13. De, F. F., Colombo, M., Rumi, M. C., Tradeti, F., Prati, D., Zenella, A. *et al.*, *Blood*, 1997, **11**, 4634–4637.
14. Panigrahi, A. K., Saxena, A., Acharya, S. K. and Panda, S. K., *J. Gastroenterol. Hepatol.*, 1998, **13**, 902–906.
15. Masuko, K., Mitsuy, T. and Iwano, K., *et al.*, *N. Engl. J. Med.*, 1996, **334**, 1485–1490.
16. Lamballenif, D., Charrel, R. N. and Dussol, B., *Lancet*, 1996, **334**, 15–49.
17. Sampietro, M., Badalamenti, S., Graziani, G., Como, G., Buccianti, G. and Corbetta, N., *Kidney Int.*, 1997, **51**, 348–352.
18. Gunaydin, M., Bedin, A., Akpolat, T., Kuku, I., Pekbay, A., Esen, S. *et al.*, *Infection*, 1997, **25**, 307–309.
19. Alter, H. J., *New Engl. J. Med.*, 1996, **334**, 1356–1357.
20. Kojima, M., Kanazawa, K., Hakamada, T. and Aikawa, T., *Nippon Rinsho.*, 1997, **55**, 549–553.
21. Diamantais, I., Bassetti, S., Erb, P., Ladewig, D., Gyn, K. and Battegay, M., *J. Hepatol.*, 1997, **26**, 794–797.
22. Heringlake, S., Osterkamp, S., Trautwein, C., Tillmann, H. L., Boker, K. and Muerthoff, S., *Lancet*, 1996, **348**, 1626–1629.
23. Dawson, G. J., Schlauder, G. C., Pilot-Matiatis, T. J. *et al.*, *J. Med. Virol.*, 1996, **50**, 97–103.
24. Widell, A., Mansson, A. S., Sundstrom, G., Hansson, B. G. and Nordenfelt, E., *J. Med. Virol.*, 1991, **35**, 253–258.
25. Yoshiba, M., Okamato, H. and Mishiro, S., *Lancet*, 1995, **346**, 1131–1132.
26. Sallie, R., Shaw, J. and Mutimer, D., *Lancet*, 1996, **347**, 1552.
27. Panda, S. K., Panigrahi, A. K., Dasarathy, S. and Acharya, S. K., *Lancet*, 1996, **348**, 1319.
28. Chomzynski, P. and Sacchi, N., *Anal. Biochem.*, 1987, **162**, 156–159.
29. Madan, K., Gopalkrishna, V., Kar, P., Sharma, J. K., Das, U. P. and Das, B. C., *J. Gastroenterol. Hepatol.*, 1998, **13**, 13–18.
30. Anil, J., Kar, P., Madan, K., Das, U. P., Budhiraja, S., Gopalkrishna, V., Sharma, J. K. and Das B. C., *Eur. J. Gastroenterol. Hepatol.*, 1999, **11**, 1231–1237.
31. Anil, J., Kar, P., Gopalkrishna, V., Gangwal, P., Katiyar, S. and Das B. C., *Indian J. Med. Res.*, 1999, **110**, 37–42.
32. Bhattacharya, I., *Lancet*, 1996, **348**, 1436.
33. Heringlke, S., Tillmann, H. L. and Manna, M. P., *J. Hepatol.*, 1996, **25**, 239–247.
34. Wang, H. L. and Jin, Dy., *J. Infect. Dis.*, 1997, **175**, 1229–1233.
35. Tameda, Y., Koseka, Y., Tagawa, S., Tekese, K. *et al.*, *J. Hepatol.*, 1996, **25**, 842–847.
36. Tanaka, E., Harvey, J. A., Nakatsuji, Y., Shih, W. K., Kim, J. P., Matsumoto, A., Kobayashi, M. and Kiyosawa, K., *Annu. Int. Med.*, 1996, **125**, 740–743.
37. Masuko, K., Mitsui, T., Iwano, K. *et al.*, *N. Engl. J. Med.*, 1996, **334**, 1485–1490.
38. Arankalle, V. A., Chobe, L. P., Jha, J., Chandha, M. S., Favorov, M. D., Kalinina, T. and Fields, H., *J. Med. Virol.*, 1993, **40**, 121–125.
39. Nanda, S. K., Yalcinkaya, K., Panigrahi, A. K., Acharya, S. K., Jameel, S. and Panda, S. K., *J. Med. Virol.*, 1994, **42**, 133–137.
40. Kao, J. H., Chen, P. J. and Chen, D. S., *Lancet*, 1996, **347**, 120.
41. Nubling, C. M. and Lower, J., *Lancet*, 1996, **347**, 68.

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Shear bond strength evaluation of five bonding agents in combination with three radiopaque composites on wet/dry dentine surfaces: An *in vitro* study

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Shear bond strength of five dentine bonding agents in combination with three radiopaque composites on dry and wet dentinal surfaces was evaluated in this study. Human premolar teeth mounted on acrylic resin were sectioned to expose dentinal surfaces onto which composites were fixed using a bonding agent. An observation of the shear strengths obtained from 36 composite/bonding agent combinations on dry/wet dentinal surfaces revealed no dentine adhesion for composites in the absence of a bonding agent. Adhesion using a bonding agent was found to enhance shear strength values to varying extents depending on the composite/bonding agent system used and the nature of the dentinal surface. Bond strengths were found to be higher on wet than dry dentinal surfaces though this was found to depend to a large extent upon the nature of the composite and/or bonding agent system used. In certain cases, combination systems other than recommended ones were found to provide better strength values. This study shows that shear bond strength depends not only on the nature of the dentinal surface but also is specific of the composite/bonding agent system used, thus providing an insight into their apparent clinical behaviour.

BEING a living tissue, dentine is found to pose greater obstacles to adhesive bonding than enamel. Attaining a bond to dentine is more complex because dentine is a vital tissue with a high water or organic content[1]. Development of newer generations of dentine bonding agents in order to overcome these obstacles has become the order of the day. Since Bowen[2] developed a system using surface active N-phenyl glycine/glycidyl methacrylate (NPG–GMA) to improve the wettability and consequently enhance adhesion, significant efforts have been made to promote efficient chemical bonding between resin composite and dentine in order to produce restorations without microleakage. Subsequently, a number of new bonding agents have been developed and marketed during the last few decades[3] which have been

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classified chronologically into generations and on the basis of shear bond strength data by Eick *et al.*[4].

Evaluation of bond strength provides a screening mechanism and an indication of the potential for their clinical success. Relationship between human dentine characteristics and shear bond strength of adhesives on a flat polished dentine surface has been investigated earlier[3]. Dentine properties were found not only to vary with the type and age of the tooth but also according to the location of the tooth, mainly the distance to the pulpal wall. Erickson[5] reported that dentine surfaces can be of different structural and chemical composition and this may influence the ability of dentine bonding systems to obtain good adhesion. Asmussen and Munksgaard[6] have reported a minimum dentine adhesion of 20 MPa to ensure gap-free margins. Most modern adhesive systems are superior to their predecessors especially in terms of retention, sensitivity to substrate and other clinical covariables.

Wet dentinal surfaces have been reported to provide better bond strength compared to dry surfaces[7]. Kanca observed that when the surface is dry there is no interaction with water and the primer mixture is deposited on the surface. However, dentine being an inherently wet tissue, the ability to work with the substrate in its natural state may facilitate clinical placement of the resin bonding material. However, Charlton and Beatty[8] reported that no significant difference was observed in bond strength either in moist or dry dentine upon using Scotchbond multi-purpose and Optibond. Air thinning of the primer layer has been found to reduce the mean shear bond strength to a limited extent[9].

In this study, three radiopaque composites have been bonded onto wet and dry dentinal surfaces using five different currently used bonding agents and their shear strength evaluated. In order to obtain an insight into their apparent clinical behaviour, each composite has been bonded onto dry/wet dentine surface with all five bonding agents separately. Statistical methods have been used to evaluate the significance of changes in bond strength with respect to changes in each parameter such as dry/wet surface, type of composite, type of bonding agent, etc.

A total of 360 freshly extracted non-carious human premolar teeth were collected and stored in normal saline. They were cleaned of debris by placing them in 1% hydrogen peroxide solution for 24 h. Teeth having cracks and fissures were discarded.

Three radiopaque light-cured composites and five bonding agents (Table 1) were used in the study.

A two-piece split mould made of good quality stainless steel was fabricated. When clamped together, the mould provided a hollow cavity of required dimension to provide samples of 25 mm diameter, 6 mm thickness which in turn has a support stem of 7 mm diameter and 14 mm length. Commercially available autopolymerizing acrylic resin and monomer were mixed together as prescribed by the manufacturer and poured into the SS mould. When it reaches the dough state, the teeth samples (2 teeth per mould) were embedded horizontally on the surface of the resin such that the proximal surfaces of the teeth were just immersed (about 1 mm in depth) below the surface of the mix. The two teeth were embedded in opposite directions so as to facilitate easy fixation of the composite and smooth testing procedure. Embedded specimens were stored in distilled water.

The specimens were then mounted on a low speed diamond saw (Buehler Isomet, UK) and sectioned carefully to expose the underlying dentine. The dentinal surfaces on the sectioned specimens were then polished using a wet 600 grit silicon carbide paper for 20–30 s.

Table 1. Radiopaque composites and bonding agents used in the study

Composites	Lot no.	Source	Composition
Radiopaque composite			
Z100	19970702	3M Co., MN, USA	BIS-GMA, TEGMA, Zr or SiO_2
Spectrum TPH	9606006	Dentsply DeTrey GmbH, Germany	BIS-GMA & HMDI adduct, BIS-EMA, TEGDMA, SiO_2, Ba, Al, Si glass
Chitra	Under trials	SCTIMST, Thiruvananthapuram, India	BIS-GMA, TEGDMA, radiopaque glass, SiO_2
Bonding agent			
Single bond	19970414	3M Co., MN, USA	BIS-GMA, HEMA, alcohol, copolymer of PAA & PIA
Scotchbond MP+	19951211	3M Co., MN, USA	Primer: Aqueous solution of HEMA & PAA Resin: BIS-GMA/HEMA
Prime and bond 2.0	9607059	Dentsply DeTrey GmbH, Germany	PENTA, dimethacrylate resin, acetone
Prime and bond 2.1	9712000721	Dentsply DeTrey GmbH, Germany	PENTA, dimethacrylate resin, acetone, cetylamine fluoride
Chitrabond 1.0	Under trials	SCTIMST, Thiruvananthapuram, India	Primer: Maleic acid/HEMA solution, Resin: BIS-GMA/HEMA

BIS-GMA; Bisphenol A-glycidyl methacrylate; BIS-EMA; Bisphenol A-ethyl methacrylate; HMDI, Hexamethylene diisocyanate; TEGDMA; Triethylene glycol dimethacrylate; TEGMA, Triethyleneglycol methacrylate; SiO_2, Silica; PENTA; dipenta erythritol penta-acrylate monophosphate; PAA; Polyacrylic acid; PIA, Polyitaconic acid; HEMA, 2-Hydroxyethyl methacrylate.

Table 2. Eighteen composite/bonding agent systems selected for the study on both dry and wet dentine

Batch no.	Dry dentine			Wet dentine		
	Composite	Bonding agent	No. of teeth used	Composite	Bonding agent	No. of teeth used
1	Spectrum	P&B 2.0	10	Spectrum	P&B 2.0	10
2	Z100	Scotchbond MP+	10	Z100	Scotchbond MP+	10
3	Spectrum	P&B 2.1	10	Spectrum	P&B 2.1	10
4	Z100	Single bond	10	Z100	Single bond	10
5	Chitra	Chitrabond 1.0	10	Chitra	Chitrabond 1.0	10
6	Spectrum	No bonding agent	10	Spectrum	No bonding agent	10
7	Z100	No bonding agent	10	Z100	No bonding agent	10
8	Chitra	No bonding agent	10	Chitra	No bonding agent	10
			Combination study ↓			
9	Z100	P&B 2.0	10	Z100	P&B 2.0	10
10	Spectrum	Scotchbond MP+	10	Spectrum	Scotchbond MP+	10
11	Z100	P&B 2.1	10	Z100	P&B 2.1	10
12	Chitra	P&B 2.1	10	Chitra	P&B 2.1	10
13	Chitra	Single bond	10	Chitra	Single bond	10
14	Spectrum	Single bond	10	Spectrum	Single bond	10
15	Spectrum	Chitrabond 1.0	10	Spectrum	Chitrabond 1.0	10
16	Z100	Chitrabond 1.0	10	Z100	Chitrabond 1.0	10
17	Chitra	Scotchbond MP+	10	Chitra	Scotchbond MP+	10
18	Chitra	P&B 2.0	10	Chitra	P&B 2.0	10

Eighteen groups of different composite/bonding agent combinations were used in this study on wet and dry dentinal surfaces (36 systems in all) as represented in Table 2. A minimum of 10 teeth were used for measurement of shear bond strength in each group.

The exposed dentinal surface was dried and etched with etching gel (37% phosphoric acid, Scotchbond, 3M Co., MN, USA) for 15 s. The surface was rinsed thoroughly for 15 s with distilled water to remove the etchant. For preparing dry dentine, the etched surface was dried using oil-free compressed air for 20 s followed by 5 s of hot air. In case of wet dentine surface, the etched surface was left moist by using a moist cotton bud and no compressed air was used at any stage for drying. The adhesive was then placed using a fully saturated brush tip for each coat. After the application of the first layer, it was kept undisturbed for 30 s and then dried with compressed air for 2–5 s and then exposed to a visible light source (Caulk the Max, Canada) for 10 s. A second coat was then applied, dried gently and light cured again for 10 s.

A brass ring of approximately 4 mm internal diameter, 3 mm wall thickness and 3 mm depth was kept on the bonded dentinal surface. The composite, as the case may be, was placed into the ring cavity in two increments with each increment being cured for 40–60 s (Spectrum TPH and Z-100 for 40 s and Chitra composite for 60 s).

Etching and preparation of dry/wet dentinal surfaces have already been described. The adhesive was applied using a fully saturated brush tip for each coat. However, in case of single bond both the coats were applied consecutively, dried gently for 2–5 s and light cured for 10 s. Composite placement and curing were as described earlier in the article.

Scotchbond MP+ being a primer/adhesive system, a single layer of the primer was applied first on the dentinal surface after etching, and dried gently for 5 s. Then the adhesive was applied (single layer) and light cured for 10 s. The composite was subsequently placed and cured as mentioned earlier.

Chitrabond is an indigenously developed light cure bonding agent based on a primer/adhesive system[10]. After etching, the surface was rinsed for 60 s and then dried with oil-free compressed air for 20 s and hot air for 5 s. A single coat of the primer was applied and left to dry for 30 s followed by 2–5 s under compressed air. A thin layer of adhesive was then applied on the surface and cured for 20 s. Composite packing was as detailed earlier.

Batches 6, 7 and 8 in Table 2 show the three radiopaque composites bonded without any bonding agent after etching onto dry and wet dentinal surfaces. This was carried out to study the significance of bonding agent in determining the final shear strength at the composite/dentine interface.

All the specimens were stored in distilled water at 37°C for 24 h in an incubator. The stored specimens were then taken out and tested for shear bond strength using a Universal Testing Machine (INSTRON, Model 1011, Buckinghamshire, UK) at a crosshead speed of 1 mm/min. The machine was interfaced with a personal computer through which operation of the equipment was controlled and the shear bond strength was calculated using a suitable software. The upper platen of the machine was mounted with a stainless steel loop wire of 0.6 mm diameter (~ 23 G) which was used to shear away the brass ring containing the composite adhered to the dentinal surface. Load at break was noted in Newtons and shear bond strength calculated from the load to surface area value. A minimum of 10 samples were tested in each group. The best six values were chosen, mean shear strength in Mega Pascals (MPa) and standard deviation were calculated.

Significance of strength values between groups was analysed statistically using the analysis of variance (ANOVA) method. Broken specimens were examined under a magnoscope (Lensel Optics, Pune) of nearly 5 × to study the nature of break at the composite/dentine interface.

Figure 1 compares the mean shear strength values obtained for all the 18 composite/bonding agent systems on dry and wet dentine surfaces. Statistical significance of the bond strengths obtained was evaluated using ANOVA single factor statistical analysis in dry and wet conditions for each individual system and the results are represented in Table 3.

Ten out of the 18 systems studied showed significant changes in bond strength when the nature of the surface was changed (Table 4) including four of the recommended systems (2, 3, 4 and 5 in Figure 1). Spectrum TPH/P&B 2.0 (1), however, did not show statistically significant changes in bond strengths in dry and wet conditions though the mean value on the wet surface was significantly higher than that on the dry surface.

A comparison of the bond strengths of the systems (Figure 1) where significant changes were observed indicate that in most of the systems, wet dentinal surface tends to improve the bond strength compared to dry dentinal surface. Exceptions to this were observed in surfaces where Chitrabond 1.0 was used (5, 15 in Figure 1) where dry surfaces provided high bond strengths compared to wet surfaces. In fact, bond strength in Chitra/Chitrabond 1.0 system (5 in Figure 1) rose from 4.6 to nearly 12.28 MPa when the surface was rendered dry. Similarly in Spectrum TPH/Chitrabond 1.0 system (15 in Figure 1) the value rose from 3.59 to 8.49 MPa in dry conditions.

Table 5 compares the bond strength values obtained for the three composites when used along with the five bonding agents on dry as well as wet dentine. ANOVA statistical analysis shows significant changes in strength with different bonding agents for each composite (Table 5). Results obtained for each composite will be discussed now in detail.

Of the five bonding agents used along with Spectrum TPH on dry dentinal surfaces, the mean shear bond val-

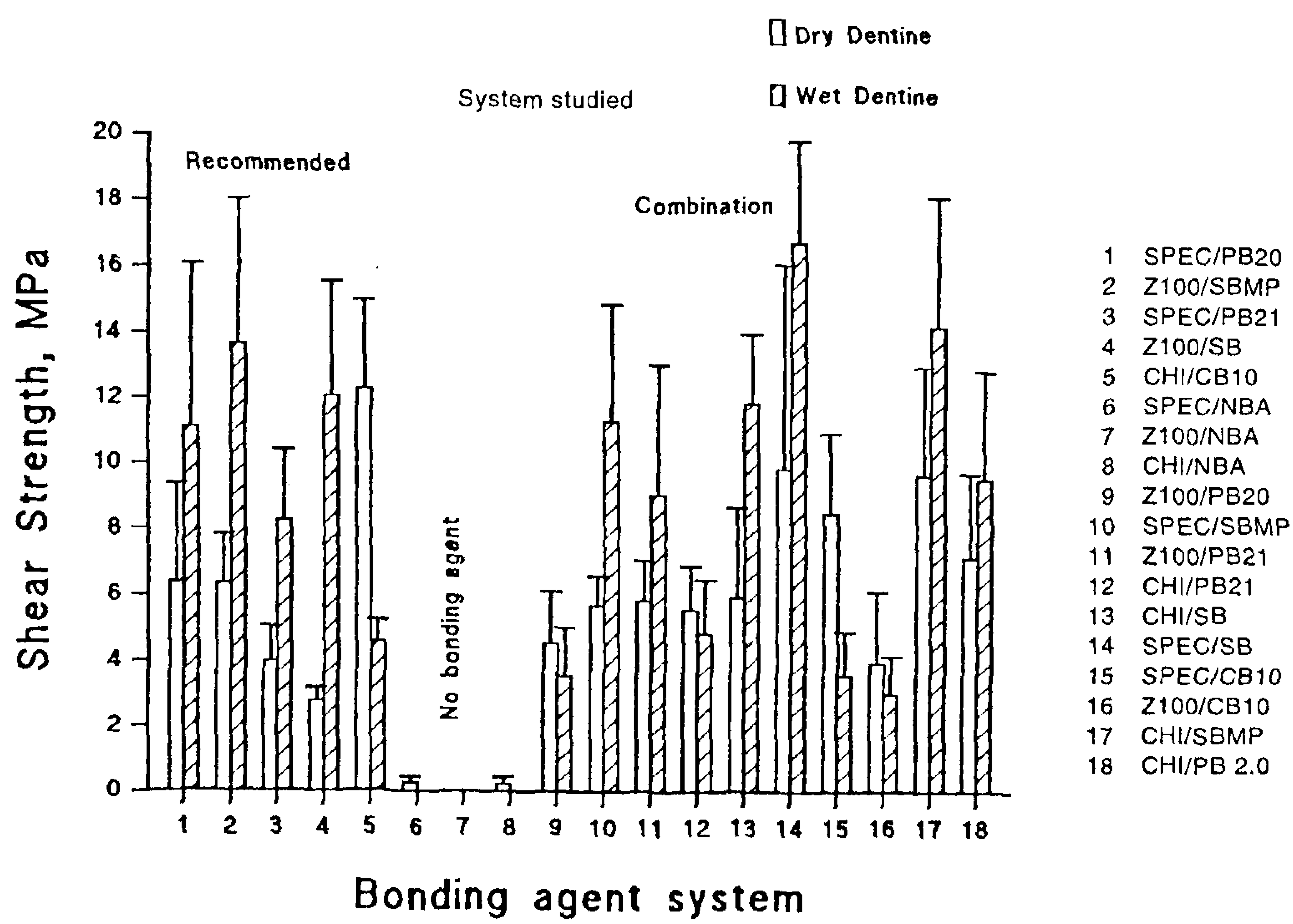

Figure 1. Bar diagram showing shear strength values obtained for 18 systems adhered to dry/wet dentinal surfaces. SPEC; Spectrum TPH; CHI, Chitra; PB, Prime and bond; SBMP, Scotchbond multi-purpose plus; SB, Single bond; CB10, Chitrabond 1.0; NBA, No bonding agent.

Table 3. Shear bond strength (MPa) values obtained for systems studied on dry and wet dentinal surfaces

Composite → Bonding agent ↓		Spectrum TPH	Z100	Chitra
NBA	Dry	0.24 (0.20)*	0.00 (0.00)	0.21 (0.24)
	Wet	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
P&B 2.0	Dry	6.38 (2.97)	4.53 (1.59)	7.19 (2.56)
	Wet	11.06 (5.01)	3.55 (1.47)	9.58 (3.33)
Scotchbond MP+	Dry	5.68 (0.91)	6.32 (1.50)	9.68 (3.35)
	Wet	11.29 (3.59)	13.65 (4.36)	14.23 (3.95)
P&B 2.1	Dry	3.96 (1.08)	5.82 (1.23)	5.55 (1.34)
	Wet	8.26 (2.15)	9.06 (3.99)	4.83 (1.64)
Single bond	Dry	9.87 (6.23)	2.77 (0.40)	5.93 (2.74)
	Wet	16.76 (3.1)	12.07 (3.48)	11.84 (2.14)
Chitra bond	Dry	8.49 (2.45)	3.96 (2.18)	12.28 (2.70)
	Wet	3.59 (1.32)	3.01 (1.16)	4.6 (0.65)

Values joined by straight vertical line are statistically insignificant ($P > 0.05$); NBA, No bonding agent used; *Values within brackets indicate standard deviation.

Table 4. Effect of nature of dentinal surface upon shear bond strength

System where nature of dentine surface *does not* affect the bond strength significantly	System where nature of dentine surface affects the bond strength significantly
Spectrum TPH/P&B 2.0*	Spectrum TPH/no bonding agent
Z100/P&B 2.0	Spectrum TPH/Scotchbond MP+
Z100/P&B 2.1	Spectrum TPH/P&B 2.1*
Z100/Chitrabond 1.0	Spectrum TPH/Single bond
Chitra/No bonding agent	Spectrum TPH/Chitrabond 1.0
Chitra/P&B 2.0	Z100/No bonding agent
Chitra/Scotchbond MP+	Z100/Scotchbond MP+*
Chitra/P&B 2.1	Z100/Single bond*
	Chitra/Single bond
	Chitra/Chitrabond 1.0*

*Indicates recommended systems.

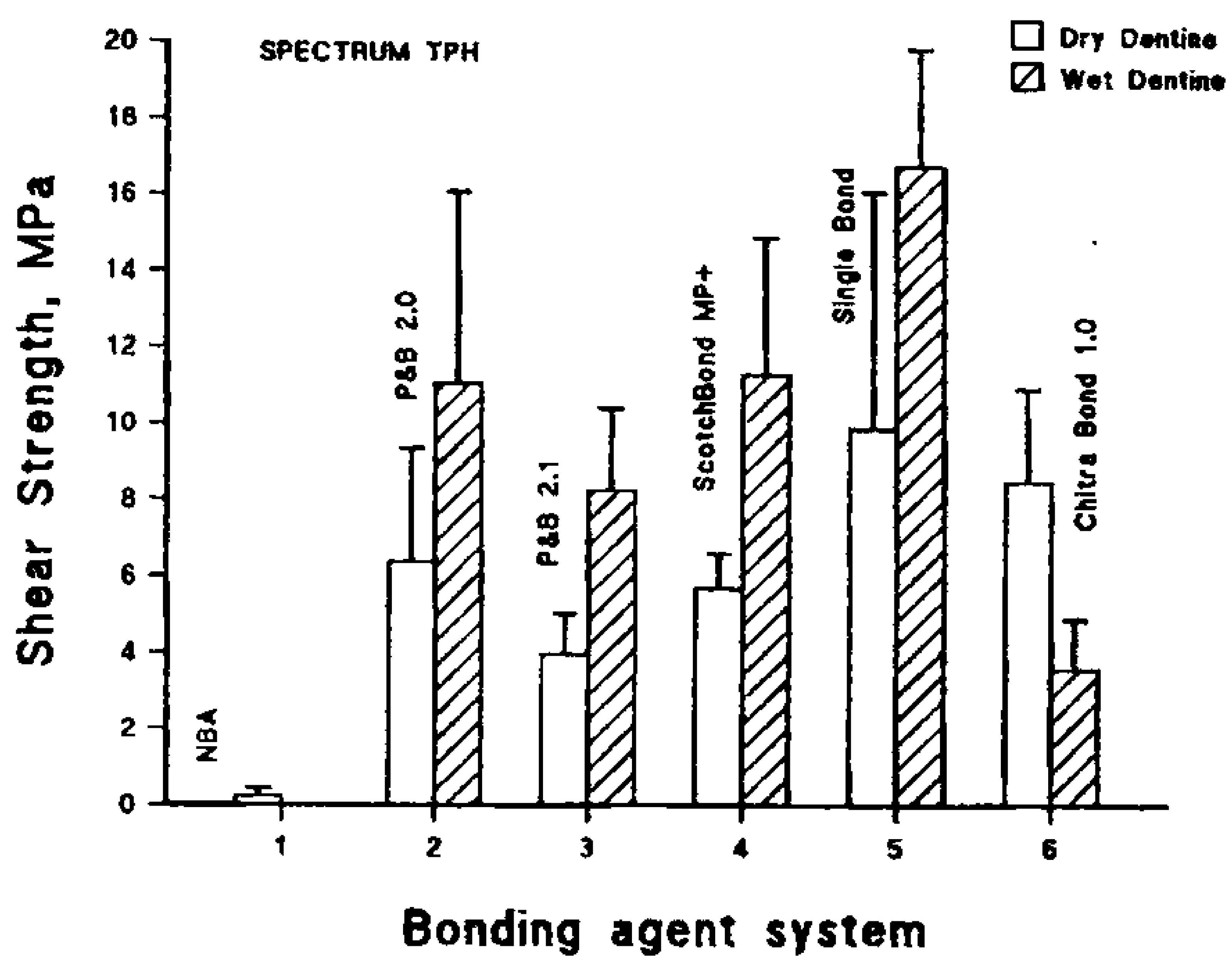

Figure 2. Bar diagram indicating shear strength values obtained for Spectrum TPH radiopaque composite used with five bonding agents on dry/wet dentinal surfaces.

ues obtained decreased in the order Single bond ≥ Chitrabond 1.0 ≥ Prime & bond 2.0 ≥ Scotchbond MP+ > Prime and bond 2.1 > No bonding agent (Figure 2 and Table 5). However, statistical analysis data reveal that there is no significant difference in bond strength values obtained when Spectrum TPH was used with Single bond, Chitrabond 1.0, P&B 2.0 and Scotchbond MP+ ($P > 0.05$). P&B 2.1 did not seem to provide adequate bond strength on dry dentine with Spectrum TPH.

All bonding agents with the exception of Chitrabond 1.0 performed better with Spectrum TPH under wet conditions showing higher bond strength values (Figure 2). Use of Single bond with Spectrum TPH in wet dentinal conditions exhibited a bond strength of nearly 17 MPa compared to 11 MPa and 8.26 MPa obtained for P & B systems (which are recommended systems by the manufacturer). Values obtained using a fourth generation bonding agent such as Scotchbond MP+, when used with Spectrum TPH, were comparable with that of P&B 2.0. In fact, bond strength decreased in the order Single bond > Scotchbond MP+ ≥ P&B 2.0 ≥ P&B 2.1 > Chitrabond 1.0 > no bonding agent.

Weak bonding was noticed in all cases when Z100 composite was adhered onto dry dentine using various bonding agents (Figure 3 and Table 5) as indicated by the low strength values. Mean values were found to decrease in the order Scotchbond MP+ ≥ P&B 2.1 ≥ P&B 2.0 ≥ Chitrabond 1.0 ≥ Single bond > no bonding agent. Single bond adhesion shows low strength (2.77 MPa), most likely due to poor behaviour of the bonding agent in the dry state.

Wet surfaces improve bond strengths for Z100 composites when used along with Scotchbond MP+ (6.32 to

Table 5. Shear strength (MPa) values for systems studied

Composite → Bonding agent ↓	Spectrum TPH		Z100		Chitra	
	Dry	Wet	Dry	Wet	Dry	Wet
NBA	0.24 (0.2)*	0.00	0.00	0.00	0.21 (0.24)	0.00
P&B 2.0	6.38 (2.97)	11.06 (5.01)	4.53 (1.59)	3.55 (1.47)	7.19 (2.56)	9.58 (3.33)
Scotchbond MP+	5.68 (0.91)	11.29 (3.59)	6.32 (1.5)	13.65 (4.36)	9.67 (3.35)	14.23 (3.95)
P&B 2.1	3.96 (1.08)	8.26 (2.15)	5.82 (1.23)	9.06 (3.99)	5.55 (1.34)	4.83 (1.64)
Single bond	9.87 (6.23)	16.76 (3.1)	2.77 (0.4)	12.07 (3.48)	5.93 (2.74)	11.84 (2.14)
Chitrabond 1.0	8.49 (2.45)	3.59 (1.32)	3.96 (2.18)	3.01 (1.16)	12.28 (2.7)	4.60 (0.65)

Values joined by the same vertical line are statistically insignificant ($P > 0.05$); *Values within brackets indicate standard deviation; NBA, No bonding agent used.

13.65 MPa) and single bond (2.77 to 12.07 MPa) systems whereas for other systems the rise is insignificant ($P > 0.05$). Mean bond strengths vary in the order Scotchbond MP+ ≥ Single bond ≥ P&B 2.1 > P&B 2.0 ≥ Chitrabond 1.0 > no bonding agent.

Third bond fourth generation primer/resin systems such as Chitrabond 1.0 and Scotchbond MP+ provide maximum bond strengths with Chitra radiopaque composite, a newly developed material[11]. Chitrabond 1.0 which is the recommended bonding agent is seen to provide a value of 12.28 MPa in the dry dentinal surface (Figure 4 and Table 5). In fact, this system is found to give the highest bond strength among all systems studied including control recommended systems on dry dentinal surfaces. Mean bond strengths varied in the order Chitrabond 1.0 ≥ Scotchbond MP+ ≥ P&B 2.0 ≥ Single bond ≥ P&B 2.1 > no bonding agent. Chitra composite was capable of bonding with all bonding agents giving a minimum bond strength value of 5 MPa whereas in other systems this was not the case.

Chitrabond 1.0 showed high values on dry dentine and not on wet dentine (4.60 MPa). This has been also observed in cases wherever Chitrabond 1.0 was used. On wet surfaces, Scotchbond MP+ showed highest bond strength with Chitra composite (14.23 MPa) followed by Single bond (11.84 MPa), a sharp rise from 5.83 MPa in the dry state, P&B 2.0 (9.58 MPa) followed by P&B 2.1 (4.83 MPa) ≥ Chitrabond. No significant difference in bond strengths was noticed when P&B 2.0, Scotchbond MP+ or Single bond was used with Chitra composite. Similarly Chitrabond 1.0 and P&B 2.1 behaved identically without showing significant changes in strength values.

Mean shear bond strengths obtained for all the 36 composite/bonding agent systems are listed in Table 6 in

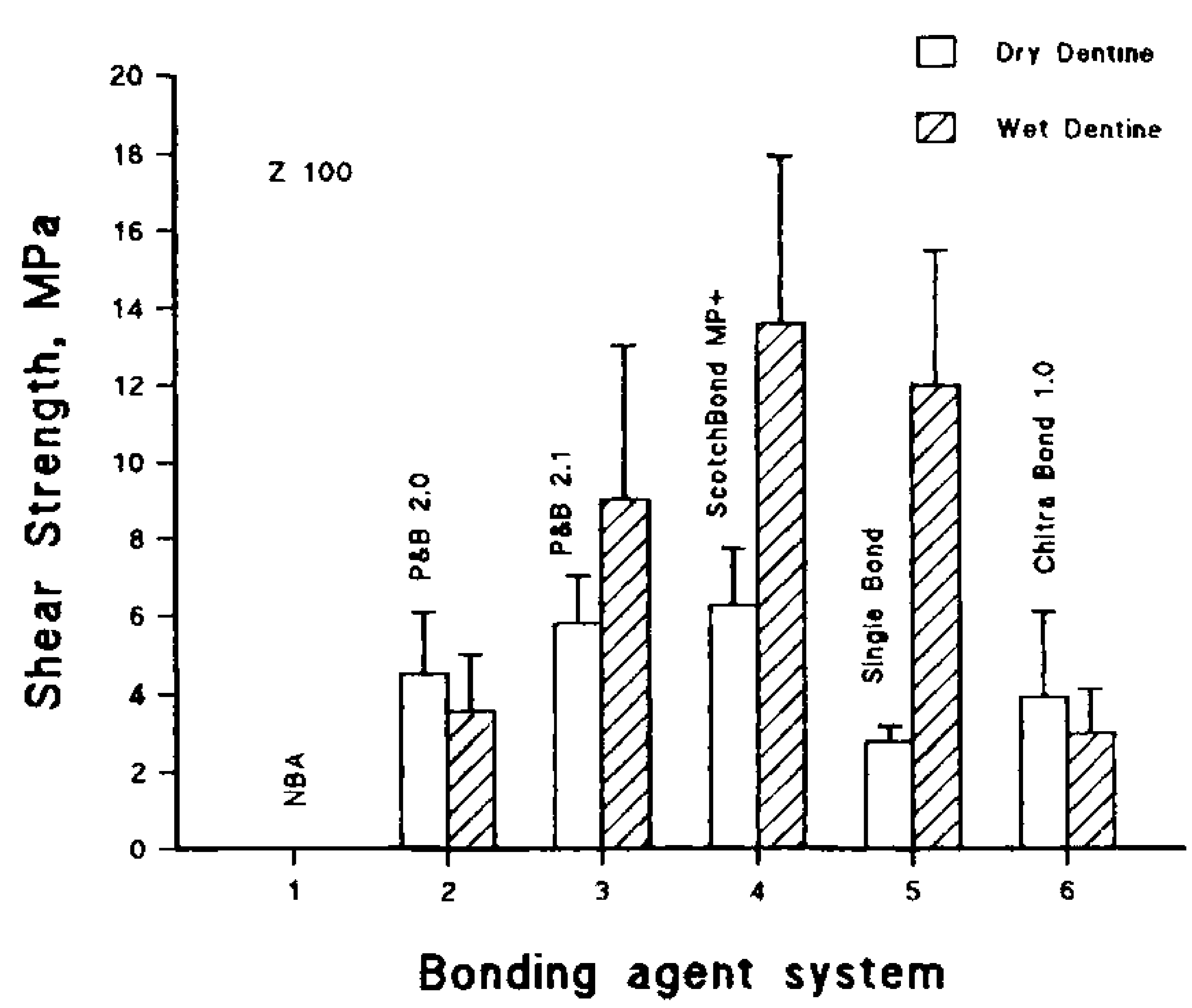

Figure 3. Bar diagram indicating shear strength values obtained for Z100 radiopaque composite used with five bonding agents on dry/wet dentinal surfaces.

a descending order to provide an idea about the performance of each system and for ready comparison.

Table 6 reveals that practically no bonding exists at the dentine/composite interface when bonding agents were not used. So it is highly essential that a suitable bonding agent system should be used along with the composite to ensure strong adhesion to the dentinal surface in clinical practice. Wet surfaces provide better bond strengths compared to dry surfaces in most cases. This may be due to collapse of the collagenous layer in the dentinal tubules after acid etching, thereby preventing the penetration of the bonding agent into the tubules for micromechanical bonding. At least 7 systems yielded

Table 6. Bond strength values obtained for systems studied on dry and wet dentinal surfaces

System		Dry	System		Wet
Composite	Bonding agent	Bond strength, MPa	Composite	Bonding agent	Bond strength, MPa
Chitra	Chitrabond 1.0	12.28 (2.70)*	Spectrum	Single bond	16.76 (3.10)
Spectrum**	Singe bond	9.87 (6.23)	Chitra	Scotchbond MP+	14.23 (3.95)
Chitra	Scotchbond MP+	9.67 (3.35)	Z100	Scotchbond MP+	13.65 (4.36)
Spectrum	Chitrabond 1.0	8.49 (2.45)	Z100	Singe bond	12.07 (3.48)
Chitra	P&B 2.0	7.19 (2.56)	Chitra	Single bond	11.84 (2.14)
Spectrum	P&B 2.0	6.38 (2.97)	Spectrum	Scotchbond MP+	11.29 (3.59)
Z100	Scotchbond MP+	6.32 (1.5)	Spectrum	P&B 2.0	11.06 (5.01)
Chitra	Single bond	5.93 (2.74)	Chitra	P&B 2.0	9.59 (3.30)
Z100	P&B 2.1	5.82 (1.23)	Z100	P&B 2.1	9.06 (3.99)
Spectrum	Scotchbond MP+	5.68 (0.91)	Spectrum	P&B 2.1	8.26 (2.15)
Chitra	P&B 2.1	5.55 (1.34)	Chitra	P&B 2.1	4.83 (1.64)
Z100	P&B 2.0	4.53 (1.59)	Chitra	Chitrabond 1.0	4.60 (0.65)
Spectrum	P&B 2.1	3.96 (1.08)	Spectrum	Chitrabond 1.0	3.59 (1.32)
Z100	Chitrabond 1.0	3.96 (2.18)	Z100	P&B 2.0	3.55 (1.47)
Z100	Single bond	2.77 (0.4)	Z100	Chitrabond 1.0	3.01 (1.16)
Spectrum	NBA	0.24 (0.20)	Spectrum	NBA	0.00 (0.00)
Chitra	NBA	0.21 (0.24)	Chitra	NBA	0.00 (0.00)
Z100	NBA	0.00 (0.00)	Z100	NBA	0.00 (0.00)

*Values in brackets indicate standard deviation; **Spectrum TPH; NBA; No bonding agent.

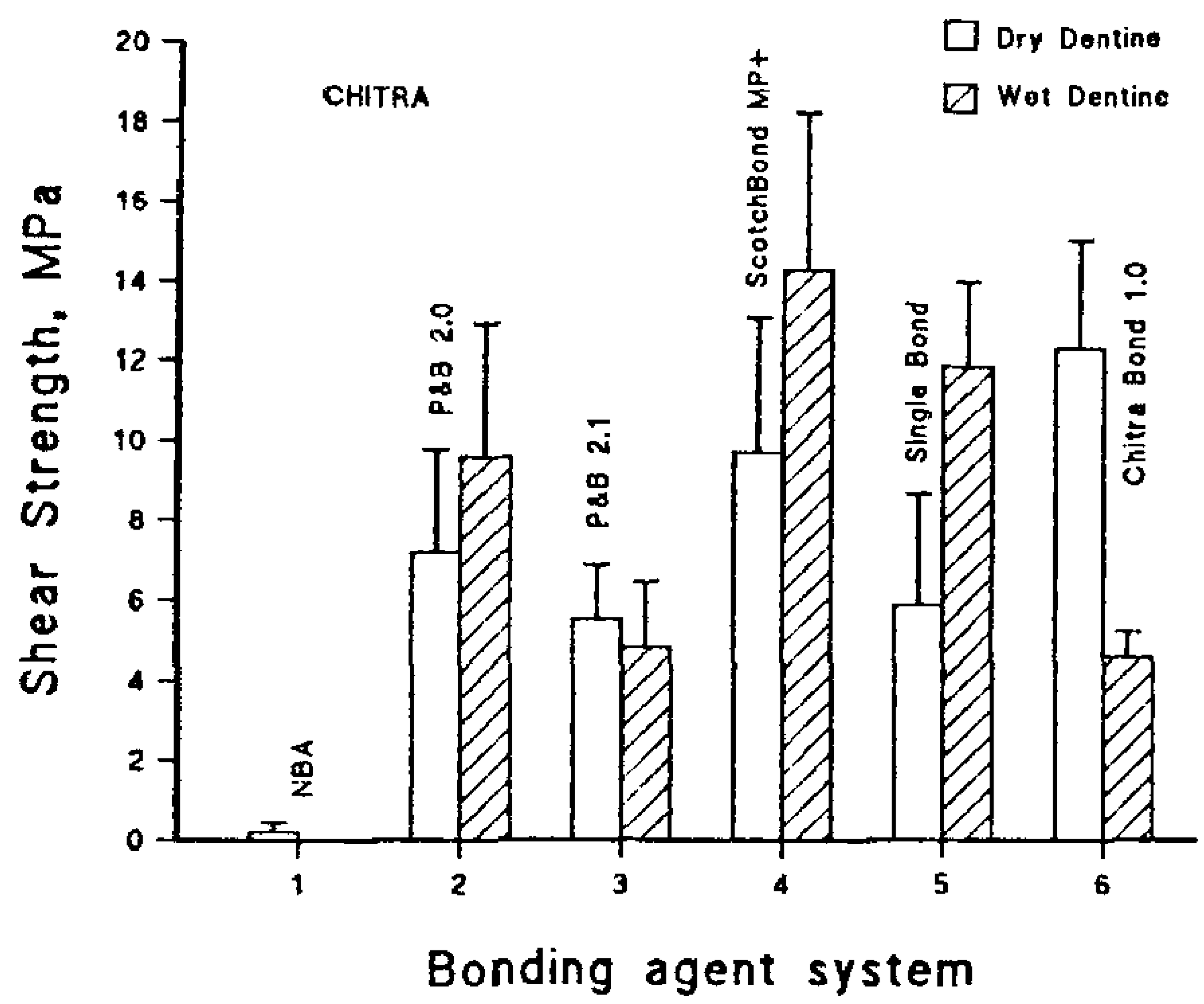

Figure 4. Bar diagram indicating shear strength values obtained for Chitra radiopaque composite used with five bonding agents on dry/wet dentinal surfaces.

mean bond strength values above 10 MPa on wet surfaces (Table 6). However exceptions do exist where the dry surfaces are found to provide better bond strengths as observed for Chitra/Chitrabond 1.0 system. Chitrabond 1.0 is a primer/resin system that does not adhere well on wet dentinal surfaces which may be due to the hydrophilic character of the surface.. P&B 2.0, 2.1, Single bond, etc. contain either alcohol or acetone which tend to dehydrate the wet surfaces, thereby facilitating easy penetration of the bonding agent into the tubules. Absence of these chemicals may also be one of the contributing factors for the sharp decrease in bond strength of Chitrabond 1.0 system on wet surfaces.

Interestingly, many of the combination systems tried provided better shear values than recommended systems. Spectrum TPH combined well with Single bond to provide the highest shear strength value. Similarly Chitra composite with Scotchbond MP+ and Single bond also showed high values. This may be of interest to clinicians and the reason for this may be mainly attributed to the chemistry of the chemicals used and better compatibility with the dentinal surface.

In many systems such as Spectrum TPH/P&B 2.0, Z100/P&B 2.0, Z100/P&B 2.1, Z100/Chitrabond 1.0, Chitra/P&B 2.0, Chitra/Scotchbond MP+, Chitra/P&B 2.1, the difference in bond strength values between dry and wet surfaces is statistically insignificant (Table 3). It can be concluded that the nature of the dentine surface is relevant in certain composite/bonding agent systems and not necessarily in all the cases.

Values for shear bond strength obtained for the 30 systems (excluding those without bonding agents) showed the values to range from a minimum of 2.77 MPa to a maximum of 16.76 MPa (Table 6). When the sheared specimens were examined under the magnoscope, it was found that most of the fracture was adhesive in nature (occurring at the dentine/bonding agent interface). Wide variations were found to occur in the bond strength values for the same system resulting in nearly 20–30% standard deviation which may be due to the variation in the nature of the dentinal surface, depth of the exposed dentinal surface, history of the tooth, storage period, etc. In this study, a minimum of 10 teeth were used for each system and in certain cases it was increased up to a maximum of 18. However, it is felt that wherever the deviation values are higher, it is necessary to subject more tooth samples to that particular system so as to obtain mean strength values with acceptable deviation ranges.

1. Jamil, M., Ahoush, Y. E. Y. and Elderton, R. J., *Br. Dent. J.*, 1992, **172**, 344.
2. Bowen, R. L., *J. Dent. Res.*, 1965, **44**, 903–905.
3. Amory, C. and Jacques, Y., *Dent. Mater.*, 1994, **10**, 203–209.
4. Eick, J. D., Cobb, C. M., Chapell, R. P. *et al. Quintessence Int.*, 1991, **22**, 967–977.
5. Erickson, R. L., *Oper. Dent.*, 1992, **5**, 81–94.
6. Asmussen, E. and Munksgaard, E. C., *Int. Dent. J.*, 1985, **35**, 160–165.
7. Kanca, J., *Quintessence Int.*, 1992, **23**, 39–41.
8. Charlton, D. G. and Beatty, M. W., *Oper. Dent.*, 1994, **19**, 154–158.
9. Barkmejer, W. W. and Erickson, R. L., *Am. J. Dent.*, 1994, **7**, 175–179.
10. Krishnan, V. K., Bindhu, D. B. and Manjusha, K., *J. Biomat. Appl.*, 1996, **10**, 348–359.
11. Krishnan, V. K. and Yamuna, V., *Curr. Sci.*, 1997, **72**, 192–195.

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Errata

Mechanism of ATP synthesis by protonmotive force

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The numbering of amino acid residues of the ε subunit of ATP synthase corresponds to *Escherichia coli* (and not to bovine heart mitochondria, as inadvertently implied). Thus, lines 36–37 on p. 718 should read, 'Further Ser-108 of the rotating ε subunit (*Escherichia coli* numbering) interacts covalently[14,17] with Glu-381 (*Escherichia coli* numbering, corresponding to Glu-395 in bovine heart mitochondria) of β_E...'. Similarly, in *figure 1, the numbering of the important amino acid* residues is for *Escherichia coli*, while the labelling in the figure is for mitochondria. Therefore, in Figure 1, the label, 'Inner membrane' should be substituted by 'Inner membrane/periplasm', while the label, 'Matrix' should be replaced by 'Matrix/cytoplasm'. The second line in the legend to Figure 1 should read, 'The important amino acid residues are shown'. These corrections do not in any way alter the results or conclusions of the communication.

Atomic Energy in India – 50 years

reviewed by

Haridas Banerjee

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The opening sentence of the concluding paragraph should read as, 'Underperformance of the PHWRs and the cost and time overruns in installing them *may* have been the underlying reasons for the decision to purchase two Russian reactors of 1000 MWe each'.