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Operative Dentistry publishes articles that advance the practice of operative dentistry. The scope of the journal includes conservation and restoration of teeth; the scientific foundation of operative dental therapy; dental materials; dental education; and the social, political, and economic aspects of dental practice. Review papers, book reviews, letters, and classified ads also are published.

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EDITORIAL

Caries-Risk Treatment--Where Are You?

Excellent research has been done on caries control, and superb speakers have filled their schedules with speaking engagements related to this issue, thereby reflecting the interest dentists have in treating caries as a disease. Yet, the majority of dental schools spend little time on this aspect of student education, and most practicing dentists don't spend time monitoring the caries risk of their patients and educating them concerning how to treat this disease. It certainly isn't because this area isn't important, nor is it because no one is interested or qualified to teach the subject. The answer involves financial reward and education. Both of these *must* be available for there to be a noticeable shift from "drill-and-fill" to prevention. If dentists are reimbursed adequately for the time necessary to inform and motivate patients about the caries process, caries-risk education and treatment would become an integral part of dental practice. Such financial emphasis on prevention would pressure dental schools, by necessity, to accommodate more aggressive teaching of prevention to dental students. Much of the treatment that dentists provide relates to what was taught to them in dental school. Unfortunately, most dental schools are poorly set up to facilitate the kind of caries-risk training needed for students. A smattering of lectures are usually given by various departments within the dental school, e g, Oral Biology, Oral Medicine, Operative, Cariology, etc, as an introduction to the topic. But the effort stops there, as if osmosis is supposed to finish the training process. The missing element is the clinical emphasis and oversight that is so important in making caries-risk assessment a viable part of the student's clinical education. Identifying specific patients in need of caries-risk treatment and then following through with specific requirements and oversight to treat these patients is mandatory, *if* students are going to have the background and necessary tools to treat these patients once they leave dental school. This would be a wonderful opportunity for establishment of an endowment for caries-prevention education and treatment, for there would be only winners. Unfortunately, most endowments are geared toward research, without a direct relationship to the clinical aspect of the program. Another problem is that some departments within dental schools resist a willingness to share teaching responsibilities with other departments. This makes it extremely difficult for a group cooperation effort to teach caries-risk assessment and treatment from beginning to end. The department that should be in charge is the one that must oversee patient contact by the student and is in a position to make such contact a clinical requirement. Students respond positively to requirements, contrary to what many dental school administrators claim. It seems obvious that the Operative or Restorative Department would be the logical choice for overseeing the formation, teaching, and clinical experience of educating dental students to treat caries as a disease.

Much of the education process could be handled by ancillary help. Here in the state of Washington, there is a referendum on the ballot to allow hygienists to practice independently of dentists. If it passes and third-party payers become willing to adequately reimburse the provider of caries-risk education and treatment, stand by for this important treatment modality to be incorporated into hygiene practices. We, as a profession, need to decide whether to be proactive and take charge of this treatment area or be prepared to help others promote reduction and/or elimination of caries. In any event, to make treatment of caries as a disease a reality instead of "table talk," we need to initiate the financial incentives, emphasize and support dental school curriculum, and aggressively promote patient education programs.

RICHARD B McCOY
Editor

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ORIGINAL ARTICLES

Marginal Adaptation of Dental Composites Containing Prepolymerized Filler

W YUKITANI • T HASEGAWA • K ITOH
H HISAMITSU • S WAKUMOTO

Clinical Relevance
Complete marginal adaptation to the cylindrical dentin cavity preparations was observed in two commercially available composites (Estelite and Silux Plus).

SUMMARY

Marginal adaptation to cylindrical dentin preparations of five commercially available dental composites—Charisma, Estelite, Herculite, Pertac, and Silux Plus—and seven experimental dental composites containing prepolymerized filler was evaluated by measurement of the wall-to-wall polymerization contraction gaps. The experimental composites were prepared with varying amounts of spherical inorganic filler particles, irregularly shaped prepolymerized filler particles, and a base resin matrix composed of BIS-GMA and TEGDMA. Cylindrical dentin preparations, approximately 3.0 mm in diameter and 1.5 mm deep, were prepared in the exposed approximal dentin surfaces of extracted human molars. These cavity preparations were pretreated with an experimental dentin bonding system consisting of 0.5 mol/L EDTA, 35% glyceryl methacrylate, and Clearfil Photo Bond, then restored with each composite. Complete marginal adaptation was observed in two composites (Silux Plux and Estelite). Wall-to-wall contraction gaps were significantly related to the amount of ashed inorganic component in the composites ($0.01 < P < 0.05$) and to the spherical inorganic filler content by volume ($P < 0.01$).

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INTRODUCTION

The adaptation of dental composites to dentin in cavity preparations is determined by the efficacy of a dentin bonding system, the behavior of the dental composite during polymerization, and their interaction (Asmussen, 1975). To prevent the formation of contraction gaps and to obtain complete cavity adaptation, the contraction stress of a dental composite induced during polymerization should be overcome by the adhesion of the dentin bonding system employed (Chigira, Itoh & Wakumoto, 1991;

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Chigira & others, 1994; Manabe, Itoh & Wakumoto, 1991a). Furthermore, to bond firmly to dentin cavity walls mediated by a highly effective dentin bonding system, the composite must compensate for all the polymerization contraction by its own flow from the free surface into the cavity. The flow of a composite during polymerization is determined by the interaction between the base resin matrix and the filler particles. The filler particles not only increase the mechanical properties of the composite but also decrease the magnitude of the dimensional changes during polymerization and thermal changes (St Germain & others, 1985; Li & others, 1985; Braem & others, 1989; Chung, 1990). It has been reported that neither the inorganic filler content nor the viscosity of commercially available light-activated composite resins showed any significant correlation with the width of the wall-to-wall polymerization contraction gap in cylindrical dentin preparations. Therefore, it was concluded that the amount of polymerization shrinkage of a dental composite was not directly related to marginal integrity (Fujimitsu & others, 1989). Furthermore, it was demonstrated that the adaptation of commercially available light-activated composites to dentin margins of cavity preparations was incomplete, probably because of the relatively rapid polymerization by light curing, whereas most of the chemically activated dental composites showed complete adaptation to the dentin margins (Kato, Itoh & Wakumoto, 1988). Kato (1987) previously demonstrated that the rate of polymerization significantly affected the marginal adaptation of composites. However, little is known about how the proportion or shape of the filler particles in the composite may influence the marginal adaptation. Recently some composites containing prepolymerized filler particles have become commercially available. In the present study, the wall-to-wall polymerization contraction gaps of five commercially available and seven experimental composites containing prepolymerized filler particles were determined in cylindrical cavity preparations. In addition, the total amounts of inorganic components of the 12 composites were measured by dry ashing.

Table 1. Commercially Available and Experimental Dental Composites Tested

Brand or Code	Manufacturer	Batch #
Charisma	Heraeus Kulzer, Wehrheim, Germany	Ch-B: 021
Estelite	Tokuyama Co, Tokyo, Japan	EUL 462
Herculite	Kerr, Romulus, MI 48174	1 2149, EXP 693
Pertac	ESPE, Seefeld/Oberbay, Germany	Ch-B: MD 0001
Silux Plus	3M Dental Products, St Paul, MN 55144	9A01
S1	Tokuyama Co	experimental
S2	Tokuyama Co	experimental
S3	Tokuyama Co	experimental
S4	Tokuyama Co	experimental
S5	Tokuyama Co	experimental
S6	Tokuyama Co	experimental
S7	Tokuyama Co	experimental

METHODS AND MATERIALS

The five commercially available composites tested are listed in Table 1. Prepolymerized filler particle, spherical inorganic filler particle, and a base resin matrix composed of BIS-GMA and TEGDMA in seven experimental composites were the same as Estelite, while keeping the viscosity at a level for easy manipulation during cavity restoration. The volume percentages of the prepolymerized irregularly shaped filler, spherical inorganic filler, and base resin matrix in experimental composites and Estelite are presented in Table 2.

Wall-to-Wall Maximum Contraction Gap Measurement

A total of 120 extracted human permanent first and second molars were used in this part of the study. After extraction, the teeth were stored in tap water at 4 °C for at least 2 weeks. The approximal enamel was ground wet on 220-grit followed by 600-grit Carborundum paper to expose a flat superficial dentin surface. Cylindrical dentin cavity preparations, approximately 3 mm in diameter and 1.5 mm deep, were prepared on the ground surfaces with fissure carbide burs at high speed and adequate water cooling. The preparation walls were cleansed with 0.5 mol/L EDTA (pH = 7.4) for 60 seconds, washed well with tap water, and dried for 10 seconds by compressed air. The experimental primer, 35% aqueous solution of glyceryl methacrylate (Blemmer GML, Nippon Oil and Fat, Tokyo, Japan), was then brushed onto the cavity walls, left for 60 seconds, and dried for 10 seconds by compressed air. A commercially available dentin bonding agent (Clearfil Photo Bond, Kuraray, Osaka, Japan) was brushed onto the cavity walls,

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Table 2. Components of Commercially Available and Seven Experimental Dental Composites by Volume

Brand or Code	Base Resin Content (V%)	Filler Content (V%) Total	Spherical Filler (S)	Prepolymerized Filler (P)	S/P Ratio
Estelite	28.8	71.1	25	46.1	35/65
S1	28.4	71.6	18.5	53.1	26/74
S2	29.9	70.1	24.7	45.4	35/65
S3	28	72	25.3	46.7	35/65
S4	28.8	71.2	31.9	39.3	45/55
S5	32.5	67.5	37.1	30.4	55/45
S6	30.1	69.9	38.4	31.5	55/45
S7	39.3	60.7	0	60.7	0/100

Components of Base Resin	
BIS-GMA	60 wt%
TEGDMA	40 wt%
camphorquinone	<0.2 wt%
N,N-dimethyl p-toluidine	<0.5 wt%
Components of Prepolymerized Filler	
Base resin	24.4 wt% (38.5 v%)
Zirconium oxide / Titania spherical filler	75.6 wt% (61.5 v%)
Density	
Base resin	1.144 g/cm^3 (unpolymerized) 1.238 g/cm^3 (polymerized)
Zirconium oxide / Titania spherical filler	2.400 g/cm^3
prepolymerized filler	1.953 g/cm^3

dried for 5 seconds, and cured by visible light (Witelite, Takarabelmont Co, Osaka, Japan) for 10 seconds prior to the transfer of the composite into the cavity in one increment. The composite was slightly overfilled in the cavity, pressed gently with a plastic matrix on a glass plate, and light cured for 40 seconds. After storage in tap water at room temperature (24±1 °C) for 10 minutes, excess composite was removed by wet grinding on 1000-grit Carborundum paper to expose the preparation margins and then polished wet with an alumina slurry (0.3 µm in diameter) on a linen sheet. The marginal gap widths between the composite and the dentin walls at the cavity margins were measured with a screw micrometer mounted on an optical lens of a light microscope (Eyepiece Digital, Leitz, Wetzlar, Germany). The maximum contraction gap was calculated and expressed as a percentage of the diameter of the cavity preparations (Asmussen & Jørgensen, 1972). Ten specimens were prepared with each composite.

Evaluation of the Total Amount of Inorganic Components in the Composites

The total amount of inorganic components was determined by dry ashing (ISO 4049, 1978). An unglazed pottery dish was heated at 575±25 °C for 15 minutes in a furnace and cooled to a room temperature of 23±2 °C in a desiccator. The composite pastes, which weighed approximately 0.5 g, were placed in the dish, heated at 200±25 °C for 15 minutes and then at 575±25 °C for 30 minutes in the furnace, then cooled to room temperature. The total amount of inorganic component in the composites was calculated and expressed as weight ratio of the residual inorganic component to the composite paste before heating.

RESULTS

The data relating the maximum contraction gap to the total amount of inorganic components in the composites are presented in Table 3. A complete marginal adaptation was observed in two groups (Estelite and Silux Plus), whereas marginal adaptation was incomplete in the other 10 groups. Among the other commercially available composites, contraction gap formation was observed on seven specimens (Charisma), five specimens (Pertac), and nine specimens (Herculite) out of 10 specimens respectively. The correlation of the polymerization contraction gap to the total amount of inorganic component is presented in Figure 1 as the curve of the second order. While the correlation coefficient was not high ($r^2 = 0.577$), the correlation was significant ($0.01 < P < 0.05$) because of its squared multiple correlation coefficient ($R^2 = 0.571$, n = 12) (Kleinbaum, Kupper & Muller, 1989). The correlations of the gap to prepolymerized filler content and spherical inorganic filler content were presented as the curves of the second order in Figures 2 and 3 respectively. The squared multiple correlation coefficient for the curves in Figure 2 and Figure 3 were $R^2 = 0.800$ (n=8) and $R^2 = 0.902$ (n = 8) respectively. The significance of the correlation of the gaps to spherical filler content was higher ($P < 0.01$) than of the gaps to prepolymerized filler content ($0.01 < P < 0.05$).

DISCUSSION

A complete cavity adaptation of a dental composite restoration is established only when all the polymerization contraction stresses are released to the free surface of the composite and the polymerization

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Table 3. Maximum Contraction Gap and Weight Ratio of Inorganic Components in the Twelve Dental Composites Tested

Brand or Code	Maximum Contraction Gap (%)	Number of Gap-free Specimens (out of 10)	Inorganic Content (wt %) n = 3
Estelite	0	10	68.2 ± 0.4
Silux Plus	0	10	55.5 ± 0.4
S1	0.001 ± 0.004	9	66.2 ± 0.6
S3	0.014 ± 0.018	6	70.9 ± 0.4
S2	0.017 ± 0.025	6	67.5 ± 0.2
S7	0.018 ± 0.037	7	55.3 ± 0.3
Charisma	0.034 ± 0.040	3	71.6 ± 0.9
Pertac	0.040 ± 0.042	5	77.1 ± 0.6
S4	0.046 ± 0.060	5	71.3 ± 0.5
S5	0.049 ± 0.042	2	70.9 ± 0.9
S6	0.066 ± 0.061	3	72.5 ± 0.2
Herculite	0.095 ± 0.050	1	76.2 ± 0.4

contraction is compensated for by the flow of the composite itself. Yanagawa and others (1996) demonstrated contraction gap formation in vivo and in vitro and concluded that the contraction gap measurement in vitro could substitute for the marginal integrity observation in vivo. Polymerization shrinkage after the composite gels (Sakaguchi & others, 1991) also presents a serious problem for maintaining marginal integrity. However, volumetric expansion due to water sorption by the dental composite may compensate for the postgel shrinkage. Koike and others (1990) found that established marginal integrity did not deteriorate and marginal gaps that had formed were decreased when specimens were stored in water. As demonstrated in a previous study (Fujimitsu & others, 1989), the commercially available light-activated dental composites still require some improvement in their adaptation to dentin cavity margins, probably because their filler contents are not optimal for the flow during polymerization. To maximize the mechanical properties and to minimize dimensional change during polymerization and thermal variation, most of the commercially available composites contain prepolymerized fillers and/or inorganic fillers at the highest possible loading. Such a high filler content may cause a lack of cavity adaptation, because the filler particles disturb the flow of the composite paste from the free surface into the cavity preparation. On the other hand, when the prepolymerized filler was incorporated into the paste, the amount of the base resin matrix that contracted during polymerization could be decreased even if the same amount of inorganic component was maintained. However, little is known

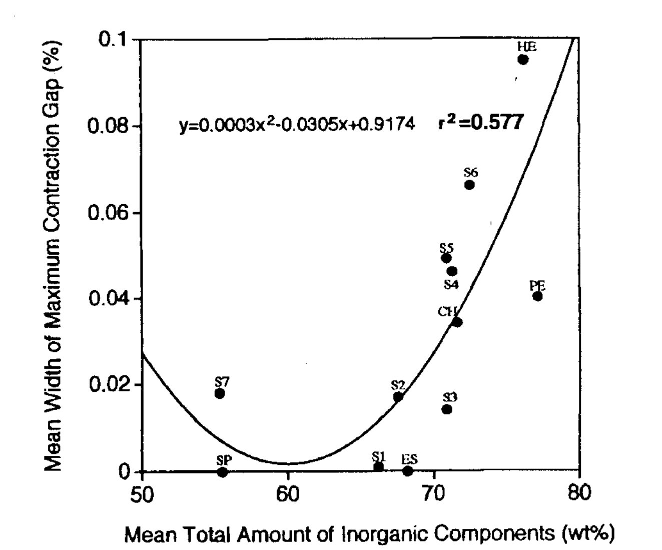

Figure 1. *Mean width of contraction gap (percentage) vs total amount of inorganic components (wt%) in 12 dental composites tested. CH = Charisma; ES = Estelite; HE =Herculite; PE = Pertac; SP = Silux Plus.*

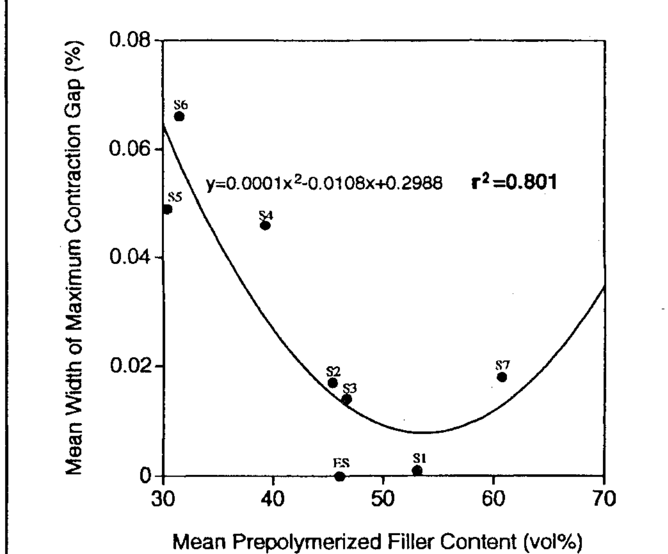

Figure 2. *Mean width of contraction gap (percentage) vs prepolymerized filler contents (vol%) in Estelite and seven experimental composites. ES = Estelite.*

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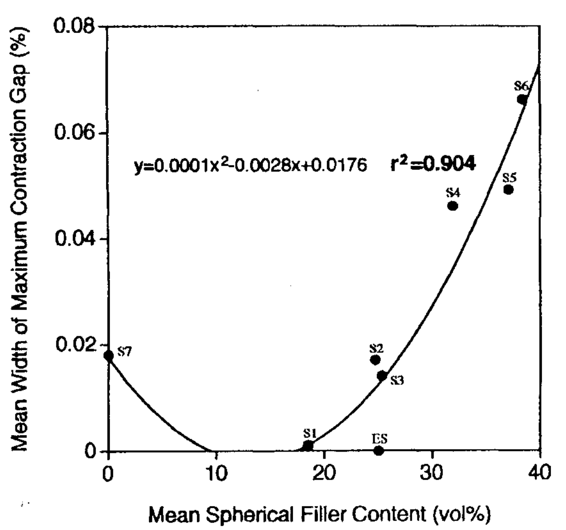

Figure 3. *Mean width of maximum contraction gap (percentage) vs spherical filler contents (vol%) in Estelite and seven experimental composites. ES = Estelite.*

about the correlation between the marginal integrity and the quantity of the base resin matrix in commercially available composites, because it is extremely difficult to measure the exact amount of the base resin matrix of the composites that contains prepolymerized filler particles. The inorganic filler contents of the five commercially available composites (Willems & others, 1993a) are quoted in Table 4. In this study, the wall-to-wall maximum contraction gap was significantly related to the total amount of ashed inorganic components ($R^2 = 0.571$, $0.01 < P < 0.05$, Figure 1). The fitted curve showed that not only too small but also too large an amount of the inorganic component decreases marginal adaptation. Furthermore, among eight composites, Estelite and seven experimental composites that were prepared with the same filler particles and the base resin matrix at the stated compositions, the contraction gap correlated with both the spherical and prepolymerized filler content by volume, and fitted lines were also curves of the second order. The irregularly shaped prepolymerized fillers in the experimental composites must be effective in increasing the viscosity of the composite paste for easy manipulation during cavity restoration, because the paste without prepolymerized filler showed too low viscosity for clinical use. The experimental composite prepared with the prepolymerized filler and the base resin matrix (S7) could not obtain complete marginal adaptation in dentin cavity preparation. When spherical inorganic filler contents in the base resin matrix were 18.5 vol% (S1), 24.7 vol% (S2), 25.0 vol% (Estelite), and 25.3 vol% (S3), the marginal gaps were reduced. However, when spherical filler contents were 31.9 vol% (S4), 37.1 vol% (S5), and 38.4 vol% (S6), marginal gaps were induced.

For geometrical reasons, however, the incorporation of spherical inorganic filler particles should achieve a higher filler content in a prepolymerized filler of a composite paste than when irregularly shaped inorganic filler particles are used. The higher filler content by volume results in the improvement of not only mechanical properties (St Germain & others, 1985; Li & others, 1985; Braem & others, 1989; Chung, 1990) but also wear resistance of the prepolymerized filler or the polymerized composite (Willems & others, 1993b). Furthermore, Matsumura, Leinfelder, and Kawai (1995) have reported high wear resistance of resin composite materials in which prepolymerized filler was present. As pointed out by Hosoda and Yamada (1992), composites containing spherical filler particles showed more polymerization contraction than composites containing irregularly shaped filler, probably because the spherical filler particles cause flow of the composite toward the bulk of the restoration rather than toward the cavity wall. In the present study, however, the relative proportions of spherical filler particles and irregularly shaped prepolymerized filler particles in the experimental composites did not appear to affect polymerization contraction in cylindrical dentin cavity preparations. The larger irregularly shaped prepolymerized filler particles not only disturbed the flow toward the bulk of the restoration but also reduced the contraction stress, because the filler particles could not decrease their interfiller distances.

In a previous report, we recommended two commercially available light-activated dental composites, Silux and Silux Plus, for use in clinical practice, because only these two composites out of 25 evaluated ensured restorations free of marginal gaps (Fujimitsu & others, 1990) when they were combined with a highly effective dentin bonding system

Table 4. Prepolymerized Filler Content of Commercially Available Dental Composites by Volume

Brand	Vol%^{A}	Vol%^{B}
Silux Plus	37.5	—
Estelite	45.8	56.0
Charisma	50.7	59.4
Pertac	53.1	61.0
Herculite	55.2	57.0

Vol%^{A} = inorganic filler volume percentage.
Vol%^{B} = inorganic filler volume percentage, as obtained from the manufacturers.
All data quoted from Willems and others (1993a).

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(Chigira & others, 1989, 1991; Manabe & others, 1991a; Manabe & others, 1991b). In the present study, an additional commercially available dental composite that produced gap-free restorations was identified (Estelite), and is recommended for clinical use. The other three commercially available composites, Charisma, Herculite, and Pertac, still require improvement in their adaptation to dentin margins. In this study, the amount of inorganic filler of commercially available contraction-gap-free composites was increased to 68.2 wt% (Estelite) from 55.5 wt% (Silux Plus) by use of spherical filler particles substituted for the irregularly shaped ultrafine filler particles in base resin matrix in order to obtain improved mechanical properties.

CONCLUSIONS

1. Complete marginal adaptation to the cylindrical dentin cavity preparations was observed using two commercially available composites (Estelite and Silux Plus), while the other 10 composites exhibited incomplete marginal adaptation. The amount of inorganic component in contraction-gap-free composites was increased by use of spherical filler particles (Estelite).
2. The percentage filler content of the spherical filler in composite by volume was related to the degree of marginal adaptation of the dental composite to dentin cavity preparations.

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The Effect of Alcoholic and Nonalcoholic Mouthwashes on Heat-treated Composite Resin

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Clinical Relevance
Heat-treated composites soaked in mouthwashes containing alcohol gained significantly more weight than those soaked in nonalcoholic mouthwashes.

SUMMARY

Studies show that mouthwashes containing alcohol soften the surface of composite resin restorations. The present study determined weight change over time in heat-treated composite resin soaked in alcohol and nonalcohol-containing mouthwashes. The results indicate that samples soaked in mouthwashes containing alcohol gained significantly more weight than samples soaked in nonalcoholic mouthwashes.

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INTRODUCTION

Posterior composite restorations are common substitutes for mercury-containing silver amalgam restorations, because they are mercury free and less expensive than cast metal. Their longevity is controversial because of the many variables in the oral environment such as temperature shifts and chemical changes. A main difference between composite and metallic restorations is that composites are water sorptive, whereas metallic ones are not water sensitive. The resin may swell or contract, thereby contributing to the possible failure of the restoration.

Composites harden by introducing an initiator (usually a light) into an already-existing paste formulation. The initiator acts on the catalyst so that the chemical reaction can take place to further the reaction towards completion. However, a composite that appears hard does not necessarily mean one that is completely cured (Ferracane, Hopkin & Condon, 1995).

It has been demonstrated that curing composites with heat provides a deeper, more infinite type of cure (Wendt, 1987a,b; McCabe & Kagi, 1991), although recent studies question whether heat-cured composites are more resistant to breakdown than those that are light cured (Ferracane & Marker, 1992; Wendt & Leinfelder, 1990). It is theorized that tempering the

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composite causes an increase in polymerization, which in turn causes an increase in tensile stress within the composite. This may in turn cause an increase in microcracks in the material (Ferracane, Antonio & Mathis, 1987). Truong, Cock, and Padmanathan (1990) have suggested that fracture resistance of very highly filled composites may be reduced by high-temperature curing, thus relieving the formation of internal stresses.

Mouthwashes of many varieties are used as a popular means for maintaining oral hygiene. They are commonly used for rinsing and at times to minimize plaque accumulation. Mouthwashes may vary in their chemical composition. Some contain alcohol, which can range up to 27% in volume (Listerine, Warner-Lambert, Morris Plains, NJ 07950), while others contain no alcohol. The negative effects of alcohol on composite are known (Wu & McKinney, 1982), but the mechanism of breakdown is not fully understood.

Weight change is a measure for assessing physical changes in a plastic material. An increase in weight may signify sorption of a soaking medium. A weight gain that does not vary over time may signify that an equilibrium has been reached between the soaking medium and the material being soaked. Any significant change in this equilibrium may result in a reversible or irreversible change in the material being soaked. A loss of weight following a weight gain could mean that some of the plasticizers in the composite have leached out and that an irreversible physical change has taken place (Söderholm, 1981).

The purpose of this study was to analyze weight change over time with heat-treated composite resin in alcohol and nonalcohol-containing mouthwashes.

METHODS AND MATERIALS

Fifty samples (Heliomolar, Ivoclar North America Inc, Amherst, NY 14228) were made in a polyvinyl siloxane impression material (Extrude putty, Kerr/Sybron, Romulus, MI 48174) mold. The mold was formed by pressing a cylindrical disk (20 mm in diameter x 2 mm thick) into an impression receptacle and inverting the receptacle onto a flat surface. When set, the disk was removed and the disk-like mold was used for sample fabrication.

A total of five molds were made and each mold was used 10 times. Heliomolar samples were made by extruding the material into the mold and by curing it with a Heliolux (Vivadent USA, Amherst, NY 14228) light with a 1/2" diameter by placing the light source at the center of the disk for 30 seconds and then by selecting a north, east, south, and west corner of the disk and curing each location for 30 seconds. The disk was removed from the mold and any gross irregularities were eliminated using a handpiece and cutting instruments.

Heat treatment was achieved by oven tempering. Disks were placed, five at a time, into a Coltène DI 500 oven (Coltène-Whaledent, Mahwah, NJ 07430) for a preset period of time of 8 minutes at a preset temperature of 250 °F. The disks were removed and allowed to bench cool.

Samples were separated into five groups of 10 each and tested as follows: Each sample was weighed, in grams, (Denver Instrument, Denver, CO 80202) prior to testing and again after being submerged in its respective solution for 6, 12, 24, and 72 hours. Five solutions (Table 1) were used: Solution #1: Listerine Freshburst, which contains 21.6% alcohol (Warner-

Table 1. Mouthwashes Used, Percent Alcohol, and Other Ingredients (According to Manufacturers)

	Mouthwash	Manufacturer	% Alcohol	Ingredients
Solution #1	Listerine Freshburst	Warner-Lambert Co, Morris Plains, NJ 07950	21.6	thymol, eucalyptus, methyl salicylate, menthol, water, benzoic acid, poloxamer 407, sodium saccharin, sodium citrate, food color, artificial flavor
Solution #2	Plax	Pfizer Inc, New York, NY 10017	8.5	thymol, water, glycerin, benzoic acid, tetrasodium pyrophosphate, poloxamer 407, sodium benzoate, sodium laurel sulfate, sodium saccharin, xanthan gum, food color
Solution #3	Rembrandt	Den-Mat Corp, Santa Maria, CA 93456	0	methyl paraben, water, sodium citrate, sodium laurel sulfate, sodium benzoate, sodium saccharin, polysorbate 20, natural and artificial flavor
Solution #4	Listermint Alcohol Free	Warner-Lambert	0	water, glycerin, poloxamer 335, sodium laurel sulfate, sodium benzoate, benzoic acid, zinc chloride, artificial color
Solution #5	distilled water	N/A	0	

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Table 2. Group Means at Specific Time Points

		Sum of Squares	df	Mean Square	F	Sig
Initial Weight	Between Groups	5.8E-02	4	1.4E-02	1.442	0.236
	Within Groups	0.449	45	1.0E-02		
	Total	0.507	49			
Hour 6	Between Groups	5.5E-02	4	1.4E-02	1.373	0.258
	Within Groups	0.452	45	1.0E-02		
	Total	0.507	49			
Hour 12	Between Groups	5.6E-02	4	1.4E-02	1.411	0.246
	Within Groups	0.447	45	9.9E-03		
	Total	0.503	49			
Hour 24	Between Groups	5.5E-02	4	1.4E-02	1.392	0.252
	Within Groups	0.443	45	9.9E-03		
	Total	0.498	49			
Hour 72	Between Groups	5.6E-02	4	1.4E-02	1.399	0.250
	Within Groups	0.447	45	9.9E-03		
	Total	0.503	49			

Welcome); Solution #2: Plax with 8.5% alcohol (Pfizer Inc, New York, NY 10017); Solution #3: Rembrandt alcohol-free (Den-Mat Corp, Santa Maria, CA 93456); Solution #4: Listermint alcohol free (Warner-Welcome); and Solution #5: distilled water (control). Prior to weighing, the samples were removed from their respective solutions, dry blotted with tissue paper, and placed on filter paper, (a new preweighed piece for each disk) and weighed. Solutions were stored in covered glass containers to prevent loss of contents. The solutions were not changed during the test period. Data were collated and statistically evaluated using SPSS (SPSS Inc, Chicago, IL 60611, Version 7.0) for Windows 95.

RESULTS

Analysis and comparisons are based on either the observed weights or weight differences at successive or selected time points. It should be noted that two components of variability exist that contribute to the sampling error. The first is the blotting/drying of the composite disks prior to weighing. The other is any vibrations on the table that housed the scale. Both of these have an effect on the stated precision.

A one-way ANOVA was performed to address the equality of initial group mean weights from the resulting randomized assignments. Equality of group means could not be rejected at traditional levels ($P = 0.23$) (Table 2). ANOVAs presented in Table 2 suggest that no statistically significant differences in group means existed at any time point.

A one-way ANOVA was performed to assess differences in group means at each time point controlling the initial weight. Significant treatment group effects occurred at each time point (Table 3). Looking at the change in weight at successive time intervals (diffl = Hour 6 - Hour 0; diff2 = Hour 12 - Hour 6, etc), helps to understand the time dependence of absorption. Table 4 shows that the only time period with a statistically significant change in group weight was the first 6 hours ($P > 0.000$). Figures 1 and 2 demonstrate distributional characteristics for the treatment groups.

DISCUSSION

The breakdown of composites in the absence of loading forces has been reported by Roulet and Walti (1984). The mechanism of this wear has been associated with solvent degradation and with fracture of the resin matrix at the filler/matrix interface (Wu & others, 1984). Mueller

Table 3. Group Means Accounting for Initial Weights

		Sum of Squares	df	Mean Square	F	Sig
DELTA1	Between Groups	4.5E-04	4	1.1E-04	12.9	0
	Within Groups	3.9E-04	45	8.7E-06		
	Total	8.4E-04	49			
DELTA2	Between Groups	8.0E-04	4	2.0E-04	21.841	0
	Within Groups	4.1E-04	45	9.1E-06		
	Total	1.2E-03	49			
DELTA3	Between Groups	7.9E-04	4	2.0E-04	20.221	0
	Within Groups	4.4E-04	45	9.7E-06		
	Total	1.2E-03	49			
DELTA4	Between Groups	1.0E-03	4	2.5E-04	26.951	0
	Within Groups	4.2E-04	45	9.3E-06		
	Total	1.4E-03	49			

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Table 4. Weight Change at Successive Time Intervals

		Sum of Squares	df	Mean Square	F	Sig
DIFF1	Between Groups	4.5E-04	4	1.1E-04	12.9	0
	Within Groups	3.9E-04	45	8.7E-06		
	Total	8.4E-04	49			
DIFF2	Between Groups	5.9E-05	4	1.5E-05	1.624	0.185
	Within Groups	4.1E-04	45	9.0E-06		
	Total	4.7E-04	49			
DIFF3	Between Groups	4.4E-05	4	1.1E-05	1.973	0.115
	Within Groups	2.5E-04	45	5.5E-06		
	Total	2.9E-04	49			
DIFF4	Between Groups	2.4E-05	4	5.9E-06	1.363	0.262
	Within Groups	2.0E-04	45	4.4E-06		
	Total	2.2E-04	49			

and others (1982) showed that the BIS-GMA-based polymer is highly susceptible to chemical softening. Asmussen (1984) and Wu (1982) demonstrated a softening and a decrease in compressive strength for composites stored in solvents such as ethanol and organic acids that are present in plaque. Penugonda and others (1994) have shown that the same is true when using mouthwashes containing alcohol. By increasing the degree of conversion in a composite, there is a lower solubility of the composite and therefore less softening in the solvents (Wu, 1982). This is important to the longevity of the restoration.

Lee, Greener, and Menis (1995) stated that when a solvent such as ethanol penetrates a composite matrix, the polymer chains expand and monomer may leach out. Such a theory would explain the significantly greater weight gain with alcohol-containing mouthwashes. There is also the factor of the frequency of exposure to a solvent. An intermittent exposure to a solvent could result in a slower leaching out of the plasticizers. Any damage done could possibly be accelerated with the next exposure (Lee & others, 1995). Furthermore, the amount of unreacted monomer that can potentially leak out may be directly related to the degree of polymerization. To minimize change, the use of heat-treated composites would be indicated, due to the greater degree of conversion. This would result in a decrease in any morphological change in the structural integrity.

In this study, it is seen that the disks soaked in Listerine Freshburst, compared to those soaked in the other solutions, gained significantly more weight. This was only true for the first 6 hours. It has also been shown that the disks soaked in a solution with a low concentration of alcohol had a weight change similar to those that were in a solution with no alcohol. However, the disks in the solutions with no alcohol showed the least weight gain.

After 6 hours, it appears the disks were approaching an equilibrium with the solutions that they were in. However, this does not assure a long-lasting restoration, since the morphological structure has already been altered during the soaking process.

In this study, weight gain was proportional to the amount of alcohol present in the mouthwash. However, each of the commerically available mouthwashes have other ingredients in them that

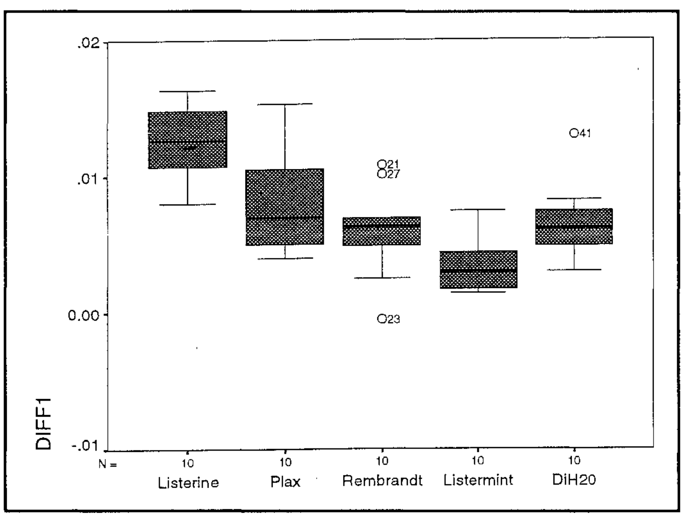

Figure 1. *Successive changes in weight gain*

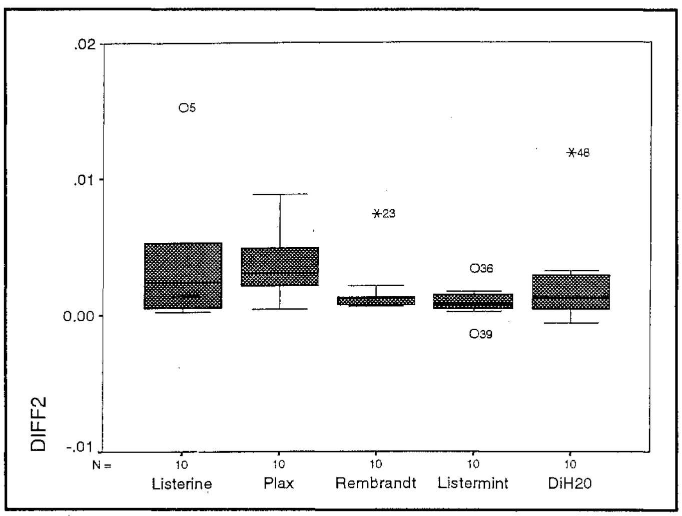

Figure 2. Weight change at 12 hours

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may also have a deleterious effect on the composite resin, and this needs to be taken into consideration. It seems likely from other studies cited that soaking in alcohol adversely affects the longevity of composite restorations. Due to the fact that this was a laboratory test, there was no effort to investigate any additional effects that occlusal forces may present along with soaking. One can assume that with an alteration of polymer structure, force may play an important part in a further degradation of the resin matrix.

CONCLUSION

Heat-treated composites soaked in mouthwashes containing alcohol gained significantly more weight than those soaked in nonalcoholic mouthwashes. Storage time was significant. The results of this study indicate the need for further studies concerning the aging of composite restorations in vivo.

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The Effect of Air Abrasion on Shear Bond Strength to Dentin with Dental Adhesives

P J RINAUDO • M A COCHRAN • B K MOORE

Clinical Relevance
Air abrasion is not a suitable substitute for acid conditioning.

SUMMARY

This study compared the effects of different dentin surface treatments on the shear bond strengths of three adhesive systems. The adhesive systems included a resin-modified glass ionomer, Fuji II LC, and two dentin bonding systems, One Step and Scotchbond Multi-Purpose Plus. The surface treatments compared for each adhesive system were as follows: 1) the controls, which were conditioned, 2) air abrasion at 120 psi without conditioning, 3) air abrasion at 160 psi without conditioning, 4) air abrasion at 120 psi with conditioning, and 5) air abrasion at 160 psi with conditioning. The KCP 1000 Whisperjet was used for all air-abrasive specimens. Controls for each adhesive material (Fuji II LC, One Step, Scotchbond Multi-Purpose Plus) were bonded using manufacturers' recommendations. Results showed that air abrasion significantly lowered bond strength of the resin-modified glass ionomer, conditioned or nonconditioned ($P < 0.01$). Air abrasion alone significantly lowered bond strengths of the dentin bonding agent systems ($P < 0.01$). However, air abrasion plus conditioning of the dentin surface resulted in bond strengths that were similar to the conditioned-only specimens ($P < 0.01$).

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INTRODUCTION

Over the past quarter of a century, the entire face and philosophy of dentistry has markedly changed. Today, preparation techniques and the relative comfort of the patient throughout the entire restorative procedure are important issues in the dental practice. Given a choice, most patients prefer treatment with up-to-date techniques and will change dental practices to obtain it. In particular, techniques for tooth preparation that eliminate pain and noise are appealing (Freedman, 1994). Prior to 1950, much had been accomplished by the dental profession to minimize patient discomfort during cavity preparation, including the use of water cooling for heat dissipation. However, the public still professed an aversion to the dental drill and its associated noise, vibration, and psychological impact. It was at this time that a possible solution to the problem, based upon a fundamentally different principle, "air abrasion" or "airbrasive," was introduced. Throughout the 1940s,

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Dr R B Black was driven by the idea of finding a replacement for the mechanical low-speed drills he used to prepare his patients' teeth. The primary objective was to find a nonmechanical method that would cut tooth structure rapidly but with comparative freedom from trauma and discomfort. He also wanted the technique to be less demanding on the physical and nervous resources of the dentist. His years of hard work came to fruition when in 1951 the S S White company began marketing the Airdent, Black's patented air-abrasive unit, the first air-abrasive unit developed for dental use (Meyers, 1994). In 1955 Dr Robert Black re-evaluated the air-abrasive technique and found the principal advantages to be: 1) most rapid method for excavating sound tooth enamel, 2) most rapid method for the removal of stains and accumulations from enamel surfaces, 3) minimum of physical fatigue and tension, 4) practically no anxiety or discomfort associated with the procedure, and 5) biologically acceptable, since there was an absence of trauma. Dental practitioners in the 1950s thought the air-abrasive technique proved to be a valuable and practical adjunct for tooth preparation and prophylaxis (Black, 1955). With the Airdent, Dr Black's objectives had been achieved. However, one fundamental problem remained. The system could only prepare shapes in tooth structure that were rounded or beveled in nature. Thus, while the technology offered some advantages, final cavity preparation still required supplementary mechanical instrumentation (Goldberg, 1952). This shortcoming coupled with the introduction of the high-speed air turbine handpiece by J V Borden (Meyers, 1994) caused air abrasion to disappear from the dental office.

In 1992 kinetic cavity preparation systems were approved for marketing by the FDA. The system propels a fine aluminum oxide powder in a high-velocity stream of air against tooth structure. The KCP 1000 is effective in class 1, 3, 4, and 6 cavity preparations and can be used in some class 2 preparations (Burback, 1993). It has been found that the aluminum oxide produces an etched surface on both enamel and dentin (Katora, Jubachn & Polimus, 1981). The combination of advanced technology and adhesive tooth restorative materials brought dentistry closer to the ideal synthetic replacement of tooth structure with the same strength and appearance of the natural structures they replace (Burback, 1993).

Recent investigations have shown that air abrasion is considered a viable and safe alternative for preparation of tooth structure and removing different restorations (Laurell, Carpenter & Beck, 1993; Laurell, Carpenter & Beck, 1994; Laurell & others, 1995). Microleakage studies thus far have shown conflicting results. Results showed that air abrasion produces a roughened surface, but resin bonded to it lacks the seal obtained with acid etching (Eackle, Wong & Huang, 1995). Another study concluded that air-abraded and bur-prepared surfaces experienced statistically similar microleakage in class 1 and 5 composite restorations (Keen, Parkins & Crim, 1995).

It has been suggested that acid etching the preparation surface can be eliminated by air abrasion (Keen, Von Freunhofer & Parkins, 1994; Clinical Research Associates, 1994). Other studies have shown that the use of air abrasion did not improve the shear bond strength of composite resin to dentin (Rainey & Barghi, 1995; Horgesheimer & others, 1995; Roeder & others, 1995). Recent studies investigating the effect of air abrasion on resin-modified glass ionomer to enamel and dentin showed significantly lower bond strengths to both enamel and dentin when conditioning the dentin with 10% polyacrylic acid was eliminated (Berry, Rainey & Powers, 1993; Berry, Berry & Powers, 1994).

The purpose of this study was to determine the effect of air abrasion on shear bond strength to dentin of a resin-modified glass ionomer and two dentin bonding systems using air abrasion pressures of 120 psi and 160 psi.

Table 1. Experimental Groups (Generic)

Control	Conditioned
120 psi	Nonconditioned
160 psi	Nonconditioned
120 psi	Conditioned
160 psi	Conditioned

Table 2. Adhesive Systems

Material	Manufacturer	Type	Batch
Fuji II LC	GC America, Chicago, IL 60658	Resin-modified glass ionomer	#040851
One Step	Bisco, Itasca, IL 60143	Acetone dentin bonding agent	#079125
Scotchbond Multi-Purpose Plus	3M Dental Products, St Paul, MN 55144	Aqueous dentin bonding agent	Primer: 5JT Adhesive: 5CE

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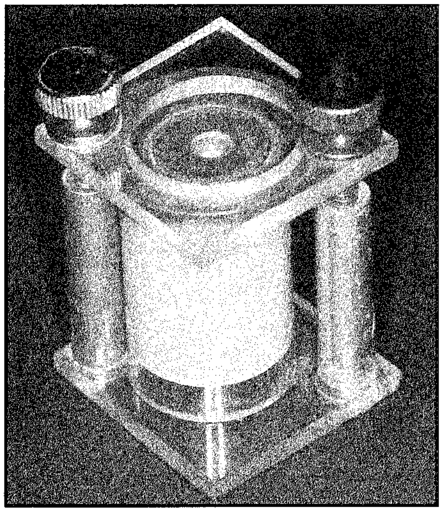

Figure 1. Clear vinyl tube under compression bonding apparatus

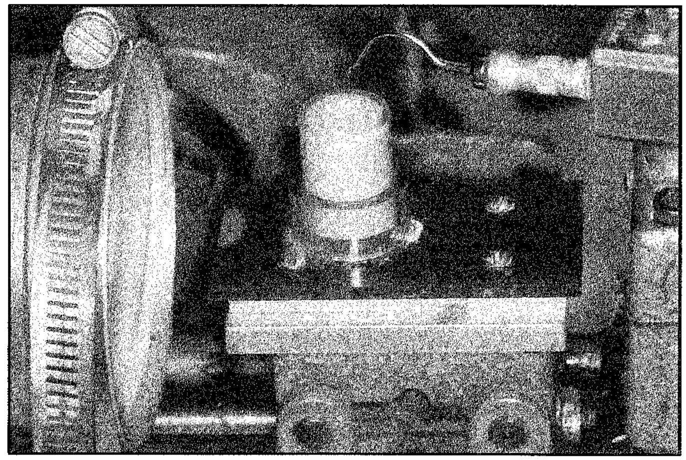

Figure 2. Air abrasion jig

METHODS AND MATERIALS

Adhesive systems for this study, listed in Table 1, were Fuji II LC, One-Step, and Scotchbond Multi-Purpose Plus. Herculite XRV (Sybron/Kerr Dental Specialties, Glendora, CA 91740) was used as a restorative material with the dentin bonding agents.

A total of 225 recently extracted, clinically noncarious, human molars were selected from a pool of extracted teeth and stored in 10% formalin solution. A flat bonding surface was prepared on the occlusal surface by wet grinding with 180-grit silicon carbide paper on a metallographic polisher (Varipol VP150, Leco Corp, St Joseph, MI 49085). The teeth were ground to expose a sufficient area of dentin, a diameter of approximately 5 mm, to accommodate the bonded restorative material. After establishing a flat bonding surface, each tooth was mounted in a Plexiglas mold with self-curing tray acrylic to allow the flat dentin surface and acrylic resin to be flush at one end of the mold. The teeth were randomly divided into 15 groups of 15 teeth each. The five generic groups tested (Table 2) were as follows: 1) control—conditioned, 2) air abrasion at 120 psi—nonconditioned, 3) 160 psi—nonconditioned, 4) 120 psi—conditioned, and 5) 160 psi—conditioned. Immediately prior to bonding, each tooth had superficial dentin removed by wet grinding with 600-grit silicon carbide paper. A clear vinyl tube was utilized (Figure 1) to restrict the restorative material to the bonding site. Other surfaces were abraded with 50 μm aluminum oxide at 120 psi and 160 psi delivered with a KCP Whisperjet 1000 (American Dental Technologies, Troy, MI 48084). Using a jig as shown in Figure 2, air abrasion was delivered at a constant rate of 6.85 mm/sec at a distance of 8 mm in the following manner: 1) Each tooth was labeled 1-15 for identification purposes and placed on a sponge saturated with distilled water; 2) In sequence, each tooth was transferred to the air-abrasion jig and set-up for treatment; 3) The handpiece was set at the proper distance with an 8 mm spacer; 4) Once the tooth was in place, air abrasion took place at 120 psi or 160 psi, depending on the group, in the following manner: (a) one pass in a forward direction and one pass in a backward direction, (b) rotate the specimen 90° and repeat procedure (a). After air abrasion, each tooth was transferred back to the sponge until adhesive application. When the entire group was abraded, each tooth, in proper sequence, was transferred to the compression bonding apparatus for adhesive application. Adhesives for each group were prepared following manufacturer's recommendations as outlined in Table 3.

Table 3. Preparation of Adhesive Systems Used in This Study

Adhesive System	Component	Manufacturer's Instructions
Fuji II LC	Conditioner	Etch 20 seconds, rinse 40 seconds
	Material	Two 90° activation turns, triturate 10 seconds, polymerize 40 seconds
One Step	Etchant	Etch 15 seconds, rinse 1 minute
	Adhesive	Apply two coats, gently air dry for 10 seconds, irradiate 10 seconds
Scotchbond Multi-Purpose Plus	Etchant	Etch 15 seconds, rinse 1 minute
	Primer	Apply, gently air dry
	Adhesive	Apply, irradiate 10 seconds

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All specimens were stored in distilled water at 37°C for 2 weeks prior to testing. Specimens were tested by use of an Instron Universal Testing Machine Model 1123 (Instron Corp, Canton, MA 02021) with an applied cross-head speed of 0.5 mm per minute until bond failure occurred. The shear apparatus uses a circular knife edge applied at the line angle between the tooth surface and the tested material. The knife is loaded in tension, which results in a 90° angle application of the load (Stanford, 1985). The shear strength of the bond was expressed in MPa.

Table 4. Shear Bond Strength (±Standard Deviation, MPa)

Fuiji II LC				
Control	120NC	160NC	120C	160C
9.64 ± 2.74	4.43 ± 1.97 a	5.20 ± 1.05 a	6.94 ± 1.75 b	6.22 ± 1.59b

Similar lower-case letters after SD indicate no significant difference.

Means and standard deviations were recorded. Separate analyses were performed for each of the three dental adhesives. Each adhesive system was evaluated independent of the other systems; therefore, the systems were not compared to each other. One-way analysis of variance models were used to compare the treatment groups versus the control with comparisons made using Dunnett's test at a 0.05 significance level.

RESULTS

The data obtained in shear bond strength tests are provided in Tables 4-6. For Fuji II LC (Table 4), the control group specimens had significantly higher mean load at failure than any of the treatment combinations. Conditioned specimens had higher mean values than nonconditioned specimens.

For One Step (Table 5), the conditioned group specimens had significantly higher mean load at failure values than nonconditioned specimens. The control group and 120 psi group had significantly lower mean values than conditioned 160 psi specimens. The control specimens were not significantly different from the conditioned 120 psi specimens.

For Scotchbond Multi-Purpose Plus (Table 6), the control group specimens had significantly higher mean load at failure values than the nonconditioned 120 psi and 160 psi specimens, but were not significantly different from the conditioned 120 psi and 160 psi specimens. Conditioned specimens had significantly higher mean load at failure values than nonconditioned specimens.

DISCUSSION

The selection of adhesives for this study was based on having a cross section of available adhesives in clinical practice that would be used with air abrasion. Since each adhesive is classified differently, there was no attempt to compare the results. Results are based on comparisons within each adhesive system. This allowed the study to encompass a more generalized approach in evaluating adhesive systems.

This study showed that air abrasion alone does not eliminate the need for conditioning the preparation before bonding with a dentin bonding system. In fact, the use of air abrasion on tooth surfaces in preparation for use of a resin-modified glass-ionomer restoration may significantly lower the material's bonding ability even if it is subsequently acid conditioned. This finding is consistent with the results of Berry and others (1994). Dentin bonding agents acquire their bond strengths from the micromechanical bond formed in the demineralized zone of dentin. This hybrid layer consists of monomers polymerized within the collagen network of dentin and is essential for the success of the restorative material when bonding only to dentin. There are three elements in the process of forming the hybrid layer: 1) an acidic agent is applied to the dentin surface to remove or alter the smear layer and partially

Table 5. Shear Bond Strength (± Standard Deviation, MPa)

One Step				
Control	120NC	160NC	120C	160C
14.06 ± 3.55 a	9.71 ± 1.98 b	10.69 ± 1.72 b	15.57 ± 2.92 a	16.90 ± 1.75

Similar lower-case letters after SD indicate no significant difference.

Table 6. Shear Bond Strength (± Standard Deviation, MPa)

Scotchbond Multi-Purpose Plus				
Control	120NC	160NC	120C	160C
15.15 ± 4.93 a	5.59 ± 1.79 b	5.10 ± 2.57 b	14.76 ± 2.30 a	14.67 ± 2.81 a

Similar lower-case letters after SD indicate no significant difference.

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demineralize the dentin surface, 2) primer agents consisting of a bi-functional, hydrophilic and hydrophobic molecule penetrate the demineralized collagen network and enable good wetting and penetration by the bonding resin, and 3) an unfilled resin is placed that will attach to the hydrophobic portion of the primer. The resin is polymerized to provide a micromechanical interlocking within the collagen network (Inagaki & others, 1989). Resin-modified glass-ionomers combine the acid-base reaction of a conventional glass ionomer with the polymerization of methacrylate functional groups present on water-soluble monomers or as pendant groups on the polyacid chains (Mitra, 1991). The polymerization of the resin component is the same as for composite resin materials. It is possible that both chemical and micromechanical bonding can take place with resin-modified glass ionomers.

During air abrasion at 120 psi and 160 psi, a smear layer was produced on the dentin surface that appeared different under SEM analysis than the one produced from 600-grit grinding. Removal of the smear layer is important to enable the resin component of adhesive systems to penetrate into the demineralized dentin surface. Nonconditioned air-abraded dentin surfaces were not rinsed prior to Fuji II LC placement. This protocol was followed per instructions of the clinical technique manual of the KCP 1000. When Fuji II LC was placed on an air-abraded surface that was not followed by conditioning, bond strengths went down significantly. Under the conditions of this study, the possibilities for lower bond strengths for this material were: 1) nonremoval of the smear layer, thus not allowing adequate chemical adhesion and penetration of the resin component into the dentin surface, and 2) not rinsing the surface, thereby allowing aluminum oxide particles to remain, thus interfering with the chemical bond and micromechanical attachment. Even when groups were conditioned after air abrasion and rinsed, bond strengths remained significantly lower than the control. Incomplete removal of the smear layer or possible plugging of the dentinal tubules would interfere with both chemical adhesion and/or micromechanical bonding. Bond strength of conditioned Fuji II LC groups were significantly higher than for nonconditioned, further suggesting that conditioning of the dentin surface is necessary to form good bonds when using Fuji II LC.

One Step and Scotchbond Multi-Purpose Plus are new-generation dentin bonding agents that are also dependent on removal of the smear layer and formation of a hybrid layer (Nakabayashi, Nakamura & Yasuda, 1991); Van Meerbeek & others, 1992). Evaluation of these systems showed that bond strengths were significantly lowered when dentin surfaces were air abraded and not conditioned. This could have occurred for two reasons: 1) the smear layer produced by the air abrasion did not allow penetration into the dentin surface, and 2) aluminum oxide left on the surface after air abrasion contaminated the surface, thus interfering with the formation of the hybrid layer. One Step, air abraded at 160 psi and conditioned, gave significantly higher bond strengths than all other groups. However, it is felt that the difference between this group and the control and 120 psi conditioned groups would not be clinically significant because the differences in the means of the groups were approximately 2 MPa and the maximum bond strengths attained by either treatment was approximately 19 MPa. These small differences at these bonding levels do not justify the use of air abrasion to achieve higher dentin bond strengths. Scotchbond Multi-Purpose Plus had the same trend as the One Step groups, with the exception of the 160 psi conditioned group. This group was not significantly different from the control and 120 psi conditioned group. For the dentin bonding systems, air abrasion, at either 120 psi or 160 psi and conditioned, did not enhance the shear bond strength, a finding that is consistent with the results of Rainey and Barghia (1995).

This study investigated the effect of air abrasion on the shear bond strength to dentin using dental adhesives. Following air abrasion, conditioning versus nonconditioning of the dentin surface made a significant difference on the bond strength.

CONCLUSIONS

Under the conditions of this in vitro study:

1. Air abrasion significantly lowered the bond strength of the resin-modified glass ionomer, Fuji II LC, conditioned or nonconditioned;
2. Air abrasion alone significantly lowered bond strengths with the dentin bonding systems One Step and Scotchbond Multi-Purpose Plus;
3. Air abrasion plus conditioning of the dentin surface resulted in bond strengths with the dentin bonding agents similar to the conditioned-only controls.

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Surface Characteristics of Tooth-colored Restoratives Polished Utilizing Different Polishing Systems

A U J YAP • K W LYE • C W SAU

Clinical Relevance
The smoothest surfaces were produced when restoratives were allowed to cure against a Mylar Uni-strip.

SUMMARY

The surface characteristics of different tooth-colored restoratives polished with the Enhance system, white stones, and the Super-snap system were evaluated using profilometry and microhardness testing. Surface characteristics of materials cured against a Mylar Uni-strip were used as a control. The results of this study show that the surface characteristics (roughness and hardness) following polishing with different systems are material dependent. The result may be attributed to the discrepancy between filler and matrix hardness of the restorative. Filler content, particle size, and the ability of the polishing system to abrade the filler may also contribute to the observed change in surface characteristics.

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INTRODUCTION

The ongoing search for biologically and esthetically acceptable adhesive restorative materials has brought new varieties of tooth-colored materials to the dental market. Some of the recently introduced materials include resin-modified glass-ionomer cements, polyacid-modified composite resins, and heavily filled composite resins with monomodal particle distribution. The esthetics of these tooth-colored restoratives are heavily dependent on surface finish. Due to the greater tendency for plaque to accumulate on rough surfaces, surface finish of restorations located near the gingiva will also influence periodontal health (Dunkin & Chambers, 1983). The various phases of these restoratives differ in hardness, so finishing and polishing may be a problem, as the different components do not abrade uniformly.

Although much work has been done on composite resins and conventional glass-ionomer cements (Chen, Chan & Chan, 1988; Jefferies, Barkmeier & Gwinnett, 1992; Liberman & Geiger, 1994), there is no general agreement in the dental literature on the best method for finishing and polishing these new tooth-colored restoratives. This study was initiated on the basis of this controversy and is aimed at determining the effects different polishing systems have on surface roughness and hardness of two

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Table 1. Polishing Systems and Sequence Tested

Product	Usage
Enhance polishing system	
Sensor disk	Wet, 10 strokes
Polishing foam with Prisma Gloss	Dry, 10 strokes
Polishing foam with Prisma Gloss Extra-fine	Dry, 10 strokes
White stones	Dry with vaseline, 30 strokes
Super-snap disks system	
Medium-grit	Dry with vaseline, 10 strokes
Fine	Dry with vaseline, 10 strokes
Super-fine	Dry with vaseline, 10 strokes

composite resins, a polyacid-modified composite resin and a resin-modified glass-ionomer cement.

METHODS AND MATERIALS

Materials used in the study included two composite resins, a resin-modified glass-ionomer cement and a polyacid-modified composite resin. The composite resins examined included a microfilled composite resin, Silux (SX) (3M Dental Products, St Paul, MN 55144), and a heavily filled composite resin, Z100 (ZO) (3M Dental Products). The polyacid-modified composite resin was Dyract (DY) (Dentsply, Weybridge, UK), and the resin-modified glass-ionomer cement examined was Photac-Fil (PF) (ESPE Dental-Medizin, Seefeld/Oberbay, Germany). All materials were manipulated according to the manufacturers' instructions.

A rubber mold was fabricated for the preparation of specimen disks that was 10 ± 1 mm in diameter and approximately 1.5 mm thick. The mold was first slightly overfilled with material under evaluation, placed between two celluloid matrix strips (Mylar Uni-strip, L D Caulk/Dentsply, Milford, DE 19963) and sandwiched between two quartz glass plates to extrude the excess material. Materials were then light polymerized using the Max Polymerization unit (L D Caulk/Dentsply) for the recommended exposure time through the glass plate. Due to the larger area of the specimen relative to the exit window of the light source, overlapping irradiation was essential. This was done until the whole specimen had been irradiated for the recommended exposure time. A total of 48 specimens was made for each material, and these were randomly divided into four groups of 12. The first group (control) received no further treatment after polymerization against the Mylar strip. The remaining three groups were immediately finished and polished after polymerization, with one of the following systems (Table 1): Enhance polishing system (L D Caulk/Dentsply), white stones (Shofu, Kyoto, Japan) with vaseline, and Super-snap disks system (Shofu). For all techniques, finishing and polishing were done only in one direction with a low-speed handpiece at 1000 rpm. Each 5-second movement of the polishing apparatus across the diameter of specimen disks constituted a 'stroke.' The specimens then were stored in distilled water at 37 °C for 1 week prior to surface roughness and hardness evaluation.

Surface Roughness Evaluation

Profilometric analyses were carried out using the Talycontour analyzer (Rank Taylor Hobson, Leicester,

Table 2. Mean Ra (μm) Values and KHN for the Various Materials and Polishing Systems Evaluated

Materials/ Technique	Ra [Standard Deviation]				KHN [Standard Deviation]			
	Control	Enhance	White Stones	Super-snap	Control	Enhance	White Stones	Super-snap
Silux (SX)	0.07 [0.02]	0.23 [0.23]	0.67 [0.29]	0.27 [0.56]	28.99 [4.18]	24.83 [2.54]	22.89 [1.32]	23.06 [1.93]
Z100 (ZO)	0.02 [0.01]	0.30 [0.07]	0.63 [0.10]	0.22 [0.09]	51.79 [3.81]	71.79 [2.41]	75.43 [1.08]	41.28 [3.68]
Dyract (DY)	0.05 [0.02]	0.47 [0.18]	0.66 [0.15]	0.48 [0.11]	28.64 [0.80]	26.46 [3.03]	26.15 [4.04]	24.98 [2.04]
Photac-Fil	0.20 [0.05]	1.19 [0.26]	1.35 [0.43]	0.54 [0.40]	19.45 [1.56]	29.00 [2.36]	16.43 [3.25]	14.03 [0.49]

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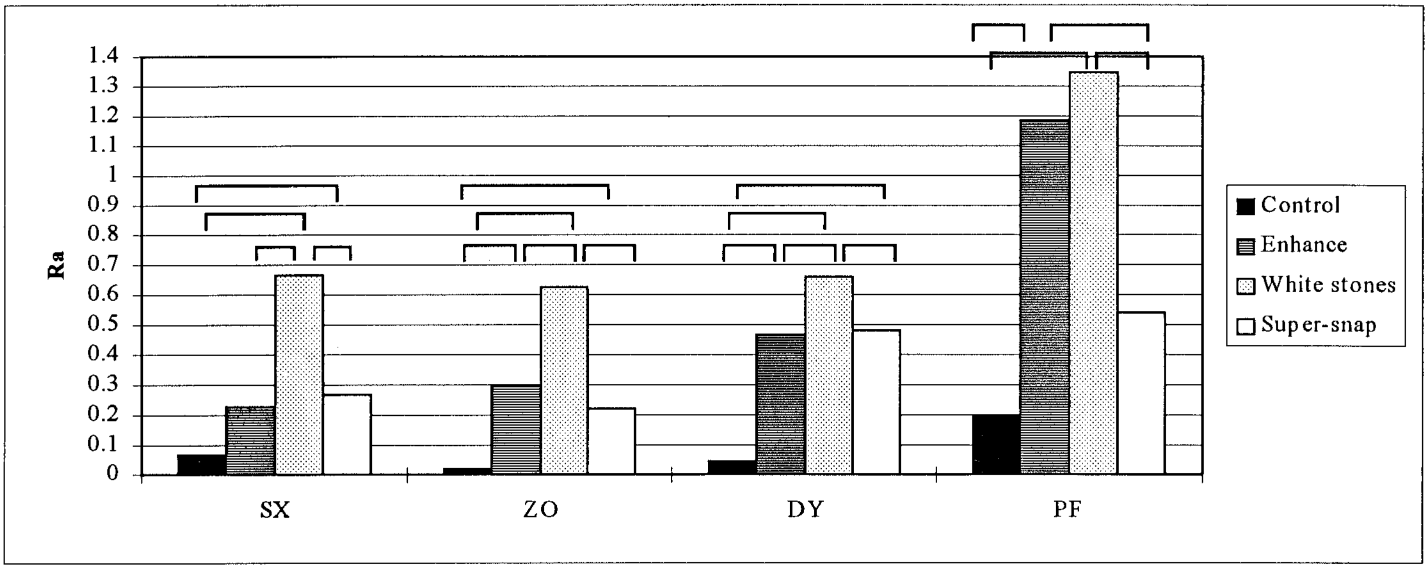

Figure 1. *Mean Ra (µm) values for materials and polishing systems. SX = Silux; ZO = Z100; DY = Dyract; PF = Photac-Fil. Brackets indicate statistically significant* (P < *0.05) differences in Ra values.*

England). The typical profile tracings for the various materials and polishing techniques were compared and Ra values recorded. The Ra value is the arithmetic mean of the departures of the roughness profile from the mean line calculated by the computer. Two traces were recorded for each specimen on two different locations, each over a standard length of 0.25 mm X 8, and across the grooves created by the different polishing systems.

Microhardness Test

A Knoop hardness number (KHN) was determined for each specimen using the Matsuzawa MXT50

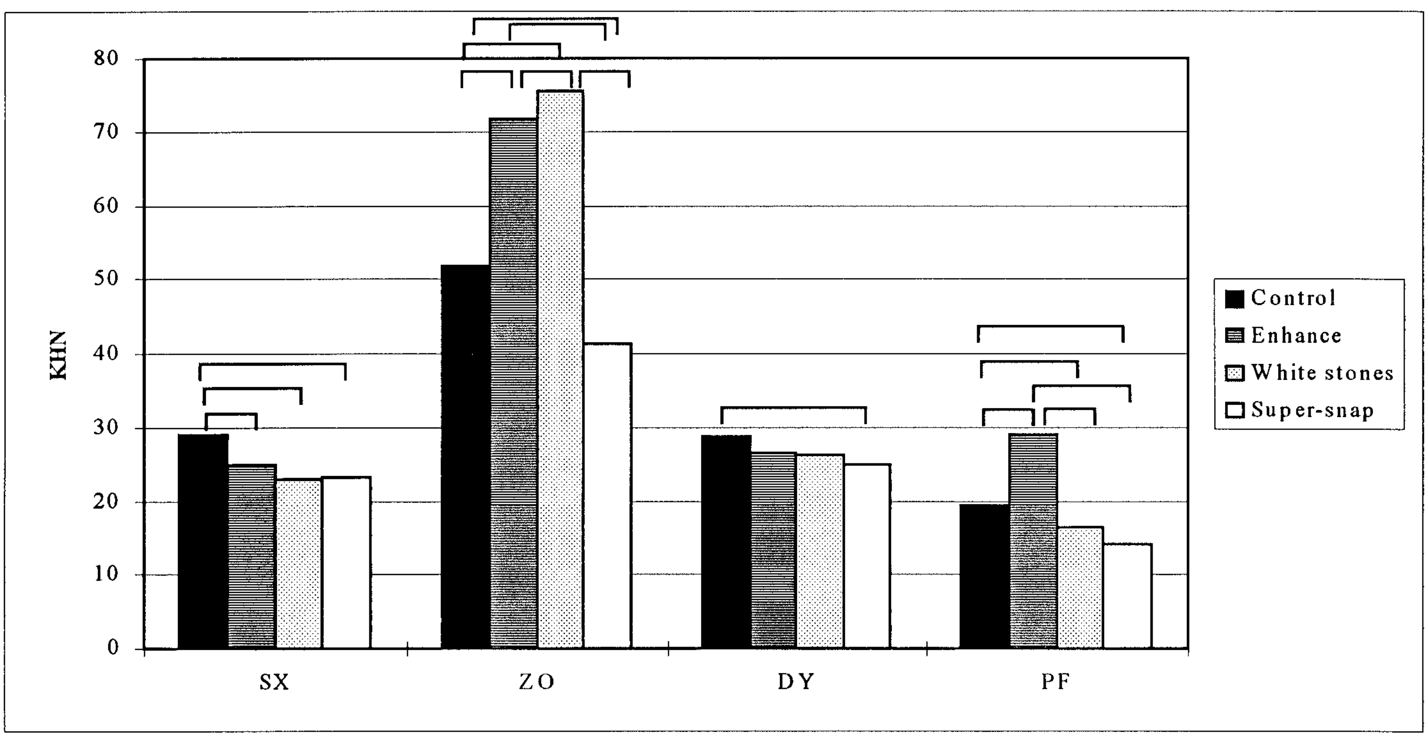

Figure 2. *KHN for materials and polishing systems. SX = Silux; ZO = Z100; DY = Dyract; PF = Photac-Fil. Brackets indicate statistically significant* (P < *0.05) differences in KHN.*

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digital microhardness tester (Matsuzawa Seiki Co, Tokyo, Japan). Indentations were made with a 25g load applied for 12 seconds.

Data obtained were subjected to one-way ANOVA and Scheffé's test at a 0.05 significance level.

RESULTS

The mean Ra values and KHN for the different materials and polishing techniques are shown in Table 2 and Figures 1 and 2. The control (unpolished) groups of all materials demonstrated the lowest Ra values when compared with all other samples. For the composite resins SX and ZO, and polyacid-modified composite resin DY, white stone-polished surfaces were significantly rougher than surfaces polished with the other techniques. With the exception of SX polished with Enhance, significantly smoother surfaces were obtained following curing against a Mylar strip (unpolished) when compared with various polishing techniques. For the resin-modified glass-ionomer cement PF, white stone- and Enhance-polished surfaces were significantly rougher than Super-snap and unpolished surfaces. No statistically significant differences in surface roughness existed between Super-snap-polished and unpolished surfaces.

Table 3. Comparison of Materials by Ra Values for Each Polishing System

Polishing System	Differences
Control (Mylar finish)	PF > SX, ZO, DY Also SX > ZO
Enhance	PF > SX, ZO, DY Also DY > SX
White stones	PF > SX, ZO, DY
Super-snap	PF > SX, ZO Also DY > ZO

SX = Silux; ZO = Z100; DY = Dyract; PF = Photac-Fil

Results of one-way ANOVA and Scheffé's test ($P < 0.05$); > indicates statistical significance.

For SX, the control (unpolished) group had a significantly harder surface than the other polished surfaces. Results obtained with ZO were, however, different. White stone-polished surfaces were significantly harder than the unpolished surfaces and surfaces polished with Enhance and Super-snap. Enhance-polished surfaces were, in turn, significantly harder than the unpolished surfaces and surfaces polished with Super-snap. The unpolished surfaces were significantly harder than the Super-snap-polished surfaces. For DY, the unpolished surface was again significantly harder than the Super-snap-polished surfaces. No other significant differences in hardness were noted. For PF, Enhance-polished surfaces were significantly harder than the unpolished surfaces and surfaces polished with white stone and Super-snap. The control (unpolished) group had significantly harder surfaces than the white-stone- and Super-snap-polished surfaces. Comparisons of materials by Ra values and KHN for each polishing system are shown in Tables 3 and 4.

DISCUSSION

Finishing refers to the gross contouring or reducing of the restoration to obtain the desired anatomy. Polishing refers to the reduction of the roughness and scratches created by the finishing instruments. Improper application of these instruments could lead to decreased effectiveness. For example, disorderly application of different grits of Super-snap instead of descending order could markedly reduce the smoothness of the polished surfaces (Kanter, Koski & Bogdan, 1983). Strict adherence to the manufacturers' instructions on polishing procedures was thus observed. Every effort was also made to standardize the different aspects of the methodology in this study. Variations of Ra values and KHN within each treatment group may be accounted for by differences in pressure exerted during finishing and polishing procedures. This was kept to a minimum by using a single operator to conduct the experiment.

For all materials, the smoothest surfaces were produced when restoratives were allowed to cure against a Mylar strip (unpolished control group). This finding was consistent with the results obtained in several previous studies on composite resins (Pratten & Johnson, 1988; Stoddard & Johnson, 1991).

Table 4. Comparison of Materials by KHN for Each Polishing System

Polishing System	Differences
Control (Mylar finish)	ZO > SX, DY, PF Also SX > PF and DY > PF
Enhance	ZO > SX, DY, PF Also PF > SX
White stones	ZO > SX, DY, PF Also DY > SX, PF and SX > PF
Super-snap	ZO > SX, DY, PF Also DY > PF and SX > PF

SX = Silux; ZO = Z100; DY = Dyract; PF = Photac-Fil

Results of one-way ANOVA and Scheffé's test ($P < 0.05$); > indicates statistical significance.

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Although the control group gave the lowest Ra values, the surfaces produced were not without surface imperfections (Ra = 0). This may be explained by the fact that any surface imperfections in the Mylar strip will be reproduced in the surface of restoratives (Van Noort, 1983). Inherent surface properties of materials may also contribute to the significantly greater Ra values obtained with the resin-modified glass-ionomer cement. This inherent surface roughness must be equal to or lower than the surface roughness of human enamel on enamel-to-enamel occlusal contact areas (Ra = 0.64 μm) (Willems & others, 1993). For the composite resins and polyacid-modified composite resin evaluated, white stones consistently produced rougher surfaces than the other polishing systems. Enhance-polished surfaces of the microfilled composite resin SX were not significantly different from that of the unpolished control specimens. Results are in agreement with that obtained by Chung (1994) and show that the Enhance polishing system is highly effective for polishing microfilled composites. For the heavily-filled composite resin ZO and polyacid-modified composite DY, both Enhance- and Super-snap-polished surfaces were significantly rougher than the unpolished surfaces. The difference in surface roughness between the composites when polished with the identical polishing systems may be indicative of the fillers in the system. In composite systems where the fillers are markedly harder than the resin matrix, the resin phase may suffer a preferential loss during finishing and polishing, leaving the filler phase in positive surface relief. The larger the filler particle sizes, the greater will be the resulting Ra value. The presence of large unreacted glass particles on the surface of the polyacid-modified composite resin and resin-modified glass-ionomer cement after polishing with the Enhance and Super-snap system accounted for the higher Ra values observed. The ability of polishing procedures to abrade the filler phase will also influence the surface roughness. The latter explains in part the observation of similar Ra values obtained when composite and polyacid-modified composite resins are polished with white stones. Significant differences between the composite and polyacid-modified composite resins were observed when they were polished with the Enhance and Super-snap system. For the resin-modified glass-ionomer cement PF, the smoothest polished surfaces were obtained when the specimens were polished with the Super-snap system. No statistically significant differences in Ra values were observed between the unpolished group and specimens polished with the Super-snap system. Unfortunately, the application of Super-snap disks is not always possible: for example, the lingual surfaces of anterior teeth. In such instances, white stones provide an alternative means of instrumentation, since they are cheaper and less technically demanding than the Enhance polishing system. Although polishing with white stones resulted in a rougher surface than polishing with the Enhance system, the differences in Ra values observed were not statistically significant.

Results when translated clinically suggest that the surfaces of microfilled, heavily filled, polyacid-modified composite resin, resin-modified glass-ionomer cement restorations are best left unpolished after curing against a Mylar strip. When microfilled composite resins are to be polished, the Enhance system is strongly advocated. Both Enhance and Super-snap polishing systems are recommended for the polishing of heavily filled and polyacid-modified composite resins. White stones produced the roughest surfaces for all composite materials and should be avoided if possible. With the resin-modified glass-ionomer cements, disk polishing systems like Super-snap are encouraged. If anatomical constraints do not allow the usage of disk polishing systems, polishing with white stones will suffice, as other systems may produce equally rough surfaces.

Hardness may be defined as the resistance to permanent indentation or penetration. It is, however, difficult to formulate a definition that is completely acceptable, since any test method will involve complex stresses in the material being tested from force applications, with the result that a variety of qualities is involved in any single hardness test (Craig, 1989a). The composite resin ZO had the hardest surface of all treatment groups. With the exception of the Enhance-polished specimens, the resin-modified glass-ionomer cement was significantly softer than all the other materials for all treatment groups. Polishing of the resin-modified glass-ionomer cement with the Enhance system increased the hardness substantially. The reason for this phenomenon is unclear. Two possible hypotheses may, however, be put forth: Polishing with the Enhance system may generate heat, resulting in a greater degree of resin conversion, leading to an increase in surface hardness. Impregnation of the 0.3 to 1 μm aluminum oxide particles into the porous cement during polishing may also cause the increase in hardness observed. Changes in color and translucency that may be associated with this hardness change also warrant further investigation. For both microfilled composite SX and polyacid-modified composite resin DY, the hardest surfaces were obtained when the materials were cured against the Mylar strip. All finishing and polishing procedures resulted in lower surface hardness. Although finishing and polishing procedures resulted in the exposure of filler particles, which should theoretically result in higher KHN, these procedures could also cause

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subsurface damage by stress propagation through filler particles and exposure of partially polymerized resin, which may result in decreased hardness. The latter is influenced by the filler content and particle size that are critical to light dispersion (Craig, 1989b). The microfilled composite resin SX with its smaller (0.06 to 0.04 μm) and more numerous particles will not cure as effectively as the heavily filled composite resin ZO, which has larger (3 to 0.1 μm) and fewer particles to scatter light. Together with the high hardness of the zirconia-silica fillers present in ZO, the aforementioned may explain the significantly higher KHN obtained when ZO is polished with white stones when compared to the unpolished Enhance- and Super-snap-polished surfaces.

CONCLUSIONS

This study evaluated the surface characteristics of two composite resins, a polyacid-modified composite resin and a resin-modified glass-ionomer cement, polished with the Enhance system, white stones, and the Super-snap system. Surface characteristics of materials cured against a Mylar Uni-strip were used as a control. Evaluations were carried out employing two techniques: profilometry and microhardness testing. For all materials, the smoothest surfaces were produced when restoratives were allowed to cure against a Mylar strip (unpolished control group). Finishing and polishing of the various restoratives resulted in increased surface roughness, though this was not significant for some material-polishing system combinations. The hardness of the restorative after polishing procedures appears to be influenced by the different constituents of the material. The results of this study show that the surface characteristics (surface roughness and hardness) following polishing with different systems are material dependent. The results may be attributed to the discrepancy between filler and matrix hardness of the restorative. Filler content, particle size, and the ability of the polishing system to abrade the filler may also contribute to the change in surface characteristics observed.

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Three-Year Clinical Evaluation of the Clearfil Liner Bond System

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Clinical Relevance
This study demonstrates excellent clinical performance and a high retention rate of a restorative system used in class 5 lesions.

SUMMARY

Modern dental adhesive systems have improved the bond of restorative materials to mineralized tooth structures. The purpose of this study was to evaluate the clinical performance of composite restorations placed in abrasion and erosion lesions using the Clearfil Liner Bond dental adhesive system. Following ADA clinical guidelines for dentin and enamel adhesive materials, 62 facial class 5 smooth surface erosion or abrasion lesions with no undercuts and involving primarily root surfaces were restored in 25 adult male and female patients.

The teeth were restored without preparations using Clearfil Liner Bond and Clearfil Photo Anterior composite resin. The clinical performance of the restorations was assessed by two examiners at baseline, 6 months, 1, 2, and 3 years using the following evaluative parameters: color match, marginal discoloration, and marginal integrity according to modified Ryge criteria; the presence or absence of recurrent decay; pre- and postoperative sensitivity; and restoration failure due to loss of retention or other causes. At the end of 3 years, four of the 55 restorations remaining in the study failed due to lack of retention (92.7% retention rate). The evaluations of the other clinical parameters demonstrated excellent performance by this system.

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INTRODUCTION

Conservation of tooth structure and good esthetics have always been of primary significance in restorative dentistry. Yet without sufficient bonding at the tooth-restoration interface, this is difficult to achieve. Successful bonding to enamel has been demonstrated, and laboratory values for shear bond strength of composite resin to enamel are typically in the range of 20 MPa (Barkmeier, Shaffer & Gwinnett, 1986; Barkmeier & Cooley, 1992; Nordenvall, Brännström & Malmgren, 1980). Bonding of resins to dentin has proved to be more difficult than bonding to enamel. The early dentin adhesives had low laboratory bond strengths and performed poorly clinically (Chan, Reinhardt & Boyer, 1985; Eliades, Caputo & Vougiouklakis, 1985). Recent developments of hydrophilic adhesive systems, however, have made dentin bonding a more reliable and consistent procedure. Modern dental adhesive systems have demonstrated laboratory bond strengths approaching or exceeding 20 MPa for various current-generation adhesive systems (Triolo, Swift & Barkmeier, 1995;

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Table 1. Adhesive System Composition

Agent	Composition
CA Surface Treatment Agent	10% citric acid -20% calcium chloride
SA Adhesive Primer	3% NMSA-N, methacryloyl 5-aminosalicylic acid
PhotoBond Bonding Agent	10-methacryloyloxydecyldihydrogen phosphate (MDP), hydroxyethyl methacrylate (HEMA), BIS-GMA resin
Protect Liner F	resin with silanated microfiller and prepolymerized filler

Barkmeier & others, 1990; Barkmeier, Suh & Cooley, 1991; Cooley, Tseng & Barkmeier, 1991; Triolo & Swift, 1992; Los & Barkmeier, 1994).

Dental restorations have primarily relied on mechanical retentive locks or phosphoric acid etching of enamel for clinical retention. However, in abrasion, erosion and/or abfraction lesions, such retention is difficult to obtain without some type of cavity preparation (Jordan, Suzuki & Boksman, 1988). The clinical significance of the high dentin bond values for modern adhesive systems is that a more conservative approach, minimizing cavity preparation, may now be employed when restoring class 5 nonretentive lesions. While no clear correlation exists between in vitro bond strength and in vivo retention, it can be assumed that if a dentin adhesive system exhibits low bond strengths under ideal laboratory conditions, it is very likely that the restorations will not be retained successfully in the oral environment without providing mechanical retention. It has been postulated that a composite-to-dentin bond strength of greater than 17 MPa is required to overcome the contraction shrinkage of composite materials (Munksgaard, Irie & Asmussen, 1985). Once satisfactory bond strengths are obtained in vitro, clinical studies are necessary to demonstrate the success of a dentin adhesive system. A shear bond strength of 17.5 MPa by the Clearfil Liner Bond System has been demonstrated (Barkmeier, Douville & Matranga, 1993). The purpose of this study was to evaluate the clinical performance of this current-generation adhesive system.

METHODS AND MATERIALS

A total of 62 facial class 5 smooth surface erosion or abrasion lesions with no undercuts and involving primarily root surfaces were selected in accordance with the *American Dental Association Acceptance*

Table 2. Modified Ryge Criteria

COLOR MATCH	A = imperceptible in room light in 3-4 seconds (margins excepted; interfacial staining should not affect grading). B = perceptible/clinically acceptable. C = esthetically and clinically unacceptable.
MARGINAL DISCOLORATION (Interfacial Staining)	A = no staining. B = superficial (removable, usually localized). C = deep (not removable, generalized).
RECURRENT DECAY (Secondary Caries)	A = no. B = N/A. C = yes.
MARGINAL INTEGRITY (Ditching/Adaptation)	A = undetectable. B = detectable (catches explorer going both ways; V-shaped defect). C = V-shaped defect to DEJ.
PRE- & POSTOPERATIVE SENSITIVITY	A = none reported. C = reported.
FAILURE	A = not a clinical failure. B = failure due to tooth fracture. C = failure due to restoration fracture.
MATERIALS-RELATED FAILURE	A = not a failure. B = failure not material related. C = failure is material related.
RETENTION	A = restoration completely retained. B = partial restoration loss. C = complete loss of restoration.

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Table 3. Percent Scores

	Baseline			6 Months		
	A%	B%	C%	A%	B%	C%
Color Match	100	0	0	96.6	3.4	0
Margin Discoloration	100	0	0	98.3	1.7	0
Margin Integrity	100	0	0	100	0	0
Recurrent Decay	100	0	0	100	0	0
Preop Sensitivity	48.4	--	51.6	--	--	--
Postop Sensitivity	90.8	--	9.2	100	--	0
Retention	100	0	0	98.3	0	1.7
Failure	100	0	0	98.3	0	1.7

Program Guidelines for Dentin and Enamel Adhesive Materials (American Dental Association, 1991) from 15 adult female and 10 adult male patients in the general patient population at the Creighton University School of Dentistry. No greater than approximately 50% of the margin of each restoration involved enamel, allowing more than 75% surface area in contact with dentin in the preparation. Each restored lesion was classified according to the following criteria: Type I—V-shaped lesion less then 1 mm in depth; Type II—V-shaped lesion greater than 1 mm in depth; Type III—a saucer-shaped lesion less than 1 mm in depth; and Type IV—a saucer-shaped lesion greater than 1 mm in depth. Of the 62 lesions restored, 12 were Type I, 31 Type II, 7 Type III, and 12 Type IV.

The various components of the Clearfil Liner Bond System (Table 1) were applied according to the manufacturer's instructions (Kuraray Co Ltd, Osaka, Japan). Clearfil Photo Anterior restorative material was then placed and the restorations were finished and polished with fine diamonds, composite finishing burs, aluminum oxide finishing disks and strips, and a polishing paste. Photography and data forms were used to record clinical evaluations. Preoperative, baseline, and recall exam color slides were made for each restoration. Restorations were evaluated by two examiners on the basis of color match, marginal discoloration, marginal integrity, recurrent decay, pre- and post-operative sensitivity, failure, materials-related failure, and retention according to the modified criteria given in Table 2 (Cvar & Ryge, 1971). Recall exams were performed at 6 months, 1, 2, and 3 years. Each examiner independently evaluated the clinical performance of the restorations, and in case of examiner disagreement, a forced consensus was reached and recorded.

RESULTS

Baseline and 6-month evaluations are presented in Table 3. The color match of the Photo Anterior material was excellent (100% Alfa) at baseline. Preoperative sensitivity was reported by patients for 32 of the 62 teeth restored (51.6%). Immediately following restoration, only five of the original 32 teeth with preoperative sensitivity experienced postoperative sensitivity.

Sixty of 62 restorations were recalled at the 6-month evaluation period (96.8% recall rate). Only one restoration failed due to retention loss at 6 months (retention rate 98.3%). There was no reported postoperative sensitivity at 6 months. Color match was excellent with 57 of 59 restorations rated as Alfa and two as Bravo. Marginal discoloration was observed in only one of the 59 restorations examined.

The rating scores for the restorations examined at the 1-year, 2-year, and 3-year evaluation periods are presented in Table 4. Fifty-eight of the original 62 restorations were recalled at 1 year (93.5% recall rate). One restoration failed at 6 months, which brought the total number of restorations included in the study at 1 year to 59. The failure percentage was calculated according to the ADA guidelines. There was no reported postoperative sensitivity at the 1-year evaluation period. Color match was excellent with 54 of 58 restorations rated as Alfa. Marginal

Table 4. Percent Scores

	1 Year			2 Years			3 Years		
	A%	B%	C%	A%	B%	C%	A%	B%	C%
Color Match	93.1	6.9	0	91.2	8.8	0	90.2	9.8	0
Margin Discoloration	96.6	3.4	0	91.2	8.8	0	90.2	9.8	0
Margin Integrity	100	0	0	100	0	0	100	0	0
Recurrent Decay	100	0	0	100	0	0	100	0	0
Preop Sensitivity	--	--	--	--	--	--	--	--	--
Postop Sensitivity	100	--	0	100	--	0	100	--	-
Retention	98.3	0	1.7	98.3	0	1.7	92.7	0	7.3
Failure	98.3	0	1.7	98.3	0	1.7	92.7	0	7.3

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discoloration was observed in only two of the 58 restorations examined.

At the 2-year evaluation period, 57 of the original 62 restorations were recalled (91.9% recall rate). One restoration was removed from the study at the 2-year recall because the patient elected to have the tooth crowned, and since one restoration failed at 6 months, the total number of restorations included in the study at 2 years was 58. The failure percentage at 2 years was 1.7%. No postoperative sensitivity was found at the 2-year recall period. Color match and marginal discoloration were excellent with 52 of 57 restorations rated as Alfa in both categories.

Fifty-one of the original 62 restorations were recalled at the 3-year evaluation period (82.2% recall rate). Seven restorations were lost to recall. One restoration failed at 6 months and three restorations failed between 2 and 3 years, which brought the total number of restorations in the study to 55. The retention rate for the restorations in this study was 92.7% (51 of 55 restorations at 3 years). No postoperative sensitivity was found at the 3-year recall period. Both color match and marginal discoloration were still excellent with 46 of 51 restorations rated as Alfa in each category.

DISCUSSION

The Clearfil Liner Bond System employs an interesting mechanism of bonding. CA Agent, a citric acid-calcium chloride-based tooth surface conditioner, removes the smear layer and dentinal plugs that may hamper adhesion, thereby exposing dentin collagen fibers. It contains a weak acid to minimize any possible decalcification of tooth structure. The primer in this system contains salicylic acid derivative monomer (5-NMSA), which has methacryloyl groups at one end and salicylic acid groups at the other end (Kuraray Co, Ltd). It is postulated that this monomer promotes the affinity to collagen fiber, allowing SA Primer to fix the dentin collagen exposed by the conditioner and form a thicker, stronger, resin-impregnated layer, thus reinforcing tooth structure. In addition, 5-NMSA has been shown to desensitize hypersensitive dentin (Tagami & others, 1987b).

Clearfil Photo Bond catalyst contains a phosphate derivative of decylmethacrylate containing a $-(CH_2)_{10}$- carbon chain known as 10-methacryloyloxydecyldihydrogen phosphate or MDP (Kuraray Co, Ltd). This bonding agent purportedly bonds to dentin through ionic bonding of the phosphate group to calcium-rich tooth structure. By incorporating a long hydrophobic component and a short hydrophilic component, Clearfil Photo Bond improves wetting of the hydrophilic dentin surface. Together with the hydrophilic monomer HEMA, which is highly permeative into demineralized dentin, high bond strengths and good marginal seals can result.

Protect Liner is a low-viscosity photoactivated resin with a microfiller content of 42% by weight. Due to its low viscosity and good wetting capability, it can completely seal the exposed tooth surface and also decrease sensitivity. Protect Liner offers very good wear resistance at the cavity margin (Tagami & others, 1987a).

Most of the later-generation adhesives involve the penetration of resin monomer into the smear layer on the dentin or into a dentin surface that has been decalcified, forming an "interdiffusion layer" (Van Meerbeck & others, 1992). This "hybrid layer"(Nakabayashi, Nakamura & Yasuda, 1991) is believed to be the critical mechanism for the adhesion of the hydrophilic adhesive systems (Eick & others, 1991). The formation of a "resin-reinforced" zone appears essential for a durable bond to dentin.

The excellent retention rate of the Cleafil Liner Bond System appears to confirm the effectiveness of the formation of the resin-reinforced zone in promoting a reliable and stable bond in the oral environment. The results of this study are also significant in that a high laboratory value for shear bond strength of composite to dentin for this system correlates to high retention rates for composite resin in nonretentive class 5 lesions.

CONCLUSION

It has been postulated that a composite-to-dentin bond strength of greater than 17 MPa is required to overcome the contraction shrinkage of composite materials. A newer-generation adhesive system exceeding this threshold in a laboratory evaluation exhibited a high retention rate (92.7%) in a clinical study where class 5 restorations were placed in nonretentive lesions near the gingival area. In essentially all cases, the enamel margin of the lesions was limited to the occlusal/incisal margin. The clinical performance with this system with respect to color match, and marginal discoloration and integrity was also excellent after 3 years.

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REVIEW OF LITERATURE

Trends in Clinical Dentistry Skills Observed by Board Examiners: a 15-Year Comparison

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SUMMARY

This study compares and analyzes the clinical performance of recent dental graduates over a 15-year period. A majority of the 981 board examiners, cumulatively surveyed, observed an increase in diagnosis/treatment planning and periodontal skills, and a decrease in operative and prosthodontic skills, while many other skills were performed at approximately the same level.

INTRODUCTION

The outcomes of dental curricula must be constantly evaluated to encourage maintenance of clinical skills. Recent increases in the failure rate on board examinations indicate a need to more closely investigate the current trends in clinical skills (Pink & Smith, 1993; Smith, Bomberg & Bauer, 1980; McCoy, 1995; Yaple, 1995). The purpose of this study is to review and compare the responses about dental candidate ability based on surveys of 981 members of dental examination boards in the United States that were conducted in 1980, 1990, and 1995, and to make recommendations based on the outcomes of these studies. This study is not meant to be a "meta" analysis in any way, only to elucidate the perceptions of current board examiners of candidate skills in a format previously used to study this issue.

Numerous papers discuss the many issues and concerns over licensure examinations: high failure rates, candidate ability, patient availability and selection, simulation, evaluation, calibration, and reliability of testing mechanisms, (Alpert, 1973; Allen, 1992; Bales, 1988; Berry, 1995; Butts, 1975; Dugoni, 1992; Hamilton, 1983; Hutchinson, 1992; McCoy, 1995; Nash, 1992).

In 1980 Smith, Bomberg, and Bauer showed in their study that for two-thirds of the examiners surveyed, their perception was that the skills of recent graduates in operative dentistry had declined. In a similar survey, first distributed in 1990 and published in 1993, Pink and Smith reported an observed decrease in clinical restorative skills as perceived by dental examiners in the United States over that most recent decade. Now 15 years after the original study, this paper compares and evaluates the trends in

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dental clinical skills observed by board examiners during licensure examinations.

METHODS AND MATERIALS

Questionnaires were mailed to the central office of the Northeast Regional Board (NERB) of Dental Examiners, Inc in Washington, DC and to the Central Regional Dental Testing Service (CRDTS), Inc in Topeka, Kansas. They were inserted into the portfolio of information presented to each board examiner upon registration at the joint Spring General Assembly on the new Combined Regional Examination (CORE) for NERB and CRDTS in Kansas City, in April, 1995. This meeting was composed of dental board examiners from 24 states and the District of Columbia. Most examiners had already participated in several examinations using the new, revised, examination format. All board examiners scheduled to examine dental students during the following year were required to register and attend the training sessions at the Spring General Assembly Meeting. Therefore, the response to our questionnaire was a very high percentage of the board examiners for the 25 jurisdictions and not meant to be a sample.

A total of 364 members of dental examination boards were surveyed during 1995 to continue the comparison of trends in dental clinical skills from earlier studies on this subject. The questionnaire administered to the examiners was patterned after the questionnaire used by Pink and Smith in the 1990 survey. It included a cover page to collect demographic information, along with an additional three-page clinical skill questionnaire composed of Likert-type scales (e g, skill level = improved - no change - decreased) covering the areas of general clinical skills, amalgam preparation and restoration, composite resin preparation and restoration, the new manikin prosthodontic and endodontic areas, and general performance skills. At the end of the first page an inclusion criterion asked whether the respondent had served as an examiner in the last 3 years. This question was asked to verify current experience.

The data from the questionnaires were entered by two independent research assistants (NP and EK) into a database using a desktop PC. Statistical manipulation was undertaken with SYSTAT software (SYSTAT for Windows, Version 5.1 Edition, Evanston, IL 60201-3793) (SYSTAT, Inc, 1992). Comparisons and relationships in the data were analyzed by descriptive procedures and Kruskal-Wallis statistical testing (the nonparametric equivalent of a one-factor ANOVA). A significance level of $P(\alpha) = 0.05$ was utilized for all testing. The reported median values were obtained by removing those responses in the Not Observed column, which resulted in a three-choice ordinal scale for analysis. Calculation of the median for any particular skill question will identify the category with over 50% of the responses in a three-choice scale when the median is the extreme high or low category. By definition, the median is the middle response for a set of data; therefore, if only three choices are possible and the calculated median is one of the extreme values, then the median must, by definition, account for at least 50% of the responses for that question. When the median is the middle category, no inference can be made regarding 50% of the responses. The authors felt this was a valid method to report the trends in the data and substantiate the percentage calculations.

In addition, the authors felt it important to report

Table 1. Clinical Skills (%)

Skills	n	Improved	No Change	Decreased	Median	n	Not Observed
Operative	236	10.9	21.8	67.3	decreased	7	2.9
Endodontics	130	11.3	63.2	25.5	N/A	98	43.0
Periodontics	208	27.4	49.7	22.9	no change	30	12.6
Fixed Pros	174	6.9	26.2	66.9	decreased	56	24.3
Removable Pros	166	7.8	74.5	17.7	N/A	67	28.8
DX & TX Plan	187	14.4	68.8	16.9	no change	48	20.4
Radiographic Inter	192	15.3	70.6	14.1	no change	42	17.9
Radiographic Tech	183	16.9	68.2	14.9	no change	53	22.5
Oral Pathology	86	21.4	57.1	21.4	no change	141	62.1
Oral Surgery	53	10.0	70.0	20.0	no change	173	76.5
Pedo/Ortho	61	20.8	60.4	18.8	N/A	166	73.1
Basic Science	95	27.3	55.8	16.9	no change	132	58.1

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the Not Observed column as an indication of the context of current board examinations. However, calculation of the median for the data without the Not Observed responses allowed a clear understanding of what the majority of the respondents with exposure to the skill felt the current skill levels were.

RESULTS

Out of the 364 questionnaires distributed in 1995 to the board examiners, 307 (84.3%) were returned with sufficient data to be incorporated into the analysis. There were 250 general practitioners and 44 specialists participating in the survey (13 examiners were not categorized). Out of the 307 questionnaires answered, 78.8% were generalists; 3.5% were oral surgeons; 2.5% were periodontists; 3.5% were anesthesiologists; 2.5% were orthodontists; 2.5% were prosthodontists; 1.6% were endodontists; 0.3% were oral medicine; 0.8% were pedodontists; 0.8% marked other; 3.2% did not report their field.

The experience of the examiners ranged from 1 year to over 20 years: 27.1% had examined for 1-5 years; 20.8% for 6-10 years; 28.1% for 11-15 years; 12.3% for 16-20 years; and 7.6% for 20+ years. The median time period of examiner experience was 11-15 years. The remainder of the questionnaire was completed by only the 80.8% of examiners who had participated as an examiner in clinical board exams during the past 3 years, as instructed in the directions to participants.

The first portion of the study surveyed the trends in clinical skills of the candidates as observed by the examiners during licensure examinations. Each examiner marked scales indicating Improved, No Change, Decreased, or Not Observed, based on their perception of direct contact to candidate skills. Of the total, 65.8% of the examiners answered at least one area of the clinical skills questions. It is reasonable that 34.2% of examiners would not respond to a single clinical skills question. Examiners are trained at the Spring General Assembly in all areas of the clinical examination. However, in order to balance the assignments to all dental schools, some examiners might end up re-examining in the same clinical area and therefore cannot respond to certain other clinical skills at this time. Table 1 shows that 67.3% of examiners observed that operative skills were decreasing, with a recorded median response of "decreasing skills." Also a majority of examiners (66.9%) indicated that clinical skills in fixed prosthodontics were declining. Many examiners felt that the clinical skills remained

Table 2. Restorative Dentistry Skills (%)

	n	Often	Seldom	Almost Never	Median	n	Not Observed
Preparation too deep	230	59.7	38.3	2.0	Often	10	4.2
Preparation too shallow	237	39.9	54.2	5.9	Seldom	5	2.1
Retention too deep	228	39.0	47.2	13.8	Seldom	8	3.4
Retention too shallow	231	31.5	59.9	8.6	Seldom	6	2.5
Isthmus too wide	233	48.0	45.5	6.5	Seldom	6	2.5
Cusps weakened	232	23.1	67.8	9.0	Seldom	5	2.1
Exposed pulp	234	16.4	63.7	19.9	Seldom	6	2.5
Caries remains	235	49.0	34.7	16.3	Seldom	6	2.5
Adjacent tooth damage	239	33.7	54.1	12.2	Seldom	3	1.2
Poor occlusal anatomy	234	36.0	56.5	7.5	Seldom	6	2.5
Poor approximal anatomy	235	27.2	64.9	7.9	Seldom	5	2.1
Contact absent	236	47.8	42.4	9.9	Seldom	4	1.7
Occlusion inadequate	233	41.1	43.6	15.3	Seldom	7	2.9
Composite Resin Skills	**n**	**Often**	**Seldom**	**Almost Never**	**Median**	**n**	**Not Observed**
Inadequate outline	184	53.6	39.3	7.1	Often	49	21.0
Retention too deep	183	20.4	67.1	12.6	Seldom	50	21.5
Retention too shallow	182	26.5	66.3	7.2	Seldom	50	21.6
Poor cavosurface	179	44.8	46.6	8.6	Seldom	231	22.5
Poor finish	179	55.2	35.6	9.2	Often	51	22.2
Material porosity	177	38.3	43.8	17.9	Seldom	54	23.4

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Table 3. Manikin Procedure Skills (%)

Prosthodontic Manikin	n	Often	Seldom	Almost Never	Median	n	Not Observed
Cavity overprepared	114	51.9	44.2	3.8	Often	112	49.6
Cavity underprepared	115	17.1	78.1	4.8	Seldom	111	49.1
Adjacent tooth damage	111	31.7	55.4	12.9	Seldom	116	51.1
Cusps inadequately reduced	109	12.1	81.8	6.1	Seldom	115	51.3
Faulty fit of provisional	112	74.5	22.5	2.9	Often	115	50.7
Improper occlusal anatomy	109	49.5	46.5	4.0	Seldom	115	51.3
Improper approximal anatomy	109	30.3	66.7	3.0	Seldom	115	51.3
Approximal contact absent	109	62.6	32.3	5.1	Often	115	51.3
Inadequate occlusal contact	109	49.5	49.5	1.0	Seldom	115	51.3
Poor finishing	108	71.7	23.2	5.1	Often	116	51.8
Endodontic Manikin	**n**	**Often**	**Seldom**	**Almost Never**	**Median**	**n**	**Not Observed**
Adequate access location/size	94	56.3	36.8	6.9	Often	130	58.0
Perforations	90	9.4	50.6	40.0	Seldom	134	59.8
Canal length good	91	45.2	48.8	6.0	Seldom	131	59.0
File breakage	77	8.5	28.2	63.4	Never	148	65.8
Biomechanical good	95	59.8	29.9	10.3	Often	128	57.4
Obturation good	96	60.2	25.0	14.8	Often	126	56.8

nearly the same and marked No Change in the areas of periodontics, endodontics, diagnosis and treatment planning, radiographic interpretation, and technique. A large percentage of the total examiners had Not Observed clinical application of oral pathology (62.1%); oral surgery (76.5%); pedodontics/orthodontics (73.1%); and basic science knowledge (58.1%) (Table 1). This would be expected during examinations of this nature and shows close attention to the questionnaire and thus indicates a degree of reliability in the study.

The next area surveyed errors in technique for amalgam preparations and restorations (Table 2). The scale Often, Seldom, Almost Never, or Not Observed was utilized in this section. The errors most frequently observed by examiners were: preparation isthmus too wide (48.0%); cavity preparation too deep (59.7%); approximal contact absent (47.8%); caries remaining (49.0%); occlusion inadequate (41.1%). Most of the other errors were marked Seldom.

Table 2 also shows the different categories for composite resin observed by examiners using the same scales of Often, Seldom, Almost Never, and Not Observed. Only 57.6% of all examiners had observed composites during licensure examinations. However, 53.6% of examiners observed that preparation outlines were Often inadequate; 55.2% of examiners observed that finishing technique/result was Often poor; and 38.3% of examiners felt porosity in the composite restorations occurred Often.

The fourth area surveyed identified errors in the new prosthodontic manikin section of licensure examinations (Table 3). The scale used for marking errors was Often, Seldom, Almost Never, and Not Observed. Only 37.5% of the examiners responded in this area. This is attributable to the new manikin portion of the examination, which was recently added to the examination.

In the endodontic manikin portion of the questionnaire (Table 3) only 31.3% of examiners responded. These data indicated that 45.2% of examiners observed acceptable canal length; only 8.5% of examiners observed endodontic file breakage; 59.8% of examiners observed acceptable biomechanical preparations; 60.2% of examiners observed acceptable obturation.

The last area of the questionnaire identified changes in performance skills by the candidates as observed by the dental examiners (Table 4). The headings Improved, No Change, Decreased, and Not Observed were used in this section. A majority of the examiners observed a decreased level of clinical skills in the area of operative dentistry (67.3%) and prosthodontics (66.9%). Examiners believed skills to have decreased in: amalgam preparations (62.6%), amalgam restorations (62.1%), composite preparations (55.9%), composite restorations (51.6%), caries identification (59.8%), and adequate caries removal (57.7%).

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It should be noted in Table 4 that the Not Observed category was selected in approximately the same ratio as in the separate sections for the first appearance of questions on similar areas of competency. The inclusion of these additional questions helped to verify the reliability of the responses through completion of the questionnaire. Furthermore, the additional clinical skills in this section were observed by the majority of the examiners as having No Change in skills. The results for general performance skills were additionally analyzed and stratified by examiners' years of experience. This analysis indicated that there was no significant difference ($P = 0.01$) in the perception of performance skills of board candidates based on the examiners' number of years of experience as a board examiner utilizing Kruskal-Wallis statistical analysis.

DISCUSSION

Examination protocol for the Northeast Regional Board is presently in the third year of manikin examination, while the Central Regional Dental Testing Service examiners participated in the examination with manikins for the second time during the spring series of examinations in 1996. CRDTS and NERB examiners have been cross-trained and cross-assigned between 24 states and the District of Columbia. Many had also been coordinated and calibrated during the pilot and prototype examinations, thus lending a great degree of experience and reliability to this study. The new results for the manikin prosthodontic and endodontic areas are being reported, especially at this early stage, to serve as base-line reference for future studies. There has been recent interest by dental educators for increased use of manikins during licensure examinations (Scheid, Zacherl & Metzler, 1987; Meskin & Entwistle, 1985). This study was carefully controlled for respondent calibration and instruction far better than either of the previous studies were able to obtain. Even with that fact in mind, the trends in perception of candidate skill show very similar results with apparent trends over the 15-year period.

The data in Tables 5 and 6 compare the results from the 1980 and 1990 studies to those from the current survey (1995). The data show that perceived skills have Improved in the areas of periodontics and diagnosis and treatment planning (Figure 1). There has been decreased perception of skills in the area of operative dentistry for amalgam and composite preparations and restorations, caries identification and removal, candidate ability to create anatomy on restorations and fixed prosthodontic procedures (Figure 2). All other skills are perceived by examiners as having shown No Change. However, a closer look at the results reveals that even in those skill areas that are reported as

Table 4. Overall Performance Skills (%)

Performance Skills	n	Improved	No Change	Decreased	Median	n	Not Observed
Amalgam preparation	220	11.1	26.3	62.6	Decreased	15	6.4
Composite preparation	180	10.6	33.5	55.9	Decreased	51	22.1
Amalgam restoration	219	8.4	29.5	62.1	Decreased	13	5.6
Composite restoration	182	8.7	39.8	51.6	Decreased	47	20.5
Diagnosis	200	11.0	68.8	20.2	No change	33	14.2
Anesthetic injection	191	10.4	74.8	14.7	No change	45	19.1
Patient management	214	15.2	60.3	24.5	No change	22	9.3
Rubber dam application	221	12.1	55.3	32.6	No change	15	6.4
Caries identification	226	6.7	33.5	59.8	Decreased	9	3.8
Caries removal	227	10.7	31.6	57.7	Decreased	9	3.8
Base/liner use	226	11.9	42.8	45.4	No change	10	4.2
Material selection	217	11.8	56.5	31.7	No change	17	7.3
Material use	221	7.3	56.0	36.6	No change	14	6.0
Understand occlusion	222	5.7	49.0	45.3	No change	13	5.5
Create proper anatomy	224	6.7	41.8	51.5	Decreased	11	4.7
Organization	219	12.6	50.8	36.6	No change	16	6.8
Professionalism	224	15.0	46.1	38.9	No change	13	5.5

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Table 5. Comparison Chart of Clinical Skills over 15 Years

Skills	% of Total Response	1980 Median	% of Total Response	1990 Median	% of Total Response	1995 Median
Operative	70	Decreased	51.1	Decreased	67.3	Decreased
Endodontics	N/A	N/A	N/A	N/A	63.2	N/A
Periodontics	82.1	Improved	50.3	No change	49.7	No change
Fixed Prosthodontics	57.9	Decreased	48.9	No change	66.9	Decreased
Removable Prostho	57.9	Decreased	N/A	N/A	74.5	N/A
DX & TX Planning	43.8	Improved	55.3	No change	68.8	No change
Radiographic Inter	58.1	No change	72.1	No change	70.6	No change
Radiographic Tech	48.8	No change	72.9	No change	68.2	No change
Oral Pathology	88.1	No change	60.8	No change	57.1	No change
Oral Surgery	53.8	No change	68.2	No change	70.0	No change
Pedo/Orthodontics	50.0	No change	65.7	No change	60.4	No change
Basic Science	78.3	No change	56.1	No change	55.8	No change

Improved or No Change, the magnitude of the improvement, and/or the status quo, has been decreasing as well. In practically every area of skills surveyed, the amount of improvement or stability has decreased while the areas of reduction in skills has increased. The authors feel this area demands further study in as controlled a manner as possible. It is obvious that this finding has important implications to the dental profession and lay population as a whole and is specifically important to dental education.

The in-depth comparison of results from this study shows a 15-year continual decline in clinical skills as observed by examiners during licensure examinations (Smith & others, 1980; Pink & Smith, 1993). It was determined that only 10.9% of the examiners saw an increase in operative skills recently, and there is definitely a trend toward decreasing operative skills, revealed by over 50% of examiners responding as decreased in all three surveys, with 70.0% reported in 1980, 50.2% reported in 1990, and 67.3% reported in 1995. The decline in operative skills was noted in 1990 to be decreasing at a lower percentage than reported in 1980; however, the 1995 survey indicates an increased percentage of decline in this skill again. There was also a decrease in prosthodontic skills; however, skills in periodontics and other areas have slightly improved or at least remained the same over the 15-year period.

The most prevalent errors in technical skills in cavity preparation noted in this study for amalgam are: excessive cavity width, excessive cavity depth, caries identification, and caries removal. Lack of approximal contact and poor anatomy were listed by the examiners as the main errors made on amalgam restorations and may be interpreted as inadequate practice in carving procedures. The 1990 survey reported less concern, with lack of contact (22.0%) and poor anatomy (46.0%) as the most frequent errors.

The errors most noticed in the composite resin section were in the restoration area and included faulty margins, poor finishing technique, and porosity. Few examiners noted errors in the composite preparation area. The technical skill required for composite preparations might be somewhat less demanding than gold foil or cast gold preparations and also possibly more difficult to evaluate. Errors in the technique-sensitive composite restoration will probably take longer to show up, and based on the 15-year trend in decreasing clinical skills, could be an area of concern in the future.

It might be recognized that errors in the basic design of preparations for operative and prosthodontic procedures probably contribute to the overall decrease in essential skills. The 1980 and 1990 studies also included information pertaining to a decline in cast gold and gold foil preparations and restorations as perceived by the board examiners. The 1995 study questionnaire removed the gold foil and cast gold questions, since these areas no longer

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Table 6. Comparison Chart of Performance Skills over 15 Years

Skills	% of Total Response	1980 Median	% of Total Response	1990 Median	% of Total Response	1995 Median
Amalgam preparation	51.3	Decreased	43.6	No change	62.6	Decreased
Composite preparation	71.7	No change	49.9	No change	55.9	Decreased
Amalgam restoration	55.8	No change	56.9	No change	62.1	Decreased
Composite restoration	N/A	N/A	60.6	No change	51.6	Decreased
Diagnosis	52.3	No change	66.5	No change	68.8	No change
Anesthetic injection	77.0	No change	87.2	No change	74.8	No change
Patient management	66.3	No change	77.4	No change	60.3	No change
Rubber dam application	54.8	No change	66.3	No change	55.3	No change
Caries identification	64.5	No change	68.0	No change	59.8	Decreased
Caries removal	62.5	No change	70.5	No change	57.7	Decreased
Base/liner use	59.0	No change	54.2	No change	42.8	No change
Material selection	55.9	No change	N/A	N/A	56.5	No change
Material use	65.1	No change	71.7	No change	56.0	No change
Understand occlusion	50.5	No change	70.1	No change	49.0	No change
Create proper anatomy	69.4	No change	N/A	N/A	51.5	Decreased
Organization	60.7	No change	62.0	No change	50.8	No change
Professionalism	N/A	N/A	46.7	No change	46.1	No change

are an option on the examination. Prosthodontic and endodontic manikin questionnaire areas were added to fit the new format. Some board examiners have not had the opportunity yet to extensively examine and evaluate the manikin portion of the examinations. A future study will be needed to determine the trends of clinical skills in these two areas after the manikin examinations have been given several more times.

The data from the current study indicate that the perceived ability of candidates to prepare teeth for restoration has declined. Also of concern is the reported decline in candidate ability to diagnose and completely remove carious tissue as a part of the restorative procedure. Much of operative dentistry involves replacement services rather than treatment of new incipient or advanced caries. That being the case, students likely receive less experience in the removal of new caries than in years past; however, licensure examinations tend to concentrate on student ability to remove caries. Innovative approaches to create simulations in caries diagnosis and removal, as well as the creation of teaching aids on caries detection and removal during the cavity preparation process to improve student learning, are needed for this important skill. Licensure examinations need to explore ways to assess candidate ability to diagnose caries in vivo, to determine carious versus noncarious tissue (perhaps in some manikin simulations created for this purpose), and to remove carious tissue completely. Calibration and training sessions for board examiners on caries removal are important areas for consideration as well.

A recent article (DiMatteo & others, 1995) reported results of public attitudes toward dentists and the dental profession. This random sample survey of the US public was the first population-based study in more than 30 years on the topic. It was part of a larger research project "to examine a set of competencies (identified by the PEW Health Profes-

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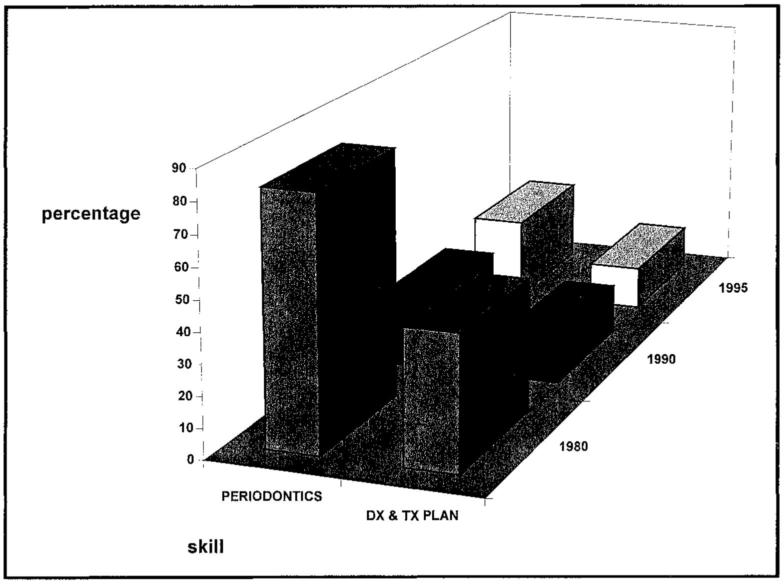

Figure 1. *Three-study comparison of skills that improved*

sions Commission) that dentists should have to meet the emerging needs of both the public and the health care system as it is reformed." The research presented ratings in the importance of eight competency areas in dentists' treatment of patients and showed that "both the public and practicing dentists considered ethical conduct, diagnosis/treatment and communication most important." This study on public attitudes toward dentists indicating that dental treatment is highly ranked substantiates the importance of maintaining adequate clinical dental skills for graduates.

The questionnaires for this study were revised (from the 1980 and 1990 studies) and distributed in the spring of 1995 when CRDTS and NERB formed a joint venture to give a common licensure examination, CORE (COmbined Regional Examination), for 24 states and the District of Columbia. At that time the authors, many dentists, ADA, AADE, dental educators, and dental examination boards had high expectations for the new CORE examination and most felt that it was a very positive step forward. The joint regional CORE examination helped to standardize the licensure examination and improve the licensing system that presently inhibits a dentists' economic opportunity and freedom of interstate movement. Unfortunately, at the date of submission for this paper, CRDTS has withdrawn from the CORE examination. The decision not to participate in a joint regional CORE examination at this time is a definite setback, but hopefully only a temporary one, as the entire dental profession works together to help standardize licensure examinations and lead dentistry into the 21st century.

CONCLUSIONS

The decline in operative and prosthodontic clinical performance skills of recent dental graduates, as perceived by dental examiners, during licensure examinations has continued based on comparison of three studies conducted over the last 15 years. The areas of diagnosis/ treatment planning and periodontal skills were observed to have improved slightly, while many other skills were still performed at approximately the same level.

Clinical curriculum time is under extreme pressure from the rapidly expanding knowledge base in the basic sciences, oral and general medicine, pharmacological agents, and dental material science. Today's dental practitioner must be competent in all these areas, but new technology and the occurrence of multiple treatment options place additional demands on limited available clinic time. This fact results in reduced exposure to

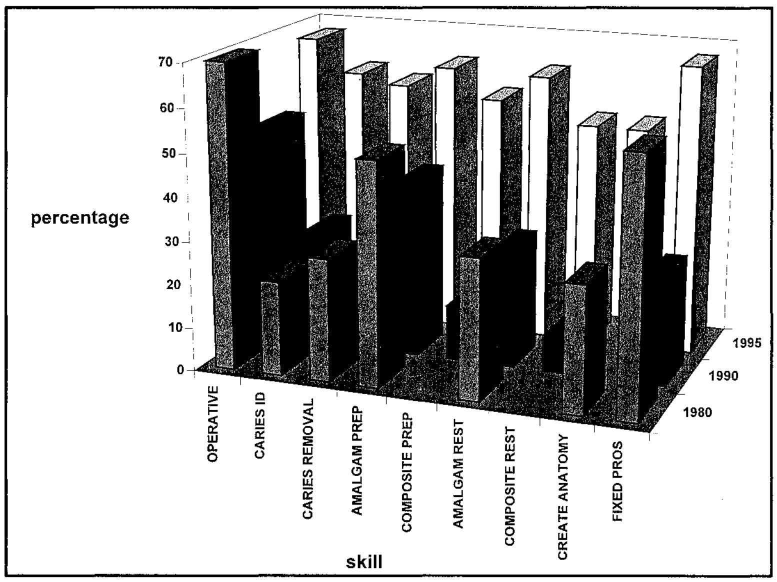

Figure 2. *Three-study comparison of skills that decreased*

basic procedures and techniques for the student dentist. Most restorative treatment modalities are technique sensitive and require more than casual clinical experience to develop proficiency. Manual dexterity is no longer a credential evaluated prior to admission of dental students, and reduced clinical curriculum time has a much greater impact on candidates weak in manual skills. Most practicing dentists perform irreversible procedures on living tissue every day. The recent dental graduates of the 1990s have a wider range of knowledge in many disciplines than their colleagues from past decades,

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but the profession must guard against erosion of the basic clinical performance skills.

Suggestions based on the three surveys reported between 1980 and 1995, which include the observations of 718 examiners and 981 questionnaires, include the following:

1) There is a need for continued communication among dental educators, ADA, AADE, and boards of dentistry;

2) New evaluation methods that are highly reliable should be developed for evaluating clinical competency of candidates for licensure;

3) The curriculum time for the basic clinical disciplines of operative and prosthodontic dentistry needs to be revised in creative, contemporary, and innovative ways to teach these skills in a more effective manner to dental students;

4) Simulation for teaching caries treatment should be emphasized to address the current limitation that students have in clinical experiences with diagnosis and removal of new carious lesions;

5) Independent states should be encouraged to join regional examination boards, and further, regional examination boards should continue to be progressive and work on additional joint ventures.

These suggestions, especially the last, are imperative to standardize clinical examinations and help the competent dentist with the national mobility that is the standard for the medical profession.

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DEPARTMENTS

BOOK REVIEWS

PAIN MANAGEMENT SECRETS

Ronald Kanner

Published by Hanley & Belfus, Inc, Philadelphia, 1997. 246 pages, indexed, $35.95, softbound.

This textbook is part of the Secrets Series of handbooks distributed by Mosby for medical and dental students and postdoctoral trainees. They incorporate a question-and-answer format to explore various issues and clinical disciplines. Apparently, the goal is to familiarize readers with the types of questions (and appropriate responses) that they will encounter on rounds, in clinical settings, and on oral examinations. While this is a common means of teaching within medicine, it is less so in dentistry.

The book is divided into nine chapters with multiple sections for each chapter. It is a generic text on pain with sections on everything from migraine headaches to chronic pelvic pain. The initial chapter deals with definitions of pain syndromes and the classification of pain, with some discussion on the basic anatomy and physiology. Chapter 2 covers the clinical approaches and includes history, physical examination, and delineation of various pain-measurement parameters. Clinical pain syndromes are explored in Chapter 3 and to some degree in Chapters 4 and 5. Pain management is discussed from a pharmacological standpoint in Chapter 7 and from a nonpharmacologic perspective in Chapter 8. The final chapter deals with pain clinics and regulatory issues. There is a 15-page index following the last chapter.

It is clear that this text is designed for clinicians with major involvements with pain syndromes. While the textbook appears to be well written and organized, the question-and-answer format is unusual and not very well suited to someone without prior knowledge and experience in the field. This book would not likely be appropriate for most dentists, but would be pertinent in a limited fashion for those dealing with facial pain, neuralgias, and temporomandibular disorders. It is really best suited for medical students, residents, or clinicians in pain clinics or related disciplines.

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CLINICAL DECISION MAKING AND TREATMENT PLANNING IN OSSEOINTEGRATION

Michael J Engelman

Published by Quintessence Publishing Co, Inc, Chicago, 1996. 219 pages, 272 illustrations, $82.00, softbound.

As dentists incorporate osseointegrated implants into their practices, they soon realize that there are many additional factors to take into account when treatment planning. With implants the clinician is faced with such considerations as dealing with compromised implant placement, avoiding the overload of components, and choosing from an ever-increasing abutment armamentarium. The purpose of this text, as stated by the author, is to aid thinking, decision making, and treatment planning in osseointegration. The first five of the 16 chapters could fall into the category of practice management, where he provides good examples of patient letters, develops formulas for fee determination and provides worksheets and overviews for treatment sequencing. The remaining chapters discuss different combinations of missing teeth, ranging from a single missing tooth to the completely edentulous patient. In each scenario he discusses, with excellent schematic illustrations, the relevant treatment planning issues if implants are being considered. Flow-sheet diagrams help put into perspective the sequence of treatment of the different scenarios.

This book is well illustrated with excellent drawings. The clinical photographs vary in quality and are probably unnecessary. Only the Nobel Biocare components are illustrated, but the basic concepts are very well explained. The author is also very wisely conservative in his treatment planning approach. The book makes for very easy reading. It may seem repetitive if read from beginning to end, because it is meant to be accessed as a reference text, where the clinician can refer to the section that applies to the specific patient being treated.

I recommend this book not only for the restorative dentist or prosthodontist with limited-to-moderate experience with implants, but also for surgeons and periodontists who desire a better understanding of the restorative treatment planning concepts.

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Dr Henry St Germain, Chair
University of Nebraska Medical Center
College of Dentistry
Department of Adult Restorative Dentistry
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PROSTHODONTIST (Positions #7-6139 and #7-6140). Responsibilities include teaching undergraduate preclinical restorative dentistry and conducting clinical and/or laboratory research. DDS/DMD from an ADA-accredited institution, MS in prosthodontics or graduate of a residency program is preferred; prior teaching and research experience is desirable.

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OPERATIVE (Position #7-6142). Responsibilities include teaching undergraduate preclinical and clinical restorative dentistry, conducting clinical and/or laboratory research. DDS/DMD from an ADA-accredited institution, completion of an accredited residency in Operative Dentistry/Restorative Dentistry, and eligibility for board certification is preferred; prior experience in teaching and research is desirable.

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The University of Tennessee is searching for applicants for a full-time, tenure-track position in the Division of Operative Dentistry. Responsibilities include didactic, preclinical, clinical, and Graduate AEGD instruction and research. Teaching experience is preferred. The position requires a DDS/DMD from an ADA-accredited dental school. Salary and rank will be commensurate with experience. Starting date 1 July 1998. Submit curriculum vitae to:

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Department of General Restorative Dentistry
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ANNOUNCEMENT

27th ANNUAL MEETING of the ACADEMY OF OPERATIVE DENTISTRY

18-20 February 1998
WESTIN HOTEL
CHICAGO, ILLINOIS

The 27th annual meeting of the Academy of Operative Dentistry will focus on the use of dental materials and clinical techniques by the general dentist. Thursday will feature Dr Max Anderson ("When to Place a Restoration"), Dr Ivar Mjör ("What Materials To Use To Replace a Restoration"), Dr Ken Anusavice (Buonocore Lecture), Dr John Osborne ("Dental Amalgam, Mercury, and Gallium Alloys"), Dr Jan Pameijer ("Restorative Treatment behind the Cuspids"), and Dr Terry Donovan ("Another Look at Cementation"). Friday's schedule includes Dr Mark Friedman ("Porcelain Veneers"), Dr Terry Tanaka ("TMJ and Restorations—the Relationship"), and Dr Karen Baker ("Medications—Actions and Reactions"). Friday afternoon will offer an outstanding array of Table Clinics. In addition, an excellent companion activities program will include a special program by Mark McCauley, senior interior designer for Marshall Field's, and a delightful "From Market to Menu" tour that includes the Chicago Board of Trade, Randolph Street and South Water Street Markets, and a visit to Treasure Island for a tour and cooking demonstration. Of course, the famous Gala Reception on Thursday evening is a must for everyone.

For meeting information please contact Dr Gregory Smith, P O Box 14996, Gainesville, FL 32604-2996; FAX (352) 371-4882.

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OPERATIVE DENTISTRY

Aim and Scope

Operative Dentistry publishes articles that advance the practice of operative dentistry. The scope of the journal includes conservation and restoration of teeth; the scientific foundation of operative dental therapy; dental materials; dental education; and the social, political, and economic aspects of dental practice. Review papers, book reviews, letters, and classified ads also are published.

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