primary teeth. They reported that the peritubular dentin was two- to five-times thicker in primary teeth and that there was a variation in the symmetry of the width of the peritubular dentin surrounding the tubular lumen.[15] If primary peritubular dentin is two- to five-times thicker, it may be presumed that its relative intertubular dentin content is less. This may account for the reported weaker DBS shear bond strengths to primary dentin.[16]

The purpose of this study was to determine the bond strength of composite resin to primary dentin using three adhesive systems, and to determine if primer had a significant effect on the shear bond strength for each system.

Methods and materials

One-hundred eleven extracted human primary teeth, which were noncarious and free of obvious defects, were selected for this study. All specimens were stored in distilled water at room temperature. Each tooth was embedded in autopolymerizing tray acrylic (Fastray™, HJ Bosworth Co, Skokie, IL), making the labial tooth surface perpendicular to the walls of a rubber mold.

Ninety-six of the 111 specimens were chosen randomly and divided into six groups of 16, with two groups allocated for each of the three adhesive systems (Table 1). A flattened labial dentin surface for bonding was prepared by wet grinding each tooth with 320-grit Silicon carbide paper (Buehler LTD, Lake Bluff, IL). A 3.5x2.0-mm Teflon® split-mode matrix was used to fabricate a resin button on each tooth. As shown in Table 1, the resin restorative system recommended for each DBS was used. Restorative materials used were Prisma TPH™ (Caulk-Dentsply, Milford, DE), Herculite XR-V® (Kerr Manufacturing Co, Romulus, MI), and Z100 Restorative™ (3M, St Paul, MN). The bonding sites were prepared according to manufacturers' instructions (to include acid etching only for the Scotchbond and enamel samples). The Scotchbond™ Multi-Purpose Dentin Adhesive (3M, St Paul, MN) uses a 15-sec exposure to 10% maleic acid, providing effective etching of both dentin and enamel.[17] Sixteen primed and 16 unprimed dentin samples were tested for each system. The resin buttons were polymerized with a visible light (Visilux 2™, 3M, St Paul, MN) according to manufacturers' instructions for each adhesive system. The Teflon matrix was removed and the specimens were placed in distilled water at room temperature for 12 hr and subsequently thermocycled for 2000 cycles between 5 and 55°C. Shear bond strength was measured with an Instron Testing Machine® (Instron, Canton, MA) at a crosshead speed of 1 mm/min, using a sharp blade parallel and immediately adjacent to each bonded tooth surface.

The remaining 15 primary tooth samples were divided randomly into three groups of five. These specimens were used to test each adhesive system's shear

Table 1. Resin systems tested

DBS	*Etchant/Primer*	*Adhesive*	*Resin*
3M: Scotchbond Multi-purpose Dental Adhesive System (S)	Etchant: 10% maleic acid HEMA Vitrebond polyalkenoic acid copolymer	Bis-GMA HEMA	Restorative Z100
Caulk-Dentsply: Prisma Universal Bond 3 Multi-purpose Bonding System (P)	Etchant: None Ethanol HEMA PENTA	UDMA/TEGMA resin PENTA Glutaraldehyde	Prisma TPH
Kerr: Optibond Multi-use Bonding Agent (O)	Etchant: None HEMA GPDM Mono Phthalate Water Ethyl Alcohol	TEGDM GPDM Urethane dimethacrylate	Herculite XR-V

Resin systems tested (Scotchbond Multi-purpose Dental Adhesive System, 3M.
Technical Product Profile, 1992; Prisma Universal Bond 3 Adhesive System, Caulk Clinical.
Update, 1991; Optibond Multi-Use Bonding Agent, Kerr, 1992).

bond strength to primary enamel (etched 15 sec with 10% maleic acid). The same methods were employed as for the 96 dentin specimens excluding the use of primer and preparation of a flat enamel surface due to its variable thinness.

Following shearing, fracture at the resin-tooth interface was microscopically examined for all 111 specimens.

ANOVA and multiple comparison tests were used for the statistical analysis.

Results

Mean shear bond strength for each group is presented in Table 2. Optibond™ Multi-Use Bonding Agent (Kerr Manufacturing Co, Romulus, MI) (O) had the highest mean shear bond strength to dentin (20.5 MPa), followed by Prisma Universal Bond® 3 Multi-purpose Bonding System (Caulk-Dentsply, Milford, DE) (P) (9.1 MPa) and Scotchbond Multi-Purpose Dental Adhesive System (S) (7.3 MPa). There was no statistically significant difference in mean shear bond strength for the three adhesive systems to primary etched enamel (E); therefore this data were combined (9.8 MPa).

ANOVA and Scheffe's multiple comparison test showed a statistical difference in mean shear bond strength at $P < 0.05$ between primed (O) and (E), primed (S) and primed (P). There was no significant difference in mean shear bond strength between primed and unprimed (P), primed (S), and (E) at $P < 0.05$. Student's t-test demonstrated a significant difference in mean shear bond strength at $P < 0.01$ for (O) and (S) between their primed and unprimed samples. (P) did not show a significant difference in mean shear bond strength between its primed and unprimed samples at $P < 0.01$.

Microscopic evaluation of the specimen fracture sites revealed a 30:70% adhesive / cohesive fracture ratio for both (O) and (S) when their respective priming agents were employed. (P) showed a 50:50% adhesive / cohesive fracture ratio with the use of its primer. A 100% adhesive fracture rate occurred at the resin-tooth interface for each system when no primer was used. The resin systems had a 27% combined adhesive fracture rate when bonded to (E).

Discussion

Both (O) and (P) systems achieve their bonds to dentin by penetrating / modifying the smear layer. (S) completely removes the smear layer using 10% maleic acid. Differences in mean shear bond strength between these systems may reflect the extent of primer penetration and resin intimacy within primary dentin. A proposed reason for (O)'s superior mean shear bond strength may be an increased depth of primer penetration as a result of burnishing the primer for 30 sec on dentin and then stabilizing it by light curing. The lack of statistical difference in mean shear bond strength between primed and unprimed (P) samples may suggest that these bonds to primary dentin are not as effective compared with the other groups. In general, one may expect lower bond strengths and greater variation for (P) groups.

Table 2. Shear bond strengths

Adhesive system	N	*Mean (MPa)*	*SD (MPa)*
(S) with primer	16	7.3•†	3.7
(S) without primer	16	2.9†	3.0
(P) with primer	16	9.1•	4.4
(P) without primer	16	8.8	4.0
(O) with primer	16	20.5•‡	3.5
(O) without primer	16	3.5‡	2.3
(E) etched primary enamel	15	9.8•	4.4

• ANOVA and Scheffe's significant at $P < 0.05$.

†, ‡ Student's t-test significant at $P < 0.01$.

Shear bond strength (MPa); 1 MPa = 10 kg/cm^2.

The 20% increased adhesive fracture rate of (P) is not attributed to resin tensile strength. For (P), Prisma TPH has a reported tensile strength of 69 MPa. Tensile strengths for Z100 Restorative resin and Herculite XR-V were 83 and 74 MPa, respectively, as reported by manufacturers' technical services. Because of high standard deviations, these tensile strengths are essentially the same.

Alves et al. reported higher resin bond strengths to primary enamel than to primary dentin.[18] (E)'s mean shear bond strength was not statistically greater than the primed dentin or unprimed (P) samples. This may be a result of currently improved DBS's ability to bond to dentin levels of varying moisture content.

This in vitro study was performed on noncarious primary teeth; in vivo conditions may not be as ideal. The shear bond strength of resin systems to dentin may depend on the patient's age, depth of the lesion, and extent of caries involvement.[12] Primary teeth with a history of carious dentin have tubules that are less patent and the effect of acid conditioning is less than in noncarious primary dentin.[19] Increasing DBS acid concentration and application time may create weaker adhesive bonds by removing the smear layer, smear plugs, and peritubular dentin, and by excessive demineralization of intertubular dentin.[6] Since the number and width of dentinal tubules diminishes from the DEJ to the pulpal chamber, resin penetration may be less with deeper lesions.[19] Aging causes an increased type I collagen crosslink density in the dentin microstructure,[6] which may also decrease the dentinal penetration of primer and adhesive resin.

Low shear bond strength is associated with inadequate bonding and wider gaps between resin restoration and tooth. These gaps may allow marginal discoloration, microleakage, bacterial infiltration, and postoperative pulpal inflammation.[5] This in vitro investigation demonstrated that shear bond strengths comparable to those of permanent tooth dentin and acid etched enamel (18–21 MPa)[20] could be achieved to primary dentin. Similar bond strength efficacy may facilitate the restoration of severely damaged primary anterior teeth.

Conclusion

1. The greatest mean shear bond strength to primary dentin was exhibited by Optibond Multi-use Bonding Agent followed by Prisma Universal Bond 3 Multi-purpose Bonding System and Scotchbond Multi-purpose Dental Adhesive System.
2. Using the primer was statistically efficacious in the increased mean shear bond strength for Optibond and Scotchbond, yet did not affect the mean shear bond strength for Prisma Universal Bond 3.

Dr. Mazzeo is LCDR, Dental Corps, US Navy and chief, pediatric dentistry, Dental Branch Clinic, Naval Base, Keflavik, Iceland. Dr. Ott is LTC, Dental Corps, US Army and assistant director, US Army Pediatric Dentistry Residency Program at US Army Dental Clinic Command, Fort George G. Meade, MD. Dr. Hondrum is Colonel, Dental Corps, US Army, and chief, Applied Dental Sciences Branch, Dental Research Detachment, Walter Reed Army Institute of Research, Washington, DC.

1. McDonald RE, Avery DR: Dentistry for the Child and Adolescent, 6th Ed. St Louis: CV Mosby Co, 1994, p 422.
2. Atkins CO, Rubenstein L, Avent M: Preliminary clinical evaluation of dentinal and enamel bonding in primary anterior teeth. J Pedod 10:239–46, 1986.
3. Salama FS, Tao L: Comparison of Gluma® bond strength to primary vs. permanent teeth. Pediatr Dent 13:163–66, 1991.
4. Phillips RW: Skinner's Science of Dental Materials, 9th Ed. Philadelphia: WB Saunders Co, 1991, p 240.
5. Kanca J 3d: A method for bonding to tooth structure using phosphoric acid as a dentin-enamel conditioner. Quintessence Int 22:285–90, 1991.
6. Heymann HO, Bayne SC: Current concepts in dentin bonding: focusing on dentinal adhesion factors. J Am Dent Assoc, 124:26–36, 1993.
7. Retief DH, Rozalia SM, Russell CM, Denys FR: Phosphoric acid as a dentin etchant. Am J Dent 5:24–28, 1992.
8. Van Meerbeek B, Inokoshi S, Braem M, Lambrechts P, Vanherle G: Morphological aspects of the resin-dentin interdiffusion zone with different dental adhesive systems. J Dent Res 71:1530–40, 1992.
9. Gwinnett AJ, Kanca J 3d: Micromorphological relationship between resin and dentin in vivo and in vitro. Am J Dent 5:19–23, 1992.
10. Davis EL, Wieczkowski G, Yu XY, Joynt RB, Gallo J: Adhesion of dentin bonding agents after smear layer treatments. Am J Dent 5:29–32, 1992.
11. Nakabayashi N, Ashizawa M, Nakamura M: Identification of a resin-dentin hybrid layer in vital human dentin created in vivo: durable bonding to vital dentin. Quintessence Int 23:135–41, 1992.
12. Duke ES, Lindemuth J: Variability of clinical dentin substrates. Am J Dent 4:241–46, 1991.
13. Linde A: Dentin and Dentinogenesis, Vol I. Boca Raton: CRC Press Inc, 1984, pp 2–6.
14. Duke ES, Lindemuth J: Polymeric adhesion to dentin: contrasting substrates. Am J Dent 3:264–70, 1990.
15. Hirayama A, Yamada M, Miake K: An electron microscopic study on dentinal tubules of human deciduous teeth. Shikwa-Gakuho 86:1021–31, 1986. [in Japanese]
16. Bordin-Aykrod S, Sefton J, Davies EH: In vitro bond strengths of three current dentin adhesives to primary and permanent teeth. Dent Mater 8:74–78, 1992.
17. Leinfelder K: Current developments in dentin bonding systems: major progress found in today's products (publisher's erratum 124:22, 1993). J Am Dent Assoc 124:40–42, 1993.
18. Alves LD, Hondrum SO, Ajagbe O, Mollere RD, Koonce JD: Bonding of resin to primary dentin using dentin bonding agents. Pediatr Dent 13:391, 1991.
19. Hosoya Y: Effect of acid etching on normal and carious primary dentin: scanning electron microscopic observations. J Pedod 12:362–69, 1988.
20. Jordan RE, Suzuki M, Davidson DF: Clinical evaluation of a universal dentin bonding resin: preserving dentition through new materials. J Am Dent Assoc 124:71–76, 1993.

From the Archives

But aren't they just going to fall out anyway?

Why does not the important subject of the management and treatment of of children's (deciduous) teeth engage more of the attention of dental writers? Among all the dental periodicals that we see, we remember of reading very few articles on this subject. Why do not some of our more learned and experienced brethren, who talk so much in our conventions upon almost every other conceivable subject in dentistry, give us their experience and views upon this particular topic?

Dental Cosmos, 1872