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Bonding to dentin achieved by general practitioners

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Summary

The objectives of this study were (1) to investigate the effect of operator variability on the shear bond strength of adhesives to dentin and (2) to determine the effectiveness of education on bonding performance for different types of adhesives. Thirty general practitioners were recruited for a CE course by a regional mailing. They used bovine dentin as a substrate for bonding the adhesive system they routinely used in practice and two other materials (no previous experience). Each adhesive OptiBond FL, ScotchBond Multipurpose Plus, ScotchBond 1 and Clearfil SE was applied according to manufacturer's instructions and immediately tested using a shear bond strength test. Shear bond strengths between adhesives and dentin were compared before and after a 90 min lecture on bonding principles and materials.

For dentists with and without previous experience with a material, there were no statistically significant differences seen before and after the lecture (paired t-tests, $p \leq 0.05$). However, in every case, the bond strengths after the lecture were higher than those before (range of improvement from 15 to 150%). For dentists with routine experience with a particular material, all materials were statistically equivalent after the lecture, although the OptiBond FL was the highest. For dentists who had no previous experience with a material, the ScotchBond 1 had lower bond strengths than the other materials after the lecture.

There was a large range in the ability of dentists to manipulate adhesive systems correctly. However, if a dentist has sufficient experience and receives sufficient education, any of these materials can give reasonable results.

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Introduction

Improvements in the composition and chemistry of resin composite materials have undoubtedly contributed to the increased clinical longevity of resin-based restorations in posterior teeth. However, marginal discolorations and secondary caries observed at the dentin-resin interface remain the main reasons for clinical failure (Hickel et al. 2000). Recent reports have identified factors that can modify the clinical performance of adhesive systems.

One factor affecting dentin bonding is the variability of the dentin substrate (Nakabayashi & Pashley 1998). Dentin exposed after cavity preparation contains areas of superficial, deep, caries-affected, and sclerotic dentin that all differ in structure and composition. Under these conditions, variations in bonding performance are likely to occur because adhesives will react differently to these substrates (Marshall et al. 1997).

A clear understanding of the mechanisms involved in dentin hybridization with adhesive resins contribute to bond quality (Nakabayashi & Pashley 1998). Although most current adhesive

systems rely on the hybridization concept, they all differ in composition, mode of interaction and number of application steps (Van Meerbeek et al. 1998). Conventional and one-bottle adhesives are designed to remove the smear-layer by acid etching the dentin before the application of the adhesive resin. With conventional adhesives, hydrophilic monomers dissolved into solvents are applied to the etched dentin, gently dried with air, and finally coated with hydrophobic resins. The clinical application of conventional adhesives is performed in 3 separate steps. These adhesives produce strong dentin-resin bonds, but reports have shown that over-etching the dentin can produce weak bonding because collagen fibers are not completely impregnated by the resin (Pashley et al. 1993). Further, the degree of hydration of the substrate has been shown to be a critical factor. Overdrying of the acid-etched substrate will cause collapse of the collagen network (Tay et al. 1996a). Such collagen collapse can be avoided by using a wet bonding technique, but, overwet conditions from the incomplete evaporation of the water solvent are also detrimental to bond quality (Tay et al. 1996b). Using the concept of total etching and wet bonding, manufacturers have recently introduced the so-called one-bottle adhesives. These systems contain a mixture of hydrophilic and hydrophobic monomers dissolved into organic solvents such as acetone or ethanol, and can be applied in two clinical steps. Despite a reduction in the number of clinical steps, these systems suffer from basically the same problems as conventional adhesives. Further, recent studies have shown that they are unable to infiltrate the collapsed collagen after excessive drying and that the thickness of the adhesive can modify hybridization effectiveness (Jacobsen & Soderholm 1998, Zheng et al. 2001). Other materials are designed to dissolve the smear-layer and the superficial dentin with acidic monomers and to incorporate these substrates in the bonding process. These materials are known as self-etching adhesives and require two separate clinical steps. With these systems, the risk of dehydration after etching and the problems of incomplete resin penetration are eliminated. However, there are some concerns about the efficiency of these adhesives in properly hybridizating thick smear-layers and enamel (Miyasaka & Nakabayashi 1999, Sano et al. 1999).

Despite many laboratory studies that have confirmed the superiority of most current adhesives over older adhesives, there are few reports on the bonding performance of these materials when used by general practitioners. Ciucchi et al. (1997) were the first to report on the influence of the operator on dentin bonding with adhesives. Whereas variation among materials, ranging from 40% to 60%, was reported, a 300% variation was observed among operators. Some materials were less technique-sensitive than others, and the authors concluded that bonding performance is heavily operator-related. Later, Sano et al. (1998) attempted to evaluate the operator variability for two dentin bonding systems. They reported that the operator should be aware of the technique sensitivity of some adhesive systems and confirmed the problem of operator variability. Recently, Finger & Balkenhol (1999) demonstrated that acetone-based adhesives are extremely technique-sensitive but that proper information about the system can significantly improve the performance of practitioners. Therefore, the hypotheses tested in the current study were that familiarity with a bonding adhesive is important to successful dentin bonding, and that the operator must be familiar with each type of material used. Our specific aims were (1) to have dentists bond composite to dentin using their own and new bonding adhesives and (2) measure their performance using the shear bond test. Then we repeated these measurements after a lecture on the proper use of bonding agents to determine the effectiveness of education on bonding performance for different types of adhesives.

Materials and Methods

Thirty general practitioners were recruited for a continuing education course by a regional mailing. Upon their registration for the course, they specified the name of the adhesive they currently used in practice. To preserve confidentiality, the age, name, and address of each dentist were not recorded for the purpose of this study. The adhesives were classified as (1) conventional or three steps adhesives, (2) one-bottle adhesives, or (3) self-etching adhesives. During the course, each dentist used his own adhesive and two other types which he did not use in practice. All dentists received a self-etching adhesive.

Table I : Summary of materials tested by the participants.

Name	Company	Type
ScotchBond MP Plus	3M ESPE, St Paul MN USA	Conventional adhesive: 1. Etching 2. Priming 3. Bonding
ScotchBond 1	3M ESPE, St Paul MN USA	One-Bottle adhesive: 1. Etching 2. Priming & Bonding
Optibond FL	Kerr (Romulus MI, USA)	Conventional adhesive: 1. Etching 2. Priming 3. Bonding
SE Bond	Kuraray Co., Ltd, Osaka, Japan	Self-etching adhesive 1. Priming 2. Bonding
Others	Prime&Bond NT (Dentsply) One Coat Bond (Coltène) Prompt L-Pop (3M ESPE) Clearfil Liner Bond 2V (Kuraray)	One-Bottle adhesive One-Bottle adhesive All in one adhesive Self-etching adhesive

Table II Summary of materials distributed to dentists with the number of replicates per group. For both groups, each material was tested before and after the lecture.

Material	Routine use in practice	No previous experience
ScotchBond MP Plus	N = 9	N = 11
ScotchBond 1	N = 8	N = 10
OptiBond FL	N = 9	N = 10
SE Bond	-n/a-	N = 22
Others	N = 11	-n/a-

Participants arrived at the school in the morning and were given the three materials and bonding supplies. The dentists followed the manufacturers' instructions on their own and bonded three specimens to dentin, one specimen for each type of material. Then, the dentists attended a 90 minutes lecture on bonding principles and materials. After that the dentists returned to the lab and repeated the bonding exercises they had done in the morning. The specimens were debonded using a shear test method (see details below). The bond strengths were calculated and compared and the results were discussed at the conclusion of the course. Sufficient numbers of dentists used several materials (Scotchbond Multi Purpose Plus [SBMP], Optibond FL [OPTI], Scotch Bond 1 [SB1], and SE Bond [SE]) to allow comparisons before and after the lecture (Tables I and II). Several materials used by the dentists were excluded for this type of analysis because the number of replicates was too small.

Sixty bovine teeth were collected and stored in isotonic sodium chloride containing 0.2% sodium azide. All teeth were used within one week after extraction. A flat dentinal surface was created on the radicular surface of each tooth by grinding the root with 200-grit silicon carbide paper under running water. The teeth were embedded in acrylic resin (Technovit, Kulzer, Germany) and the dentin surface was finished with 600-grit silicon carbide paper under running water to create a smear layer. The dentin area was demarcated by attaching a piece of vinyl masking tape with a 4 mm hole. Each participant received a pair of teeth stored into isotonic sodium chloride solution. One tooth was used before and one tooth after the lecture.

The adhesive systems were applied to dentin according to the manufacturers' instructions. For the Scotchbond MP Plus adhesive system (3M ESPE, St Paul MN, USA), the dentin surface was acid-etched for 15 s with 37% phosphoric acid gel, rinsed for 10 s and lightly blot-dried. The primer was then applied to the etched dentin and gently air-dried prior to the application of the adhesive resin. A prefabricated composite buildup (4 mm diameter, 3 mm thick) made of Z100 resin was placed on top of the uncured adhesive layer and photocured for 40 s. Bonding with Optibond FL (Kerr, Romulus MI) was performed by brushing the Optibond FL prime with the applicator for 30 s onto the dentin surface previously etched for 15 s with the Kerr etchant gel. Then, the Optibond FL adhesive was applied in a uniform layer and light-cured for 30 s together with the precured Z100 composite buildup. For the Scotch Bond 1 adhesive (3M ESPE, St Paul MN, USA), the dentin surface was acid-etched for 20 s with the 37% phosphoric acid get, rinsed for 10 s, and lightly blot-dried. Two consecutive coats of adhesive resin were applied to dentin and gently dried for 5 s to evaporate the solvent. The composite buildup and the adhesive layer were light-cured together for 20 s. For the SE Bond, the primer was applied for 20 s onto the dentin surface and gently air-dried prior to the application of the adhesive resin. The composite buildup and the adhesive layer were light-cured for 20 s.

Immediately after bonding, the specimens were tested in shear mode in a universal testing machine (Instron 1114, Instron Corp., High Wycomb, England) using a cross-head speed of 0.5 mm/min. The cross-sectional area of bonding was 4 mm, and the shear bond strength was calculated in MPa. A paired t-test was used to compare the bond strengths before and after the lecture for each material. These data were stratified into dentists who had or did not have previous experience with the material. Materials were compared using One-way ANOVA and Tukey multiple comparison intervals with $\alpha = 0.05$. Materials were compared before and after and with or without previous operator experience.

Results

Statistical comparison (paired t-tests, $p \leq 0.05$) of bonding values prior and after lecturing on handling instructions of bonding agents revealed no significant differences for both groups of dentists (with and without previous experience with a specific bonding agent). The high variation in these data prevented good statistical power to see such differences. However, in every case, the bond strengths after the lecture were higher than those before (range of improvement from 15 to 150%).

Bond strengths were compared among materials for dentists with and without experience (Fig. 1 a, b). For dentists with routine experience with a particular material, the SBMP had significantly lower bond strengths than the OPTI before the lecture (ANOVA, Tukey, $\alpha = 0.05$). There was statistical overlap between the SBMP and the SB1 and between the SB1 and the OPTI. After the lecture, all three materials were statistically equivalent, although the OPTI showed the highest bond strength. SE Bond was not tested in this case because no dentist had previous experience with this material (Fig.1 a).

For dentists who had no previous experience with a material, the OPTI had significantly higher bond strengths than the other materials (ANOVA, Tukey, $\alpha = 0.05$) before the lecture. After the lecture, the SB1 had lower bond strengths than the other materials, all of which were equivalent statistically (Fig.1 b).

Coefficients of variation were plotted to determine if any material offered more consistent bonding (Fig. 2 a, b). For dentists with routine experience with a material, the SBMP had the highest variation among dentists before the lecture (> 90%). After the lecture, all materials had similar variation ranging from 40% (SBMP) to 60% for OPTI. The SBMP variation decreased the most (50%) after the lecture. Note that no statistical comparisons were possible with the variation data because, by their nature, these data do not have replicates (Fig. 2 a).

For dentists with no previous experience with a material, the SBMP had by far the highest variation among dentists (> 140%). Variation with the other materials ranged from 40% (OPTI) to 80% (SE Bond). The variation after the lecture was dependent on the material (Fig.2 b).

For some (SBMP, SE Bond) the variation decreased. For others (OPTI, SB1) the variation increased. The biggest decrease in variation was observed for the SBMP (from 140% to 75%).

Discussion

One major function of adhesives is the bonding of the resin-based restorative material to dentin and enamel, thereby preventing loss of the restoration. Therefore, the ability of dentin

adhesives to bond composite to dentin needs to be evaluated. In the current study, the selection of the immediate shear-bond test might be considered as less than appropriate to assess the performance of the materials (BOUILLAGUET et al. 2001, PASHLEY et al. 1999). Further, the use of pre-polymerized composite buildups might also be questioned. However, these choices were made to keep the sessions as simple as possible and to ensure an optimal cooperation of the dentists. Further, previous research has shown that a bond strength of 17 MPa was commonly accepted as the minimum acceptable bond strength to dentin (DAVIDSON et al. 1984).

The large variation observed in the current results, even with these compromises in procedure, are testimony to the difficulties which dentists encounter when using bonding adhesives (CIUCCHI et al. 1997).

This variation was particularly large for some materials if the dentist had no previous experience with the material (SBMP, Fig. 2). The large variation also compromised the ability of statistical tests to detect an effect of the lecture. Nevertheless, the bond strengths increased in every case after the lecture (Fig. 1). We therefore suspect that the lecture had a positive effect, whether the dentist had previous experience with the material or not. This observation is in agreement with previous reports (FINGER & BALKENHOL 1999, SANO et al. 1999). Further, more targeted and more extensive lectures might produce more significant results and might reduce the variation seen among dentists. Power calculations using the variation observed in the current study indicate that over 50 dentists for each material (vs. the 10-11 in the current study) would be necessary to detect a 5 MPa difference in bond strength with an alpha error set at 0.05. Thus, future studies may also focus on fewer materials.

The current study showed that not all materials were equivalent in terms of a dentist's ability to obtain appropriate bond strengths to dentin (Fig. 1). Among dentists with previous experience with a material, the SBMP was the worst and the OPTI was the best. Again, large variations limited statistical comparisons. However, the lecture increased bond strengths for all the materials used and the SBMP showed the biggest improvement (from 6 to over 15 MPa). For OPTI the bond strength after the lecture was about 17 MPa which is near the expectation for this material on bovine dentin under a shear test (MAY et al. 1997, WILDER et al. 1998).

If dentists had no previous experience with a material, then the type of material was even more important (Fig. 1). The OPTI material seemed to be the easiest to get good results with, before as well as after the lecture. Dentists achieved nearly 18 MPa bond strengths after the lecture for OPTI which is impressive, considering they had no previous experience with this material. Conversely, the SB1 and SBMP were the most difficult materials to work with, perhaps reflecting the more technique-sensitive nature of these materials. Dentists who want to use these materials should make sure they receive adequate instructions in order to achieve as results good as those reported in the literature (BARKMEIER & ERICKSON 1994, HARA et al. 2001).

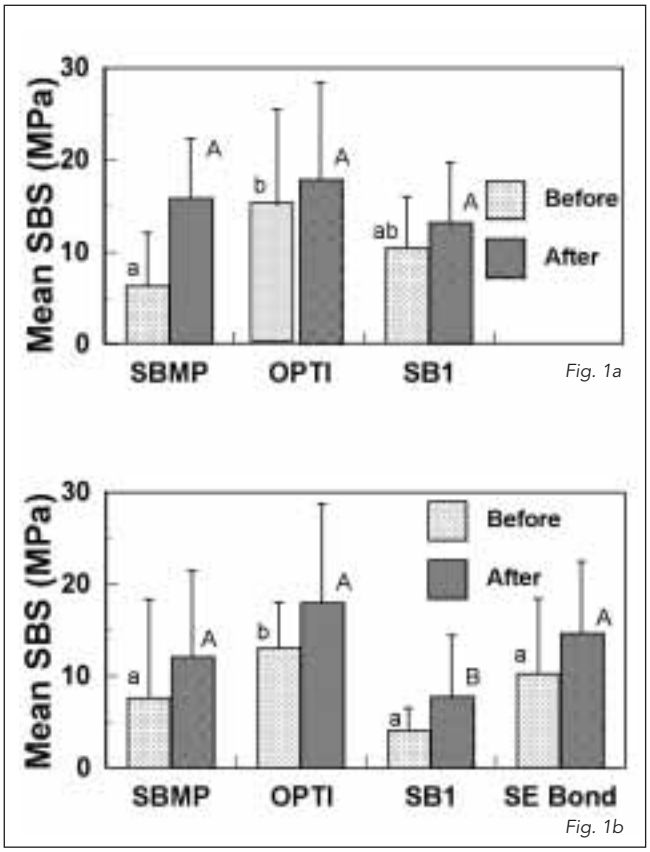

Fig. 1 Mean shear bond strength achieved by dentists a) with and b) without previous experience using Scotchbond multipurpose plus (SBMP), Optibond FL (OPTI), Scotchbond 1 (SB1) and SE Bond (SE Bond) before and after the lecture, respectively. Bars identified by the same superscript letter are not statistically different (p< 0.05)

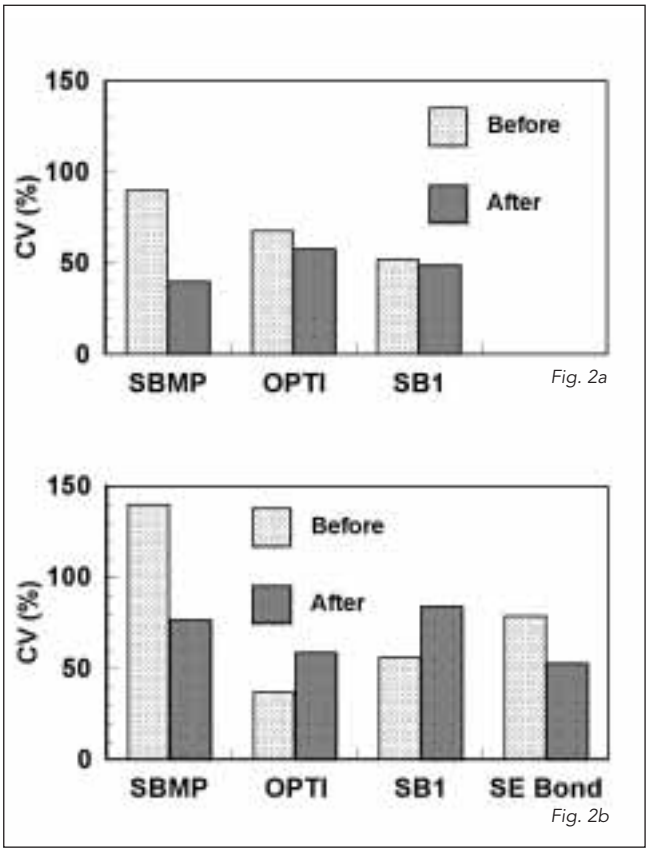

Fig. 2 Coefficients of variation (CV%) reported for dentists a) with and b) without previous experience with a material before and after the lecture. The SBMP variation decreased by 50% after the lecture.

The SB1 is a one-bottle system that was introduced to simplify bonding procedures and to improve bond strengths for practitioners of all experience levels. However, the current data show that without experience, this material did not achieve good bond strengths even after education (Fig. 1). The bonding results were somewhat better when a dentist had more experience with this material, but other materials such as OPTI were superior. Thus, the one-bottle system may not provide much advantage in facilitating the success of the bonding procedure.

Conclusions

Although the current study could not give many statistically significant conclusions, the data are valuable because they point out the difficulties dentists have in using these adhesive materials. Furthermore, there appears to be a large range in the ability of dentists to manipulate these materials and the type of material used appears to be very important. Education seemed to help, but probably needs to be more focused and extensive to get good results. This observation is particularly true for dentists who use a material for the first time. Finally, it appeared that if a dentist has sufficient experience and receives sufficient education, any of these materials can give reasonable results.

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Résumé

Les objectifs de cette étude étaient (1) d'analyser l'influence de la manipulation clinique et (2) d'évaluer l'importance des connaissances théoriques sur les performances de collage de quatre systèmes adhésifs (OptiBond FL, ScotchBond Multipurpose Plus, ScotchBond 1, Clearfil SE). Trente praticiens privés ont participé à un cours de formation continue sur les collages dentinaires. Parmi eux, certains avaient une expérience clinique avec ces adhésifs alors que d'autres n'avaient aucune expérience préalable. Les collages ont été effectués sur des échantillons de dentine bovine et testés immédiatement à l'aide d'un test de cisaillement. Les tests ont été répétés après un cours théorique de 90 min. sur les principes de l'adhésion à la dentine.
Les valeurs d'adhésion enregistrées après le cours étaient généralement supérieures à celles obtenues avant le cours théorique (amélioration variant de 15 à 150% selon les adhésifs), bien que ces résultats ne soient pas statistiquement différents. Après le cours théorique, l'Optibond FL a donné les meilleurs résultats avec les praticiens qui avaient une expérience préalable, alors que le ScotchBond1, utilisé par des praticiens sans expérience préalable avec ce matériau, a enregistré les résultats les plus faibles.
Cette étude confirme les difficultés que rencontrent certains praticiens à manipuler correctement les adhésifs dentinaires. Cependant, une bonne information théorique et un minimum d'apprentissage pratique permettent de réduire ces difficultés.

Zusammenfassung

Ziel der Studie war zu ermitteln, inwieweit (1) der Einfluss des Behandlers Auswirkungen auf die Abzugskraft von Adhäsiven auf Dentinoberflächen hat und (2) in welchem Masse die Effizienz der Adhäsion mit verschiedenen Produktsystemen durch Ausbildung der Behandler verbessert werden kann. Dreissig praktische Zahnärzte wurden schriftlich zu einem Fortbildungskurs eingeladen. Als Substrat wurde bovines Dentin verwendet, welches vom jeweiligen Teilnehmer mit dem Adhäsivsystem behandelt wurde, welches er routinemässig in seiner Praxis verwendet. Im Weiteren applizierte jeder Teilnehmer zwei weitere Systeme, mit denen er keine praktische Erfahrung hatte.
Jedes Adhäsiv (Optibond FL, ScotchBond Multipurpose Plus, ScotchBond1 und Clearfil SE) wurde gemäss den Angaben des Herstellers aufgetragen. Anschliessend wurde ein Test zur Ermittlung der Abzugskraft durchgeführt. Nach einer 90-minütigen Vorlesung über die Prinzipien der Haftung und Materialien wurde erneut ein praktischer Test durchgeführt, und die erzielten Abzugskraft-Werte wurden mit den vorherigen Werten verglichen.
Für die Zahnärzte mit oder ohne Erfahrung mit einem Adhäsivsystem waren vor und nach der Vorlesung keine statistisch signifikanten Unterschiede feststellbar (gepaarter t-test, $p > 0.05$). Dennoch war in allen Fällen die Haftkraft nach der Vorlesung grösser als vorher (Verbesserung zwischen 15 und 150%). Diejenigen Zahnärzte, welche routinemässige Erfahrung mit einem Produkt hatten, erzielten vor und nach dem theoretischen Kurs gleiche Haftwerte, wobei Optibond FL unabhängig vom Behandler die höchsten Werte erreichte.
Für die Zahnärzte ohne vorige Erfahrung mit einem Produkt erreichte ScotchBond 1 nach der Vorlesung die geringsten Haftwerte. Die Fähigkeit der Zahnärzte, Adhäsivsysteme korrekt zu verwenden, ist sehr variabel. Besitzen Praktiker eine ausreichende Erfahrung mit einem spezifischen Produkt und erhalten den entsprechenden theoretischen Hintergrund, können mit allen geprüften Produkten zufriedenstellende Ergebnisse erzielt werden.

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