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GUEST EDITORIAL

Coming to Terms with Terminology

J A WARREN, Jr

It might be successfully argued that a discipline such as operative dentistry can be no more rigorous than its terminology. Accuracy of definition and use of terms is essential to clear thinking and communication.

I have more than just an academic concern about some of our terms as they are currently defined and used. My suspicion is that terminological errors are an unrecognized source of some frequently held, though often subconscious, flawed predispositions that have a negative impact on the study and practice of our discipline. Due to space limitations, only two such errors will be presented here: the first is an example of inaccurate use, and the second an example of inaccurate definition.

Caries [dental]. Caries is a disease process. Unfortunately, in the use of our terminology, we often confuse the disease process with the damaged tissue(s) evidenced during and after the disease process. An example of this is found in the frequently heard or asked question, "Have you removed all of the caries?"

Caries, being a process, is intangible and, therefore, cannot be surgically removed. Only cariously damaged tissue(s), a tangible ill effect evidenced during and after the *caries process*, can be surgically removed.

To the extent that this misuse goes undetected, it fosters the flawed, often subconscious, predisposition that caries is somehow tangible. From this flawed predisposition, certain faulty assumptions usually follow.

First, it is not unusual to encounter the faulty assumption that caries can be diagnosed with "certainty." After all, can't we see it and feel it intraorally? Can't we view it on our radiographs? Absolutely not! What we are seeing, feeling, and viewing is not caries, but a lesion, a result of the *caries process*. Sometimes we inaccurately refer to this lesion as a carious lesion when, in fact, at that time we have no information about its disease activity. We should more accurately refer to it as a caries lesion (Dawes, 1984), a lesion resulting from the *caries process*.

Only in a probabilistic sense, and always with less than certainty, can caries ever be diagnosed. Such probability estimates and our confidence in them can be substantially strengthened by observations (visible, tactile, radiographic, and bacteriological) repeated over appropriate time intervals (e g, 3-6 months). Yet, owing in part to the prevalence of this faulty "certainty" assumption, such techniques are seldom employed in our discipline, and many

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practitioners base their diagnosis and treatment planning on the extremely limited information available from single-session evidence.

Second, it is not unusual to encounter the faulty assumption that surgical removal of all caries lesions in a particular patient is equivalent to at least temporary eradication of the disease. To the contrary, even after the most meticulous and complete surgery, the disease may still be ongoing, still producing ill effects, the evidence of which is as yet undetectable by our senses or technology.

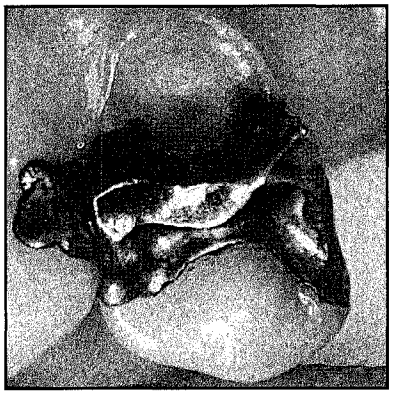
Surgery is at best only symptomatic treatment for caries. Other therapies (e g, pharmacologic, physiologic, dietary, hygienic, etc) are necessary, and sometimes sufficient, to successfully treat the disease. If such therapies are not appropriately administered, unwarranted blame for postoperative caries lesions, including so-called recurrent carious lesions, is often misassigned to the patient or the restorative effort.

In short, our misuse of the term *caries* inappropriately de-emphasizes essential evaluation techniques and emphasizes surgical treatment at a time in our discipline's development when just the reverse seems called for. Incipient (i e, noncavitated) caries lesions are now often being remineralized, not just passively monitored, and certainly not surgically removed. Slowly progressing caries lesions are now often being actively monitored over long periods of time, sometimes never requiring surgical intervention. Definitive restorative surgery is now often postponed until the disease process can be brought under control.

Spin-offs of such misuse of the term *caries* are such inaccurate terms, often found in our textbooks, as *incipient caries*, *recurrent caries*, *cavitated caries*, *remineralized caries*, *arrested caries, class 1 caries*, etc. These terms have in common an inaccuracy of reference error and also evidence, individually, other inaccuracies too numerous to discuss here. For example, the term *incipient caries* is conventionally intended to refer to an incipient (initial, small, noncavitated) caries lesion, not, as the term inaccurately indicates, some unobservable beginning stage of the disease "caries." To be referentially accurate, *caries lesion* should be substituted for *caries* in each of these terms. G V Black clearly recognized this distinction (Black, 1917) when he classified by location what he called *cavities* or *decays*, not caries, as sometimes misstated. In fact, all of the arguments presented above with reference to the term *caries* apply equally as well to the term *decay*.

Restoration [dental]. The term *dental restoration* is used in our discipline to refer to both an action and a result. As an action it refers to the act of restoring a tooth. As a result it most often refers to the prosthesis (i e, MOD amalgam, class 3 composite resin, class 2 inlay, etc) fabricated in the act of restoring a tooth. Occasionally, though inappropriately, it refers to the dental restorative material (e g, as in "to do an amalgam, composite resin, etc") used to fabricate the prosthesis (International Organization for Standardization, 1989; Manhold & Balbo, 1985; Jablonski, 1992; Zwemer, 1993). By any usage standard other than dental, the results of the restorative act to which this term refers appear inaccurate. Such inaccurate reference again leads to flawed predispositions usually followed by faulty assumptions.

The photograph presented is that of a maxillary first premolar evidencing an MOD amalgam restoration (prosthesis) and a lingual cusp lost to fracture. The MOD amalgam prosthesis is intact and has not separated from the tooth. To the contrary, part of the tooth has separated from it. By our currently accepted definitions of a dental restoration (as stated above), there is absolutely nothing wrong with this dental restoration. Clearly this is a ridiculous assertion to defend. But what is the error here?



Perhaps this question can best be addressed by way of an analogy. Suppose we undertake to restore a wooden table top (a definable portion of a table) that has a small dent in its surface. There are a number of techniques for accomplishing this restoration, but no matter which is chosen, the final product will involve filling the dented volume (or some larger volume cut around it) with some material (actual wood, plastic wood, etc).

The question then arises, "What is the restoration here?" Is it the material used in the restorative act (i e, wood)? Is it the final volumetric shape of the material used in the restorative act (i e, the prosthesis)? In restorative woodworking it is neither, but rather, the restored table top.

So I believe it should be in restorative dentistry. A dental restoration in operative dentistry should be a restored tooth (or a definable portion thereof). This dental restoration would consist of a marriage between two components: the remaining healthy tooth structure (natural or previously restored) and the prosthesis.

Defining a dental restoration in this way appropriately focuses our concerns about it. It is the health and longevity of this combination that should be of

most concern. And of the components of this combination, more concern should be given to the initial (i e, surgical) and future fate of the remaining, irreplaceable healthy tooth structure than to the fate of the replaceable prosthesis.

These terms I have presented above represent only two of a number of such terms in operative dentistry that appear in need of scrutiny as to accuracy of definition and/or use. A partial list of others might include *permanent (*or *final) restoration, cavity, cavity preparation, box, proximal, internal line/point angle*, *microleakage*, *etching*, *open contact, occlusal adjustment*, *tooth sensitivity*, *lesion*, the terms *arrested*, *recurrent,* and *secondary* as applied to caries or caries lesions, etc. My hope in this present editorial is to stimulate further critical review of our terminology, as I believe its accuracy is fundamental to the clarity of our thoughts and communications.

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ORIGINAL ARTICLES

Early Fracture Resistance of Amalgapin-retained Complex Amalgam Restorations

G A SCHULTE • C B HERMESCH
K S VANDEWALLE • D J BUIKEMA

Clinical Relevance
The combination of spherical and admixed amalgam alloys in a restoration may reduce the potential for early dislodgment while allowing time for carving.

SUMMARY

Amalgapins are susceptible to early fracture during matrix removal and carving. The purpose of this study was to examine the early fracture resistance of amalgapin-retained restorations using a spherical amalgam alloy, an admixed amalgam alloy, a combination of admixed alloy over the spherical alloy, and a recently introduced modified spherical amalgam alloy. Four amalgapin channels with a diameter of 1.4 mm and depth of 2 mm were prepared in cylinders of Macor, a machinable ceramic material. The amalgapins were hand condensed, and the bulk of the restoration was mechanically condensed. In the group using the combination of alloys, 800 mg of spherical alloy was condensed into the amalgapins and over the floor of the preparation. The admixed alloy was then condensed over the spherical alloy to build up the bulk of the restoration. Using an Instron Universal Testing Machine, the restorations were tested to shear failure at an average of 15.8 ± 1.3 minutes after the initiation of trituration of the amalgam alloy. A metal ring was placed around the restoration and pulled 90 degrees to the long axis to simulate matrix band removal. Data were analyzed using Kruskal-Wallis procedures. The fracture resistance of the spherical alloy group and the spherical/admixed group were significantly higher than admixed or Tytin FC. All fractures occurred in amalgam at the entrance to the amalgapin channel. The combination of spherical and admixed amalgam alloys in a restoration may reduce the potential for early dislodgment while allowing additional time for carving.

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INTRODUCTION

Obtaining adequate resistance and retention for an amalgam restoration in a tooth that is badly broken down continues to be a challenge in restorative dentistry. Additional retention and resistance is usually gained with mechanical measures. In vitro studies commonly compare resistance and retention features to threaded pins (Buikema & others, 1985; Summitt & others, 1994; Davis & others, 1983). Pins offer excellent retention and resistance; however, there are potential shortcomings with their use. They include perforation into periodontal ligament and pulp, crazing of tooth structure, and weakening of the amalgam (Dilts & others, 1970; Plasmans & others, 1987; Seng & others, 1969; Outhwaite, Garman & Pashley, 1979; Welk & Dilts, 1969; Going & others, 1968).

Shavell (1980) introduced the amalgapin retention technique as an alternative to pins. The reported advantages of amalgapins are: no reduction in tensile and compressive strengths of amalgam as associated with pins, no stress to the surrounding dentin induced during placement, no additional armamentarium required for placement, no additional reduction of tooth structure for occlusal clearance (Davis & others, 1983), less time to place and lower cost (Shavell, 1980), and comparable fracture resistance to restorations retained with threaded pins (Plasmans & others, 1987; Certosimo, House & Anderson, 1991). Some disadvantages with amalgapins are that they are difficult to completely condense and are susceptible to early fracture (Outhwaite & others, 1979; Leach, Martinoff & Lee, 1983). Shavell (1980) warned against removing the matrix band for at least 5 minutes postcondensation to lessen the risk of early dislodgment of the amalgapin-retained restoration.

Anecdotal reports and in vitro studies suggest that amalgam restorations with amalgapins, slots, and peripheral shelves are susceptible to dislodgment before and during carving (Summitt & others, 1991). Outhwaite and others (1979) postulated that the early dislodgment of slot-retained restorations is due to movement of the restoration or matrix band during condensation or due to the forces applied during removal of the matrix band. Reagan, Gray, and Hilton (1993) speculated that early dislodgment of amalgapin restorations was due to the difficulty of completely condensing the amalgapin channels and the weakness of amalgam to tensile forces. Using an amalgam alloy that condenses easily and has higher early tensile strength might decrease the possibility of early dislodgment of complex amalgapin-retained restorations.

The physical properties and handling characteristics of amalgam vary greatly between the different types of amalgam. Spherical alloys tend to set quickly and provide higher early strength. For example, the 15-minute compressive and tensile strengths of Tytin are 70.3 and 6.8 MPa respectively (Osborne & others, 1978). However, carving time is decreased and, therefore, may preclude its use in complex amalgam restorations. Spherical alloys require less condensation pressure to adapt the amalgam to the tooth, but development of interproximal contacts has been described as problematic. In contrast, admixed alloys tend to set more slowly than spherical alloys and display lower early strength. The 15-minute compressive and tensile strengths of Dispersalloy are 42.8 and 3.9 MPa respectively (Osborne & others, 1978). The admixed alloys require more condensation pressure for proper adaptation, but contact development is easier than with sphericals (Brown & Miller, 1993; Brown, Maiolo & Miller, 1993; Duke & others, 1982; Eden & Waterstrat, 1967; Leach & others, 1983; Clark & others, 1981). The ideal amalgam alloy would exhibit high early strength with sufficient carving time.

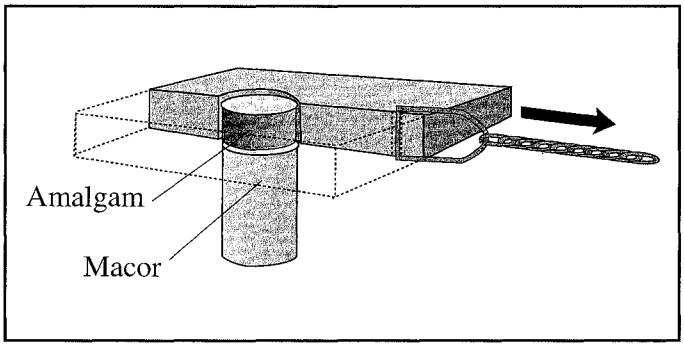
The combination of spherical and admixed amalgam alloys in a single restoration may offer a solution to the early dislodgment problem associated with amalgapin use. The combined use of two amalgam alloys appears to be metallurgically possible in the laboratory. The strength of a combination of two alloys was not statistically different from the single alloy control (Gordon & others, 1989; Overton, Long & Pruette, 1995).

In complex amalgam preparations incorporating only amalgapin retentive features, the use of a combination of spherical and admixed amalgams may offer a superior alternative to a single amalgam alloy restoration. However, it has not been demonstrated that initial placement of a spherical alloy in the amalgapins and over the floor of the preparation and an admixed alloy for the remainder of the restoration will reduce the potential of dislodgment during matrix band removal. The condensation of an admixed alloy over the spherical alloy may allow the longer carving time often needed for complex amalgam restorations. The purpose of this study was to determine the early fracture resistance of amalgam restorations retained with amalgapins condensed with a spherical amalgam alloy, an admixed amalgam alloy, a combination of admixed alloy over the spherical alloy, and a recently introduced modified spherical amalgam alloy.

METHODS AND MATERIALS

To evaluate the fracture resistance of various amalgapin-retained amalgam restorations, four groups of 15 specimens were prepared. A cylinder of Macor (Corning Inc, New York, NY 14831) 11.12 mm in diameter was used to model dentin. A placement

guide was utilized to standardize the placement of the amalgapin channels. A regular TMS pin drill (Whaledent Intl, New York, NY 10001) 0.68 mm in diameter was used to prepare pilot holes. The amalgapin channels were prepared with a #4 round bur to a depth of 2 mm. A custom-made split mold was used as a matrix. Group 1 had one 800 mg capsule of Tytin (regular set, Kerr Corp, Romulus, MI 48174) condensed into the amalgapin channels and over the floor of the preparation, followed by Dispersalloy (regular set, Dentsply Intl, Milford, DE 19963) condensed over the Tytin to build up the remainder of the restoration. Groups 2, 3, and 4 used the same regimen described for Group 1 except that they used Tytin, Tytin FC, and Dispersalloy alone. The amalgam was triturated according to the manufacturers' instructions using an Automix triturator (Kerr) and hand condensed into the amalgapin channels. A mechanical condenser (Condensaire, Densco, Division of Teledyne-Getz, Elk Grove Village, IL 60607) was used to condense the remainder of the alloy. Thirteen minutes after the initiation of trituration, the matrix band was removed and the cavosurface margin of the restoration was trimmed with a carver to remove any flash around the cylinder of amalgam. The restorations were tested to failure at an average of 15.8 ± 1.3 minutes from the beginning of trituration using a Universal Testing Machine (Instron Corp, Canton, MA 02021). A metal ring was placed around the amalgam cylinder at the cavosurface margin and pulled in a direction 90 degrees to the long axis of the Macor cylinder using a crosshead speed of 1 mm/min (figure). The specimens were tested in shear to simulate matrix band removal. The restorations were loaded at the cavosurface margin to standardize the forces and to avoid tensile forces. The peak load (in Newtons) when the amalgam restoration dislodged from the Macor was recorded.



Schematic of shear bond testing (1 mm/min) of the amalgam/Macor bond

Mean Resistance to Dislodgment of the Four Experimental Groups

Amalgam Alloy	Number of Specimens	Mean Dislodgment Load (Newtons + 1 SD)
Tytin & Dispersalloy	15	40.3 ± 7.2
Tytin	15	36.2 ± 5.6
Tytin FC	15	15.1 ± 2.3
Dispersalloy	15	10.3 ± 5.8

Vertical lines connect group means not significantly different ($P \leq 0.05$).

RESULTS

The data were normally distributed but did not have equal variance across groups according to the Modified-Levene Equal-Variance Test. Therefore, the data were analyzed with the Kruskal-Wallis procedures at alpha < 0.05. The Tytin and Tytin/Dispersalloy groups demonstrated the highest resistance to dislodgment, nearly four times higher than the Dispersalloy group (table). All the amalgam restorations failed within the amalgam at, or very near, the entrance to the amalgapin channels. The Tytin and Tytin/Dispersalloy groups were statistically higher ($P < 0.05$) than the Dispersalloy and Tytin FC groups. No statistically significant difference existed between the Disperalloy group and the Tytin FC. The Tytin group and the Tytin/Dispersalloy group were not statistically different.

DISCUSSION

In the Tytin-Dispersalloy combination group, no failure occurred at the interface between the Tytin and Dispersalloy alloys. Similar findings have been reported by Overton and others (1995) and Gordon and others (1989). Concern that lamination may occur between dissimilar alloys due to their different setting times did not appear warranted.

Macor is a machineable ceramic material that has been used in typodonts because of its similarity to natural tooth structure. Its modulus of elasticity, compressive strength, and hardness are between that of enamel and dentin (Atkinson, 1983; Taira & others, 1990; Wilwerding & Aiello, 1990). Macor was used in this study as a tooth model and offered certain advantages over extracted teeth: Macor is free from potential extraction-induced fractures and defects, homogeneous in size and composition, requires no additional infection control protocol, and matrix band adaptation may be more efficiently standardized to a

cylinder of Macor than irregularly shaped natural teeth.

All 60 of the samples failed at, or very near, the entrance to the amalgapin channels. However, the irregular surface of a severely broken-down tooth may lead to fractures propagating differently than those produced by the smooth-surfaced Macor used in this study. The irregular surface may also increase the fracture resistance of the restoration such that the amalgapins may no longer be the weakest area.

Amalgapin channels prepared with #330 and #245 burs may be too small to predictably condense. During a pilot study, many amalgam restorations fractured upon matrix removal. A #1 Markley condenser (Hu-Friedy/American Dental, Chicago, IL 60618) (0.6 mm in diameter) would frequently bind in the amalgapin channels prepared with a #330 bur, making it difficult to condense the amalgam. Roddy and others (1987) reported that the average fracture resistance of amalgapins prepared with a #330 bur were as high as larger burs. However, 30% of Roddy's #330 bur group failed prior to testing due to inconsistent condensation. It would seem unlikely that the clinician could improve on these in vitro results considering the rigors of the intraoral environment. The #4 round bur, as used in this study, created a 1.4 mm-in-diameter channel, which improved the thoroughness of amalgam condensation. Clinicians may consider using a #330 bur to create the amalgapin channels, but enlarge them slightly to allow for better condensation access.

Reagan and others (1993) speculated that amalgapin-retained amalgam restorations failed early because of poor condensation of amalgam into the amalgapin channels and due to the low tensile strength of amalgam. Shavell (1980) recommended leaving the matrix band on amalgapin-retained restorations for an additional 5 minutes to decrease the risk of early dislodgment. Tytin's 15-minute tensile strength is nearly twice that of Dispersalloy, and according to Brown and others (1993), it is easier to condense than Dispersalloy. The increased early tensile strength and condensability make a spherical amalgam alloy like Tytin a better amalgam choice for amalgapins. Our results showed the Tytin-Dispersalloy combination group was as resistant to dislodgment as Tytin alone. Overlaying the Tytin with Dispersalloy has the advantage of increased carving time, which is needed with complex amalgam restorations or with the novice user of amalgapins.

CONCLUSIONS

1. The early fracture resistance of amalgapin-retained complex amalgam restorations using Tytin or a combination of Dispersalloy over Tytin was significantly stronger than with Dispersalloy or Tytin FC.

2. Delamination was not a problem when combining two brands of amalgam in the complex amalgapin-retained amalgam restoration.

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Effects of Lining Materials on Shear Bond Strength of Amalgam and Gallium Alloy Restorations

B P NG • D G PURTON • J A A HOOD

Clinical Relevance
The use of Vitrabond, Vitremer, or Resinomer as a liner significantly enhanced the shear bond strength of amalgam and gallium alloy restorations.

SUMMARY

In this in vitro study, where alloys were condensed into unset paste lining materials, shear bond strengths were significantly greater than with the unlined controls. The use of varnish or Paama 2 linings did not significantly increase the shear bond strength of amalgam or gallium alloy restorations. The use of Vitrabond, Vitremer, or Resinomer liners significantly increased the shear bond strength compared to unlined restorations. Permite C restorations lined with Resinomer all showed cohesive failure within the mixed alloy/liner.

Of the unlined restorations, Permite C had significantly higher shear bond strength than Lojic Plus.

The experimental method used in the present study proved to be suitable for quantitative comparison of the shear bond strength of different dental materials.

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INTRODUCTION

Recently, attention has turned toward the use of adhesive materials as cavity liners in an attempt to improve the retention of amalgam restorations. There are two main groups of adhesive resin liners, one based on the bisphenyl-A glycidyl methacrylate (BIS-GMA) monomer, and the other based on methyl methacrylate.

The possible advantages of using adhesive resin liners include preservation of tooth structure, resistance to dislodgment, reduction of microleakage, and increased resistance of restored teeth to fracture (Staninec, 1989). Several mechanisms for the bonding of adhesive resins to dentin have been proposed. These include tag formation; the formation of precipitates on pretreated dentin surfaces to which an adhesive resin may chemically or mechanically bond; chemical bonding to inorganic and/or organic components of dentin; diffusion and impregnation of monomers into the subsurface of pretreated dentin and subsequent polymerization, resulting in a hybrid layer of resin-reinforced dentin (Nakabayashi, 1992).

Methacrylates that contain both hydrophobic and hydrophilic groups on ester molecules have been developed. These groups improve the adhesive strength of resins to teeth by promoting intertubular penetration, impregnation, and entanglement of the methacrylate-based monomers into the dentin (Nakabayashi, 1992). The diffusion rate of monomer is a function of both the diffusivity of the dentin and the diffusivity of the monomer itself. According to Nakabayashi (1992), the application of 2-hydroxyethylmethacrylate (HEMA) to the dentin substrate encouraged the diffusion and impregnation of monomer into the dentin.

The adhesive resin liners used in the present study were Paama 2 (SDI, Melbourne, Australia), All-Bond 2 (Bisco, Itasca, IL 60143), and Resinomer (Bisco). Paama 2 is a light-cure dentin and enamel adhesive. All-Bond 2 is a fourth-generation dual-cure dentin and enamel adhesive resin liner system. Resinomer is a dual-cure, glass-filled, fluoride-releasing composite resin that facilitates adhesion to metals. It is used together with the All-Bond 2 primer. In one study, the shear bond strength of amalgam to dentin with All-Bond 2 as a liner after 7 days' storage in saline at 37 °C was 14.17 ± 1.67 MPa (Art-Smart, Retief & Russell, 1992).

Glass ionomer has been increasingly adapted for use as a liner under amalgam restorations due to properties such as the ability to release fluoride (Maldonado, Swartz & Phillips, 1978; McCourt, Cooley & Huddleston, 1990), the ability to bond to both enamel and dentin (Maldonado & others, 1978), and having a low coefficient of thermal diffusivity (Watts & Smith, 1981). The bond between glass ionomer and amalgam alloy is thought to be, in part, a result of the affinity of the numerous carboxyl end group anions of polyacrylic acid for the metal cations of the alloy (Hotz & others, 1977; Negm, Beech & Grant, 1982). The more recent light-cure glass-ionomer materials offer more convenient handling properties and may overcome the problem of initial high water absorption of these aluminosilicate-based liners (Crisp, Lewis & Wilson, 1980). Warren and Söderholm (1988a) demonstrated a mechanical component bond ("tags") between amalgam and glass-ionomer liner, but no chemical bond. Short-term water immersion (6 days) had no significant effect on the bond strength (Warren & Söderholm, 1988b). However, the early strength of glass-ionomer liners appears to vary greatly (Cattani-Lorente, Godin & Meyer, 1993; Tam & others,1989), which may be due to the influence of the different molecular weight of the polyacid component. Wilson and others (1989) found that the molecular weight of the polyacid can influence the setting rate, acid erosion rate, compressive strength, fracture toughness, and wear resistance. The higher the molecular weight, the better the physical properties. Clinically, this trend will be ultimately limited by the viscosity of the liquid. In the present experiment, Vitrabond (3M Dental Products, St Paul, MN 55144) and Vitremer (3M Dental Products) were the glass-ionomer liners tested. Studies had shown that specimens lined with a light-cured glass ionomer (Vitrabond) had better physical properties than a chemically cured glass ionomer (al-Moayad, Aboush & Elderton, 1993; Cole, Aboush & Elderton, 1991).

With the recent interest in the possible cytotoxic effect of mercury from amalgam, a metallic material with the properties of amalgam without any mercury content could be an attractive alternative. In earlier experimental attempts to find an alternative to amalgam alloy, Smith and Caul (1956) and Smith, Caul, and Sweeney (1956) showed that gallium-copper-tin alloys exhibited little change in dimension during hardening, and that their physical and mechanical properties were superior to silver amalgam. Waterstrat (1969) studied the physical and mechanical properties of a gallium-palladium-tin alloy and found that the alloy exhibited superior strength and resistance to flow under an applied load at mouth temperature. The coefficient of thermal expansion closely matched that of human teeth.

A study by Okabe and others (1992) showed that when gallium alloys were triturated, grains of In_4Ag_9 and $CuGa_2$ were found. The high compressive strength and low creep values suggested that the In_4Ag_9 grains effectively hold their structural integrity during deformation of the set alloy. According to Okamoto and Horibe (1991), Ga-In-Zn liquid, when mixed with Sn-Pd-Cu-Zn-Ag, hardened relatively rapidly at mouth temperature. The strength of this alloy increased markedly immediately after mixing, and polishing was possible on the same day. A good marginal seal can be expected, for this material expands on setting.

In the present study, Galloy (gallium alloy, SDI) was chosen as one of the restorative alloys to be tested. According to the manufacturer, Galloy is a gallium-based amalgam-type restorative material. It consists of a spherical alloy powder and a gallium alloy liquid in a predosed direct placement capsule system. It is essentially similar to the Lojic Plus (60 wt% silver) spherical alloy (SDI), with mercury being substituted by gallium alloy liquid.

A number of factors can influence the results of shear bond tests. These include the restorative materials, the method of force application, the quality of the substrate, and the storage conditions of the specimen prior to testing (Øilo, 1993). Researchers have used methacrylate disks instead of dentin disks to eliminate the variation in substrate quality (Fanian, Hadavi & Asgar, 1983; Watts, Devlin & Fletcher, 1992). The shear bond test of the present experiment, utilizing a Universal Testing Machine, has been used

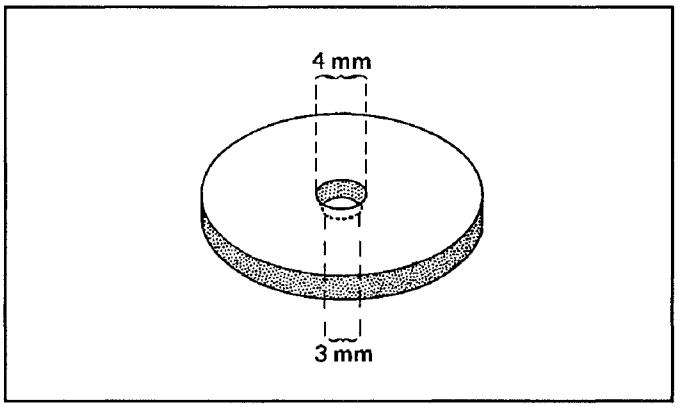

Figure 1. The nominal dimensions of the finished cavity preparation in the methyl methacrylate disk

by other researchers (Hood, Childs & Evans, 1981). Methacrylate was chosen for the substrate in preference to dentin because of easy access and constant quality.

The present experiment was undertaken to study the effectiveness of glass-ionomer liners (Vitrabond and Vitremer) and adhesive resin liners (Paama 2, All-Bond 2, and Resinomer) in improving the retention of alloy restorations. It was also undertaken to determine the effectiveness of the tapered-plug shear technique in determining retention.

METHODS AND MATERIALS

Standard cavities were prepared centrally in 4.0 mm-thick methyl methacrylate disks using an 8-degree taper conometric cutter (Komet ISO-021, Gebr Brasseler, Lemgo, Germany) in an engineering lathe. The nominal dimensions of the prepared cavity are illustrated in Figure 1. The prepared disks were allocated to 21 groups of 10, in preparation for testing seven linings in combination with three restorative alloys.

The tapered preparations were lined with the test lining materials, which were applied following the manufacturers' instructions. The lining materials tested were Fuji Varnish (GC, Tokyo, Japan), Vitrabond, Vitremer, All-Bond 2, Resinomer, and Paama 2. The Fuji varnish was applied in two layers to the walls of the tapered cavities. Vitrabond, Vitremer, and Resinomer liners were not light cured prior to the placement of alloy restorations. In the control groups, no lining material was placed.

The restorative alloys tested were Permite C (admixed amalgam alloy, SDI), Lojic Plus, and Galloy. The alloys were triturated according to the manufacturers' instructions using an amalgamator (Silamat type S3, Vivadent, Schaan, Liechtenstein). Standard amalgam carrier and technique were used to transfer increments to the cavity preparation. The preparations were packed with the restorative alloys immediately using a hand-held flat-ended condenser (FE0264, American Dental Mfg Co, Chicago, IL 60618). One end of the condenser was 1.5 mm and the other 2.0 mm in diameter. With Lojic Plus and Galloy, only the 2.0 mm end was used. With Permite C, both the 1.5 and 2.0 mm ends were used. All the alloys were condensed with a force of approximately 5.0 kg, the force being monitored by a force cell (Transducer/Converter Type SE905, Sample Electronics Laboratories (Feltham, England). The rate of condensation was 40-45 thrusts per minute, and each restoration was packed for 1 minute before the excess alloy was removed. The restorations were stored in a water bath at 37 °C for 7 days.

The test assembly consisted of a supporting apparatus that held the test specimen (Figure 2). One end of this consisted of a sliding punch, the other end contained a central hole with a diameter of 5 mm, which was 1 mm greater than the largest diameter of the alloy plug. The alloy plug was punched from the tapered cavity using the drive system of the testing machine (Instron Ltd, High Wycombe, England) that was operated at a crosshead speed of 5 mm/min. The test apparatus was positioned centrally on the load cell compression table of the testing machine. As the alloy plug was extruded, the load change over time was recorded by an Apple

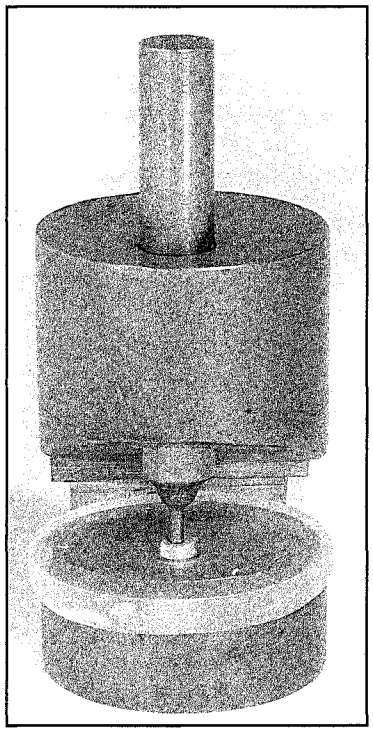

Figure 2. The supporting apparatus that held the specimen in the shear bond test assembly

Table 1. Mean Shear Bond Strength of Permite C/Liner Interface (MPa). n = 10 specimens/group.

	Mean	SD	Duncan New Multiple Range Test at $P < 0.05$		
Paama 2	5.416	1.416	a		
All-Bond 2	5.706	2.514	a		
Varnish	6.223	2.707	a		
No lining	6.254	3.411	a		
Vitrabond	9.335	1.417			b
Vitremer	9.766	2.812			b
Resinomer	10.939	2.552			b

Similar letters = no significant difference.

Table 2. Mean Shear Bond Strength of Lojic Plus/Liner Interface (MPa). n = 10 specimens/group.

	Mean	SD	Duncan New Multiple Range Test at $P < 0.05$			
No lining	3.416	2.340	a			
Paama 2	4.991	1.857	a	b		
Varnish	5.177	2.373	a	b		
All-Bond 2	6.700	1.720		b	c	
Vitrabond	6.902	2.381		b	c	
Vitremer	7.730	2.223			c	d
Resinomer	9.112	0.547				d

Similar letters = no significant difference.

Macintosh Plus computer (Apple Computer Inc, Cupertino, CA 95014), which utilized the MacLab Chart V3.2.8 software (Analogue Digital Instruments Ltd, Dunedin, New Zealand). The type of failure at the interface was observed under a binocular microscope (SZ-ET, Olympus, Tokyo, Japan) and recorded.

Analysis

For the shear bond strength, the stress required to dislodge the alloy plug was expressed in force per unit area (MPa). The surface area of the alloy/lining interface was the curved surface of the Grustrum of a right cone (Hodgman, 1954). A total of 50 specimen cavities were measured using a pair of digital callipers (Mitutoyo, Tokyo, Japan) with a resolution of 0.01 mm to establish an average height dimension. The larger and smaller diameters were measured using the measurescope (Nikon, Tokyo, Japan) with a resolution of 0.001 mm, connected to a digital counter (CM-6S, Nikon). The average surface area of the alloy/lining interface was 43.31 mm^2.

A two-way analysis of variance (ANOVA) statistical test was used, followed by a one-way ANOVA and the Duncan New Multiple Range test to analyze the statistical significance of the differences of the means between each alloy used with the seven lining materials.

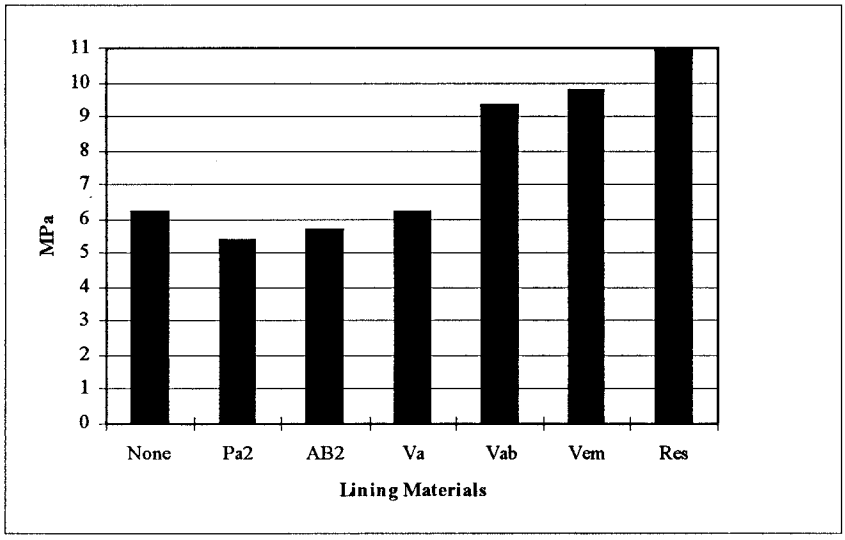

Figure 3. Mean shear bond strength of Permite C with different lining materials. Pa2 = Paama 2; AB2 = All-Bond 2; Va = Varnish; Vab = Vitrabond; Vem = Vitremer; Res = Resinomer.

RESULTS

Effects of the Liners on Shear Bond Strength

For the Permite C restorations, there was no significant difference in the shear bond strength for those lined with varnish, Paama 2, or All-Bond 2 when compared with no lining. Statistically significant differences were found between the Vitrabond-, Vitremer-, or Resinomer-lined restorations when compared with the unlined restorations ($P < 0.05$) (Table 1 and Figure 3).

For the Lojic Plus restorations, there was a significant difference in shear bond strength for those lined with Vitrabond, Vitremer, All-Bond 2, and Resinomer when compared with the unlined restorations ($P < 0.05$). However, there was no significant difference

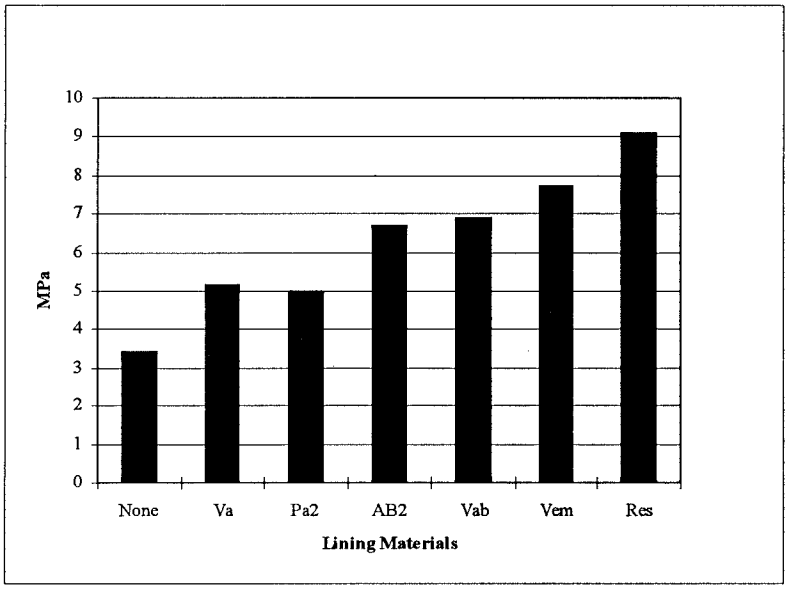

Figure 4. Mean shear bond strength of Lojic Plus with different lining materials

between Fuji varnish- or Paama 2-lined restorations compared with the unlined restorations (Table 2 and Figure 4).

For the Galloy restorations, results were similar to those of the Lojic Plus. Statistically significant differences were found with the Vitrabond-, Vitremer-, All-Bond 2-, and Resinomer-lined restorations when compared with the unlined restorations. Resinomer-lined restorations gave significantly higher shear bond strength values when compared with all the other lined and unlined groups ($P < 0.05$) (Table 3 and Figure 5).

For Vitrabond-lined restorations, Permite C gave significantly higher shear bond strength than Lojic Plus ($P < 0.05$). For Vitremer-lined restorations, Permite C gave significantly higher shear bond strength than Galloy ($P < 0.05$).

All-Bond 2-lined amalgam alloy restorations gave significantly higher shear bond strength than Galloy restorations ($P < 0.05$). Resinomer-lined Galloy restorations had significantly higher shear bond strength than Lojic Plus restorations ($P < 0.05$).

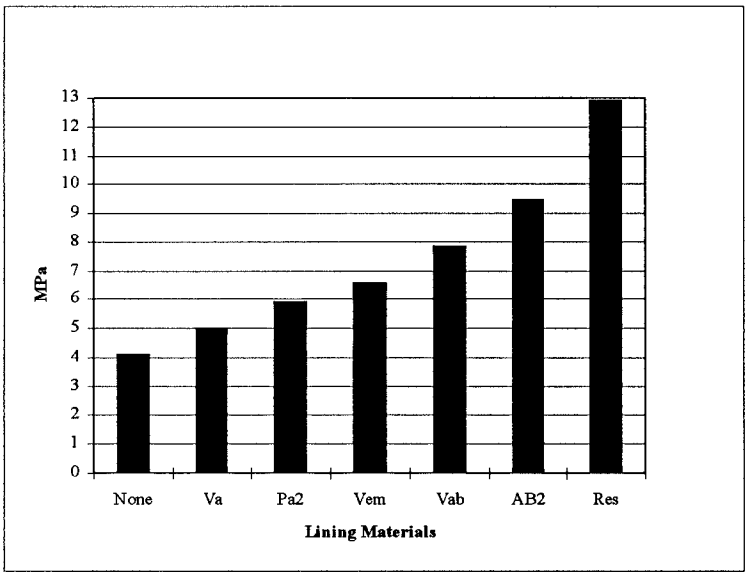

Figure 5. Mean shear bond strength of Galloy with different lining materials

Shear Bond Strength of the Unlined Alloy Restorations

With the unlined restorations, the only statistically significant difference in shear bond strength was found between Permite C and Lojic Plus. Permite C restorations exhibited the highest shear bond strength of the three test alloys ($P < 0.05$) (Table 4 and Figure 6).

Table 3. Mean Shear Bond Strength of Galloy/Liner Interface (MPa). n = 10 specimens/group.

	Mean	SD	Duncan New Multiple Range Test at $P < 0.05$				
No lining	4.076	1.955	a				
Varnish	4.997	1.220	a	b			
Paama 2	5.912	3.328	a	b	c		
Vitremer	6.599	3.025		b	c		
Vitrabond	7.843	1.260			c	d	
All-Bond 2	9.477	3.471				d	
Resinomer	12.894	2.253					e

Similar letters = no significant difference.

Mode of Failure in the Shear Bond Test

In all cases where a glass-ionomer lining or an adhesive resin lining was used, the lining material was found partially attached to the methyl methacrylate disk following the shear bond tests. This confirmed that the shear bond strength results were related to the lining material/restorative alloy interface. The mode of failure of the restorations is detailed in Tables 5, 6, and 7.

These results indicated that some form of adhesion existed between Resinomer and Permite C, resulting

Table 4. Mean Shear Bond Strength of the Unlined Alloy Restorations (MPa). n = 10 specimens/group.

	Mean	SD	Duncan New Multiple Range Test at $P < 0.05$	
Lojic Plus	3.416	2.340	a	
Galloy	4.076	1.955	a	b
Permite C	6.254	3.411		b

Similar letters = no significant difference.

in a cohesive failure within alloy/liner in all 10 restorations. For the Galloy restorations, complete cohesive failure occurred within the lining material for Vitrabond, Vitremer, Paama 2, and All-Bond 2.

DISCUSSION

Shear Bond Strength of Lined Alloy Restorations

This experiment utilized the tapered-plug shear test that was developed by Hood and others (1981). Tapered cavity preparations were used in preference to cylindrical ones, as minor roughness of the cavity walls would not provide additional resistance to dislodgement, which could affect the results of the shear bond test.

The purpose of the present experiment was to test the shear bond strength of the lining material/restorative alloy interface. For all the restorations lined with either a glass-ionomer liner or an adhesive resin liner, the lining material was found to be partially attached to the methyl methacrylate disk following the shear bond test. Therefore, since the interface being tested was the restoration/liner interface and the fact that liner still adhered to the acrylic in all cases after the shear bond tests were completed, the use of acrylic disks proved to be satisfactory for this experiment. The consistency of using acrylic disks also served to reduce potential variables in this study.

The ability to bond amalgam to cavity walls would improve the clinical performance of restorations. In the present experiment, the mean shear bond strength of Vitrabond to Permite C was 9.3 ± 1.4 MPa. By comparison, Martin and Jedynakiewicz (1991) obtained a mean shear bond strength of 6.2 ± 1.8 MPa using an unknown glass-ionomer cement with human enamel as a substrate. The difference is probably due to the use of different experimental methods and substrates. In the present experiment, there was no significant difference in mean shear bond strength between the two glass-ionomer liners tested. Both of these liners are pastes, and were light cured after the alloys were condensed.

Of the adhesive resin liners, the mean shear bond strength of restorations lined with Resinomer was significantly higher than the mean shear bond strength of restorations lined with All-Bond 2. Both Resinomer and All-Bond 2 use the same primer. The difference in mean shear bond strength may be due to the fact that Resinomer is an unset paste lining material compared to All-Bond 2, which is a preset lining material.

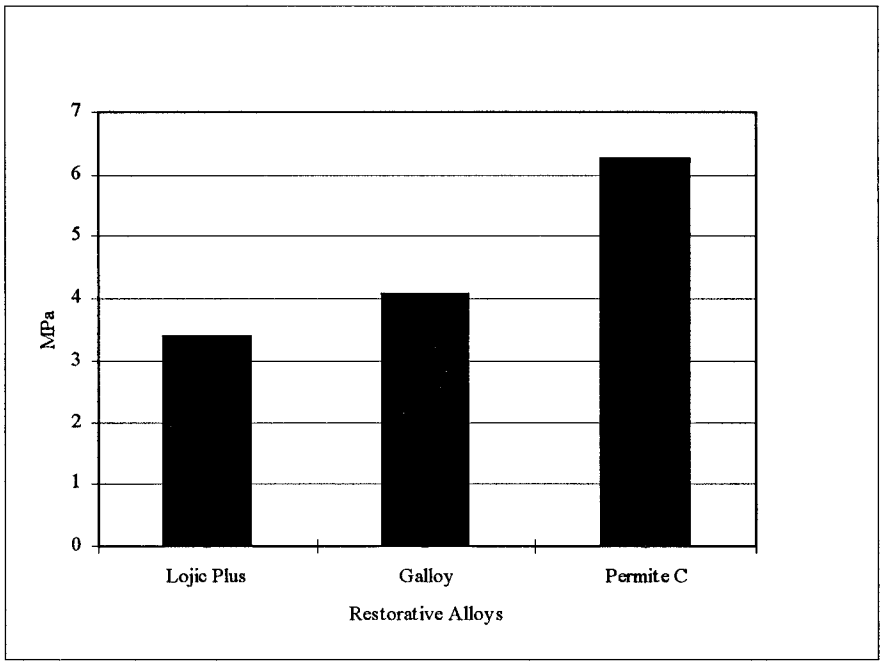

Figure 6. Mean shear bond strength of the unlined alloy restorations

All-Bond 2 is the only lining material used in the present experiment that is recommended by the manufacturer for bonding new to old amalgam restorations. In the present research, restorations lined with All-Bond 2 did not produce the highest mean shear bond strength. This is probably because All-Bond 2 is a preset lining material, therefore unlikely to form any mechanical bond with the alloy restorations.

Paama 2 is recommended for use as a lining material for Galloy restorations by the manufacturer, to prevent water contamination and thereby prevent corrosion of the alloy. In the present study, the other adhesive resin and glass-ionomer liners tested produced greater shear bond strengths with Galloy than

Table 5. Mode of Failure of Lined Permite C Specimens

	Cohesive Failure within Lining Material	Cohesive Failure within Mixed Alloy/Liner
Vitrabond	3	7
Vitremer	5	5
Paama 2	2	8
All-Bond 2	9	1
Resinomer	0	10

Table 6. Mode of Failure of Lined Lojic Plus Specimens

	Cohesive Failure within Lining Material	Cohesive Failure within Mixed Alloy/Liner
Vitrabond	9	1
Vitremer	7	3
Paama 2	2	8
All-Bond 2	5	5
Resinomer	3	7

they did with Paama 2. This difference may be caused by a lack of mechanical bonding between Paama 2 (preset lining material) and Galloy.

In the shear bond tests where the alloys were condensed into unset paste lining materials, bond strengths were significantly higher than those achieved with unlined restorations. This suggests that some form of mechanical interlocking between the paste lining materials and restorative alloys contributed to the higher shear bond strength of the restorations. The condensation of alloys onto unset pastes also aids in the elimination of voids within the interface.

Shear Bond Strength of Unlined Alloy Restorations

Significantly higher mean shear bond strength was shown with unlined Permite C restorations than with unlined Lojic Plus restorations. In the present experiment, a constant condensation force was used for all three restorative alloys. Spherical amalgam alloys are very plastic and have less resistance to condensation force than admixed alloys (Phillips, 1991). Therefore using the same high condensation pressure with both alloy types may have adversely affected the adaptation of Lojic Plus to the cavity walls.

Permite C has the highest setting expansion (0.03%) of the three test alloys, while Lojic Plus does not expand on setting (0%). The setting expansion of Galloy is 0.01%. A greater setting expansion will result in a greater wedging effect of the alloy against the cavity wall, thereby enhancing the retention of the restoration.

Lojic Plus is a regular-set amalgam alloy, whereas Permite C is a slow-set alloy. There is a possibility that the faster hardening rate of Lojic Plus would cause it to be more sensitive to manipulation technique. Condensation of partially set material probably fractures and breaks up the matrix that has already formed. Also, when the alloy has lost a certain amount of plasticity, it is more difficult to remove voids.

Further study is needed to determine the nature of the bond that might exist between the lining materials and the restorative alloys. With the information available to date, the use of a liner and the provision of proper retention in cavity design is still a prudent measure.

Table 7. Mode of Failure of Lined Galloy Specimens

	Cohesive Failure within Lining Material	Cohesive Failure within Mixed Alloy/Liner
Vitrabond	10	0
Vitremer	10	0
Paama 2	10	0
All-Bond 2	10	0
Resinomer	5	5

CONCLUSION

In the present in vitro study, the use of Fuji varnish or Paama 2 linings did not significantly increase the shear bond strength of the alloy restorations. The use of Vitrabond, Vitremer, or Resinomer significantly increased the shear bond strength compared to the unlined restorations. Permite C restorations lined with Resinomer all showed cohesive failure within the mixed alloy/liner.

Of the unlined restorations, Permite C had significantly higher shear bond strength than Lojic Plus.

The experimental method used in the present study proved to be suitable for quantitative comparison of shear bond strength of different dental materials.

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Shear Bond Strength of Immediately Repaired Light-cured Composite Resin Restorations

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Clinical Relevance
An air-inhibited layer should not be allowed to form on the surface of a newly placed composite resin restoration prior to its immediate repair by a layer of the same resin.

SUMMARY

The goal of this study was to examine the extent to which the state of the surface of newly placed restorations made of one of two commercial formulations of composite resin (Pertac-Hybrid and Z-100) affects the interfacial bond strength when such restorations are immediately repaired with the same resin. Three groups of specimens for each material were prepared: one group in which there was an air-inhibited film on the surface of the initial layer of the restoration, another in which that film was prevented from being formed, and a third in which that surface was abraded prior to placement of the repair layer. All specimens were stored for 6 weeks in water at 23°C before being loaded to fracture in shear at a rate of 5 mm/min. The shear bond strength results were treated using the three-parameter Weibull equation and a clearly defined index of performance (I), which is a measure of both the magnitude and variability of the shear bond strength. It was found that, for two states of the surface of the initial layer, I for Pertac-Hybrid specimens is about the same as that for Z-100 specimens. For specimens made of either material, there was a demonstrable difference in I between specimens with or without an air-inhibited film on the initial layer, while abrading the surface of that layer severely degraded I.

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INTRODUCTION

A newly placed restoration is sometimes considered unacceptable or unsatisfactory, the main reasons for this being inadequate contour, overfinishing, color mismatch, presence of voids, or fracture. In such cases, the usual recourse is to either repair or

replace the restoration. Mainly because of its relatively low potential for pulpal trauma and cost-effectiveness, the repair option is preferred and has proved to be clinically viable (Croll, 1990). Thus, repairability is now recognized as a highly desirable property of a restorative material. One measure of repairability is the development of an excellent bond at the interface between the surfaces of the initial and repair layers in the restoration. This development, in turn, is reflected in the magnitude of the strength of the bond at that interface, usually referred to as the interfacial bond strength.

Many commercial formulations of three classes of restorative materials, namely, glass-polyalkenoate (ionomer) cements, composite resins, and "hybrids," have been the subject of in vitro evaluation of repairability. Such evaluations have taken the form of the experimental determination of a measure of the interfacial bond strength in repaired specimens, and the dependence of this parameter on various factors.

In the case of selected glass-ionomer cements, it has been found that the interfacial bond strength decreases with the age of the initial layer in the restoration (Parra & Kopel, 1992; Charlton, Murchison & Moore, 1991; Robbins & others, 1989; Scherer & others, 1989; Pearson & others, 1989), while the state of the surface of that layer exerts a variable effect (Jamaluddin & Pearson, 1994; Parra & Kopel, 1992; Charlton & others, 1991; Scherer & others, 1989; Brackett & Johnston, 1989).

For various composite resins, it has been found that the interfacial bond strength of the repaired restoration is clearly affected by: the age of the initial layer (Boyer, Chan & Reinhardt, 1984; Boyer, Chan & Torney, 1978); the condition of the surface in the initial layer (Li, Liu & Sundstrom, 1995; Turner & Meiers, 1993; Chiba, Hosoda & Fusayama, 1989; Kao, Pryor & Johnston, 1988; Miranda, Duncanson & Dilts, 1984); the curing medium (Causton, 1975); contamination of the surface of the initial layer by saliva (Chiba & others, 1989); the use of a silane coupling agent (Swift, Cloe & Boyer, 1994); the use of a bonding agent (Puckett, Holder & O'Hara, 1991; Chiba & others, 1989; Kao & others, 1988; Boyer & others, 1984; Chan & Boyer, 1983; Chen & Brauer, 1982; Boyer & others, 1978); various characteristics of the bonding agent, when used, notably its viscosity and wettability (Turner & Meiers, 1993); the viscosity of the composites (Causton, 1975); the filler loading of the composites (Kao & others, 1988; Pounder, Gregory & Powers, 1987; Miranda & others, 1984; Boyer & others, 1984); and the time of aging of the repaired specimen in water (Kao & others, 1988).

"Resin-ionomer hybrids" are a relatively new type of material in which a resin-based material is compositionally altered by the addition of certain glass-ionomer ingredients. In the case of one example of such a hybrid, in which the additive ingredients are polyacrylic acid and aluminum fluorosilicate glass powder, the effect of the age of the initial layer and the state of its surface on the shear bond strength of repaired specimens has been investigated (Flores, Charlton & Evans, 1995).

From all of these studies, a consensus is emerging that interfacial bond strength decreases: as the age of the initial layer increases; as the surface roughness of that layer increases (by, for example, finishing with an abrasive paper or carbide tool); as the viscosity of the bonding agent decreases; with contamination of the surface of the initial layer (by, for example, saliva for even a very short time); as the filler loading, when composite resins are used, changes from highly filled to microfilled; and as the time of aging of the repaired specimen in water increases.

It is well recognized that, as restorative materials, composite resins possess both attractive properties

Table 1. Shear Bond Strength of Immediately Repaired Composite Resin Specimens (MPa)

	Pertac-Hybrid			Z-100		
	Group A	**Group B**	**Group C**	**Group A**	**Group B**	**Group C**
Specimen #1	12.48	12.08	12.82	21.87	8.90	6.66
Specimen #2	13.49	15.92	8.02	9.25	2.37	18.67
Specimen #3	14.87	18.69	8.30	2.18	11.87	1.96
Specimen #4	11.98	1.63	4.56	13.91	3.35	11.53
Specimen #5	9.51	15.12	5.12	2.49	17.97	2.42
Specimen #6	12.70	2.41	9.11	5.61	24.65	3.15
Specimen #7	12.85	11.18	9.04	13.73	19.52	1.16
Specimen #8	10.94	7.56	5.54	20.07	13.27	8.95
Specimen #9	15.78			3.87	2.69	6.95
Specimen #10				2.52	7.52	

and drawbacks. Among the former are appealing aesthetics and the ability to be used in many restorative situations. The drawbacks include microleakage at the restoration-tooth surface interface (stemming from volumetric shrinkage upon polymerization), propensity for colonization by *Steptrococcus mutans* (Friedl, Hiller & Schmalz, 1995), and technique-sensitivity in placing restorations. Although there are unresolved concerns about the longevity and long-term occlusal wear rate of restorations made of these materials (Mair & others, 1996; Mjör, Jokstad & Qvist, 1990), their use and acceptance by patients have risen dramatically in the past decade (Lutz, 1995; Pink, Minden & Simmonds, 1994). The main reason for this trend is patient demand for a mercury-free restorative material in light of continuing reports of the deleterious effect of mercury in the oral environment (Corbin & Kohn, 1994). It is suggested that the use and acceptance of composite resins will expand further in the future.

The purpose of this study was to determine how different surface treatments of the initial layer affected interfacial bond strengths when immediate repair of newly placed composite resin was done.

METHODS AND MATERIALS

Two commercial composite resins were used: Pertac-Hybrid (ESPE America, Inc, Norristown, PA 19404) and Z-100 (3M Dental Products, St Paul, MN 55144).

A wax circle was made with a punch hole and inserted halfway into a 12.5-mm-in-diameter nut, then the nut was filled with a 1 mm-high layer of the material and polymerized by exposure for 40 seconds to a visible-light source (The Max, L D Caulk/ Dentsply, Milford, DE 19963). Immediately following this, another 1 mm-high layer of the material (or repair layer) was placed flush on the first (or initial) layer and similarly polymerized. Three groups of such specimens were prepared, with the distinguishing feature between each group being the state of the surface of the initial layer to which the repair layer was bonded after a delay of approximately 5 minutes.

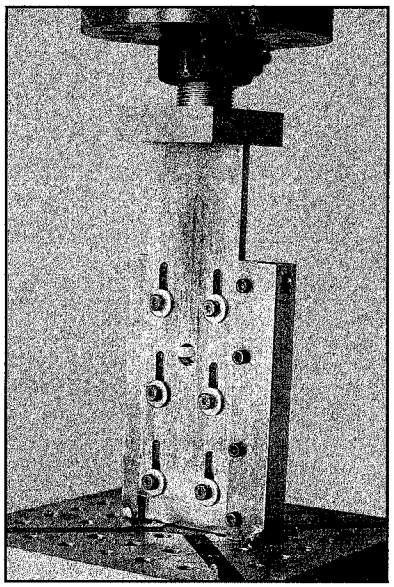

Figure 1. *Fixture for the shear bond strength determination*

In group A (air-inhibited specimens), the repair involved filling a 9.4 mm-in-diameter, 20 mm-high gelatin capsule with the material and placing it on top of the initial layer in as vertical a manner as possible. Then the material in the capsule was light cured for 80 seconds. In group B (nonair-inhibited specimens), the surface of the cured layer was covered with a 0.05-mm thick Mylar matrix strip (DuPont polyethylene terephthalate matrix, Union Broach Corp, Division of Moyco Industries, York, PA 17402) prior to the placement of the capsule and its polymerization. In group C (abraded specimens), no Mylar strip was used, but the surface of the cured layer was abraded with fine Sof-Lex disks (3M Dental Products) prior to the placement of the capsule and its polymerization. In all groups, the capsule was dissolved following its polymerization, and excess material was carefully cleaned from the bonded site. Then the specimens were stored in water at 23°C for 6 weeks, after which they were loaded to failure in a shear mode. In all, 54 specimens of both materials were prepared and tested (Table 1).

For the shear bond strength testing, a special fixture was designed and fabricated (Figure 1). Its essential features comprised a top plate (63.5 mm x 63.5 mm x 19.1 mm), which was set into a shearing plate (6.4 mm x 63.5 mm x 203.2 mm); a mounting plate (19.1 mm x 101.6 mm x 152.4 mm), which was welded into a machine base plate (19.1 mm x 101.6 mm x 101.6 mm); and six restraining screws that were used to hold in place the nut section of the repaired specimen in a 12.8 mm-diameter hole that was drilled into the shearing and mounting plates. Following its assembly, the fixture was mounted on a Universal Testing Machine (Model 1331, Instron Corp, Canton, MA 02021) and the test specimen was then inserted such that the nut section was fully positioned within the hole in the shearing and mounting plates, while the newly placed layer was protruding through that hole (Figure 1).

The shearing plate was aligned flush with the interface between the top of the nut and the repair layer. Then the machine was started, allowing the repair layer to be sheared from the initial layer in the nut at a crosshead displacement speed of 5 mm/min. The fracture force, P_f, was recorded, and the shear bond strength was calculated as the ratio of P_f to the area

of the interface (=69.41 mm^2) and expressed in N/mm^2 or MPa.

RESULTS

When data in a population are normally distributed, it is acceptable to use the mean and standard deviation as measures of central tendency and scatter of the data respectively. When, however, it is known or there is good reason to expect that the data are not normally distributed (for example, the distribution is highly skewed or symmetrical but not bell-shaped), other measures should be sought. In the case of highly skewed populations (for example, return periods of earthquakes or failure stresses of a brittle material), it is usual to employ the statistics of extreme values. The three-parameter Weibull equation is an example of such statistical methods. Its linearized format is

$$\ln \ln [1/(1-P)] = - b \ln (\sigma_a - \sigma_o) + b \ln (\sigma - \sigma_o) \quad (1)$$

where P is the probability of shear failure of the interfacial bond [= (Y - 0.3) / (M + 0.4)], with Y being the failure order number of the specimen in the set of M specimens when the shear bond strength, σ, results are arranged in ascending order of magnitude (1 = lowest shear bond strengh; M = highest shear bond strength); b is the Weibull modulus; σ_a is the characteristic shear bond strength; and σ_o is the minimum or guaranteed shear bond strength. b is a measure of the scatter of the σ results; σ_a is a measure of the central tendency of the results; and σ_o may be employed as the most conservative estimate of the true level of σ.

σ_o is estimated from an appropriate plot of ln ln [1/(1-P)] versus ln σ (Shigley & Mischke, 1989), while b and σ_a are determined from the slope and intercept of the plot of Equation (1). The σ results are presented in Table 1, while illustrative plots are presented in Figures 2 and 3. A summary of the values of these parameters for all the specimens is presented in Table 2.

A high value of σ_a is desirable, for this means that the bond between the initial and repair layers is very strong. A high value of b is also desirable, for this indicates that there is small scatter in the σ results; in other words, the specimen is very reliable. Thus, an index of performance of the specimen (I), should include both σ_a and b. Britton and others (1990) introduced one such collection, $\sigma_a\sqrt{b}$, and this expression is adopted here for I; that is, we say $I = \sigma_a\sqrt{b}$. Thus, from a set of candidate specimens, the one with the highest value of I should be selected. Alternatively, for a given specimen, factors that enhance its I value should be sought.

Clinical conditions that yield high values of I for

Table 2. Estimates of Weibull Parameters and Index of Shear Bond Performance of Immediately Repaired Composite Resin Specimens

	Pertac-Hybrid			Z-100		
Weibull Parameter	**Group A**	**Group B**	**Group C**	**Group A**	**Group B**	**Group C**
σ_o (MPa)	8.40	1.20	3.90	1.50	1.60	0.80
b	1.87	0.76	1.20	0.83	0.89	0.92
σ_a (MPa)	5.42	11.39	4.51	8.35	10.66	7.06
I (MPa)	7.41	9.93	4.94	7.61	10.06	6.77

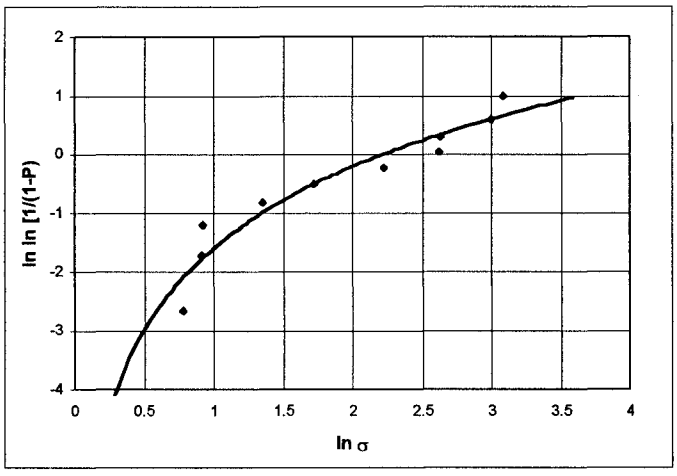

Figure 2. *Estimation of σ_o, the guaranteed shear bond strength: Z-100, "air-inhibited" specimens*

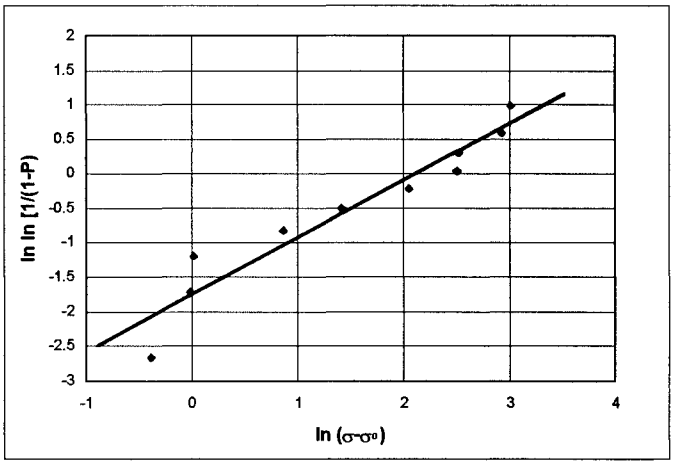

Figure 3. *The linearized three-parameter Weibull plot: Z-100, "air-inhibited" specimens*

test specimens may be used as a guide when immediately repairing composite resin restorations.

DISCUSSION

In previous in vitro studies of repairability of restorative materials, various statistical methods were employed to analyze the results. Some of these methods (Student's *t*-test and ANOVA), however, were not appropriate in the context of bond strength testing of restorative materials, because a central assumption underlying the use of these methods is that the bond strength, σ, results are drawn from a normally distributed population. In many cases, the σ distribution is highly skewed, thus making the lower values of σ (the tail of the distribution) of the greatest importance. This means that survival analysis of the σ results using, for example, the Weibull method is more appropriate.

Survival analysis using the Weibull approach has been used in analyzing various results: of a number of orthodontic bracket bond strength tests (Bearn, Aird & McCabe, 1995; Sargison, McCabe & Gordon, 1995; Fox & McCabe, 1992; Fox & others, 1991; Britton & others, 1990); in one repaired restoration study (Chadwick & Woolford, 1993); and in one study of orthodontic bands cemented with glass-ionomer cement (Millett & others, 1995).

In all of these studies, the two-parameter relation was employed. Here, σ_o was put equal to zero in advance. While this assumption considerably simplified parameter estimation, it was tantamount to restricting the set of admissible parameters. From mathematics, it is known that the maximum of any function over a restricted set is smaller or, at best, equal to the maximum over the nonrestricted set. Thus, to ensure that parameter estimates are actually found, σ_o should not be set to zero in advance, but rather estimated. In other words, it was proposed here that the three-parameter Weibull fit to the σ results be used.

There was greater scatter in the results from the Z-100 specimens than from the Pertac-Hybrid ones, although the results from Pertac-Hybrid Group B specimens showed the most scatter (lowest value of b) of all six groups tested. This level of scatter is not uncommon when dealing with brittle fractures, as in the present work. In fact, such scatter underscores the need for using an appropriate statistical method, such as the Weibull equation, to analyze the test results.

The present results (Table 2) showed that, for the nonair-inhibited or air-inhibited surface state of the initial layer, the values for I for groups of specimens made of Pertac-Hybrid and Z-100 were within 1-3% of each other. However, irrespective of the material used, there was a large difference in I (11-50%) between specimens with either of these surface states and those in which the initial layer was abraded.

The aggregates in both of the composite resins used are very similar in composition and size: quartz and yttrium fluoride, < 2 μm, in the case of Pertac-Hybrid; and quartz and zirconia, 0.04 - 3.5 μm, in the case of Z-100. Thus, it appeared that the sameness in the trends of the I values for the two materials reflected this compositional similarity.

For specimens made of either Pertac-Hybrid or Z-100, the absence of an inhibited air film at the surface of the initial layer led to an increase in I. This result was not consistent with the hypothesis by other researchers that a thin viscous layer comprising unreacted methacrylate groups is formed on the cured layer during polymerization because of the inhibition by oxygen (Van Kerchoeven & others, 1982; Rutyer, 1981), which enhances bonding between the initial and repair layers through the formation of covalent bond, creation of interpenetrating networks and secondary bonds, mechanical interlocking (Li & others, 1995; Eliades & Caputo, 1989), and/or improvement of graft polymerization (Kao & others, 1988).

The present results supported results of others (Eliades & Caputo, 1989; Boyer & others, 1978), who found that the oxygen-inhibited film between adjacent composite layers reduced interfacial bond strength. This, they argued, was because of inadequate bonding, which was attributable to the topical reduction of the initiator concentration arising from a diffusion process and copolymerization of the inhibited film with the repair composite.

For specimens made of either Pertac-Hybrid or Z-100, abrading the surface of the initial layer prior to placement of the repair layer produced decidedly weaker bonds. Abraded surfaces consisted of exposed inorganic filler particles and, when microfilled composites were used, exposed prepolymerized resin particles. Bonding to either of these types of particles would be expected to be less favorable compared to bonding to a resin-rich layer (unabraded surface) because of the decreased propensity for primary bonding to methacrylate groups (Boyer & others, 1984).

Differences in the method of application of the shear force to the interface between the initial and repair layers, the rate of application of that force, R, the state of the surface of the initial layer prior to placement of the repair section, and specimen storage medium and time make it inadvisable to compare the values of shear bond strength obtained in the present work with those reported by previous workers.

There is always the question of the extent to which in vitro bond strength value for a material may be

used in predicting in vivo performance of repaired restorations made of that material. This question arises because of the difficulty in fully simulating, in a laboratory test, the combined loading that the restoration experiences in vivo. Even if this could be achieved, the question would still be germane because of a further factor--that of the structural integrity of the restoration--that is not considered in conventional laboratory materials testing. This integrity depends on a number of variables, notably applied stress, flaw population characteristics, and oral environment.

Thus, the usefulness of the present results lies more in their being utilized for ranking materials, for a specified state of the surface of the initial layer, than in predicting clinical repair durability. The latter issue will have to await the analysis of results from prospective, randomized, long-term, multicenter clinical investigations. Furthermore, it is re-emphasized that the present study does not relate to repairs of aged restorations (that is, refurbishment of restorations that have been in clinical service), but rather to immediate repair of newly placed restorations prior to their being left in the mouth.

Three points related to clinical relevance can be made from results of the present study.

First, most sources (Chan & Boyer, 1983; Miranda & others, 1984) warn practitioners against using a different material to repair a composite than was used in the restoration initially. This can be a real concern to practitioners, since they may not know what material was used in the original restoration. This is not a problem in the immediate repair of a composite resin restoration, as was done in our study.

Second, if the adherent surface has been untouched since the initial polymerization of the material, whether there is a shiny surface from polymerization against a matrix or if there is an oxygen-inhibited layer present, it is recommended that the new material be simply added to the existing material without abrading its surface.

Third, if the surface has been cut or polished, the following steps are recommended: rinse off any loose debris; etch the adherent surface with the composite resin kit's etchant for 15 seconds; rinse and dry the surface; and then place a thin layer of unfilled, bonding agent on the surface followed by the new increment of the composite resin (Boyer & others, 1978; Chan & Boyer, 1983; Boyer & others, 1984; Chiba & others, 1989).

CONCLUSIONS

Three main conclusions may be presented from results of this project. First, in immediately repaired restorations, the absence of an air-inhibited film on the surface of the initial layer increased the interfacial bond strength performance. Second, for specimens with an air-inhibited film on the initial layer, abrasion of that layer led to a marked decrease in the shear bond performance. Third, irrespective of the condition of the surface of the initial layer, the shear bond performance of immediately repaired Pertac-Hybrid specimens was about the same as that of Z-100 ones, except in the case of specimens in which the surface of the initial layer was abraded, where Z-100 appeared to have a better performance.

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Using Double-poured Alginate Impressions to Fabricate Bleaching Trays

V B HAYWOOD • A POWE

Clinical Relevance
An alginate impression can be poured twice with the same degree of accuracy as two separate impressions, provided that during the setting of the first pour of stone, the alginate impression is kept humid by wrapping in a wet paper towel and the impression is repoured within 45 minutes of the initial pour.

SUMMARY

Esthetic and diagnostic treatment often requires two casts of one arch, one for baseline and one for alterations (diagnostic wax-up, bleaching tray, occlusal analysis). The purpose of this study was to compare the accuracy of stone casts generated from a second pour of a properly handled alginate impression with first-poured casts. A maxillary dentoform was indexed with six reference spaces (#8-15, 9-2, 2-15, and incisal-to-gingival of #3, 9, 14). Irreversible hydrocolloid (Jeltrate) impressions were made in perforated steel trays by a single investigator. Impression material was spatulated for 1 minute. The seated impression and dentoform were wrapped in a damp paper towel to simulate intraoral conditions, and allowed to set for 2 minutes. Upon separation, the impression was stored in a damp towel for 5 minutes. The impression was poured in cast stone (Microstone) according to the manufacturer's instructions. The stone-filled impression was immediately rewrapped in a damp paper towel and allowed to set for 45 minutes at room temperature. Upon removal of the stone, the impression was rinsed with cold water, shaken dry, and repoured in the same manner. Ten impressions were made: the first five impressions were poured to make casts for Group A, then repoured as described above for casts for Group B. The remaining five impressions were poured once to make casts for Group C. The six spaces of each cast were measured three times in random order using a dial caliper and the space average calculated for the cast. At each space, analysis of variance showed no significant difference among

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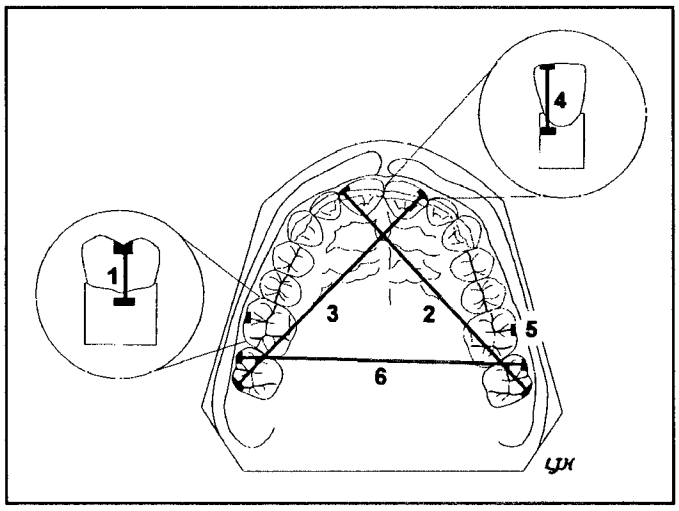
Groups A, B, or C ($P < 0.05$). When alginate impressions that have been poured with cast stone are kept moist during stone setting and repoured within 45 minutes, two casts can be generated from one impression with the same degree of accuracy as two casts made from taking two separate impressions, providing the alginate does not tear during first cast removal.

INTRODUCTION

Esthetic and diagnostic treatment planning often requires two casts of one arch. Two casts may be needed when bleaching is anticipated prior to composite bonding or veneers. In this situation, one cast must be trimmed into a horseshoe shape or with a hole in the center, have composite reservoirs added, and be sized to fit into the vacuum-forming machine for the bleaching tray. The other cast may need a diagnostic wax-up to demonstrate the feasibility of bonding plans, with or without being mounted on an articulator. Two casts are also needed to demonstrate the before and after possibilities of changing the anterior esthetics with crowns or veneers. Also, if occlusal adjustment is anticipated, the feasibility of success is tested by performing the procedure on one set of mounted casts, and comparing the result to the original casts. If the altered casts determine that the occlusal adjustment is not possible, then the original casts would be mounted in maximum intercuspation for further diagnosis and treatment.

There are a number of ways to generate two casts of one arch. Normally, an alginate impression is made and poured with cast stone for the first diagnostic cast. Then the original cast can be duplicated by a commercial laboratory using a refractory investment.



Schematic drawing of the six spaces measured on dentoform using a dial caliper

However, this duplication approach involves additional time and expense, which may discourage the dentist from following proper diagnostic procedures. For duplication in the dental office, the cast could be soaked in water until all air bubbles cease to form, then an alginate impression made of the first cast. However, this second-generation impression may not equal the accuracy of the first impression. Also, this duplication approach involves considerable time and jeopardy to the first cast. Another option is to make two separate impressions of the patient. Two impressions involves additional chair time and supplies, and is not generally well received by the patient; however, making two separate impressions does offer the most accurate option for generating two casts.

The purpose of this study was to compare the accuracy of stone casts generated from a second pour of a properly handled alginate impression with first-poured casts.

METHODS AND MATERIALS

Several other authors (Heartwell & others, 1972; Woodward, Morris & Khan, 1985; Kern, Rathmer & Strub, 1993) have demonstrated methods for determining the accuracy of impressions. For this study, a maxillary dentoform (Columbia Dentoform Corp, Long Island, NY 11101) was indexed with six reference spaces. The screws of dentoform teeth were tightly screwed, then three spaces were selected to measure accuracy anterior-posteriorally (from tooth #8 to tooth #15, from tooth #9 to tooth #2), and cross-arch accuracy (from tooth #2 to tooth #15). Three additional spaces were defined to measure the incisal-to-gingival accuracy of the resultant casts on three sites (at tooth #3, #9, #14). Notches were prepared in the dentoform that allowed measurements using a dial caliper (Dial Caliper Series 505, model #505-633, Mitutoyo, Tokyo, Japan) that had a measuring accuracy of 0.05 mm. The notches were prepared with a high-speed handpiece to resemble shallow approximal boxes for an inlay, and were slightly larger than the flat-sided tips of the dial caliper. The facing walls across each measured space (axial walls of the box) were prepared parallel to one another (figure). In this manner, the dial caliper could be inserted into the notch such that the flat portion of the tips of the caliper engaged the two facing parallel walls, while the point of the tip rested on the floor of the notch. One evaluator made three measurements in millimeters of each defined space on the dentoform in random order. These measurements were averaged and the standard deviation calculated to determine a value for each space.

Irreversible hydrocolloid (Jeltrate, LD Caulk, Milford, DE 19963) impressions were made in perforated steel trays (Coe Laboratories Inc, Chicago, IL 60658) by a

Average and Standard Deviations of Measurements of Three Cast Groups and the Original Dentoform in Millimeters

Group	Position	Mean	SD
Original	1	9.53	0.08
A		10.04	0.01
B		10.12	0.38
C		9.89	0.14
Original	2	50.08	0.00
A		51.05	0.14
B		51.13	0.01
C		51.04	0.16
Original	3	50.78	0.41
A		51.01	0.28
B		51.15	0.02
C		51.04	0.00
Original	4	9.94	0.15
A		10.00	0.07
B		10.03	0.08
C		10.11	0.15
Original	5	9.44	0.01
A		9.76	0.27
B		9.89	0.21
C		9.78	0.27
Original	6	46.27	0.15
A		46.68	0.47
B		46.96	0.40
C		47.07	0.27

single investigator. The impression material was spatulated for 1 minute, alginate material was wiped on the occlusal surfaces of the teeth with a finger to avoid air entrapment, and the tray was loaded and seated. In order to simulate intraoral conditions for the setting of the alginate, the seated impression and dentoform were wrapped in a damp paper towel. The alginate was allowed to set for 2 minutes as if in the mouth. Upon separation, the impression was stored in a damp towel for 5 minutes to simulate the approximate time it would take before pouring the impression could be accomplished (Cohen & others, 1995). Then the impression was poured in hand-mixed cast stone (Microstone, Whipmix, Louisville, KY 40217) according to the manufacturer's instructions. The stone-filled impression was immediately rewrapped in a damp paper towel and allowed to set for 45 minutes at room temperature. The first stone cast was then removed from the alginate impression. Upon removal of the stone cast, the impression was rinsed with cold water, shaken dry, and repoured with cast stone in the same manner as before.

Ten impressions of the dentoform were made. Casts from the first five impressions were designated as Group A. These impressions were then used for a second pour as described above to generate casts for Group B. The remaining five impressions were poured once and the casts designated as Group C. The six spaces of each cast were measured three times in random order using a dial caliper and the space average and standard deviation calculated for the cast. Groups A, B, and C were compared with one another and with the original dentoform measurements. Analysis of variance was used to evaluate potential differences between like spaces on the four groups.

RESULTS

The average and standard deviation of the four groups at the six spaces are shown in the table. At each space, analysis of variance showed no significant difference among Groups A, B, or C ($P < 0.05$). There was also no significant difference among any of the groups and the original dentoform, although the means of the original dentoform were less than any of the casts.

DISCUSSION

In this study, conditions were used that closely replicated the clinical environment. The alginate and stone were both hand-mixed, and no control was attempted for impression material thickness or repeatable seating of the loaded tray. This approach offered a more realistic expectation, one the dentist would experience in a clinical setting. However, there was no disinfecting of the impression. When disinfectants are sprayed on alginate, it is crucial that the disinfectant be adequately rinsed prior to pouring to avoid surface inhibition by the disinfectant of the setting stone. No obvious differences were noted between surface detail of the two casts from one impression in this study, although that was not critically evaluated. Clinically, it was difficult to distinguish the two casts unless some tearing had occurred during removal of the first cast. The author always marked the casts as first or second pour, because they were often indistinguishable clinically.

Dental stone will generally be completely set in 20 minutes (when the stone loses the feel of heat to the touch). Forty-five minutes was chosen as the maximum evaluation time to ensure complete setting of the stone, but more realistically because dentists or office staff are generally elsewhere while the stone is setting, and may not return within 20 minutes. Extensive clinical experience (Dr H V Murray, personal communication), both from dental school clinics and private practice experience, had indicated approximately 45 minutes as the longest time that could be repeatably tolerated without sacrificing accuracy. However, no

attempt in this study was made to determine the point at which casts from a wrapped poured impression begin to lose accuracy, or to compare casts from a wrapped poured impression with casts from an unwrapped poured impression. Also, this study does not imply that final prosthesis such as cast removable partial denture frameworks should be fabricated on second pours of alginate impressions.

Proper diagnosis and treatment planning is essential for proper dental treatment. The need for diagnostic casts and testing proposed treatment is often hampered by the time and effort it takes to generate the casts. This technique affords a time- and materials-efficient method to generate duplicate casts from a single impression. The only situation in which this is not favorable is when the alginate tears. When pouring a mandibular impression, it may be possible to avoid tearing the alginate impression material, as well as breaking the stone cast, by placing a wet paper towel in the tongue space level with the depth of the lingual vestibule. For the maxillary impression, the stone should not be allowed to extend beyond the depth of the vestibule.

Often, when a maxillary impression for a bleaching tray is poured, the goal of the dental office is to fabricate the tray while the patient waits. This approach reduces the number of patient visits, minimizes infection-control costs, and allows the patient to start immediately on the treatment. When a one-appointment impression/delivery is desired, a fast-setting hard stone is used (Snapstone, Whipmix). This special fast-setting stone hardens to comparable strength with die stone in 8 minutes. When making the first pour, the stone is not allowed to cover the palate, but rather the stone is formed into a horseshoe shape approximately 1 inch thick (personal communication, Sheila Marsh). This approach minimizes the amount of cast trimming required after removal. This special stone has sufficient strength to be easily removed from the impression even in the horseshoe shape. After pouring, the impression is wrapped in the damp towel as previously described and supported by the impression handle during setting. After the first cast is removed for fabrication of the bleaching tray, the impression can be rinsed, shaken dry, and repoured with conventional cast stone for the second diagnostic cast. Some dentists choose to offer one in-office bleaching treatment while the impression is poured and the tray fabricated, depending on the amount of office personnel available, and the personal desires and financial ability of the patient (Garber, 1997).

CONCLUSION

When alginate impressions are kept moist by completely wrapping in a damp paper towel during stone setting and poured within 45 minutes, two diagnostic casts can be generated from one impression with the same degree of accuracy as two casts made from taking two separate impressions, providing the alginate does not tear upon removal.

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Weight Change of Various Light-cured Restorative Materials after Water Immersion

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Clinical Relevance
Compared to conventional glass-ionomer cement, several light-cured glass-ionomer cements and other restorative materials showed significant increases or decreases in weight after water immersion. Resin composites demonstrated the least water sorption.

SUMMARY

This study investigated weight changes of various light-cured glass-ionomer cements and other restorative materials during water immersion and compared findings with those of conventional glass-ionomer cement and light-cured resin composites. Three light-cured glass-ionomer cements, two polyacid-modified composite resins, one conventional glass-ionomer cement, and one light-cured composite resin were evaluated in this study. The weight changes of these specimens after water immersion were measured using an electronic analytical balance and adjusted according to water solubility measured at the same time weight change was measured. The results were analyzed by one-way ANOVA and Scheffé's F test at $P < 0.05$. The weight change of Photac-Fil Aplicap was the largest, and there were significant differences among the materials ($P < 0.05$). Weight change after 6 weeks' water immersion was noted in the following order: Fuji Ionomer Type II LC, Vitremer, Fuji Ionomer Type II, VariGlass VLC, Geristore V, and Clearfil AP-X. It is suggested that the amount of water sorption of light-cured glass-ionomer cements is greater than that of polyacid-modified composite resins.

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INTRODUCTION

Various conventional glass-ionomer cements have been used clinically because of their beneficial

properties, such as adhesion to enamel and dentin (Mitra, 1991; Elaine & others, 1993; Cortes, García-Godoy & Boj, 1993; Charlton & Haveman, 1994; Swift, Pawlus & Vargas, 1995) and fluoride release (Takahashi, Emilson & Birkhed, 1993; Burgess & others, 1993; Forss, 1993; Woolford & Grieve, 1995). However, several problems have also been demonstrated. For example, conventional glass-ionomer cements are difficult to handle because working time is so short, while setting time is long (Plant & others, 1977; Aboush & Jenkins, 1986).

To overcome such problems, various light-cured glass-ionomer cements have recently been developed. These cements are hardened by light-curing or dual-curing reactions and by normal acid-base reactions. Light-curing or dual-curing reactions were adopted for polymerization of resin composites. It is known that the water sensitivity of cements appreciably decreases quickly when exposed to light compared with the acid-base reaction of conventional glass-ionomer cements (Wilson, 1989; Eliades & Palaghias, 1993; Cho, Kopel & White, 1995). It was reported that the adhesion of cements to dentin was superior to that of conventional glass-ionomer cement, because the resin components were thought to form a resin-infiltrated layer in the dentin (Nitta & others, 1994). In addition, physical properties, such as compressive and tensile strengths, were greater than that of conventional glass-ionomer cement due to setting by polymerization of resin monomers (Mitra, 1991; Mitra & Kedrowski, 1994; Kovarik & Muncy, 1995; Uno, Finger & Fritz, 1996).

Not only in conventional glass-ionomer cements but also in light-cured glass-ionomer cements, which include those with acid-base setting reactions, water sorption causes degradation of the physical properties by the dissolution of the components or by hydrolysis of the cement matrix (Crisp, Lewis & Wilson, 1980; Forss, 1993; Cattani-Lorente, Godin & Meyer, 1994). Thus, to develop a light-cured glass-ionomer cement with improved physical properties, it is necessary to evaluate water sorption. The present study investigated weight changes of various light-cured glass-ionomer filling cements after water immersion.

METHODS AND MATERIALS

As shown in the table, the following were used in the experiment: three light-cured glass-ionomer cements (Fuji Ionomer Type II LC—FLC, Photac-Fil Applicap—PFA, and Vitremer—VIT); two polyacid-modified composite resins (VariGlass—VLC and Geristore V—GE); one conventional glass-ionomer

Materials Used

CODE	MATERIAL	MANUFACTURER	BATCH #	POWDER/LIQUID	SHADE
Light-cured Glass-Ionomer Cement					
FLC	Fuji Ionomer Type II LC	GC Corp, Tokyo, Japan	050831	Precapsulated	A3
PFA	Photac-Fil Aplicap	ESPE, Seefeld/Oberbay, Germany	0011	Precapsulated	A3
VIT	Vitremer	3M Dental Products, St Paul, MN 55144	P:319R L:322	2.5 g/1.0 g	A3
VG	VariGlass VLC	Dentsply Intl Inc, Milford, DE 19963	P:9202291 L:92120011	3.5 g/1.0 g	U
GE	Geristore V	Den-Mat Corp, Santa Maria, CA 93456	A:802145 B:804074	1.0 g/1.0 g	A3
Conventional Glass-Ionomer Cement					
FI	Fuji Ionomer Type II	GC Corp	P:140533 L:100531	2.7 g/1.0 g	22
Light-cured Composite Resin					
APX	Clearfil AP-X	Kuraray Co, Ltd, Osaka, Japan	0043		A3

cement (Fuji Ionomer Type II—FI), and one light-cured composite resin (Clearfil AP-X—APX).

These filling materials were placed into a Teflon mold (10 mm in diameter and 2 mm in depth). The light-cured materials were irradiated for 120 seconds from both sides with a visible-light-curing unit (Quick Light, J Morita Corp, Osaka, Japan) through a Mylar matrix, while the conventional glass-ionomer cement was left for 5 minutes. The specimens were removed from the Teflon mold and air dried for 1 hour. The specimens of conventional glass-ionomer cement were covered with cocoa butter (Cocoa Butter, GC Corp) after removal of the Teflon mold. The cocoa butter on the specimens was removed before water immersion. Six specimens were made from each material and were divided into three groups according to ADA Specification No 8 (American Dental Association, 1978). Two specimens of each group were immersed in a glass flask filled with 50 ml of distilled water at 37 °C for 6 weeks. Specimens were briefly removed for weighing at specified intervals, then returned to a new flask. According to the ISO 4049 original plan (International Organization for Standardization, 1985), specimens were removed from the water and weighed after 1 minute. The weights were measured using an electronic analytical balance (HA202A, A & D Company Ltd, Tokyo, Japan) every day for the first week, then once a week for 6 weeks. After weighing, the specimens were transferred to a new flask filled with 50 ml of distilled water. The flask was placed in an incubator at 37 °C until the specimens were weighed.

The flasks from which the specimens were removed were placed in an incubator at 90 °C for 12 hours and then at 150 °C for 1 hour to vaporize the water content. The flasks were then put into a desiccator for complete drying. The weight of the flasks after drying was measured using an electronic analytical balance. Water solubilities (abbreviated as Ws) were calculated as Ws=(Wb-Wa)/2, where Wa=the weight before the two specimens and distilled water were added, Wb=the weight after the two specimens were removed, and after drying. Weight changes that were adjusted by water solubility (abbreviated as Wadj) were calculated as Wadj=W+Ws, where W = the weight change of each specimen.

The results of cumulative weight changes (W, Wadj) after water immersion for 6 weeks were analyzed by one-way ANOVA and Scheffé's F test at $P < 0.05$.

RESULTS

Figure 1 shows cumulative weight changes adjusted by water solubility up to 6 weeks. As a result, the weight change of PFA was greatest, followed in order by those of FLC, VIT, FI, VG, GE, and APX after 6 weeks' water immersion (Figure 1). Regarding the cumulative weight changes at 6 weeks, there were significant differences among materials

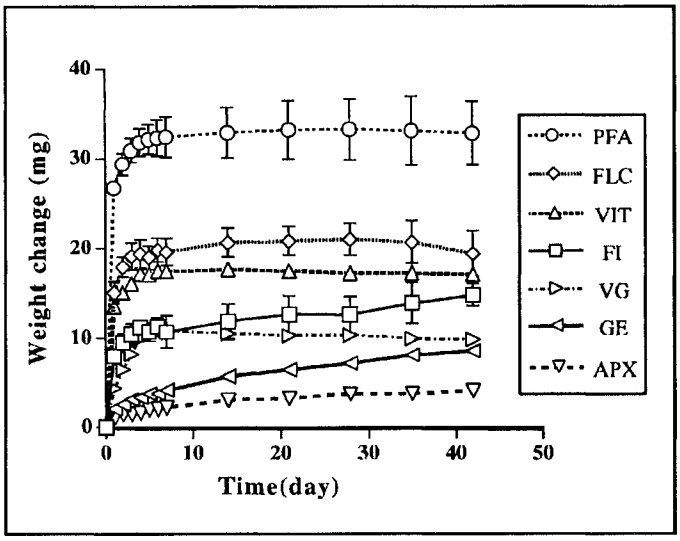

Figure 1. Course of weight changes (mg) adjusted by water solubility up to 6 weeks. The weight change of PFA was the greatest, and there were significant differences among the materials ($P < 0.05$), except for those between FLC and VIT, between VIT and FI, and between VG and GE.

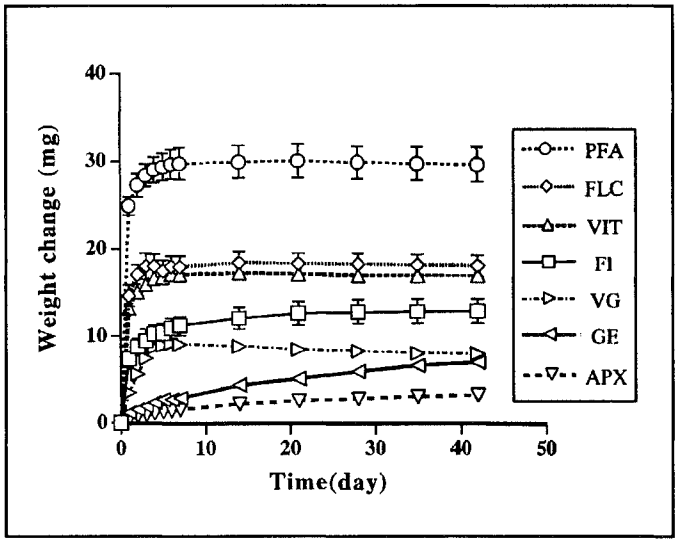

Figure 2. Course of weight changes (mg) not adjusted by water solubility up to 6 weeks. The weight change of PFA was the greatest, and there were significant differences among the materials ($P < 0.05$), except for those between FLC and VIT, and between VG and GE.

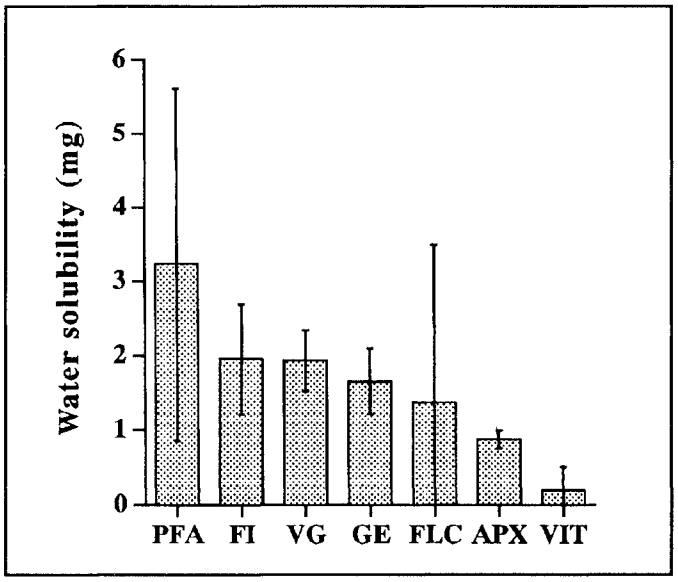

Figure 3. The cumulative water solubilities of the materials (mg) at 6 weeks.

($P < 0.05$), except between FLC and VIT, between VIT and FI, and between VG and GE. Figure 1 shows that the rates of weight changes were greatest immediately after water immersion. Weight changes of materials at 4 days amounted to more than 80% of total weight change after 6 weeks, except for that of GE (Figure 1).

Figure 2 shows the cumulative weight changes that were not adjusted by water solubility over the 6 weeks. As a result, the weight change of PFA was greatest, followed by those of FLC, VIT, FI, VG, GE, and APX after 6 weeks' water immersion. In cumulative weight changes that were not adjusted by water solubility after water immersion for 6 weeks, significant differences were found among materials ($P < 0.05$), except for those between FLC and VIT, and between VG and GE.

Figure 3 shows the cumulative water solubilities of materials up to 6 weeks. Although the water solubility of PFA was greatest, followed by those of FI, VG, GE, FLC, APX, and VIT, there were no significant differences among values ($P > 0.05$).

DISCUSSION

The water sorption of glass-ionomer cements is difficult to compare with that of resin composites, since conventional and light-cured glass-ionomer cements are hydrophilic materials, and water sorption and dehydration occur easily. Therefore, the optimal time for measuring water sorption is difficult to determine. As these cements naturally contain varied amounts of water, water solubility values cannot be determined by weight changes during water immersion alone, and the determination of "true" water sorption values is difficult. Due to these problems, there have been few reports concerning water sorption of glass-ionomer cements (Crisp & others, 1980; Kanchanavasita, Pearson & Anstice, 1996), though there have been a number of reports about the water sorption of resin composites (Pearson & Longman, 1989; Momoi & McCabe, 1994).

In the present study, weight changes of the specimens were measured according to the ISO 4049 original plan (International Organization for Standardization, 1985), and the water solubility of the specimens was determined by ADA Specification No 8 (American Dental Association, 1978). According to this specification, the disintegration rate of the respective materials is determined by the weight of water solubility after water immersion for 1 day. However, because the real water solubility of the specimens changes over time, the water solubilities of the specimens were also measured at the same time weight changes were measured. When specimens of each material were immersed in water, increases in these weights by water sorption and decreases in weight by dissolution of the material into water both occurred. Thus, it was assumed that the adjusted weight changes of these specimens correlated better with the real water sorption values than unadjusted weight changes.

According to McLean, Nicholson, and Wilson (1994), these light-cured restorative materials can be divided into two groups. One group consists of resin-modified glass ionomers, such as PFA, FLC, and VIT. The other consists of polyacid-modified composite resins (so-called compomer) and includes VG and GE. This study showed that water solubilities and water sorption of PFA and FLC were greater than those of VG and GE. Generally, the amount of water sorption and water solubility of glass-ionomer cements is greater than that of resin composites. Thus, it was suggested that the ratio of acid-base reaction against all curing reactions was higher than those in PFA and FLC. However, the ratio of the monomer curing reaction against all reactions in VG and GE was higher than those in PFA and FLC.

The results of this study demonstrating water sorption and solubility may be valuable for understanding the discoloration of glass-ionomer cements and polyacid-modified composite resins, because discoloration is known to be related to water sorption and water solubility (Charbeneau & Bozell, 1979; Rosen & others, 1989). Furthermore, water sorption of materials is well correlated with physical properties (Mitra, 1991; Mitra & Kedrowski, 1994;

Kovarik & Muncy, 1995; Uno, Finger & Fritz, 1996). Therefore, when each material is selected for clinical use, the amount of water sorption should be considered as well as adhesion to enamel and dentin and fluoride release. Differences in components and curing reactions of each material may influence adhesion to enamel and dentin and fluoride release over an extended period.

CONCLUSION

The weight change after water immersion of three light-cured glass-ionomer cements, two polyacid-modified composite resins, one conventional glass-ionomer cement, and one light-cured composite resin were investigated in this study. The weight change of PFA was greatest, and there were significant differences among the materials ($P < 0.05$). Weight changes of the other materials followed in the order of FLC, VIT, FI, VG, GE, and APX after 6 weeks' water immersion. Although the water solubility of PFA was greatest among the materials tested, there were no significant differences noted, because variances in the samples were large.

From the results of this study, it was concluded that the amount of water sorption of light-cured glass-ionomer cements was greater than that of polyacid-modified composite resins, while that of resin composites was the smallest.

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Temperature and Humidity Effects on Bond Strength of a Dentinal Adhesive

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Clinical Relevance
Conditions of humidity and temperature simulating those found intraorally can have a significant effect on the adhesive resin-to-dentin bond strength.

SUMMARY

Dentin specimens from 46 extracted human molar teeth were used in a matched-pair design examining the factors of temperature/humidity on shear bond strength of a dentinal adhesive to dentin. For one tooth-half, all procedures using restorative materials were accomplished in a controlled temperature and humidity chamber (humidity 95.0 ± 2.0%, temperature 37.0 ± 0.3 °C). For the other matched tooth-half all procedures were performed at ambient room conditions (humidity 52%, temperature 23.3 °C/74 ° F). Oil-free air and water were used in all restorative procedures. Application of Scotchbond Multi-Purpose Adhesive System was followed by placement of Z100 Restorative Resin, and thermocycling 1000 cycles from 5 to 55 °C. Each matched specimen was tested 24 hours later in an Instron Testing Machine. A paired *t*-test was performed for comparison of bond strength set values, since they were obtained from matching halves of the same teeth. Paired *t*-test comparison showed that the average humidity/temperature chamber mean of 7.14 ± 3.12 MPa was significantly less than the ambient conditions mean of 14.29 ± 5.07 ($P = 0.0000$). Bond strength testing under simulated oral conditions may produce significantly different findings than customary bench-top laboratory experiments.

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INTRODUCTION

Laboratory adhesion and microleakage evaluation of dentin bonding agents serve a useful purpose when used as a screening test for these materials (Retief, 1991; Barkmeier & Cooley, 1992). Variables to consider include: microleakage (Retief, Woods & Jamison, 1982), tensile vs shear bond strength tests

(Øilo & Austrheim 1993), human vs bovine dentin (Mitchem, Terkla & Gronas, 1988; Fowler & others, 1992), dentin depth (McCabe & Rusby, 1992; Perinka, Sano & Hosoda, 1992), surface roughness (Winkler & Moore, 1994), curing-light performance (Sakaguchi, Douglas & Peters, 1992), the effects of storage media and time (Goodis & others, 1993), and moist vs dry dentin (Gwinnett, 1992).

The presence of moisture, either from intrinsic or extrinsic sources, is of great importance with respect to optimal bonding of an adhesive resin to dentin. Extensive efforts have been made to simulate the presence of moisture on the dentinal surface from the dentinal tubules as a result of capillary forces and intrapulpal pressure (Derkson, Pashley & Derkson, 1986; Terkla & others, 1987; Mitchem & others, 1988; Tao & Pashley, 1989; Prati, Pashley & Montanari, 1991b). Extrinsic sources of moisture, e g, blood or saliva, the air syringe, or from intraoral humidity, can be of concern when using adhesive resins. Use of the rubber dam by clinicians would limit extrinsic moisture from tooth surfaces; however, the majority of dentists in practice do not use the dam (Hagge & others, 1984). Comparatively speaking, little effort has been expended in evaluating the effects of moisture extrinsic sources on the adhesion of a resin to dentin; however, several studies have demonstrated a diminished bond strength to dentin for the materials tested when humidity and temperature were increased to a level simulating intraoral conditions (Fundingsland, Aasen & Bodger, 1992; Plasmans & others, 1993).

The aim of the present study was to compare the effects on shear bond strength of humidity and temperature similar to those encountered in the oral cavity to those effects caused by ambient room/laboratory conditions.

METHODS AND MATERIALS

Forty-six human molars with caries-free opposing smooth coronal surfaces were obtained within a few days of extraction from the School of Dentistry's Oral Surgery Clinic and several oral surgery offices in the community. Upon extraction they were immediately placed in distilled water at room temperature with no attempt towards sterilization. The teeth were stored in distilled water at room temperature for a period not exceeding 1 week. Materials and technical equipment used are depicted in Table 1.

Specimen Preparation

Mechanical debridement of the teeth was accomplished with a Bard Parker blade (Miltex Instrument Co, Lake Success, NY 11042) followed by a rag wheel with a pumice-water slurry. The teeth were again stored in distilled water at room temperature. A Faskut lab wheel (L D Caulk/Dentsply, Milford, DE 19963) under constant oil-free water flow was used initially to reduce the enamel to the dentinoenamel junction on the opposing smooth coronal surfaces, with further reduction to follow, as described below. The root was amputated with a carborundum disk at the cementoenamel junction and discarded. The coronal portion was then sectioned to produce a pair of opposing, now slightly flattened, caries-free dentinal surfaces. The paired halves thus obtained were maintained throughout the study for proper comparisons. Each of the partially prepared dentin surfaces was centered on a flat surface covered with cellophane. A small aluminum cylinder was then centered over the specimen and filled in one increment with

Table 1. Materials/Technical Equipment Used

Materials/Equipment	Manufacturers
Faskut Abrasive Wheel	L D Caulk/Dentsply, York, PA 17405-0872
Polishing Machine, Model 5060	Covington Mfg Co, Redlands, CA 92373
Scotchbond Multi-Purpose Adhesive System	3M Dental Products, St Paul, MN 55144
XL300 Curing Light	3M Dental Products
Z100 Restorative Resin	3M Dental Products
Perfect Duster II	Perfect Data Corp, Simi Valley, CA 93065
Thermotron SM-5.5S Temperature/Humidity Chamber	Thermotron Industries, Holland, MI 49424
Instron Testing Machine, Model 4204	Instron Corp, Canton, MA 02021

a mounting medium of orthodontic resin. Following setting of the resin, each specimen was positioned in a jig that pushed the resin-encased specimen so that the dentin surface protruded slightly beyond the rim of the cylinder. The samples were placed against the slowly revolving disk of a commercial polishing machine (Covington Mfg Co, Redlands, CA 92373) and surfaced first with 120-grit and then with 600-grit paper (3M Dental Products, St Paul, MN 55144) under oil-free water flow to produce a flat surface of dentin. The paired samples were placed in a sealed plastic pouch together with an oil-free water-moistened 2 x 2 gauze square while awaiting treatment, a period of no longer than 1 hour. The pairs were then removed from the pouch and randomly assigned and labeled as a control or experimental specimen. The control was replaced in the pouch with moist cotton gauze and placed on the lab bench for conditioning to ambient room conditions, while the paired experimental specimen was conditioned for a period of 1 hour prior to restorative procedures in the humidity/temperature chamber (Thermotron SM-5.5S, Thermotron Industries, Holland, MI 49424).

Restorative Procedures

Application of the dentin adhesives and restorative composite resin was accomplished in strict accordance with the manufacturer's instructions. An oil-free air source (Perfect Duster II, Perfect Data Corp, Simi Valley, CA 93063) was used for all drying procedures. Restorative procedures for the control specimen of the pair were conducted on the bench top at ambient conditions, 52% humidity and 23.3 °C (74 °F). Procedures for the experimental specimen were conducted within the controlled humidity and temperature environment of the testing chamber at 95% ± 2.0% humidity and 37 ± 0.3 °C (98.6 °F). Placement of restorative materials for each of the control and experimental specimens was treated in an identical fashion, except for their respective environment. The exposed dentin surface was dried with oil-free air, etched for 15 seconds with 10% maleic acid, rinsed with water, and again dried. The primer of the adhesive system was applied to the dentin surface and dried gently. A small Teflon sheet, measuring 2.5 mm in thickness and bored with a 4 mm-in-diameter hole, was then dried and clamped to the cylinder in direct apposition to the dentin specimen with the hole centered over the dentin surface. A cavity preparation 4 mm in diameter and 2.5 mm in depth was thus formed by the dentin surface and the cylindrical internal surface of the disk. The adhesive resin was applied to the dentin in the base of the cavity and light cured for 10 seconds using a XL3000 Curing Light (3M Dental Products), which has a built-in light-intensity meter to verify the light-output level. At least 600 milliwatts output is necessary to trip the light, allowing a test of the light output before each use. Z100 Restorative Resin (3M Dental Products) was then placed in a single increment and light cured for 40 seconds per the manufacturer's instructions.

Upon completion of the placement of the restorative materials, the specimens, prepared at ambient conditions with the Teflon sheet still clamped in place, were returned to the plastic bag with water-moistened gauze. The experimental samples, with the Teflon sheet still clamped in place, were retained within the chamber at set humidity and temperature. In each case, the Teflon sheet was removed after 1 hour by holding the composite post with a plastic instrument and carefully rotating the Teflon sheet until free. The paired specimens were then returned to their original plastic bag and thermocycled in water for 1000 cycles from 5 to 55 °C, each cycle of 60 seconds (with a dwell time of 18 seconds in each bath and a 12-second transport time between each immersion). Flash was removed around the periphery of the composite post with a #25 Bard Parker knife using X4 magnification. Shear bond strength testing was conducted 24 hours after placement of the restorative materials.

A jig with a #20-gauge piano wire placed closely around the base of the composite post was placed in an Instron Testing Machine (Model 4204, Instron Corp, Canton, MA 02021), which was configured with a cross-head speed of 0.5 mm/minute. Peak break points (kg) were recorded for the paired specimens.

RESULTS

Shear bond strength values (kg/cm2) were calculated from peak break points as the load to produce failure (kg) divided by the area (cm2) of the bonding agent, which was assumed to be a constant. These values were then converted to MPa. Matched-pair shear bond strength means and statistical data (MPa) for restorative procedures performed with multipurpose dentinal adhesive system in controlled temperature/humidity versus ambient conditions are presented in Table 2. The results of a paired *t*-test used to examine the data generated by this experiment are summarized in Table 3. An average mean difference was calculated from values created by subtracting the MPa of each ambient conditions mean from each MPa value obtained from the matching tooth-half subjected to the conditions in the humidity/temperature chamber. This average difference, -7.151, was then compared to the null hypothesis that these differences were equal to zero. The *P*-value 0.0000 provided strong evidence that the mean difference is not zero.

Table 2. Matched-Pair Shear Bond Strength Means and Statistical Data for Restorative Procedures Performed with 3M Multi-Purpose Dental Adhesive System in Controlled Temperature/Humidity versus Ambient Conditions (MPa)

Condition	Mean	SD	Minimum	Maximum	Range	Count
Chamber T/H	7.14	3.12	0.56	15.75	15.20	46
Ambient T/H	14.29	5.07	3.05	26.65	23.60	46

DISCUSSION

The purpose of this study was to examine the effects of temperature and humidity on the shear bond strength to dentin. A single dentinal adhesive system was used. Restorative procedures were performed in two environments: (1) under typical ambient room conditions that may be found in the laboratory (52% humidity and 23.3 °C/74 °F); and (2) in a controllable temperature and humidity chamber set to approximate conditions found in the mouth (37 °C and 95% humidity).

Typical microleakage testing for in vitro evaluation of adhesive resin systems use class 5 cavity preparations at the cementoenamel junction of molar teeth, the margins of the preparation being 50% in enamel and 50% in dentin/cementum (Leclaire, 1988; Kanca, 1989; Prati, Nucci & Montanari, 1991a). Shear bond strength tests commonly use dried, flattened dentinal surfaces (Dickinson & others, 1991; Mandras, Retief & Russell, 1991; Burgess, Álvarez & Stattmiller, 1993; Los & Barkmeier, 1993). Generally, such tests do not consider the possible effects of either intrinsic or extrinsic sources of moisture.

Intrinsic moisture from the dentinal tubules as a result of hydrostatic intrapulpal pressure in vital teeth is of particular concern (Brown & Beveridge, 1966; Tonger & Kvinnsland, 1983; Prati & others, 1991a). Most of the current adhesive systems use an acid conditioner to remove the smear layer, which, when present, serves as a barrier to the passage of intratubular fluid. Removal of the smear layer results in an increase in dentin surface wetness (Brännström, 1984; Pashley, 1984).

Extrinsic sources of moisture, such as blood, saliva, intraoral and ambient conditions of humidity and temperature, as well as from other sources (moisture or oil from a chairside air syringe or a dental handpiece) are also of concern. This is most meaningful to those dentists who still do not use the rubber dam during restorative dental procedures (Hagge & others, 1984).

Plasmans and others (1994) found clinically that intraoral conditions are cyclical, and fluctuate as the patient inhales and exhales. They noted that a "dry" field in the oral cavity cannot be gained without the application of a rubber dam. Even with a dam, however, the ambient conditions in the dental treatment room have an influence on the relative humidity and temperature: the temperature and relative humidity are about the same as that in the room. Also with respect to a rubber dam, they stated that temperature may increase as a result of the absorption of infrared from the operating light while directed at the operating site. It may be possible, however, for the field to be "too dry." Tay and others (1996) stated that in the absence of water, re-expansion of a dehydrated and collapsed collagen matrix is prevented, resulting in the restriction of resin infiltration. They speculated that in some adhesive systems currently being used,

Table 3. Paired t-test Data: Average Mean Difference Calculated by Subtracting MPa Values of Each Ambient Conditions Mean from Each MPa Value Obtained from Matching Tooth-Half Subjected to Conditions in Humidity/ Temperature Chamber

Sample Size	Average Mean Difference	SD	T-Value	*P*-Value
46	-7.151	5.084	-9.54	0.0000

water could be an essential component by allowing the rewetting of desiccated collagen prior to the infiltration of the resin agents.

Prior to restorative procedures, the teeth of each category were "soaked" in their designated environment. During specimen fabrication in the humidity chamber, every attempt was made to follow manufacturer's recommendations for application of the dentin adhesive. The surface was not intentionally left wet or blotted dry as done in some previously published articles. Even though a moisture-free air source was used, it was not possible to determine through the rather small viewing window of the chamber if the dentin surface was completely dry before or after etching, or if the primer was dried without moisture contamination. The adhesive system used contained a primer that may be described as hydrophilic in nature. Nevertheless, it was apparent from the results observed that compared to the ambient laboratory conditions, humidity and temperature conditions within the chamber significantly affected the adhesive resin's shear bond strength to dentin (14.29 ± 5.07 MPa for ambient conditions in the laboratory, and 7.14 ± 3.12 MPa for the chamber). The shear bond strength is probably dependent upon the development of a hybrid layer, although the significance of differences in the morphology of the hybrid layer remain unknown (Van Meerbeek and others, 1996).

It might be speculated that moisture contamination from the intrachamber environment caused a decrease in the surface energy of the primer after it was applied and dried. That, in turn, affected its wettability with respect to the adhesive resin. This decrease in wettability could result in the lower shear bond strengths observed. The chamber did not allow for the replication of the cyclical nature of the oral cavity, i e, the down time between inhalation and exhalation when the oral cavity could, in fact, be drier than the chamber, as noted by Plasmans and others (1993). This phenomenon could be responsible in some degree for the results observed. Another possibility might be that the dentinal surface was not dry when the primer was applied, as directed by the manufacturer's instructions, due to the high humidity in the chamber. In this case the primer, even though it is described as being hydrophilic in nature, may not have penetrated the dentinal surface to the degree desired. This circumstance might be similar to that noted when testing procedures include a simulation of fluid release from the dentinal tubules as a result of the intrapulpal pressure. Yet another factor to consider would be that a threshold level of either humidity or temperature, or both of these factors, could be involved in producing the results observed. Determination of such a threshold value would require further research. It is possible that a similar factor, e g, a decrease in the surface energy of the primer, as was suggested for the dentinal specimens fabricated in the chamber, may be operating here as well.

The results of the present study, along with those of Fundingsland and others (1992) and Plasmans and others (1993), confirmed that for the adhesive system evaluated in this study, conditions of humidity and temperature simulating those found intraorally can have a very negative effect on the bond strength of an adhesive resin to dentin. As this study used only one adhesive system, extrapolation of these findings cannot be made to other systems. Further work under similar conditions using other adhesive systems would be beneficial. For dentists to draw meaningful conclusions from laboratory adhesion tests, the tests should allow for effects of intraoral conditions, such as temperature and humidity, as well as other potentially significant variables that would be encountered in clinical practice.

CONCLUSIONS

Humidity and temperature approximating those found intraorally produced a decrease in bond strength to dentin for an adhesive resin, when compared to bench-top ambient conditions. It is suggested that these conditions (in addition to moisture from intrinsic sources) be simulated in in vitro tests used to evaluate the effectiveness of adhesive systems if these tests are to be as realistic as possible and have maximum relevance for the practicing dentist.

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Resin-modified Glass Ionomers: Dentin Bond Strength versus Time

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Clinical Relevance
It is important to consider the rate of development of dentin adhesion to allow the materials sufficient maturation time prior to functional loading or other external stress applications.

SUMMARY

Most dentin bond strength tests of resin-modified glass-ionomer cements have been conducted after at least 24 hours' storage in water. In a clinical situation, debonding might occur soon after the restoration was placed if subjected to stress. The purpose of this study was to investigate the rate of development of shear bond strength of resin-modified glass-ionomer cements, two Type IIs of which, Fuji II LC and Vitremer, were used. A conventional glass-ionomer cement, Fuji II, and a resin composite, Herculite XRV/OptiBond system, were also employed as controls. Bovine incisors were mounted in self-curing resin, and the facial surfaces wet ground with 600-grit SiC paper to expose dentin. Materials were condensed into a vinyl mold and bonded following the manufacturers' instructions. The shear bond strengths of 10 specimens per group were measured at a crosshead speed of 1.0 mm/minute after 1, 5, 10, 30, and 60 minutes' and 2, 5, and 24 hours' storage in water at 37 °C. One-way ANOVAs followed by the Dunnet test ($P < 0.05$) were used to test for significant differences between the mean bond strength at 1 minute and each of the other test periods. The test period when there was a significant increase in bond strength was defined as the "initial increasing time." The dentin bond strengths of all the materials tested increased with prolonged storage time. The initial increasing times were 10 minutes for Fuji II LC and OptiBond, 20 minutes for Fuji II, and 60 minutes for Vitremer. The differences in the initial increasing time might have clinical implications if the restoration is subjected to significant stress immediately after placement.

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INTRODUCTION

Conventional glass-ionomer restorative materials offer attractive mechanical and physical properties, such as adhesion to wet tooth structure for good marginal sealing, good shade selections, the release of fluoride ions over a prolonged period of time (Swartz, Phillips & Clark, 1984), and good biocompatibility (Walls, 1986). Compared with resin composites, the major disadvantages of conventional glass-ionomer cements are water sensitivity in early stages of setting/hardening and susceptibility to damage by excessive moisture or desiccation (Causton, 1981). To reduce these weaknesses, resin-modified glass-ionomer restorative cements, whose setting is due to dual- or tri-cure reactions, have been developed (Smith, 1990; Mount, 1994). Mixing powder and liquid initiates the acid/base setting reaction of conventional glass-ionomer cements. In addition, light exposure initiates polymerization of resin components. The resin-modified glass-ionomer cements have a longer working time, so that operators have control over the setting reaction by light exposure. The light-activated setting reaction results in early development of bond strength and higher moisture resistance compared to a conventional glass-ionomer cement (Smith, 1990).

In a clinical situation, debonding might occur soon after the restoration was placed if it was subjected to stress. These stresses may be due to the restorative procedure, contraction shrinkage of the material, or normal oral function such as mastication. Sufficient mechanical strength is one of the determinant factors contributing to the clinical success of dental restorations, and 24-hour data has been used to measure the bond strength to dentin. Burrow and others (1994) reported the importance of early bond strength of dentin bonding systems and stated that the materials used in restorative dentistry must be strong enough to withstand both long-term and short-term forces.

The purpose of this study was to evaluate the rate of development of shear bond strength from 1 minute to 24 hours after curing, and to investigate the differences in behavior among the materials studied.

METHODS AND MATERIALS

The resin-modified glass-ionomer cements employed in this study were Fuji II LC (GC Corp, Tokyo, Japan) and Vitremer (3M Dental Products, St Paul, MN, 55144). A conventional glass ionomer Fuji II (GC Corp) and a resin composite Herculite XRV/ OptiBond system (Kerr Mfg Corp, Romulus, MI, 48174) served as controls (Table 1). The input voltage for the curing unit (GC New Light VL-2, GC Corp) was fixed by using a variable transformer in order to control the light intensity (Miyazaki & others, 1995). The light intensity was adjusted to 600 mW/cm^2 as measured with a dental radiometer (Model 100, Demetron Research Corp, Danbury, CT 06810).

Mandibular incisors from 2-3-year-old cattle stored frozen (-20 °C) up to 2 weeks after extraction were used as a substitute for human teeth. After removing the roots with a low-speed saw (Isomet, Buehler Ltd, Lake Bluff, IL 60044), pulps were removed, and the pulp chamber of each tooth was filled with cotton to avoid penetration of the embedding media. The labial surfaces of the bovine incisors were ground on wet 240-grit SiC paper to a flat surface. Each tooth was then mounted in cold-cure acrylic resin (Tray Resin II, Shofu Inc, Kyoto, Japan) to expose the flattened area and placed in tap water to reduce the temperature rise from the exothermic polymerization of the acrylic. Final finish was accomplished by grinding on wet 600-grit SiC paper until a sufficient area of dentin was exposed. After ultrasonic cleaning with distilled water for 3 minutes to remove the excess debris, these surfaces were washed and dried with oil-free compressed air.

Double-sided adhesive tape with a hole 4 mm in diameter was firmly attached to the flattened surface to restrict the adhesive area, and then these surfaces were treated with the conditioner/primer according to each manufacturer's instructions, as shown in Table 2. For the resin system, bonding agent was applied and then irradiated

Table 1. Materials Tested

Filling Material	Lot #	Conditioner/Primer Bonding Agent	Lot #	Manufacturer
Fuji Ionomer Type II LC	P: 041034 L: 240931	Dentin Conditioner	290501	GC Corp, Tokyo, Japan
Vitremer	P: 474 L: 433	Vitremer Primer	420	3M Dental Products, St Paul, MN 55144
Fuji Ionomer Type II	P: 161021 L: 070921	Dentin Conditioner	290501	GC Corp
Herculite XRV	755010	OptiBond Prime Dual-Cure Activator Dual-Cure Paste	755127 754872 755135	Kerr Mfg Co, Romulus, MI 48174

Table 2. Procedures for Making Bond Strength Specimens

Material	Conditioner/ Primer	Bonding Agent	Mixing Time (P/L Ratio)	Irradiation Time
Fuji II LC	Apply 20 seconds Rinse	—	25 seconds (3.0g/1.0g)	20 seconds
Vitremer	Apply 30 seconds Irradiate 20 seconds	—	45 seconds (2.5g/1.0g)	40 seconds
Fuji II	Apply 20 seconds Rinse	—	30 seconds (2.7g/1.0g)	—
Herculite RV/ OptiBond	Scrub 30 seconds			

with the curing unit. Vinyl molds (height 2 mm, diameter 4 mm) were used to form and hold the restoratives to the dentin surface. The restorative was condensed into the mold, and then compressed with a 0.5 N load followed by light exposure. For the conventional glass-ionomer cement, specimens were allowed to set for 5 minutes in test-room conditions.

After light exposure of the restorations or the setting time of the cement, the finished specimens were transferred to 37 °C distilled water and stored for 1, 5, 10, 30, and 60 minutes, and 2, 5, and 24 hours. After removal of the molds, 10 samples per test group were tested in a shear mode with a Universal Testing Machine (Instron Type 4204, Instron Corp, Canton, MA 02021) at a crosshead speed of 1.0 mm/min. Shear bond strength values (MPa) were calculated from the peak load at failure divided by the specimen surface area. All the tests were conducted at a temperature of 23 ± 1°C and relative humidity 50 ± 5%.

The mean and standard deviation for each group were tested for homogeneity of variance using Bartlett's test, and then subjected to one-way ANOVAs followed by the Dunnet test to test for presence of a significant difference between the mean bond strength at 1 minute and at each of the other test periods. The test period when there first was a significant increase in bond strength was defined as the "initial increasing time." All statistical tests were performed at the 95% level of significance.

After the testing, the specimens were examined by use of an optical microscope (SZH-131, Olympus, Tokyo, Japan) at a magnification of X10 to define the location of the bond failure.

For the ultrastructure observation of the material/dentin interface, bonded specimens stored in 37 °C distilled water for 24 hours were embedded in epoxy resin and then longitudinally sectioned with a diamond saw. The sectioned surfaces were polished with diamond pastes. These surfaces were then subjected to argon-ion beam etching (EIS-200ER, Elionix Ltd, Tokyo, Japan) for 15 seconds for the glass-ionomer cements and 30 seconds for the resin composite with the ion beam (accelerating voltage 1.0 kV, ion current density 0.4 mA/cm^2) directed perpendicular to the polished surface as described by Inokoshi and others (1993). The surfaces were coated in a vacuum evaporator (Quick Coater Type SC-701, Sanyu Denshi Inc, Tokyo, Japan) with a thin film of Au (about 250 μm). Observations were done using a scanning electron microscope (JSM-5400, LEOL Ltd, Tokyo, Japan) at magnifications of approximately X3500.

Table 3. Shear Bond Strengths (MPa) of the Restorative Materials Measured at Various Storage Times

	Storage Time								
Material	**1 Minute**	**5 Minutes**	**10 Minutes**	**20 Minutes**	**30 Minutes**	**60 Minutes**	**2 Hours**	**5 Hours**	**24 Hours**
Fuji II LC	3.5 (1.3)	3.5 (1.2)	**4.9 (1.3)**	5.0 (1.1)	5.7 (1.0)	6.2 (1.0)	6.3 (1.4)	6.5 (1.3)	6.6 (1.0)
Vitremer	1.8 (0.3)	2.2 (0.4)	2.2 (0.5)	2.4 (0.7)	2.5 (0.7)	**3.1 (1.0)**	3.6 (0.5)	3.9 (1.2)	4.2 (1.4)
Fuji II	0.6 (0.3)	0.7 (0.2)	0.7 (0.2)	**1.8 (0.4)**	2.1 (0.2)	2.1 (0.3)	2.2 (0.3)	2.2 (0.3)	2.4 (0.3)
Herculite RV/ OptiBond	6.9 (1.3)	8.0 (1.2)	**11.0 (1.3)**	12.2 (1.6)	12.3 (1.7)	12.7 (1.4)	13.2 (1.4)	13.4 (1.6)	13.5 (1.4)

Standard Deviations are in parentheses; N = 10. Values in bold indicate the first test period of significant increase in bond strength compared with 1-minute value (initial increasing time) found by Dunnet test ($P < 0.05$).

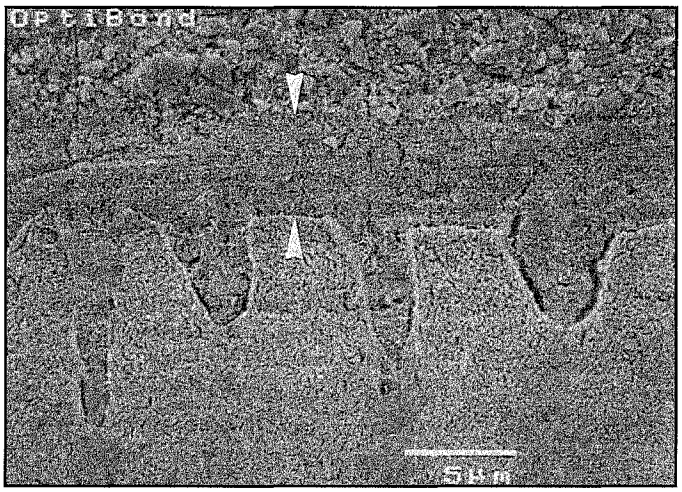

Figure 1. *SEM observation of Herculite XRV/OptiBond bonding system/dentin interface after argon ion etching for 30 seconds (magnification X3500). The hybrid layer was clearly observed (between arrows) between the bonding agent and the dentin.*

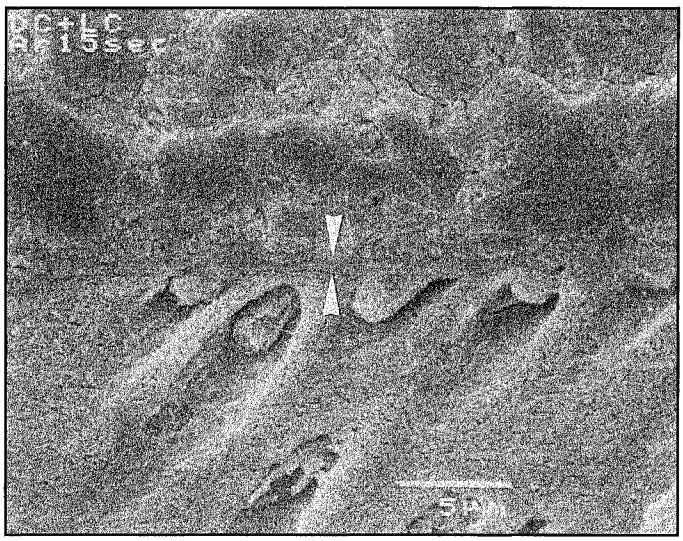

Figure 2. *SEM observation of Fuji II LC/dentin interface after argon ion etching for 15 seconds (magnification X3500). A thin layer of cement matrix/dentin interdiffusion zone (between arrows) was observed on the superficial dentin.*

RESULTS

The data for mean shear bond strength at various time intervals are shown in Table 3. At 24 hours, all the materials tested exhibited the highest bond strength and the values obtained were 13.5 ± 1.2 MPa for OptiBond; 6.6 ± 1.0 MPa for Fuji II LC; 4.2 ± 1.4 MPa for Vitremer; and 2.4 ± 0.3 MPa for Fuji II. The dentin bond strength of all materials tested increased with time, and the increasing tendency was different among the materials. The initial increasing time, when a first significant increase in bond strength was observed, was 10 minutes for Fuji II LC and OptiBond, 20 minutes for Fuji II, and 60 minutes for Vitremer.

The fracture mode of Fuji II LC, Vitremer, and Fuji II was found to be adhesive at the dentin interface and partially cohesive in the cement regardless of the test time period. For OptiBond, which exhibited the highest bond strength, the failure mode was found to be cohesive within the resin, and/or

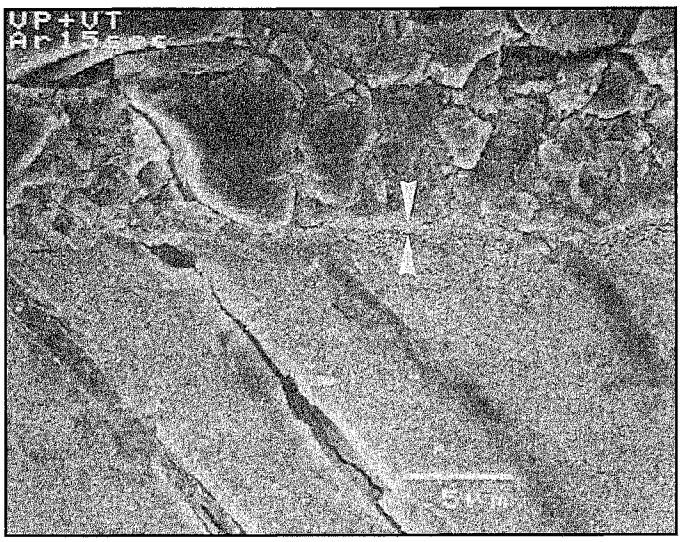

Figure 3. *SEM observation of Vitremer/dentin interface after argon ion etching for 15 seconds (magnification X3500). A thin layer of primer/dentin interdiffusion zone (between arrows) was observed between the cement matrix and dentin.*

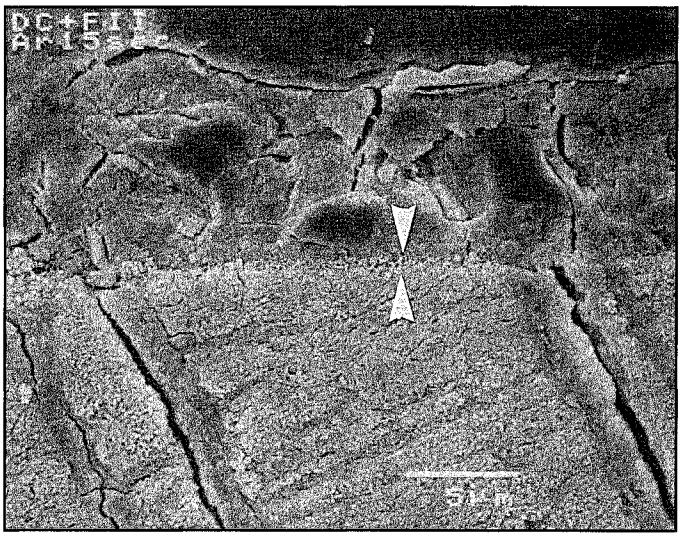

Figure 4. *SEM observation of Fuji II/dentin interface after argon ion etching for 15 seconds (magnification X3500). No layer of cement matrix/dentin interdiffusion zone was observed.*

partially in dentin for all groups after the 10-minute measurement.

Argon ion beam etching of OptiBond revealed the typical structure of the resin-dentin interdiffusion zone (Figure 1). The layer of low resistance to argon ion bombardment was defined as the resin-impregnated dentin layer (hybrid layer). The thickness of the hybrid layer was about 3 μm and was clearly observed between the filled bonding agent and the dentin surface. Though the hybrid layer of Fuji II LC was not clearly seen, a thin layer of cement matrix-dentin interdiffusion zone was observed on the superficial dentin (Figure 2). Vitremer and Fuji II showed the presence of interfacial gaps between the cement and dentin. These gaps were probably due to the dislodgment of the cement from the dentin surface during SEM preparation. Though the evidence of cement matrix-dentin diffusion was not observed, a thin layer (1~2 μm) of primer-dentin interdiffusion zone was observed for Vitremer (Figure 3), but not for Fuji II (Figure 4).

DISCUSSION

It is difficult to obtain the large number of intact extracted human teeth required for conducting bond strength tests. Therefore, bovine teeth were substituted for human teeth, since previous studies (Nakamichi, Iwaku & Fusayama, 1983; Fowler & others, 1992) determined that there was little or no difference in bond strengths between human and bovine teeth. Many dentin bond strength studies have been done using flattened dentin substrates of extracted teeth without the presence of pulpal fluid pressure. However, care must be taken when drawing conclusions from these studies done under standard laboratory conditions, for it might lead to inappropriate conclusions with respect to clinical relevance (Miyazaki, Oshida & Xirouchaki, 1996).

Although the exact mechanism of bonding of glass-ionomer cement to enamel and dentin is still unknown, it seems that the mechanism involves wetting of the tooth surface by the cement and subsequent formation of ionic bonds with the conditioned tooth substrate. It is generally believed that the adhesion of conventional glass-ionomer cements might be the result of the development of an ion-exchange mechanism, polyacrylate ions replacing phosphate ions in the surface of hydroxyapatite (Wilson, Prosser & Powis, 1983). The fractured surface after the bond strength test with the glass-ionomer cements showed adhesive failure as well as cohesive failure in the cement. The bonding of glass-ionomer cement involves various mechanisms such as chemical adhesion, micromechanical interlocking, and interdiffusion into the dentin (Lin, McIntyre & Davidson, 1992).

The bond strengths of the resin-modified glass-ionomer cements were higher than that of the conventional cement, and Fuji II LC showed the highest value among the tested cements. One explanation for this is related to the improvement of mechanical properties by incorporating resin ingredients. The resin-modified glass-ionomer cements are less brittle, less prone to bulk fracture, and should exhibit less marginal fracture than conventional cements (Kovarik & Muncy, 1995). The improvement in their cohesive strength is related to the increase in the resistance to bonding failure.

The increase in bond strength over 24 hours was seen for all materials tested and could be explained by a maturation of the material. Early work on the conventional glass-ionomer cements indicated that there was a continuing increase in the compressive strength of this material over 1 year (Crisp, Lewis & Wilson, 1976). Wasson and Nicholson (1993) proposed that the increase in the strength of the glass-ionomer cements was caused by the formation of a silica matrix network developed after the initial stage of the setting reaction. For the resin-modified glass-ionomer cements, it was reported that the acid-base reaction continued after the cement was light cured, and the poly-HEMA and polyacrylic metal salts formed a homogeneous matrix that surrounded the glass particles (Yoshikawa & others, 1994). Recently developed resin-modified glass-ionomer cements have demonstrated that they reached their initial peak strength by 24 hours and showed stability in a wet environment (Mitra & Kedrowski, 1994; Miyazaki, Moore & Onose, 1996). All these factors contributed to the improvement of their physical properties as well as bond strengths to dentin.

The HEMA concentration of resin-modified glass-ionomer cements provides good wetting ability. For Fuji II LC, which incorporates 10% polyacrylic acid as a dentin conditioner, the cement matrix including HEMA penetrates the demineralized dentin and creates a micromechanical reinforcement (Shono, 1995). Along with the improved mechanical properties of resin-modified glass-ionomer cements, micromechanical retention like that of resin/dentin bonding systems might contribute to dentin bond strength and an earlier initial increasing time.

Vitremer showed a low initial bond strength, and the increase in the bond strength was relatively slow. The initial increasing time of Vitremer was the latest of the tested materials. Vitremer uses a primer that contains HEMA and a copolymer of polyacrylic acid with a photoinitiator. The primer was applied on the smear layer-covered dentin. From the SEM observation of cement/dentin interface, Vitremer showed the presence of gaps and no evidence of a cement matrix-dentin interdiffusion zone, but a primer-dentin interdiffusion zone (Shono, 1995) was observed. This

seemed to be an indication that the bonding mechanism of Vitremer was related more to the development of physical properties of the set cement than chemical interaction of the cement matrix.

It is generally believed that one of the advantages of the resin-modified glass-ionomer cements is the ability to finish and polish them as soon as the completion of light exposure. The present study indicated that clinicians must pay attention to stresses that might occur soon after restoration placement in order to allow materials sufficient maturation time for optimal bonding ability.

CONCLUSIONS

The dentin bond strengths of all the materials tested increased with storage time. The initial strengths of resin-modified glass-ionomer cements were only 50% of those at 24 hours. While the dentin bond strengths of resin-modified glass-ionomer cements were superior to that of the conventional glass-ionomer cement, the initial increasing times were different. The differences of the initial increasing time might have clinical implications if the resulting restoration is subjected to significant stress immediately after it is placed.

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Effect of Various Infection-Control Methods for Light-Cure Units on the Cure of Composite Resins

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F K F LEE • L RAMALINGAM
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Clinical Relevance
The use of a plastic glove or cellophane wrap is recommended for protecting the light-curing unit tip from cross contamination.

SUMMARY

This study (1) compared the curing-light intensity with various barrier infection-control methods used to prevent cross contamination, (2) compared the Knoop hardness value of cured composite resin when various barrier control methods were used, and (3) correlated the hardness of the composite resin with the light-intensity output when different infection-control methods were used. The light-cure unit tips were covered with barriers, such as cellophane wrap, plastic gloves, Steri-shields, and finger cots. The control group had no barrier. Composite resins were then cured for each of the five groups, and their Knoop hardness values recorded. The results showed that there was significant statistical difference in the light-intensity output among the five groups. However, there was no significant statistical difference in the Knoop hardness values among any of the groups. There was also no correlation between the Knoop hardness value of the composite resin with the light-intensity output and the different infection-control methods. Therefore, any of the five infection-control methods could be used as barriers for preventing cross-contamination of the light-cure unit tip, for the light-intensity output for all five groups exceeded the recommended value of 300 W/m^2. However, to allow a greater margin of error in clinical situations, the authors recommend that the plastic glove or the cellophane wrap be used to wrap the light-cure tip, since these barriers allowed the highest light-intensity output.

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INTRODUCTION

A high quality of infection control must be practiced by health care professionals. However, this should not be done at the expense of efficient and effective treatment of dental patients. The light-cure

unit is no exception, for studies have shown that cross-contamination during the handling of light-cure units can occur (Autio & others, 1980; Cottone, Terezhalmy & Molinari, 1991a; Miller & Palenik, 1994).

There are two methods of infection control for light-cure tips. One of them includes using disinfectants such as ethyl alcohol, glutaraldehyde, hypochlorite solutions, iodine detergent scrubs, and benzalkonium chloride to disinfect the light-cure tips after each patient (Autio & others, 1980; Wood, 1992). The other method involves the use of nonopaque barriers such as plastic wrap, plastic gloves, fingercots, or Steri-shields to cover the light-cure tips (Cottone & others, 1991b). The use of nonopaque barriers eliminates the possibility of damaging the light-cure tip by the use of disinfectants. It is also easier and more effective to wrap the tip than to handle and disinfect it (Miller & Palenik, 1994). However, the use of disinfectants does not prevent the adhesion of restorative material residue to the light-cure tip. Nonopaque barriers, on the other hand, may decrease the light-intensity values.

The factors that influence the cure of composite resins are (1) light intensity, (2) diameter of light tube, (3) distance of light from the curing surface, (4) type of light, (5) shade, surface area, and thickness of composite resin, (6) duration of cure, and (7) the angle of the incident light.

Light output is influenced by low voltage, condition of bulb and filters, deposition of resin at the curing tip, and fracture of fiber-optic bundles within the light-cure unit (Sakaguchi, Douglas & Peters, 1992). Thus, a radiometer should be used regularly to determine the light intensity emitted by the light-cure unit (Lee & others, 1993). Most curing units emit light wavelengths between 424 nm and 515 nm, which is ideal for curing composite resins (Lee & others, 1993; Fowler, Swartz & Moore, 1994).

The purposes of this experiment were to (1) compare the curing-light intensity with various barrier infection-control methods, (2) compare Knoop hardness values of a composite resin using various barrier infection-control methods, and (3) compare the hardness of cured composite resins when different infection-control methods were used.

METHODS AND MATERIALS

Infection Control Methods

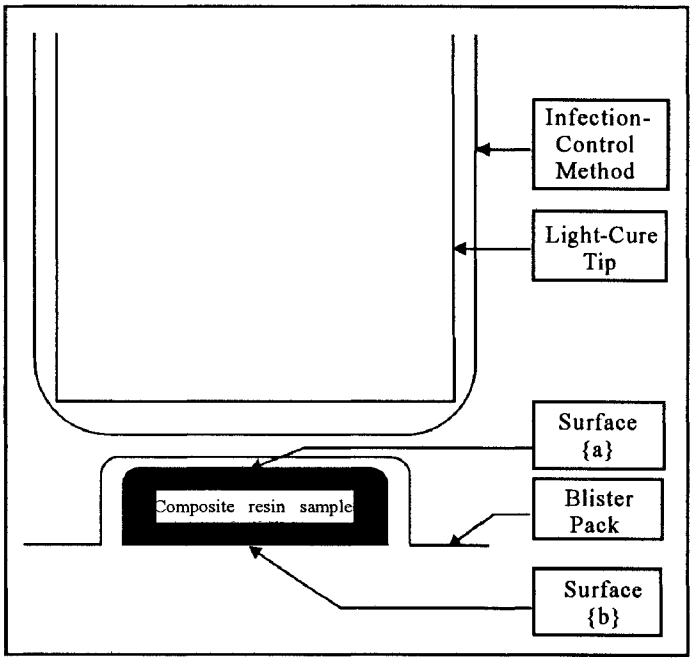
The infection-control methods tested were finger cots (Ammeda, Taiwan), Steri-shields (Steri-Shield Products, Ivyland, PA 18974), cellophane wraps (Lucky Wrap, Korea), dissection plastic gloves (Ammeda), and one without any infection-control method, as a control. Each type of barrier was randomly selected and subsequently placed over the tip of a new light-cure unit (Spectrum, L D Caulk/Dentsply, Milford, DE 19963).

Preparation of Composite Resin Sample

Concurrently, the composite resin Z100 Shade A2 (3M Dental Products, St Paul, MN 55 144) was placed up to the brim of blister packs (8.0 mm x 3.0 mm) with the aid of a spatula (Ash, Dentsply Ltd, Surrey, England). Entrapment of air was eliminated by squeezing the composite resin outwards from the base of the blister packs, compressing it thoroughly and removing any excess with the spatula.

Light-Cure Intensity and Polymerization of the Composite Resin

With the selected infection-control material still on the tip, the light-cure unit was switched on for 5 seconds for optimal intensity (Sakaguchi & others, 1992). It was then placed over the radiometer sensor (Cure-Rite, L D Caulk/Dentsply) to obtain the first light-cure intensity reading (L1). The light-cure unit was switched off for another 5 seconds before it was switched on again for 5 seconds and subsequently, its intensity was tested on the radiometer for the second light-cure intensity reading (L2). After another 10-second interval (5 seconds off and 5 seconds on), the light-cure unit, with the selected infection control, was placed perpendicularly to and in contact with the bottom surface (Surface {a} in Figure 1) of the blister pack, allowing polymerization



Curing of composite resin sample

Table 1. Relationship between Light Intensity and Hardness for the Various Infection-Control Methods

GROUP	SAMPLE SIZE	LIGHT INTENSITY (Mean) W/m²	HARDNESS (Mean) KHN kg/mm²
Control (R)	16	584.29 ± 19.23	96.87 ± 14.11
Steri-shield (B)	16	383.00 ± 27.05	92.93 ± 14.29
Finger Cot (Y)	16	326.27 ± 32.53	82.85 ± 18.17
Plastic Glove (O)	16	533.25 ± 22.79	80.62 ± 12.99
Cellophane Wrap (G)	16	566.31 ± 27.09	86.95 ± 9.74

of the packed composite resin to be carried out for 40 seconds (3M Restorative Z100 Product Profile Manual) (Figure 1) (Williams & Johnson, 1993). The light-cure unit was then switched off for 5 seconds and switched on again for another 5 seconds for the third light-cure intensity reading (L3).

The packed composite resin was then removed from its container and labeled on its cured surface (Surface {a} in Figure 1) with the appropriate code (B = Steri-shield; Y = Finger Cot; O = Dissection Plastic Glove; R = Control; G = Cellophane Wrap) and its sample number for that group. Once labeled, the sample was stored in its corresponding opaque water-filled container.

The procedure was repeated 80 times (16 samples for each of the infection control methods and the control).

Hardness of the Composite Resins

After a period of 24 hours, the 80 samples were smoothed on the unlabeled side (Surface {b} in Figure 1) with 1000-grit sandpaper (Diamond Brand Sandpaper, China) to a thickness of 2.5 ± 0.1 mm as verified by Vernier calipers (Zurcher Modell, Dentaurum, Ispringer, Germany).

The Knoop Hardness value of each sample was recorded at three different points within the central part of the sandpapered surface (Surface {b} in Figure 1) using the Digital microhardness tester (MXT50, Matsuzawa Seiko Co, Tokyo, Japan).

RESULTS

Light-Intensity Output

The mean values for the light intensity of the control, Steri-shield, finger cot, plastic glove, and cellophane wrap groups were 584.29 W/m², 383.00 W/m², 326.21 W/m², 533.25 W/m², and 566.31 W/m² respectively (Table 1).

Bartlett's test showed that the variances of the various groups were significantly different. The Kruskal-Wallis analysis (KW) was used. The KW value light intensity was 67.73, $P = 0.0000$. Therefore, there was a significant statistical difference in the light-intensity output among the five groups.

Knoop Hardness Values

The mean values for the hardness obtained by the Knoop Hardness test were 96.87 kg/mm², 92.93 kg/mm², 82.85 kg/mm², 80.62 kg/mm², and 86.95 kg/mm² for the control, Steri-shield, finger cot, plastic glove, and the cellophane wrap respectively (Table 1).

Bartlett's test also showed that the variances of these groups were significantly different. So the Kruskal-Wallis analysis was used. A KW value of 8.14, $P = 0.0866$ for the Knoop hardness was determined. Therefore, there was no significant statistical difference in the Knoop Hardness values among the five groups.

Analysis between Light Intensity and Hardness

Pearson's correlation analysis ($P = 0.05$) was used to determine the correlation between light intensity and Knoop hardness values. No significant difference was found, so it was concluded that light intensity and composite hardness were not correlated for the various groups nor for the combined group. Rank correlation coefficient analysis confirmed the same observations (Table 2).

DISCUSSION

The light-cure unit was activated for 5 seconds before any light reading was taken or any curing done. This allowed maximum light intensity to be attained. As part of the experimental method, two consecutive light-intensity readings were taken, followed by curing the composite resin sample, then a third light-intensity reading was taken. This procedure was adopted so that the average light intensity would include one reading after the composite resin. That would allow the average light intensity to take into account any possible degradation caused by a continuous period of use.

The determination of hardness of the samples was done on the side furthest from the light-cure tip (Surface {b} in Figure 1). This was done because any diminishing light intensity would adversely affect the cure and hardness of the composite resin, because

Table 2. Correlation Analysis between Light Intensity and Hardness

GROUP	r-VALUE	p-VALUE	RCC*	p-VALUE
Control (R)	-0.1747	0.5176	-0.0059	0.9818
Steri-shield (B)	0.0066	0.9805	0.0618	0.8109
Finger Cot (Y)	-0.2395	0.3716	-0.3353	0.1941
Plastic Glove (O)	-0.0664	0.8070	-0.1634	0.5269
Cellophane Wrap (G)	-0.1592	0.5559	-0.2059	0.4252
Overall	0.0249	0.8264	0.0451	0.6884

*Rank correlation coefficient

this area was the furthest away from the light source.

Light intensity ranged from 326.27 W/m^2 (finger cot) to 584.29 W/m^2 (control). Possible factors that could account for this range included thickness of the infection control material used and the degree of opacity of the material. The Cure-Rite Radiometer instruction manual states that any light intensity above 300 W/m^2 is considered adequate for curing composite resin. Thus, within the experimental conditions, light intensity was at or above acceptable curing levels using any of the tested infection control barrier methods.

Hardness varied from a low of 80.62 kg/mm^2 (plastic glove) to 96.87 kg/mm^2 (control). This range included the stated hardness of Z-100 of 84.5 kg/mm^2.

When hardness versus light intensity was analyzed, no statistical significance was noted. This was probably due to the fact that the light intensity in all cases was sufficient for complete curing of the composite resin.

It could be seen under the experimental conditions that emitted light intensity was sufficient regardless of the infection-control method used. However, several points must be noted before relating the experimental results to clinical use. They are:

1. The condition and age of the light-cure unit. Increased age and wear can diminish emitted light intensity. Also, any residue that adheres to the light tip can reduce light intensity (Strassler, 1992).

2. Distance and access of the light tip to the resin restoration in vivo. In this experiment, the light tip was brought to less than 0.5 mm from the composite resin. This is not always clinically possible: for example, in approximal boxes of class 2 restorations where the light tip must be placed further away. Therefore, additional studies are needed more closely simulating "non-ideal" clinical conditions to determine whether light intensity would remain above the 300 W/m^2 level during more normal conditions.

CONCLUSIONS

The following conclusions were reached:

1. Statistically significant differences occurred in light intensity among the five infection-control methods used in this experiment. However, all recorded values remained above the threshold (300 W/m^2) required for adequate curing of the composite resins.

2. Of the infection-control methods used for the light-cure tip, use of the cellophane wraps and plastic gloves allowed the highest light-cure intensity.

3. No correlation between Knoop hardness and light intensity was found for any of the methods, nor was there any correlation between infection-control method and resulting hardness of the composite resin.

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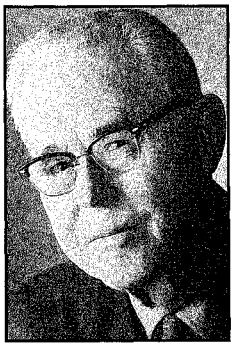
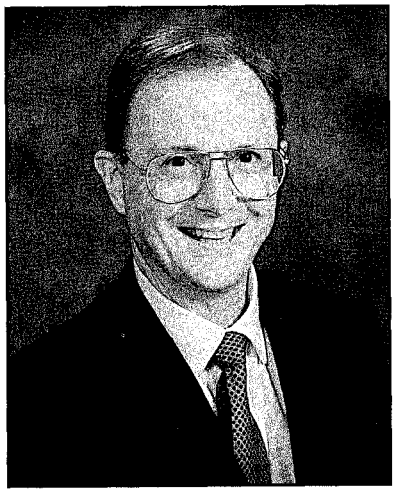
Hollenback Prize for 1998



George Hollenback



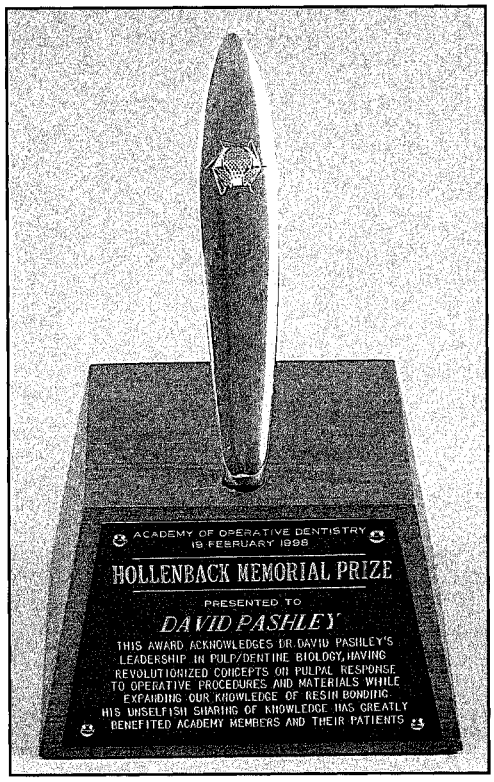
David Pashley

Dr David Pashley is the primary leader in the dynamics of pulp/dentin biology and interactions with dental materials. His investigations into dentin permeability have revolutionized concepts on pulpal response to operative procedures and has expanded our knowledge of bonding characteristics of resin systems.

David Pashley graduated from the University of Oregon Dental School in 1964 and earned a PhD in physiology at the University of Rochester. He is presently Regents' Professor of Oral Biology at the Medical College of Georgia, an honor given to few, for his recognition as an outstanding member of the faculty.

Dr Pashley has published over 200 articles, lectured worldwide, and is referenced routinely by authors for his superb publications. He has received many awards, including Outstanding Teacher, Outstanding Faculty, Distinguished Scientist from the International Association for Dental Research, and has been our Buonocore Lecturer.

David Pashley is an outstanding individual, and in his relentless pursuit of excellence, he invites investigators from around the world to train in his laboratory. In his willingness to share his knowledge, he is a compassionate, empathetic mentor who is well deserving of the loyalty and gratitude expressed by those privileged to be associated with him.



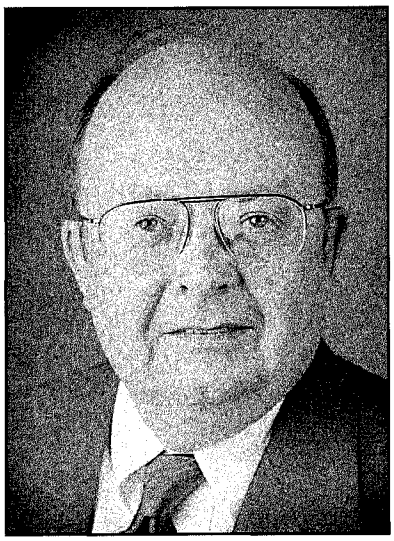
Dentists and their patients have benefited greatly from Dr Pashley's monumental work. The Academy of Operative Dentistry is honored to present the Hollenback Prize for 1998 to Dr David Pashley.

JOHN W OSBORNE

Award of Excellence

To say that I am honored to present this Award of Excellence to Dr Greg Smith would be the understatement of the year.

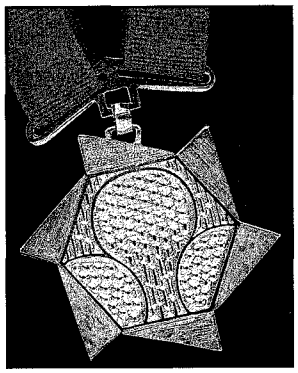
Dr Smith is presently professor and chair of the Department of Operative Dentistry at the University of Florida. He began his professional quest at the University of Washington, where he completed his DDS training and earned his master's degree in restorative dentistry. He stayed on as an assistant professor in operative dentistry until recruited to the



Gregory E Smith

University of Florida in 1972 to set up the gold foil and casting program. It was here that he began his association with this Academy, serving as assistant secretary under the tutelage of Dr Ralph Werner for 17 years until assuming the position as secretary in 1990. In 1974, Greg was lured to the University of Colorado to assist in the building and development of their new dental school. He was appointed chair of the Department of Dentistry and served in that capacity, while doubling as associate dean, until 1979, when the call came to return to chair the Department of Operative Dentistry at Florida, a position he has retained to this day.

While making this academic trek, Greg utilized his spare time to serve his profession in a number of capacities. He held at various times positions as deputy and vice regent of the International College of Dentists. Aside from this academy, he served as secretary and eventual chair of the Operative Section of the AADS, one of more than two dozen chair positions he has held. He has touched every avenue of learning and teaching, having contributed more than 50 articles to journals, produced dozens of slides and videotapes, and written a number of chapters for textbooks. Since 1987 he has been the operative



dentistry editor for *Clark's Clinical Dentistry*. He is listed in *Who's Who in Health Care*, and he is a fellow of the American Academy of Restorative Dentistry, as well as founding mentor of the Centennial Dental Study Club and the José Medina Study Group. There is a noticeable thread of interaction with students throughout his academic history, proving that he just plain loves working with young people. As proof of this, he was chosen Outstanding Clinical Instructor at the University of Washington in 1971, and elected by the University of Florida dental students as class advisor in 1986, 1989, and 1992. In addition, he was chosen Clinical Professor of the Year in 1989, and he accepted the award for Department of the Year given by the graduating class of 1997.

It is, therefore, with the greatest of personal pleasure that I represent this academy in conferring the Award of Excellence to Dr Gregory E Smith.

WILLIAM N GAGNON

DEPARTMENTS

LETTER

CARIES-RISK TREATMENT--WHERE ARE YOU?

I wish to compliment you for the insightful comments made in your recent editorial, "Caries-Risk Treatment--Where Are You?" [22(6):241]. I would like you to know that the implementation of a comprehensive clinical cariology program is well underway at the University of Florida College of Dentistry. This is a clinical program with didactic and research components designed to provide our dental students with a fundamentally sound and contemporary knowledge base that includes the nature, process, detection, diagnosis, treatment, and monitoring of the disease Dental Caries. To this end, two new courses are presented: "An Introduction to Clinical Cariology" in semester 1, and "Advanced Clinical Cariology" in semester 5. Eighteen faculty members from 10 different disciplines have come together to plan, develop, and present these two courses.

While the program is under the direction of the Department of Operative Dentistry, it has received broad support from the rest of the school. We are uniquely fortunate in having several nationally and internationally recognized scientists conducting funded research that could reflect significantly on the future treatment of dental caries. Many of them are members of the Advanced Clinical Cariology teaching team. We are convinced that students who have a comprehensive understanding of the nature and process of dental caries will better appreciate and implement new knowledge, relevant to treatment.

One additional positive result of implementing this program has been an emerging interest in clinical research that deals with caries detection, monitoring caries progression, and nonsurgical caries intervention regimens. An effort is made to include dental students in these studies, reinforcing both the didactic and clinical elements of our program.

Clinically, the students are required to construct a Cariogenic Profile for each new patient. This profile includes an assessment of disease activity and prevailing predisposing factors. Using this information, a Phase I treatment plan is formulated that will suppress the pathogenic population, thus reducing the cariogenic potential of the plaque. By integrating this modality with conventional efforts to increase tooth resistance to acid and restrict frequency of substrate exposure, an oral environment is established that will promote reversal of the disease process and remineralization. The incidence of new and/or recurrent lesions will diminish and the restoration/re-restoration cycle will be broken or avoided. The long-term prognosis of definitive restorative treatment should also be improved, especially in those patients where recurrent caries is a common cause of failure. With the infection under control, the student enrolls the patient in our Health Maintenance Clinic.

The development of the clinical cariology program has been good for our dental school. The study and treatment of dental caries is common ground among disciplines and serves as a catalyst for the blending of scientific credibility with clinical relevance, a union fundamental to the evolution of our understanding and treatment of this disease.

T DWYGHT CLARK, DDS
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BOOK REVIEWS

PROCEEDINGS OF THE SECOND EUROPEAN WORKSHOP ON PERIODONTOLOGY

Edited by Niklaus P Lang, Jan Lindhe, and Thorkild Karring

Published by Quintessence Publishing Co, Inc, Chicago, IL, 1997. 427 pages, 71 illustrations. $68.00, softbound.

Lang, Karring, and Lindhe have edited the *Proceedings of the Second European Workshop on Periodontology* very skillfully. A total of 47 contributors have provided those interested in the current thinking and research in chemicals in periodontics with a very readable document. This text follows the proceedings of this five-session conference in a clearly outlined fashion. The reader is able to select from the outline specific areas of interest without having to wade through the text in search of answers to significant clinical questions.

The five sessions focused on chemicals and their impact on microbes, plaques, bone grafting, root surfaces, and selected mucosal disorders affecting the gingiva. Both consensus reports and minority statements on sessions are included.

Summary tables are liberally distributed throughout the report, making data review easy. Topics are question-based, which this reviewer found made cruising the report both easy and enjoyable, as brief snatches of time were available to refer to the contents.

For serious clinicians interested in keeping their diagnostic and therapeutic skills up to par with the continuous influx of research and clinically based data available, this text is a must purchase.

ROBERT C KEENE, DMD
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Hanover, NH 03755

ORAL IMPLANTOLOGY: BASICS, ITI HOLLOW CYLINDER SYSTEM Second Revised Edition

Andre Schroeder, Franz Sutter, Daniel Baser, and Gisbert Krekeler

Published by Thieme Medical Publishers, Inc, New York, 1996. 528 pages, 490 illustrations. $30.00, softbound.

This text is well organized and has been updated with sound material gathered by scientific studies and clinical trials. It does a beautiful job familiarizing the reader with implants in general, then it gives a comprehensive overview of the ITI system, and compares it to other systems. The translation from German to English by Dr Jacobi is clearly written.

Dr Andre Schroeder and co-authors are well qualified to write a text covering this topic. They have written many papers on dental implants. Dr Schroeder and the ITI group have worked closely for over 20 years with Insitut Straumann. This company developed its first dental implant in 1974, although their knowledge on biomechanics, biocompatibility, and bone physiology dates back to 1960, with their involvement in orthopedic research and product development. Dr Schroeder published a paper in 1976 showing for the first time the histological phenomenon of osseointegration. The ITI system, by being the pioneer in nonsubmerged implants and titanium plasma spray, has plenty of data and information to share.

This second edition was planned soon after the first because of how rapidly the first sold out. The intent with this edition was to include advancements in implant and superstructure design as well as aesthetics. The 17 chapters are a collaboration of 12 individuals, each contributing within their expertise and giving each chapter the importance it deserves.

The first four chapters are almost identical in content to the first edition. They give a concise but well-rounded review of materials, biocompatibility, mechanical properties, and anatomy, including age-related anatomical changes, and implant history. There is also a detailed section covering titanium and plasma spray chemical behavior. The following two chapters have minor changes. These chapters cover stages in the development of the ITI system and a thorough look at tissue response with histological specimen findings and conclusions. Biomechanics and implant manufacturing procedures have been left out of chapter 5 to be later covered in chapter 7.

Chapters 7-15 are where the major changes in content have occurred. They do an excellent job covering the clinical aspects of oral implantology. They provide the reader with a rich appreciation of ITI's one-stage implant system and the Morse taper friction design. The various single cylinder one- and two-part implant designs now available from ITI are covered. What I like most about this text is how it takes you through the treatment planning phase, surgical and prosthetic treatment, and follow-up stages of various treatment modalities. It does this in a step-by-step manner, almost cookbook style. Considering its style, I believe it can also be used as an ITI manual. In most chapters, the authors make an effort to use bullet charts, boxes, and tables to identify content and clinical relevance.

Chapters 14 and 15 give emphasis to peri-implant problems and complications with ITI implants. Once again they use the same step-by-step format to cover current treatment concepts on how to proceed when these complications arise. This section of the book is extremely valuable, as the number of complications will without doubt rise as implant placement increases.

The last four chapters on documentation and statistics, long-term results, legal considerations, and final remarks are very similar if not the same as in the first edition.

I highly recommend this textbook to anyone involved in implant research or therapy and believe it would be a great addition to every dental school library. Other comments worthy of mentioning are: 1) Its unusually small size and softbound cover is convenient, but the small point lettering, which is in

proportion to its size, may be difficult to read; 2) It can be an excellent source of reference, although the style used, where references are not noted by number, makes them more difficult to look up.

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ORAL REHABILITATION: CLINICAL DETERMINATION OF OCCLUSION

Sumiya Hobo and Hasao Takayama

Published by Quintessence Publishing Co, Inc, Chicago, 1997. 169 pages, 481 illustrations, $55.00.

Occlusion, for many practitioners, is more like following religious scripture than adhering to sound scientific principles. This text moves well to the other extreme by discussing current dogmas and their inadequacies, and presents a technique based on the mathematics of the stomatognathic systems. This method of occlusal reconstruction is termed the Twin-Stage Procedure, because it begins by developing the posterior occlusion first in order to achieve eccentric harmony and then develops the anterior disocclusal component.

The text begins with a good review of the components of mandibular movement, and then develops a rationale for which components are important to consider in setting an articulator. The authors feel that a semi-adjustable articulator is the preferred instrument, since it allows a straight outward movement of the working-side condylar path on the transverse horizontal axis. Another important tenet of this system deals with which important aspect of occlusion is necessary to use to program the articulator. For the authors, the condylar path and the incisal path are too variable to use as a standard to set the articulator. Through their own studies, they have determined that the cusp inclination is more predictable; therefore, this is what drives the programming. Numerous mathematical studies by the authors on mandibular movement are utilized to add credence to their philosophy and technique. The remaining chapters show the reader the clinical techniques for various situations through text and figures.

Although there are impressive geometric studies showing mandibular movement and its correlation with the Twin-Stage Procedure, the whole philosophy is based on an inference that the estimated cusp angle should be reproduced for all occlusal reconstructions. This may connote a dogmatic approach, if every situation falls into this recipe.

This text book is a good addition for students of occlusion who wish to broaden their understanding of mandibular movement and occlusal reconstruction.

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UNIVERSITY OF MARYLAND

The University of Maryland Dental School, Department of Restorative Dentistry (consisting of operative dentistry, fixed and removable prosthodontics, and biomaterials) is seeking applicants for a full-time, tenure-track position at the rank of assistant/associate professor. A primary focus of this position will be directing faculty and students in clinical research activities for the Department. Additionally, the appointment involves teaching in the DDS and advanced dental education programs of the Department. The successful candidate will be expected to attract external research/clinical trial funding.

Requirements for the position include a DDS/DMD or equivalent, eligibility for Maryland state licensure, a demonstrated record in both in vitro and clinical research activities, and prior teaching experience in one of the disciplines of the Department. Additionally, advanced research training in a relevant biomedical field is preferred.

Salary and rank are commensurate with experience and credentials. Intramural practice opportunities are available. The University of Maryland is an AA/EOE/ADA employer and is committed to diversity in all areas. For best consideration, please submit by 15 May 1998 a letter of interest, curriculum vitae, and names and addresses of three (3) references to:

Dr Morton Wood, Chair
University of Maryland Dental School
Department of Restorative Dentistry
666 West Baltimore Street
Baltimore, MD 21201
Tel: (410) 706-7047

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Operative Dentistry can now accept Visa or MasterCard payment for subscriptions and other services. We will need the usual information: type of credit card, credit card number, expiration date, and name as it appears on the card.

THE TUCKER INSTITUTE

A course on cast gold restorations mentored by Richard V Tucker will be held at the University of Washington in Seattle on 22-26 June 1998. During this five-day clinical course each clinician will prepare and seat at least four castings and will be assisted in doing the laboratory procedures for at least one case.

The fee for the course is $2000.00; a deposit of $400.00 is required to hold a position, and the balance will be due by 25 May. Make checks payable to the Academy of R V Tucker Study Clubs and send in care of:

Dennis Miya, DDS
14027 Ambaum Blvd SW
Seattle, WA 98166
Tel: (206) 244-1618; FAX: (206) 431-9800

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Volume 21 of *Operative Dentistry* (1996, six issues) has been bound and is available for purchase from the Editorial Office in Seattle. Individual volumes sell for $35.00 each plus postage. The entire set of 21 volumes sells for $480.00 plus postage. Checks or money orders should be made payable to Operative Dentistry and sent to:

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Submit the original manuscript and one copy; authors should keep another copy for reference. Type double spaced, including references, and leave margins of at least 3 cm (1 inch). Supply a short title for running headlines and a FAX number for the corresponding author. Spelling should conform to *American Heritage Dictionary of the English Language,* 3rd ed, 1992. Nomenclature used in descriptive human anatomy should conform to *Nomina Anatomica,* 6th ed, 1989. The terms *canine* and *premolar* are preferred; the terms *vestibular*, *buccal*, *facial*, and *lingual* are all acceptable. SI (Système International) units are preferred for scientific measurement, but traditional units are acceptable. **Proprietary names of equipment, instruments, and materials should be followed in parentheses by the name and address, including ZIP code, of the source or manufacturer.** The editor reserves the right to make literary corrections. Research (original) papers must include a one-sentence **Clinical Relevance** statement, as well as **Summary**, **Introduction**, **Methods and Materials**, **Results**, **Discussion**, and **Conclusion** sections. Clinical papers should contain at least the following: **Purpose**, **Description of Technique** or **Solution** along with materials and potential problems, and a **Brief Summary** outlining advantages and disadvantages.

Authors who prepare their manuscripts on a word processor are to submit a computer disk of the manuscript (3½ - or 5¼-inch) in addition to the original typed manuscript. Identification of the operating system (Macintosh or IBM-compatible) and the word processing program used is necessary. Authors should also retain an additional manuscript copy on disk to facilitate altering the paper in response to comments by referees.

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Submit four copies of each illustration. **Line drawings** should be in india ink or its equivalent on heavy white paper, card, or tracing vellum. All lettering must be of professional quality, be legible against its background, and remain proportionally legible if reduced. Type legends on separate sheets. **Graphs** are to be submitted with any lettering proportional to their size as indicated for illustrations, and with their horizontal and vertical axes values **as well as all values used to create the graphs**. **Photographs** should be on glossy paper with a maximum size of 15x20 cm (6x8 inches). For best reproduction a print should be one-third larger than its reproduced size. Only black-and-white photographs will normally be accepted. On the back of each illustration, near the edge, indicate lightly in pencil the top, the author's name, and the number of the figure. Where relevant, state staining technique(s) and the magnification of prints. Obtain written consent from holders of copyright to republish any illustrations published elsewhere. Photographs are considered property of *Operative Dentistry*.

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Submit two copies of tables typed on sheets separate from the text. Number the tables with arabic numerals.

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