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EDITORIAL

Longevity of Amalgam Restorations

The improvement of the physical properties of silver amalgam that has been made over the past 20 years should now be manifesting itself in restorations of increased longevity. It is disturbing, therefore, to note in some of the publications, in which the longevity of sealants is compared with that of amalgams, that the average life of an amalgam is reported to range from four to eight years (Bohannan, 1982; Silverstone, 1984). This relatively short life contrasts sharply with the longevity reported by Markley (1984), for example, who has published photographs of class 2 amalgams that are still in service after 45 years. Many more amalgams that are still giving service after 30 years or longer probably would be found if a survey could be made. Are the reports on the longevity of restorations of amalgam contradictory?

In some of the studies on the longevity of amalgams, even though the average life reported was relatively short, the range extended to at least 20 years, at which time 10-25% of the restorations were still serving (Robinson, 1971; Allan, 1977). One study reports a median life of 10-14 years (Bailit & others, 1979). Averages, medians, and ranges express different statistical measurements of a particular characteristic and each measure augments our interpretation of the phenomenon. Perhaps in this case, with such a large range of values, the average alone may not give the best evaluation of the durability of amalgam as a restorative material. Moreover, statistical treatment of the data from some of the studies is suspect as a consequence of the samples not being representative, the design of the research being faulty, or the criteria of failure being questionable. In the circumstances, the results of these studies may be misleading.

Be that as it may, the evidence is overwhelming that many restorations of amalgam fail long before they should. With better alloys, however, the proportion of success should be increasing; but better alloys do not compensate for sloppy operating. The longevity of restorations of amalgam can best be increased by the operator giving scrupulous attention to the details of the preparation of the cavity, the insertion of the amalgam, and the finishing of the restoration. If the present record of success with amalgam continues we may next be comparing the longevity of such restorations not with sealants but with cotton pellets soaked in varnish.

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ORIGINAL ARTICLES

Effects of Diluents on Physical Properties of a Light-cured Composite (Prisma-Fil)

Diluting Prisma-Fil does not affect diametral tensile strength but may affect water sorption and solubility

W F CAUGHMAN • R W COMER
L D ZARDIACKAS

Summary

When Prisma-Fil, a light-cured composite resin, was diluted with isopropyl alcohol, a dimethacrylate, or Prisma-Bond the diametral tensile strength of the material was not affected. Isopropyl alcohol, however, increased water sorption and the dimethacrylate increased solubility.

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INTRODUCTION

Clinicians have reported the dilution of autopolymerizing composite restorative material with alcohol and other substances to improve the handling properties. The two commonly cited problems necessitating dilution are: the high viscosity of composites prevents proper condensation in certain situations; and the tacky nature of the material creates a drag on the contouring instrument that results in an inadequate marginal adaptation. Sneed and Draughn (1980) have reported that the practice of wetting a plastic instrument with alcohol did not affect the compressive or tensile strength of the material tested. They also determined that incorporation of alcohol during mixing yielded a polymerized composite with compressive and tensile strength significantly weaker than the control group. Metzler and Chandler (1978) have reported that incorporation of a commercial preparation of benzyl alcohol and isopropyl alcohol also significantly reduced the strength of composite material. Studies by Brauer and others (1981) and Dulik, Bern-

ier and Brauer (1981) examined physical and mechanical properties of autopolymerizing composites diluted with numerous compounds and found that the range of effects is a function of the specific diluent used.

Based upon these findings, the handling properties of a composite cured by visible light were altered to evaluate the effects of incorporating diluents. The properties selected as critical to evaluate the effect of these diluents were water sorption and diametral tensile strength.

MATERIALS AND METHODS

The composite restorative material selected as a representative of composite cured by visible light was Prisma-Fil, which was activated by means of a Prisma Lite (L D Caulk Company, Division of Dentsply International Inc, Milford, DE 19963, USA). Three diluents were selected for incorporation and the resultant material was compared with undiluted control samples. One diluent was isopropyl alcohol, a hydrophilic agent found to reduce the strength of composites (Sneed & Draughn, 1980). The second diluent was from 1,6 hexamethylene glycol dimethacrylate (1,6 HGDMA), a dimethacrylate of low molecular weight. Based on information from previous research (Brauer & others, 1981; Dulik & others, 1981), we would expect the addition of this diluent to yield tensile strengths and values of water sorption comparable to the control. The third diluent was Prisma-Bond, the unfilled resin of Prisma-Fil. The reasons for selecting these three agents were their availability to the general practitioner and the expectation of different physical effects.

The concentrations of the three diluents were selected by subjective evaluation of the handling properties. This was done by mixing samples at various concentrations until the viscosity was reduced to a clinically acceptable level. After the levels of concentration of the diluents were determined, samples were prepared at these concentrations and at double these concentrations. The selected volumes of the three diluents are listed in Table 1. Five samples at each concentration were prepared in accordance with Specification 27 for Direct Filling Resins of the American Dental Association (Council on Dental Materials and Devices, 1977). Because ADA Specification 27 was prepared for autopolymerizing composite restorative materials and not for

Table 1. Concentration of Diluents

Treatment	Water Sorption* Volume Added	Diametral** Tensile Strength Volume Added
	$\mu l\ g^{-1}$	$\mu l\ g^{-1}$
Control	0.0	0.0
Isopropyl alcohol (I)	2.5	2.5
Isopropyl alcohol (II)	5.0	5.0
1,6 HGDMA (I)	2.5	2.5
1,6 HGDMA (II)	5.0	5.0
Prisma-Bond (I)	5.0	5.0
Prisma-Bond (II)	10.0	10.0

*Medium standard mix = 0.8 ± 0.01 g
**Small standard mix = 0.6 ± 0.1 g

light-activated materials, some exceptions were made in the preparation of the samples.

Water Sorption

A medium standard mix, as described in ADA Specification 27, was prepared to evaluate changes in water sorption by comparing diluted samples with the control. The samples were prepared by mixing 0.8 g ± 0.01 g of the composite with the three selected diluents. The samples were mixed on a glass slab for 15 seconds to incorporate the diluent. After mixing, the material was inserted in a 1 ml syringe and injected into a sample ring of stainless steel on a microscope slide. The ring was covered with another microscope slide and placed in a hydraulic press for five seconds at 80 lbf in^{-2} (552 kPa) to express the excess. To ensure complete polymerization peripherally, each sample was cured with light on each side in a triangular pattern for three intervals of 10 seconds each. From this point the experiment was conducted according to the protocol in ADA Specification 27. Samples for water sorption were weighed on a Mettler H 30 analytical balance.

Diametral Tensile Strength

Small standard mixes were prepared to test for diametral tensile strength. Each sample of 0.6 g ± 0.01 g was spatulated on a glass slide for 15 seconds to incorporate the diluents. Material was injected into the stainless steel mold, described in ADA Specification 27, with a 1 ml syringe. Glass microscope slides were placed on each end of the mold and compressed at 80 lbf in^{-2} (552 kPa) for five seconds to express the excess.

The samples were activated with light on each end of the metal cylinder for 20 seconds. After the samples were removed from the metal cylinder they were treated and tested as outlined in ADA Specification 27. Diametral tensile strength was evaluated with an MTS 812 servohydraulic mechanical testing system and data were recorded on a Nicolet digital storage oscilloscope. Comparison of untreated and treated sample data was evaluated by means of Student's *t*-test at the 0.05 level of confidence.

RESULTS AND DISCUSSION

The results of the statistical analysis of the data are summarized in Tables 2 and 3.

Table 2. Results of Water Sorption and Solubility

Treatment	Change of Weight	*Differs from Control
	mg	$P < 0.05$
Control	1.84 ± 0.36	
Isopropyl alcohol (I)	2.48 ± 0.43	*
Isopropyl alcohol (II)	3.44 ± 0.87	*
1,6 HGDMA (I)	1.20 ± 0.70	
1,6 HGDMA (II)	0.60 ± 0.80	*
Prisma-Bond (I)	1.52 ± 0.84	
Prisma-Bond (II)	1.84 ± 0.52	

Table 3. Results of Diametral Tensile Strength

Treatment	Diametral Tensile Strength
	MPa
Control	64.9 ± 4.5
Isopropyl alcohol (I)	61.6 ± 3.8
Isopropyl alcohol (II)	58.3 ± 6.0
1,6 HGDMA (I)	56.6 ± 5.3
1,6 HGDMA (II)	57.5 ± 4.4
Prisma-Bond (I)	55.5 ± 1.4
Prisma-Bond (II)	59.3 ± 6.4

No treatment was different from the control ($P < 0.05$).

Water Sorption

These results indicate that the water sorption of Prisma-Fil is adversely affected by

diluting the material with a low level of alcohol, and higher levels of either alcohol or 1,6 HGDMA. Although the water sorption of samples prepared with a lower concentration of 1,6 HGDMA does not differ significantly from the control, an unusual result is achieved with a higher concentration. Within 24 hours it becomes apparent that the material is dissolving in the distilled deionized water. Within this period of time, the samples lost weight and the periphery appeared blanched. These two signs of decomposition may have resulted from incomplete activation or curing of the material. In each of the other treatments, the specimens increased in weight due to water sorption and maintained uniform appearance. To evaluate for this possibility, new samples were prepared and the activation time was increased from 60 to 80 seconds. After the samples were immersed for 24 hours, similar results were noted: a decrease in weight and peripheral blanching. Therefore, one may conclude that at the higher concentration of 1,6 HGDMA the stability of the material was adversely affected.

Diametral Tensile Strength

The mean diametral tensile strengths of the samples are presented in Table 3. The strength of the samples prepared with the three diluents did not vary significantly from the strength of the control when tested at the 0.05 level of confidence. These results, though on a composite cured by light, differ from the findings of Sneed and Draughn (1980). A possible reason for this discrepancy is that the highest concentration of alcohol used in this study is approximately 20% less than that used in their investigation.

Manufacturers of dental restorative materials analyze carefully the properties of the materials before marketing. Indiscriminate use of any diluent or variation from the manufacturer's recommended directions for the use of the material can be detrimental to its clinical performance. Even though some treatments appear acceptable, they do not account for other important variables such as color stability, resistance to abrasion, or pulp reaction to high concentration of diluents. These variables should be included in clinical trials and evaluation.

CONCLUSIONS

- When Prisma-Fil was diluted with up to 10 μl g^{-1} of Prisma-Bond, there was no change in strength, solubility, or water sorption.
- Prisma-Fil absorbs water at a significantly higher level when diluted with isopropyl alcohol.
- When diluted at a concentration of 5 μl g^{-1} with 1,6 HGDMA, Prisma-Fil showed high solubility.
- Diametral tensile strength is not significantly affected when the composite is diluted with alcohol, 1,6 HGDMA, or the Prisma bonding agents in the concentrations selected.
- Specification 27 of the American Dental Association should be amended to include a standardized method for preparation of samples for light-activated composites.
- Laboratory studies indicate that the conservative use of Prisma-Bond as a diluent may yield no adverse effects on physical properties in clinical trials.

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Cavity Sealing Ability of Lathe-Cut, Blend, and Spherical Amalgam Alloys: a Laboratory Study

A lathe-cut alloy provides an amalgam restoration that leaks less than amalgams made from blended or spherical alloys.

M A FAYYAD • P C BALL

Summary

When the degree of marginal leakage around three types of silver amalgam alloy, namely, low-copper lathe-cut (Solila), high-copper admixture (Dispersalloy), and high-copper spherical (Tytin), was investigated under two different conditions of temperature as well as under treatment to produce corrosion, the results indicate that, under changes in temperature similar to those found in the oral cavity, the sealing ability of amalgam from the lathe-cut alloy is superior to that from the alloys with spherical or blended particles. Under corrosive treatment marginal leakage was reduced around lathe-cut alloy but not around spherical or blended alloys.

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INTRODUCTION

A recent study using air pressure to measure the marginal leakage of dental amalgam reported that leakage around dental amalgams does not depend solely on the shape of particle or the proportion of copper (Fanian, Hadavi & Asgar, 1983). The purpose of the present investigation was to assess the degree of marginal leakage around three types of silver amalgam alloy under two different conditions of temperature as well as under treatment to produce corrosion.

MATERIALS AND METHODS

Several techniques have been used to determine the sealing ability of restorative materials. These include the penetration of dye (Going, Massler & Dute, 1960a), bacteria (Mortensen, Boucher & Ryge, 1965), radioactive tracers (Going, Massler & Dute, 1960b), and air (Harper, 1912). Microscopy, both light (Asmussen & Jørgensen, 1972) and scanning electron (Flynn, 1978), artificial caries (Grieve & Glyn Jones, 1980), neutron activation analysis (Douglas, Chen & Craig, 1980), replica technique (Grundy, 1971), and ion etching (Ghafouri, Fitch & Ball, 1981) have been employed.

The use of organic dyes to detect marginal microleakage around restorative materials is one of the oldest and most popular methods. In general, this method consists of placing a restoration in an extracted tooth and then immersing the tooth in a solution of the dye. After it has been sectioned, the specimen can be examined and the extent of penetration of the dye around the restoration assessed. Results in vitro, using extracted human teeth in this way, correlate with results of studies in vivo (McCurdy & others, 1974).

Ninety sound human premolar teeth with enamel free of visible cracks were washed clean of debris and stored in buffered formalin. Standard cavities, 2 mm in diameter and 2 mm deep, were prepared in each tooth with a cylindrical diamond bur with a flat end rotating slowly in a conventional handpiece. To standardize the depth of the cavity a stop was fitted around the shank of the diamond bur, leaving only 2 mm of the cutting end free. This modified bur was sunk straight into the tooth in one movement to ensure vertical walls in the cavity free of undercut. Some cavities were prepared on the facial surface of the tooth, and others on the lingual surface, depending upon which surface presented the greatest area of sound enamel. After the preparation of the cavities, the 90 prepared teeth were randomly divided into three equal groups. Each test group of 30 teeth was restored with a different type of amalgam (Table 1).

Solila alloy and mercury in the ratio 1:1 were mixed in a Dentomat amalgamator (Metall-Abteilung, Frankfurt/Main, Federal Republic of Germany). Dispersalloy and Tytin are capsulated materials and were triturated in a Silamat amalgamator (Viva-dent, Schaan –Lichtenstein). The trituration times were 20 seconds for Solila, 10 seconds for Dispersal-

Table 1. Alloys Used in the Study

Alloy	Manufacturer	Shape of Particle	Addition of Copper	Copper in Alloy %
Solila	A D International Ltd De Trey Division Weybridge, Surrey, England	Lathe-cut		0.0
Dispersalloy	Johnson & Johnson East Windsor, NJ 08520 USA	Blend	Admixture	12.0
Tytin	S S White Philadelphia, PA 19102 USA	Spherical	Ternary	12.0

loy, and 5 seconds for Tytin. These were the times specified by the manufacturers and should result in the best physical properties of the amalgams.

Before the restorations were placed, all the cavities were washed with water and then dried with compressed air from a triple syringe. Amalgam in small increments was inserted into the cavities and condensed by hand with a flat-ended condenser 1.25 mm in diameter, which was the maximum size convenient for the prepared cavities. Lateral, as well as vertical, condensation was employed to ensure optimum adaptation. The pressure used to condense spherical amalgam was less than that used for lathe-cut and admixed amalgams because spherical amalgams should be condensed with less force than lathe-cut amalgams (Greasley & Baker, 1978). After the amalgam had been carved the surface was smoothed with a pledget of moist cotton wool. The restorations were left to set for 24 hours, then finished with a dull pear-shaped finishing bur. The teeth were then stored in buffered formalin for two to seven days.

To prevent penetration of dye through the apical foramena and any accessory canals the apical region of each tooth was sealed with cold-cure acrylic resin and the roots, up to the cementoenamel junction, coated with two layers of nail varnish.

In each test group 10 teeth were stored in a 2% solution of methylene blue at 37 °C for 24 hours, and another 10 of each group were thermally stressed in a 2% solution of methylene blue contained in baths in a thermal cycling machine. The schedule of cycling was 37 °C for four minutes, 15 °C for one minute, 37 °C for four minutes, and 45 °C for one minute, with the cycling continuing for 24 hours. The remaining 10 teeth in each group were stored in Ringer's solution, which is known to promote corrosion of dental alloys. The teeth were stored at room temperature for 14 days. They were then thermally stressed for 24 hours. The cycling machine used was the one used by Kidd, Harrington & Grieve (1978).

After removal of the teeth from the dye they were washed with tap water and then sectioned longitudinally through the restoration. The sectioning disk, which was 3 in (76.2 mm) in diameter and 0.01 in (0.25 mm) thick, rotated at 1000 rev min^{-1} and was water cooled. The tooth being divided was placed on a V-shaped support and manually advanced to the cutting edge of the diamond disk. Some of the teeth were sectioned with, and some without, the use of water cooling on the disk. This was to determine if the water-soluble methylene blue would be washed out of the tooth substance by the water coolant. The sectioned teeth were then examined by reflected light under a microscope and the extent of penetration of the dye assessed.

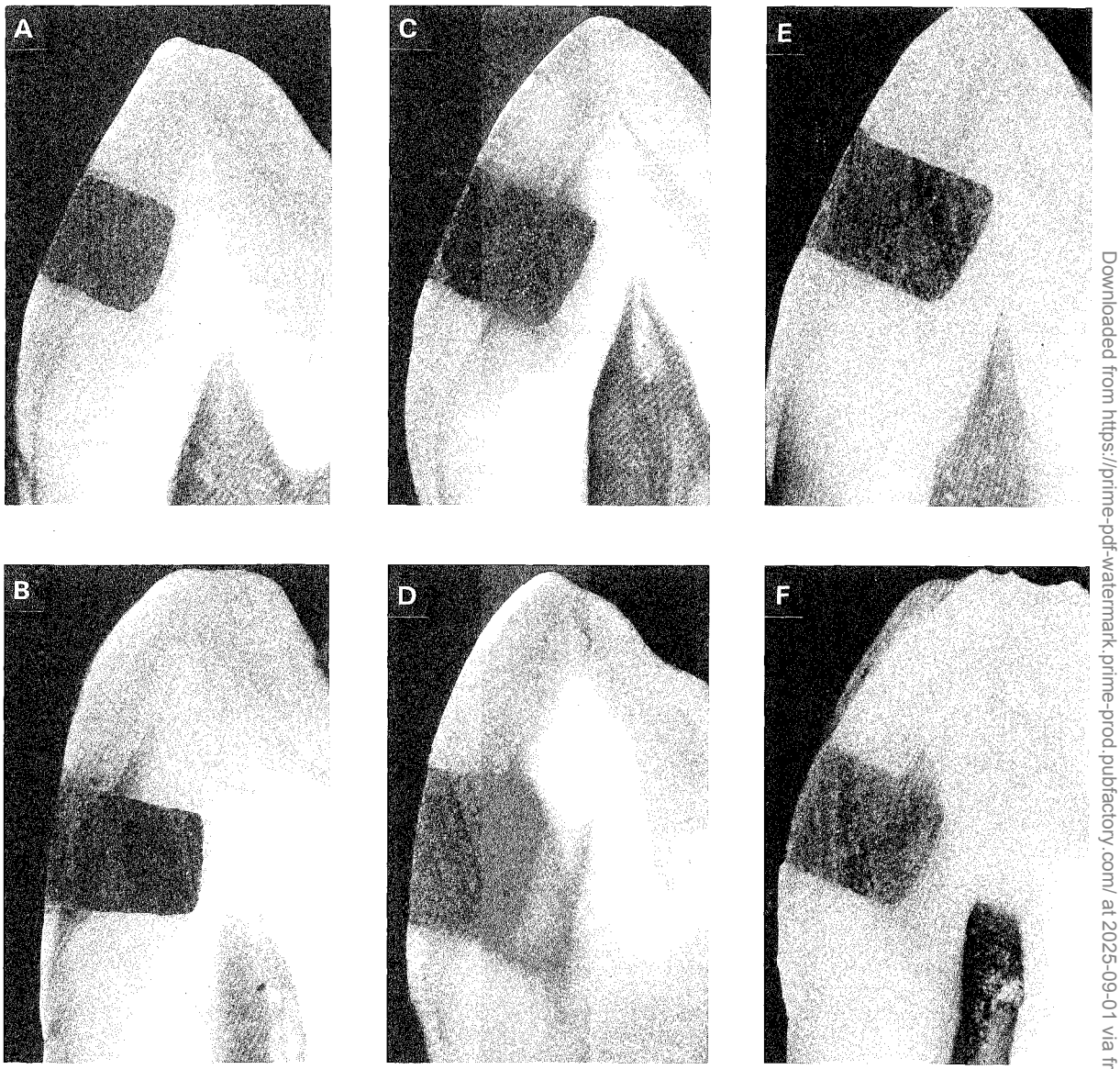
Method of Assessing Penetration of Dye

The degree of marginal leakage was determined by the scoring system described by Bassiouny (1977), which is: If the dye had penetrated between the enamel and filling material but not beyond the amelodentinal junction on one side of the restoration, a score of 1 was given. If this same degree of penetration was present on both sides of the restoration the leakage was scored as 2. An additional 2 was added for each side where the dye had penetrated beyond the amelodentinal junction but had not reached the base of the cavity. A further 2 was added to the score where the dye extended across the floor of the cavity but did not spread through the dentine toward the pulp. If the dye spread toward the pulp an additional 2 was added to the score, making a possible maximum score of 10 for any one restoration.

During examination of teeth under the microscope it was noticed that, due to uneven penetration of the dye around the restoration, the score in some specimens differed in the two halves of a sectioned tooth. For ease of comparison, the mean score of both halves was recorded for every specimen.

RESULTS

The results indicate that water cooling during sectioning of the teeth does not wash out the methylene blue dye. The figure illustrates the typical appearance of the sectioned restorations with different degrees of penetration of the dye.



Specimens kept at 37 °C for 24 h

Specimens thermally stressed

Specimens stored in Ringer's solution, then thermally stressed

A Dispersalloy showing no penetration of dye

B Solila alloy showing moderate penetration of dye

C Tytin showing moderate penetration of dye

D Dispersalloy showing high penetration of dye

E Solila alloy showing no penetration of dye

F Dispersalloy showing high penetration of dye

Sectioned teeth showing different degrees of penetration of dye around amalgam restorations

Table 2 shows the mean scores of dye penetration, standard deviations, and number of observations recorded in each of the nine subgroups. It is clear that the mean score for dye penetration around Tytin is more than that around Solila and Dispersalloy when the restored teeth have been kept in the dye solution for 24 hours at 37 °C. In the thermally cycled teeth, both with and without corrosive treatment, the mean score for dye penetration of both Tytin and Dispersalloy is higher than that for Solila.

Solila demonstrates a difference in dye penetration under corrosive treatment that, statistically, is highly significant ($P < 0.001$). Dispersalloy demonstrates a difference in dye penetration that, statistically, is highly significant ($P < 0.001$) when kept at a constant temperature compared with a changing temperature. No statistically significant difference in dye penetration was demonstrated in the behavior of Tytin under the three test conditions. Comparison of the three types of alloy when kept in the dye solution for 24 hours at 37 °C shows that there was no statistically significant difference in dye penetration between Solila and Dispersalloy. However, the difference in dye penetration between Solila and Tytin is, statistically, highly significant ($0.02 > P > 0.01$). This difference was also noted between Dispersalloy and Tytin ($0.01 > P > 0.001$).

The difference in dye penetration between Solila and Dispersalloy when the restored teeth were thermally cycled is, statistically, highly significant ($P < 0.001$). A similar difference was noted between Solila and Tytin under these conditions. There was no statistically significant difference in dye penetration between Dispersalloy and Tytin in this test.

Comparison of the three types of alloy under corrosive treatment shows that the difference in dye penetration between Solila and Dispersalloy and also between Solila and Tytin is, statistically, highly significant ($P < 0.001$). There was no statistically significant difference in dye penetration between Dispersalloy and Tytin under the same test conditions.

DISCUSSION

The mean score for dye penetration around restorations kept in methylene blue solution for 24 hours at 37 °C indicates that Solila and Dispersalloy provide a better marginal seal than Tytin, since the three alloys demonstrate a mean score for dye penetration of 3.2, 2.0, and 6.4, respectively. The clinical significance of this result is dubious since the

Table 2. Assessment of Penetration of Dye under Three Test Conditions (n = 10)

Test Condition	Solila		Dispersalloy		Tytin	
	Mean	SD	Mean	SD	Mean	SD
Immersing in methylene blue at 37 °C for 24 h	3.2	± 1.47	2.0	± 1.20	6.4	± 2.95
Thermally stressed in methylene blue for 24 h	3.5	± 1.01	6.9	± 2.56	7.6	± 1.50
Stored in Ringer's solution for 14 d then thermally stressed	1.2	± 0.71	6.15	± 2.89	7.45	± 2.39

temperature of the oral cavity is not constant at 37 °C and a wide range of thermal changes occur (Plant, Jones & Darvell, 1974). These variations in temperature can cause expansion and contraction of the restorative material and tooth structure that may affect microleakage around restorations because of the difference in the coefficient of thermal expansion of tooth structure and restorative material.

When restored teeth are thermally cycled, Solila is the best of the three alloys tested for marginal seal (mean score: Solila 3.5, Dispersalloy 6.9, and Tytin 7.6). Clinically, this result is of greater significance than that at the constant temperature because the teeth are subjected to thermal changes similar to those in the oral cavity. This work indicates that the marginal adaptation of the alloy with lathe-cut particles is superior to that of the alloys with spherical or blend particles, since the former demonstrates a lower mean score that is statistically significant for penetration of dye in the teeth that were thermally cycled. This confirms the findings of Wing & Lyell (1966), who found that even well-condensed amalgams containing spherical particles are separated from the tooth by a wider space than similarly condensed lathe-cut amalgam. The results of this study also support the findings of Symer & Wing (1981), who said that, in general, lathe-cut alloys adapt better to cavity walls than do spherical alloys.

The results of this present study, however, disagree with those of Smith, Wilson and Combe (1978), who said that the marginal adaptation of the alloy with spherical particles was superior to that of alloys with lathe-cut particles, since the alloy with spherical particles demonstrated significantly lower mean scores for microleakage. This difference in observation may, in part, be due to the different experimental procedures adopted in the two studies. Smith used thermal cycling for just one hour and cycled the restored teeth between a hot bath maintained at 60 °C and a cold bath maintained at 0-4 °C. Each immersion lasted two minutes. This thermal cycling is not realistic when compared to temperature changes in the mouth and such extreme and frequent differences in temperature may lead to fracture of the tooth structure, thereby facilitating penetration of the dye. Our study, however, used a regimen of cycling that is realistic (Plant, Jones & Darvell, 1974) in comparison with temperature changes in the oral cavity and cannot physically damage the restored tooth. Vasudev, Mohammed and Shen (1981), in their work on microleakage of radioactive tracers around amalgam restorations, also found that the chemistry of conventional amalgams is more favorable than that of spherical amalgams for sealing restorations. In addition, Greasley and Baker (1978) found that spherical amalgam contracted slightly, while lathe-cut amalgam expanded, during the first 24 hours after packing. They also noted that spherical alloys, although easier to condense than lathe-cut alloys, appear to show slightly more marginal microleakage than lathe-cut alloys condensed under ideal clinical conditions, further supporting the results of this present study.

When the restored teeth were stored in Ringer's solution, there was an improvement in marginal seal of conventional Solila alloy but there was no improvement in marginal seal for Tytin and Dispersalloy.

These observations are not in agreement with those of Fanian, Hadavi and Asgar (1983), who said that the leakage around dental amalgams does not depend solely on the shape of particles or the proportion of copper. However, as noted in this present study three types of amalgam, with different shapes of particle, do show a difference in marginal leakage that, statistically, is highly significant. In addition, the low-copper and high-copper amalgams exhibit a difference in marginal leakage under corrosion treatment that, statistically, is highly significant, presumably because of the influence of copper in the process of corrosion.

The results of this study do agree with those of Craig (1980), who said that in low-copper amalgams the most corrodible phase is the tin-mercury, or γ_2 phase. The high-copper admixed and unicompositional alloys do not have any γ_2 phase in the final set mass. Also the copper-tin (Cu_6Sn_5) that is present in these set amalgams has a higher resistance to corrosion than does the γ_2 phase. Thus the high-copper amalgams are more resistant to corrosion than low-copper amalgams due to lack of γ_2, which is responsible for the formation of the product of corrosion.

CONCLUSION

- Lathe-cut Solila alloy produced a better marginal seal than spherical Tytin.
- Thermal stress significantly increased marginal leakage around Dispersalloy restorations. No significant increase in marginal leakage was observed when Tytin and Solila dental alloys were similarly stressed.
- Corrosive treatment improved the marginal seal of Solila but there was no effect on marginal seal of Tytin and Dispersalloy due to lack of γ_2, which is responsible for the formation of corrosion products.

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Vacuum Trituration of Two Amalgam Alloys (Dispersalloy and Tytin): Clinical and Laboratory Evaluation

Triturating amalgam under vacuum reduced voids and fracture at the margins for Tytin but did not affect Dispersalloy, which gave the best results

J W OSBORNE • M S WOLFF

Summary

Two non-γ_2 amalgams, Dispersalloy and Tytin, were tested in the laboratory and clinically to determine the effect of trituration under a vacuum. The proportion of voids was reduced by 25% for Tytin but not for Dispersalloy. Mixing in a vacuum did not affect the 24-hour compressive strength or the creep of either amalgam. At the end of two years a clinical trial revealed that mixing in a vacuum gave Tytin a trend for less fracturing at the margins but did not affect Dispersalloy, and that there was less fracturing at the margins for Dispersalloy compared with Tytin.

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INTRODUCTION

Going and Jendresen (1972) have indicated that 40-60% of the dentist's time is spent replacing failed restorations. This proportion of a clinician's time may be reduced by several factors, such as improved materials, better manipulation of materials, and education of patients. A reduction in this high proportion of remake dentistry would allow the dentist to spend more time in areas such as prevention and have a profound effect on the socioeconomic impact of the profession.

The most widely used restorative material is amalgam, and if one could improve this material the impact would be most significant. One way to improve many dental materials is to reduce porosity by mixing in a vacuum. We have found that amalgam alloys have different proportions of voids and the proportions range from less than 1% to 4% (Winchell & Osborne, 1980, unpublished). Since a reduction in voids can improve mechanical properties, we wondered if amalgam could be improved by trituration under vacuum.

The purpose of this project was to examine the effect of vacuum trituration on two dental

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amalgam alloys both in the laboratory and clinically.

MATERIALS AND METHODS

The most widely used and researched amalgams were selected for this study—Dispersalloy (Johnson & Johnson Dental Products, East Windsor, NJ 08520, USA), a multicomposition alloy of lathe-cut and spherical particles, and Tytin (S S White Dental Manufacturing Company, Philadelphia, PA 19102, USA), a single-composition spherical alloy. Both these alloys are of the high-copper, non-γ_2 type and were selected not because of popularity but for wide difference in percentage of voids.

Preparation of Specimens

To obtain vacuum trituration, the inner working parts of a Silamat amalgamator (Vivadent Inc, Tonawanda, NY 14150, USA) were placed in a desiccator jar, with all electrical connections brought through the neck of the jar, and an air-tight seal obtained with RTV rubber. A vacuum hose was attached to a Doerr vacuum pump (H Millipore Corporation, Bedford, MA 01730, USA) so that the sealed chamber could be reduced by 510 mm Hg (68 kPa). Capsules for mixing the amalgam were prepared to ensure adequate evacuation of air by placing a hole in the body of the capsule with a No 8 round bur. A nucleopore filter (N 1200) was then cemented onto the side of the capsule to cover the hole. Cyanoacrylate cement was used to ensure that the filter adhered to the capsule. One capsule for Tytin and one for Dispersalloy were prepared. Amalgams for the samples both in the vacuum and at regular atmospheric pressure were triturated in the capsule prepared for the respective brand of alloy.

The amalgam alloys were triturated according to the manufacturers' directions for the Silamat—Dispersalloy for six seconds and Tytin for three seconds. For the vacuum mixed alloy, the chamber was evacuated and held for 10 seconds before the trituration was started. Specimens (4 mm x 8 mm) were prepared according to American Dental Association Specification No 1 for mechanical testing and for analysis of voids.

Test for Compressive Strength at 24 Hours

Ten specimens of each alloy, five prepared in vacuum and five prepared at atmospheric pressure, were tested for 24-hour compressive strength in an Instron 1123 at a crosshead speed of 0.5 mm min^{-1}.

Test for Creep

Twelve specimens of each alloy, six prepared in vacuum and six prepared at atmospheric pressure, were tested after seven days for creep as described by Mahler and others (1970).

Analysis for Voids

Six specimens of each alloy, three prepared in vacuum and three prepared at atmospheric pressure, were analyzed metallurgically for voids. The one-month-old specimens of amalgam were mounted in Buehler Plastic Mounting Powder (Buehler Ltd, Evanston, IL 60204, USA) and, during setting, were immersed in ice water to reduce the setting temperature. These specimens were ground with water-cooled belts and polished through 0.05 μm alumina on a microcloth with light pressure. The samples were examined with an optical metallurgical microscope. According to a standard metallurgical technique (Underwood, 1973; DeHoff & Rhines, 1968), a counting grid was superimposed on micrographs of the sample, the number of points was counted, and the voids were calculated.

Clinical Evaluation

The design of the clinical evaluation used paired class 2 restorations of amalgam triturated in vacuum and at atmospheric pressure. Teeth to be restored were selected with lesions of approximately the same size within each of five patients, premolars being paired with premolars and molars with molars.

The 20 restorations of Dispersalloy (10 mixed in vacuum paired with 10 at atmospheric pressure) were placed into 10 patients. The same number of patients received 20 restorations of Tytin (10 mixed in vacuum and 10 at atmospheric pressure). Pairs of both Dispersalloy and Tytin were common to five patients.

Conservatively prepared cavities were used wherever possible and rubber dams were used throughout the restorative procedure. Cavities that were deeper than the ideal received a thin application of Life (Kerr Manufacturing Company–Sybron, Romulus, MI 48174, USA), a commercial preparation of calcium hydroxide, in the pulpal areas; and Copalite (Teledyne Getz, Elk Grove Village, IL 60007, USA), a copal varnish, was applied to all cavities after the application of a Tofflemire matrix and wedging. Condensing was carried out with heavy hand pressure. This condensation was completed within a 3-minute time limit from the start of mixing the alloy. Carving was completed with sharp carvers and a No 2 bur used to lightly finish the occlusal surface 48 or more hours postoperatively.

For the evaluation of the restorations, clinical photographs were taken of each tooth with a Medical Nikon camera at a magnification of X1.5 at baseline and at 6, 12, and 24 months. Black and white prints were made on 4 x 5 paper, which gave an approximate magnification of X6 for each tooth. These photographs were cropped, leaving only the individual tooth with vital data such as name of patient, number of tooth, type of restorative material, and period of time placed on the back. These photographs were categorized into four groups of increasing amounts of fracture at the margins and evaluated by ridit analysis (relative to an identified distribution) as suggested by Mahler and others (1970). In addition, as suggested by Osborne and others (1978), the photographs were ranked from best to worst, that is, 1, 2, 3, etc, and a Mann-Whitney U Test was used to determine statistical differences between materials and type of trituration.

RESULTS

Results of the mechanical testing are summarized in Table 1. These data revealed that little improvement of the alloys resulted from mixing in vacuum.

Table 1. Results of Tests for 24-hour Compressive Strength, Creep, and Voids

Alloy	24-hour Compressive Strength lbf in^{-2} (MPa) Mean SD	Creep n=6 % Mean SD	Voids n=3 % Mean SD
Dispersalloy			
Vacuum	53,100 ± 3,700 (366.4 ± 25.5)	0.27 ± 0.05	1.2 ± 0.01
Atmospheric Pressure	52,300 ± 2,200 (360.9 ± 15.2)	0.32 ± 0.05	1.1 ± 0.02
Tytin			
Vacuum	66,000 ± 2,200 (455.4 ± 15.2)	0.10 ± 0.07	1.8 ± 0.03
Atmospheric Pressure	68,000 ± 2,000 (469.2 ± 138.0)	0.12 ± 0.07	2.3 ± 0.01

Compressive Strength at 24 Hours

The test for 24-hour compressive strength indicated no statistically significant difference between vacuum and regular mix, but the compressive strength of Tytin was greater than that of Dispersalloy ($P < 0.01$).

Creep

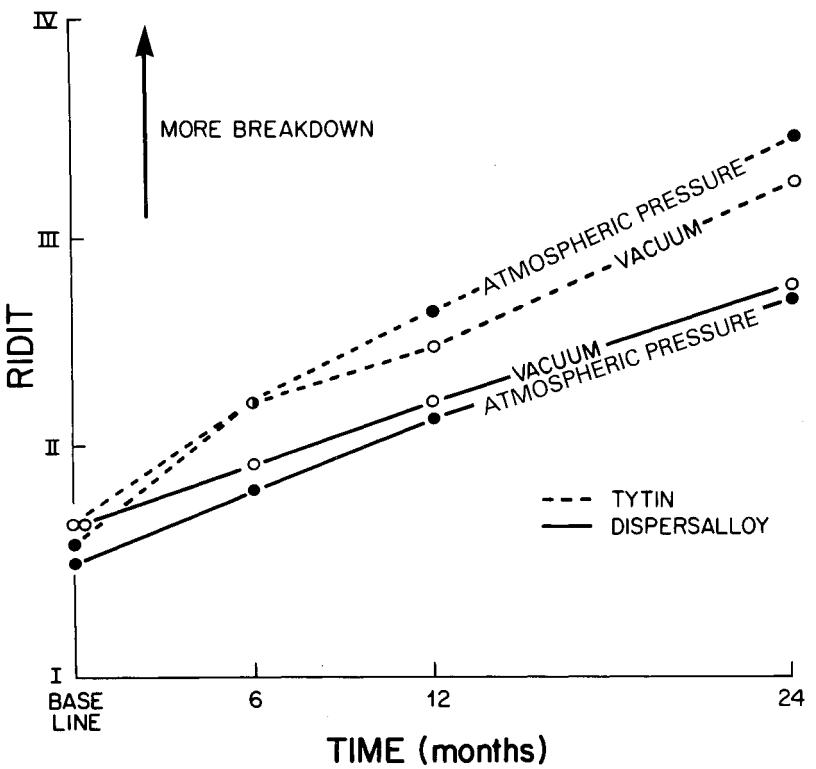
The creep test showed that the difference in creep between alloys mixed in vacuum and alloys mixed at atmospheric pressure was not statistically significant.

Voids

Analysis of the alloys for the percentage of voids is also given in Table 1. Dispersalloy showed the smallest percentage of voids of the two materials, and there was no difference with this alloy between trituration in a vacuum and at atmospheric pressure. Tytin, however, displayed a 25% decrease in voids when triturated in a vacuum compared with atmospheric pressure. Not only were there fewer voids in the vacuum-mixed Tytin, but their size and distribution were altered.

Clinical Evaluation

Results of the clinical evaluation are summarized in Tables 2 and 3. The ridit analysis of the restorations reveals that for both brands the alloys mixed at atmospheric pressure had the least number of defects at baseline (see figure). Dispersalloy mixed at atmospheric pressure had the least fracturing at the mar-



Time versus clinical performance of Dispersalloy and Tytin mixed under vacuum and at atmospheric pressure

Table 2. Categorization and Ridit Means of Amalgam Restorations

Alloy	Categories*				Ridit Mean	Variance
	I	II	III	IV		
Dispersalloy						
Vacuum						
Baseline	4	6	0	0	0.3200	0.0329
6 months	3	6	1	0	0.3897	0.0490
12 months	2	5	3	0	0.4944	0.0664
24 months	1	2	3	2	0.6709	0.0892
Atmospheric pressure						
Baseline	6	4	0	0	0.2497	0.0329
6 months	3	7	0	0	0.3500	0.0287
12 months	2	6	1	1	0.4745	0.0680
24 months	1	2	4	1	0.6523	0.0798
Tytin						
Vacuum						
Baseline	4	6	0	0	0.3200	0.0329
6 months	1	6	3	0	0.5295	0.0487
12 months	1	5	4	0	0.5642	0.0554
24 months	0	1	3	3	0.8221	0.0310
Atmospheric pressure						
Baseline	5	5	0	0	0.2848	0.0342
6 months	0	7	3	0	0.5646	0.0282
12 months	0	5	4	1	0.6490	0.0415
24 months	0	0	3	5	0.9011	0.0590
	33	73	32	13		

* Category I = least fracture at margins
Category IV = most fracture at margins

gins, and this continued for the two-year term of the study. Dispersalloy mixed in a vacuum had slightly more fracturing at the margins than that mixed at atmospheric pressure. Tytin mixed in a vacuum showed more fracturing at the margins at 6, 12, and 24 months than Dispersalloy, but less than Tytin mixed at atmospheric pressure.

Statistical analysis of the rank ordering revealed no differences between materials or methods of trituration at baseline, 6, and 12 months. There are statistically significant differences between Dispersalloy and Tytin at 24 months ($P < 0.01$), but no statistically significant differences between methods of trituration.

DISCUSSION

The results of the analysis of microstructure reveal that the alloy Tytin was influenced by trituration in a vacuum, but that Dispersalloy was not. Tytin did reveal twice as many

Table 3. Rank Ordering of Restorations (n = 40)

Alloy	Baseline	6 Months	12 Months	24 Months*
Dispersalloy				
Vacuum	22.9	18.1	15.8	12.6
Atmospheric Pressure	16.6	17.7	15.4	11.9
Tytin				
Vacuum	23.2	21.4	24.3	16.7
Atmospheric Pressure	19.2	24.8	26.5	21.9

Lower ranks = less fracture at margins

* Statistically significant difference between Dispersalloy and Tytin ($P < 0.01$) and 31 restorations evaluated

voids as Dispersalloy when both were mixed at atmospheric pressure. The mechanism and packing factors involved in these differences are not understood but are open to investigation and possible improvement by the manufacturers.

The mechanical tests reveal no significant changes with either alloy. This is somewhat surprising for Tytin, since the reduction in voids was 25%. A close examination of the technique used to mix under vacuum reveals a probable explanation in that there is a 25-second delay in retrieval of amalgam after trituration. This was caused by the releasing of the vacuum in the chamber and meant that both alloys were at a disadvantage when mixed in a vacuum, being set further before condensation than the alloys mixed at atmospheric pressure. This delay would explain the higher compressive strength of Tytin mixed at atmospheric pressure compared with Tytin mixed in a vacuum and the alteration in size and distribution of voids in both alloys.

The clinical consequences of the delay to retrieve the amalgam immediately from trituration in the vacuum shows itself at baseline. For both Dispersalloy and Tytin, the amalgam mixed at atmospheric pressure had less fracturing at the margins than the material mixed in a vacuum. This early difference between Dispersalloy mixed in a vacuum and Dispersalloy mixed at atmospheric pressure does not change throughout the two-year study. The percentage of voids in this alloy is also not altered, so we would expect this result. Tytin, on the other hand, did not follow this pattern. The Tytin mixed in a vacuum started with more discrepancies at the margins than Tytin mixed at atmospheric pressure, but at six months they were equal. By 12 months and at 24 months the Tytin mixed in a vacuum had less marginal fracture than the Tytin mixed at atmospheric pressure, probably because the voids were reduced in the amalgam mixed in a vacuum.

As with most research, more questions have surfaced. What are the effects of vacuum mixing on other alloys; what influence do amalgamators of different speeds have on the percentage of voids; can a system be devised to reduce retrieval time; and will mixing in a vacuum reduce mercury contamina-

tion are only a few of the unanswered queries. There is one question that is answered, at least partly, by this study. Numerous studies have indicated a difference in rate of fracture at the margins between Tytin and Dispersalloy where commercially available batches have been used (Osborne & others, 1978; Laswell, Berry & Osborne, 1980; Mahler & Engle, 1983). The difference in the rate of fracture at the margins may be a function of the percentage of voids. These voids are areas for propagation of cracks and a reduction in voids did reduce the rate of fracture in Tytin.

CONCLUSION

Dispersalloy and Tytin were tested in the laboratory and clinically to assess the effects of trituration under a vacuum. Metallurgical analysis revealed that, at the vacuum used, the number of voids in Tytin could be reduced, but not in Dispersalloy. Mechanical testing revealed no significant changes for creep and 24-hour compressive strength. Clinical results indicated that alloys mixed in a vacuum had more discrepancies initially than when mixed at atmospheric pressure. A delay in retrieving the mixed amalgam from the vacuum is a probable explanation. At two years, there is a trend for Tytin mixed in a vacuum to have less marginal fracture than Tytin mixed at atmospheric pressure. The rates of marginal fracture of Dispersalloy were found to be less than those of Tytin.

(Accepted 12 December 1983)

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DENTAL PRACTICE

Mercury Contamination Removed with Tin Foil

Tin foil is an excellent material for removing mercury that has been spilled

RAFAEL GRAJOWER
JONATHAN MANN • ISRAEL LEWINSTEIN

Summary

Drops of mercury placed on sheets of tin foil were found to wet tin foil, causing warpage and brittleness. Cleaning a mercury spill of 0.53 gm with 2.2 gm tin foil reduced the concentration of mercury vapor from above 0.5 mg m^{-3} to 0.02 mg m^{-3} within five minutes, as measured with a gold-film mercury-vapor analyzer. Attempts to determine the absorption by tin foil of mercury vapor in the air of a closed box were inconclusive. Metal backing for x-ray films and tin solder were found to react with mercury more slowly than did tin foil.

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INTRODUCTION

After mercury has been spilled, the dentist may feel at a loss about the way to remove the multitude of tiny droplets, which have scattered to various corners and crevices in the clinic. Not only could mercury be present in locations that are inaccessible to brushes, but brushes could also divide mercury droplets and spread the contamination. Dispensing sulfur powder on the spill may create a protective coating on the droplets but does not remove them; furthermore it causes untidiness in the clinic. Mercury droplets can also be coated with sulfur by means of solutions containing metal sulfides, which, however, could corrode metals and discolor fabrics (Eames, Gaspar & Mohler, 1976). Special vacuum cleaners with air filters are available (Eames & others, 1976), but have not found widespread use in dental offices.

Johnson (1967) reported that a mixture of tin powder and 18.5% mercury is completely amalgamated within two minutes. This observation led to the idea that tin foil could be used to clean up mercury spills. Foil rather than powder was chosen, as foil would create less disorder in the clinic.

MATERIALS AND METHODS

Interaction of Mercury and Tin Foil

The interaction of mercury and tin foil, 0.022 gm cm^{-2} (Dixon, New Dent, Jerusalem, Israel), was studied by covering an aluminum dish (61 mm in diameter x 7 mm deep) with foil, placing a drop of mercury, 0.53 ± 0.02 gm, on the foil and observing the spread of the mercury on the foil as well as changes occurring in the properties of the foil. Similar experiments were carried out with mercury drops on metal foil backings of dental x-ray films (Kodak, safety-film, Rochester, NY 14650, USA). Wetting of tin solder wire for electronics, 0.075 gm cm^{-1}, 50% Sn (Supersold, Tel Aviv, Israel), by mercury was investigated by dipping the wire in mercury droplets.

Concentrations of Mercury Vapor over Spills

Mercury spills were simulated by placing a mercury drop, 0.53 gm, on a metal dish. A sheet, 100 x 100 mm and weighing 2.2 ± 0.1 gm, was cut from a roll of tin foil (Fig 1). The

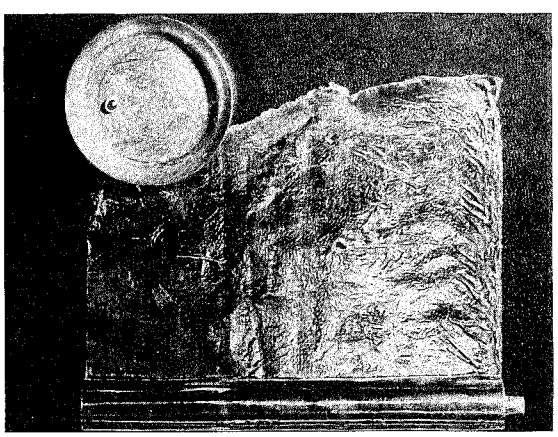

FIG 1. *Roll of tin foil and metal dish with mercury droplets*

sheet was folded into four layers. The mercury drop was dabbed lightly with the foil about 10 times during four minutes. Finally the dish was rubbed with the foil. The total operation of cleaning lasted approximately five minutes.

Mercury vapor concentrations (MVC) were determined with a gold-film mercury-vapor analyzer (Jerome Instrument Corp, Model 401, Jerome, AZ 86331, USA). The aperture of the air intake of the probe of the apparatus was held 15 mm above the examined surfaces. The MVC over the dish was measured before application of the mercury droplet, five minutes after placement of the droplet, and five minutes after termination of the cleaning operation. The MVC above the exposed side of the tin sheet was determined as well.

Removing Mercury from Crevices

The feasibility of removing mercury from crevices between sheets of vinyl covers on floors was evaluated by slowly passing the corners of tin sheets in these cracks. The appearance of the corners of the sheets after this operation was compared for crevices with and without mercury droplets.

Absorption of Mercury Vapor

Preliminary experiments were carried out to determine whether mercury vapor is absorbed from the air by tin foil, without creating contact between liquid mercury and the foil. The probe of the measuring apparatus was inserted through the lid of a box with inner dimensions of 20 x 18 x 9 cm. A dish with a mercury drop was placed at a distance of 20 cm from the aperture of the probe in the box. The increase of the MVC with time was monitored after closing the box. The results were compared with experiments with and without a sheet of tin, 15 x 18 cm, on the floor of the box.

Analysis of Data

All experiments were carried out in triplicate. Average values and standard deviations were calculated for MVC values and for timed intervals.

RESULTS

Interaction of Mercury and Tin Foil

Spreading of the mercury droplet on the tin

foil covering the dish occurred almost instantaneously. After 31 ± 3 minutes most of the surface was covered with mercury and the liquid appearance of the mercury disappeared. Warpage of the tin foil around the droplet started 14 ± 2 minutes after its application (Fig 2) and spread outward until, after approximately one hour, it affected the entire surface. After two hours the foil was removed from the dish with very little force. This created a large hole in the foil, a piece of which remained on the dish (Fig 3). The foil had become extremely brittle and fragile. It disintegrated into small crumbs when touched with a spatula.

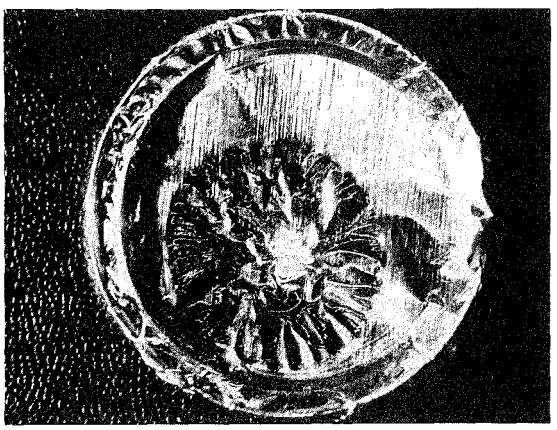

FIG 2. *Warpage of tin foil caused by spreading of mercury droplet*

FIG 3. *A large hole in the tin foil (top) is formed during its removal from the dish. Remnants of the tin mercury reaction product remain on the dish.*

Wetting of the metal backings of x-ray film occurred at a much slower rate than that of the tin foil. Some liquid mercury remained on the surface for approximately 3.5 hours. Small droplets of mercury adhered to the solder wire upon dipping and rendered the wire brittle.

Concentrations of Mercury Vapor over Spills

Placement of a mercury drop on the metal dish increased the MVC from the background value of 0.0035 ± 0.0022 mg m^{-3} to values greater than 0.5 mg m^{-3}, the maximum concentration that could be determined with the analyzer. Cleaning of the mercury with tin foil reduced the MVC above the dish and above the exposed crumbs of tin foil to 0.020 ± 0.002 mg m^{-3} and 0.022 ± 0.003 mg m^{-3}, respectively.

Removing Mercury from Crevices

Passing corners of sheets of tin through grooves containing mercury droplets resulted in disintegration of these corners. Disintegration was not observed for uncontaminated grooves.

Absorption of Mercury Vapor

The MVC near the probe in the closed box rose to 0.5 mg m^{-3} in periods between 35 and 52 minutes after placement of the mercury drop. Similar results were obtained with and without tin foil on the floor of the box. The accuracy of these measurements was poor, since the air intake at the probe in the closed box during measurements affects the results in a significant, but irreproducible, manner. Also, the number of readings of high concentrations of mercury that could be taken during each run was small before the gold foil became saturated with mercury.

DISCUSSION

The results show that cleaning a mercury spill with tin foil reduces the MVC greatly

within a few minutes. The resulting MVC is well below the maximum permissible MVC of 0.05 mg m^{-3} (US Dept HEW, National Institute for Occupational Safety and Health, 1973). The resulting tin-mercury crumbs can easily be brushed away and do not constitute a potential source of mercury vapor (Fig 4).

FIG 4. *Tin-mercury crumbs remaining after cleaning of contaminated surface*

The relatively large drops of mercury used in this investigation were not divided into smaller droplets during cleaning. Division of the drops could cause scattering of fragmentary droplets and result in spread of the contamination. Mercury spills in clinical practice usually give rise to smaller droplets, which may be cleaned with larger quantities of tin foil. Hence the cleaning process will be even more rapid than described in this study.

It was observed that mercury spills occur frequently in the refill compartment of the Dentomat dispenser-trituration apparatus (Degussa, Frankfurt, Federal Republic of Germany). A few pieces of tin foil near the mercury container of this compartment eliminated the mercury droplets.

The passage of corners of sheets of tin through grooves may serve both to detect and remove mercury contamination in these crevices. The interaction of metal backings of x-ray film and of tin solder wire with mercury is similar to that of tin foil, but occurs at a much slower rate. These materials could possibly be used in emergencies when tin foil is not available.

The results with the closed box indicate that mercury vapor does not react rapidly with tin foil. Possibly the passivating layer of tin oxide covering the foil prevents the reaction with mercury. Mechanical contact between foil and mercury may therefore be required to rupture the oxide layer and secure rapid amalgamation.

CONCLUSIONS

- Cleaning of a mercury spill with tin foil reduces the mercury vapor concentration above the spill to below the threshold limit value within a few minutes. Tin foil is a readily available, easily used, and efficient material to remove mercury spills.
- Mercury was found to react with tin solder wire and metal backings of x-ray films, but at a much slower rate than with tin foil.
- Experiments carried out to verify whether tin foil absorbs mercury vapor from air were inconclusive. However, even if some degree of absorption had occurred it would be insufficient to be of clinical importance.

(Accepted 14 October 1983)

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PRODUCT REPORT

Accuracy of a New Type of Irreversible Hydrocolloid (JLB) for Final Impressions

Unless they are poured immediately, and only if a single tooth preparation is involved, models made from impressions by JLB are not as accurate as models made from impressions by Polyjel and Reflect.

ASTERIOS DOUKOUDAKIS
JAMES C SCHNEIDER • BERNARD L ABRAMS
SALVATORE A CIGNA

Summary

Impressions made of a stainless steel die by JLB, Polyjel, and Reflect were poured immediately, and after 12, 24, and 36 hours. When the accuracy of the models was ascertained it was found that JLB, unless it was poured immediately and limited to single teeth, did not produce models that were as accurate as those from Polyjel or Reflect.

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Introduction

Irreversible hydrocolloid is one of the most commonly used dental materials, both in clinical and laboratory procedures. It is composed mainly of a salt of alginic acid such as sodium, potassium, or ammonium. These salts are soluble in water, forming a noncrystalline sol. The sol forms crosslinks with a metallic salt, producing an insoluble, irreversible alginate gel (American Dental Association, 1968).

Irreversible hydrocolloid is used primarily as an impression material, although other uses have been reported (Appelbaum, 1981; Scott, 1978; Knapp & McDowell, 1981; Fairchild, 1974).

Since the introduction of irreversible hydrocolloid in 1940, the physical properties and clinical characteristics—such as accuracy, time of removal from the mouth, storage, and dimensional stability—have been investigated. Coleman & others (1979) noted that impressions that were poured in stone immediately after removal from the mouth produced the most accurate results. If the impression cannot be poured immediately, it should be stored temporarily in a humid environment to avoid inaccuracies occurring from the continuous gelation or dehydration (Civjan, Huget & de Simon, 1972; Smith & Nakamoto, 1972; Miller, 1975). As to the time of removal from the mouth, authors have agreed that irreversible hydrocolloid impressions should be allowed to remain from two to three minutes beyond the time of gelation to obtain maximum rigidity and strength (Rapuano, Marra & Del Tufo, 1973; Skinner & Pomés, 1947).

Despite the extensive clinical use of the material and the numerous studies, problems exist with irreversible hydrocolloids, mainly because the twisting, wrenching, and bending of the material required to release it from the mouth causes visible and permanent deformation (Khaknegar & Ettinger, 1977). This deformation, associated with mistakes in manipulation of the material, has limited the use of irreversible hydrocolloid as the impression material of choice for the fabrication of diagnostic casts (Bliss & Saggs, 1967).

Recently a new irreversible hydrocolloid named JLB (Brasseler USA, Inc, Savannah, GA 31405, USA) has been introduced. The manufacturer suggests that the material is accurate as an impression material for castings that are fabricated by the regular procedures of casting crowns and bridges. The manufacturer also suggests that pouring the impression can be delayed up to 36 hours without any considerable loss in accuracy. The purpose of this study was to investigate the accuracy and dimensional stability of this new irreversible hydrocolloid and compare its performance with both a polyether and a vinyl polysiloxane impression material.

Methods and Materials

A master die of stainless steel was used that simulated two shoulderless preparations for full crowns for a fixed partial denture (Fig 1). The diameter of the first preparation

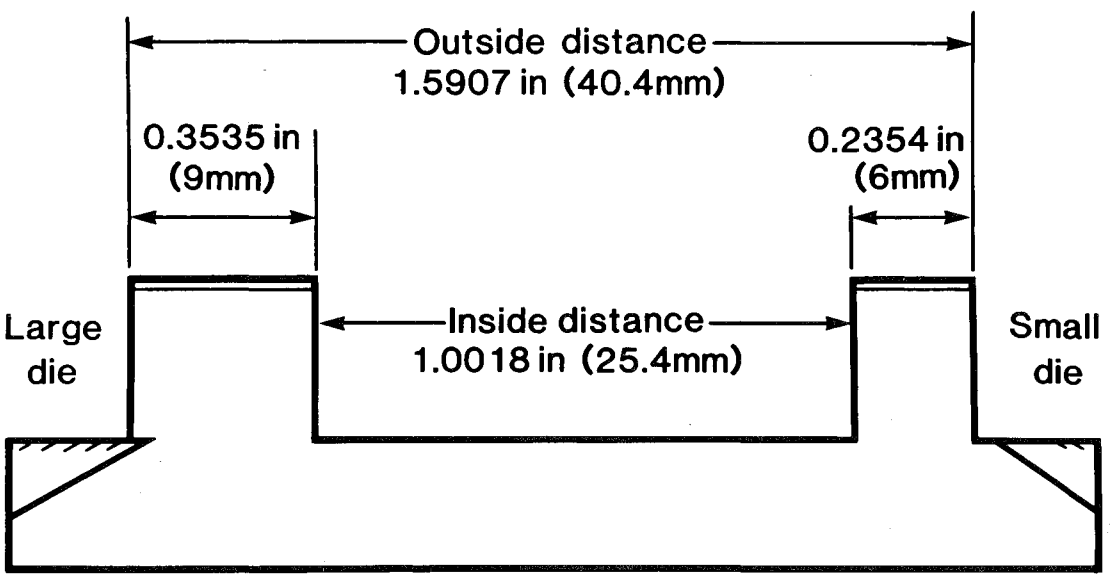

FIG 1. *Diagram of the master stainless steel die*

was 0.3535 in (9 mm), while that of the second preparation was 0.2354 in (6 mm). The outside distance between the two preparations was 1.5907 in (40.4 mm), while the inside distance was 1.0018 in (25.4 mm). The base of the master die included stops at the four corners that controlled the seating of the tray during the making of the impression. Also fabricated were perforated metal trays of aluminum that fitted accurately to the base of the master die. The bottom of the base of the master die was threaded so that a bolt could be screwed into the base to aid in removal of the impression. The impression materials used in this study were JLB, an irreversible hydrocolloid (Brasseler, batch number 185692/3/150N°/1563); Class A, Type II, Polyjel, a polyether (L D Caulk Co, Milford, DE 19963, USA, batch number 1053, MDO22282); and Reflect, a vinyl polysiloxane (Kerr Division of Sybron Corp, Romulus, MI 48174, USA, batch number 092982-1264).

All impressions were made and stored according to the manufacturers' recommendations for the impression materials. All impressions were poured with premeasured Vel-Mix die stone (Kerr Manufacturing Co) mixed under vacuum with a mechanical mixer. Six groups of models were produced according to the following specific procedures.

Group A. JLB hydrocolloid powder from a premeasured package of 20.6 grams was mixed with 43 ml of distilled water at room temperature for 30 seconds with the help of an electric Alginator (CADCO Products, Los Angeles, CA 90034, USA). The mixed material was loaded in the syringe and into the aluminum custom tray. With the help of the syringe the material was applied to the metal dies and the tray was fully seated. The master die with the tray stabilized by two C-clamps was then placed on a platform above the water level in a covered water bath to simulate the oral environment. The temperature of the water was 100 °F (37.8 °C). The impressions remained for five minutes inside the water bath and, when removed, were carefully separated from the master die and poured immediately.

Group B. The same procedures were followed as with Group A, but impressions were stored for 12 hours in a humidor before they were poured.

Group C. The same procedures were followed as in Group A, but impressions were poured after they were stored for 24 hours in a humidor.

Group D. The same procedures were again followed as in Group A, but these impressions were poured after they had been stored for 36 hours in a humidor.

Group E. Impressions were made with Reflect vinyl polysiloxane impression material. Equal lengths of base and catalyst were thoroughly mixed at room temperature for 30 seconds with a metal spatula. The material was then placed in the syringe, and the aluminum tray filled. The material was injected on the metal dies by means of the syringe and the tray fully seated. The impression with the master die and the C-clamps was placed in the water bath for five minutes, and after removal from the bath was carefully separated from the master die. Impressions remained for 12 hours at room temperature before they were poured.

Group F. Impressions were made using Polyjel polyether impression material. The same procedures were used as in Group E, but impressions remained at room temperature for two hours before they were poured.

Ten stone models were produced from each group according to the above-mentioned procedures for a total sample of 60. Models were numbered for measuring and the statistical analysis.

For measuring, two outside micrometer calipers (Hitutoyl Instrumental Caliper Co, Tokyo, Japan) were used, capable of measuring from 0 to 1 in (0-25.4 mm), and from 1 to 2 in (25.4-50.8 mm), respectively, with an accuracy of 0.0001 in (2.5 μm). The outside distance of the two cylindrical dies of all stone models was measured with the micrometer having a range of 1-2 in (0-25.4 mm). The diameters of the large and small cylindrical dies of all stone models were measured with the micrometer having a range of 0-1 in (0-2.54 mm). Each measurement was repeated three times to insure the reproducibility and

accuracy of the measurements. All measurements were recorded and compared by means of an analysis of variance.

Results and Discussion

Combined means and standard deviations of all groups of stone models are reported in the table. Deviations of the six groups from the master stainless steel die are illustrated in Fig 2. Measurements are reported both in inches and millimeters. The analysis of the data indicated that the most accurate models were produced by the Polyjel and Reflect impression materials. In these two groups there was no statistically significant difference between the stone models ($P < 0.05$). Impressions made with JLB generally did not compare favorably with either the polyether or the vinyl polysiloxane groups. Specifically, models produced from JLB demonstrated better accuracy when poured immediately after separation from the stainless steel die. Within this group, measurements of the small die were consistently accurate as indicated by the small standard deviations. Measurements of the large die and the outside distance demonstrated small mean deviations from the master die but large standard deviations were recorded, indicating that consistently accurate results could not be obtained.

Combined Means and Standard Deviations for All the Groups of Stone Models

Impression Material (time of pouring)	Small Die Measurement in (mm)		Large Die Measurement in (mm)		Outside Measurement in (mm)	
	mean	SD	mean	SD	mean	SD
JLB	0.2343	0.0013	0.3528	0.0021	1.5899	0.0029
(0 h)	(5.95)	(0.03)	(8.96)	(0.05)	(40.38)	(0.07)
JLB	0.2371	0.0017	0.3560	0.0026	1.5893	0.0069
(12 h)	(6.02)	(0.04)	(9.04)	(0.07)	(40.37)	(0.18)
JLB	0.2367	0.0017	0.3566	0.0019	1.5934	0.0015
(24 h)	(6.01)	(0.04)	(9.06)	(0.05)	(40.47)	(0.04)
JLB	0.2374	0.0016	0.3572	0.0021	1.5934	0.0019
(36 h)	(6.03)	(0.04)	(9.07)	(0.05)	(40.47)	(0.05)
Reflect	0.2360	0.0003	0.3545	0.0003	1.5911	0.0005
(12 h)	(5.99)	(0.01)	(9.00)	(0.01)	(40.41)	(0.01)
Polyjel	0.2353	0.0005	0.3534	0.0005	1.5900	0.0011
(2 h)	(5.98)	(0.01)	(8.98)	(0.01)	(40.39)	(0.03)
Stainless	0.2354	0.0001	0.3535	0.0001	1.5907	0.0002
Steel Die	(5.98)	(0.00)	(8.98)	(0.00)	(40.40)	(0.01)

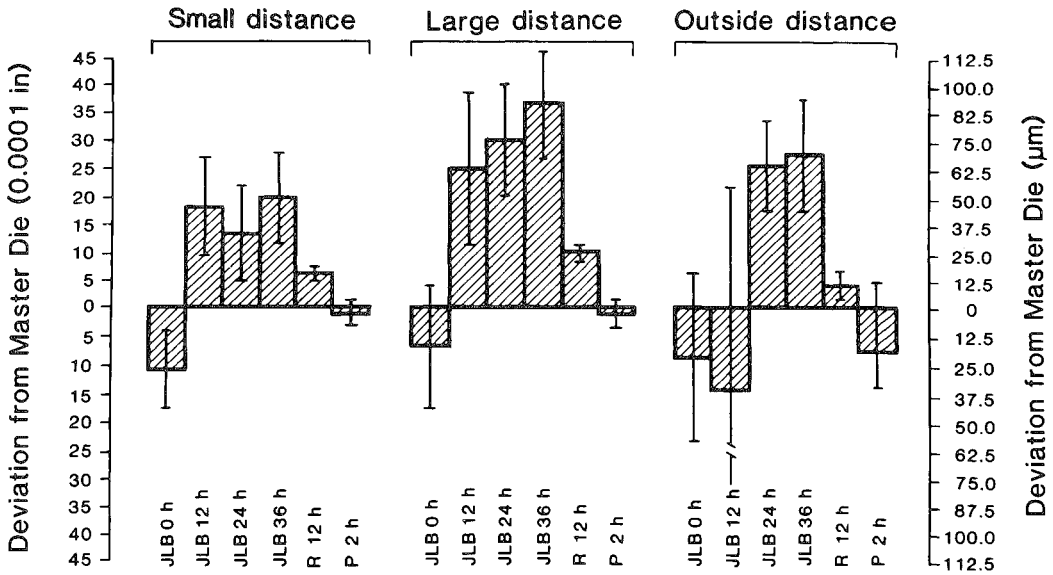

FIG 2. *Mean deviations of all groups from the stainless steel die*

In all other stone models produced from JLB, and which were poured 12, 24, and 36 hours later, it can be clearly seen that inaccurate results were obtained. By observing Fig 2 it is evident that models deviated further from the master die as the delay in pouring the die stone increased. These deviations were significant at 0.05 level of probability. The worst results were obtained when models were poured from impressions that stayed in the humidor for 36 hours.

Within the experimental limits of the present study it appears that JLB can be used as a final impression material for a single prepared tooth if the impression is poured immediately.

It seems that when the number or size of prepared teeth increases, the material does not provide consistently accurate results. At the same time, when the pour is delayed, and although models are stored in a humid environment, the results clearly indicate that stone models are inaccurate and deviate significantly from the master die. In this case the models are generally larger than the master model and their inaccuracies increase proportionally with the time of storage. The claim made by the manufacturer that stone models will be accurate even if the pour is delayed for 36 hours should, based on these data, be rejected.

CONCLUSIONS

The results of this study indicated that JLB is accurate for use for impressions of single crowns, inlays, or onlays when it is poured immediately. When the pour of the impression was delayed or when more than a single preparation was impressed the results did not compare favorably with the stainless steel die and models produced from the two elastomeric materials.

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POINT OF VIEW

Contributions always welcome

How Much Is Enough?

JUDSON KLOOSTER

The quantity of clinical experience provided for students in schools of dentistry is critically important to the completeness of their dental education. For some students, the amount of clinical activity each must complete as a prologue to graduation may seem tedious or burdensome; some resistance is perceived from at least a few students in every class. Teachers that insist on an abundance of clinical experiences in apparently similar procedures are often thought to be a little overbearing, and are criticized for having emphasized quantity to the possible exclusion of concern over quality. However, a strong case can be made for maximizing students' clinical experience within the remarkably brief time they have available during the clinical period of their dental education.

Skill training involves a four-step sequence of procedure—no one of these steps can be minimized or eliminated without loss in the completeness of learning. First, a skill is **described**: sometimes by lecture or in some mode of programed instruction (slide series, videotapes, etc.). Often this can be accomplished for an entire group of students, since they all need to hear the same message. The second step is to **demonstrate** the skill, either by live demonstration or videotaped illustration in which the student has an opportunity to see the described skill in actual use by experienced hands. The third step is **skill practice in a limited-risk environment**, such as a technique laboratory or flight simulator; in this environment, the student begins to practice the skill without doing harm to himself or others. The fourth and most realistic step

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occurs when **skills are practiced in a full-risk environment**—where the operator must indeed practice the skill safely, in order to avoid adverse results to himself or others.

The student's first experience in a full-risk environment embodies a tangible amount of new learning. The forecasted outcomes of the procedure materialize for the first time in the operator's hands in this real-life environment, sometimes accompanied by elements that have **not** been predicted by the instructor! Obviously, a maximum amount of new learning may occur in this first experience. Second, third, and fourth experiences with the same skill are accompanied by progressively smaller amounts of new learning, and may serve merely to confirm what has been learned in the early experience. However, at some point a sufficiently atypical experience is encountered so that a higher level of new learning is involved. Perhaps the predicted characteristics of this skill arrange themselves in a somewhat different matrix or format, or perhaps the real-life situation is enough different from what had been described or demonstrated or previously experienced, so that a new level of resourcefulness and judgment is required, indeed a new level of skill development is necessary to complete the procedure. If skill practice had been cut off before this dramatic new experience developed, the learner would have been cheated out of this expansion of his resourcefulness, judgment, and finesse. These experiences continue in cycle throughout life, so that practicing dentists find long periods of fairly routine application of learned skills, with less and less frequent clinical encounters that involve very dramatic new levels of learning.

However, in dental school it does not seem prudent to limit skill practice to a few experiences with each procedure since there is so much need for developing performance skill, clinical judgment, and procedural finesse, all the while protecting the quality standards of each clinical service. A study done many years ago suggested that the total amount of clinical procedures involved in the average dental student's experience during the entire four years of his dental education was roughly equivalent to the productive output of a general dentist in approximately three weeks of a busy practice. In schools with particularly high expectations in clinical procedures or requirements, perhaps this could be expanded to four weeks—in any case it is a pitifully narrow base of clinical experience on which to build a lifetime of practice!

Dental students sometimes feel that their school asks them to perform high volumes of clinical service in order to maximize clinic income, with a lesser concern for the quality of their total learning experience. Particularly in private schools this financial motivation may work to the student's advantage, since a larger level of clinic income makes it possible to hold tuition costs at or near present levels. However, the major concern in quantity of service is to provide the student with enough experience so that he becomes comfortable in providing a broad range of general dentistry services without having available the consultative expertise of his teachers. No dental school should apologize for high levels of clinical requirements, **provided** there is a commensurate concern for the completeness of patient care, the tangible expression of caring concern for each patient, and the maintaining of high standards of quality in every aspect of clinical procedures.

WIT AND WISDOM

Saturday

Dear Uncle IaN,

How are you? I am fine. Things ain't so good down here on the farm. Aunt Gertrude died Thursday. Boy, did she have a spell of bad luck. It started when she went down to that brand new dental school last month. This docter told her that she could get her rottening teeth fixed free if she came on this special deal called state board. So she got gussied up and went to town.

Well, when she got there, she sat in this fancy chair for three days and got to watch this BIG FIGHT. Aunt Gertrude said it was better than Saturday night Wrestlin'—and you know how she liked that Saturday night Wrestlin'! This young 'un docter drilled holes in her teeth and the fight got started over sand burs. This big 'un docter told the young 'un that he outta use buns what were jes half round, and the young 'un said the only buns he ever saw were whole round and boy did they get into it!! Then the young 'un docter made this beutiful gold tooth for Aunt Gertrude, and while he was shinin' it on this shinin' machine, it flipped right outta his hand, bounced over on the spittin' sink, and flew right out the winder. The big 'un docter started screamin' about what he learned in that damned school anyway, and the young 'un docter said that since there warn't so many rottenin' teeth now-a-days, they didn't have to learn all that horse manure.

Things got really turrible when the big 'un looked in Aunt Gertrude's mouth and started yellin' about exposing her. WELL - Aunt Gertrude told him that she warn't that kind of lady, and she was gonna call the Police. So we picked her up and took her home. Her teeth were hurtin' awful bad, but she said she wouldn't never go back to that place!

For days and days them teeth hurt, but we couldn't get Aunt Gertrude to do nothing about it. Then last week she started gettin' these pains in her chest. We finally taked her to the horsepital last Thursday. These docters hooked her up to this big autograph machine and when it started scratchin' like wildfire, they got awful scared. They started yellin' "Verapamil - Verapamil" - and they stuck this big bottle of soda-pop to her arm and kept givin' it more shots. Poor ole Aunt Gertrude got worser and worser, so the docters started yellin' "Inderal - Inderal" - and they gave her that Inderal medicine fer about an hour. Then this funny lookin docter with big thick glasses ryn over to the autograph machine and said that if they'd slow that thang down to the right speed limit they wouldn't get so many false tachycardias — and he wanted to know what they'd learned in that damned school anyway. And the other docters said that since there warn't so many hearts attackin now-a-days, they didn't have to learn all that horse manure.

Well, Aunt Gertrude left 3 pigs and 6 chickens in her will. The pigs went to Aunt Lucy, Uncle Elmo, and Uncle Luther. You get one of the chickens, so the postman will probably be bringing it to you sometime next week.

Yore precious neice,
Caralyn Sue

DEPARTMENTS

Book Review

RESTORATION OF THE ENDODONTICALLY TREATED TOOTH

By Herbert T Shillingburg, Jr, and James C Kessler

Published by Quintessence Publishing Co, Inc, Chicago, 1982. 382 pages, 739 illustrations. $68.00

In the preface to this book, the authors describe their purpose and the audience for which this publication is intended. They claim to have "... attempted to focus on the underlying principles and the common aspects of the restoration of endodontically treated teeth, while presenting as many different techniques and systems as possible." The authors hope that the reader will become familiar with different methods of restoring pulpless teeth and learn the detailed procedures that are required for each technique. It is also hoped that the knowledge gained about current methods should prepare the reader to assess techniques, materials, and products that will undoubtedly be developed in the future.

This book is intended for undergraduate dental students and practicing dentists. The realization that Herbert Shillingburg, Jr, is one of the authors of this book should capture the attention of both teachers and practitioners of restorative dentistry. Shillingburg and colleagues have published the comprehensive reference, *Fundamentals of Fixed Prosthodontics,* which has been an outstanding textbook for use in teaching programs. Although it describes a more limited subject, *Restoration of the Endodontically Treated Tooth* should be a useful reference for students in restorative teaching programs and dentists that restore pulpless teeth.

The restorative considerations unique to endodontically treated teeth are described in 16 well-written and extensively illustrated chapters. The first chapter is devoted to the principles of restoring pulpless teeth, each of the following 14 chapters describes a different general design of dowel-core or pin-retained core, and the last chapter presents two methods for fabricating temporary dowel-crowns.

The opening chapter, entitled "Principles of Restoration of Endodontically Treated Teeth," begins with an interesting historical review of the subject. The efforts of the legendary 18th- and 19th-century figures Pierre Fauchard and G V Black are particularly impressive. Fauchard is credited with using wooden posts placed in pulp canals to retain crowns and Black developed a porcelain-faced crown that was retained by a screw inserted into a canal filled with gold foil. This chapter also includes clear definitions of terms frequently found confusing to readers of technique articles written on this topic. The precise use of such descriptive terms as core, dowel-core, pin-retained core, prefabricated dowel, and custom-core will, it is hoped, be adopted in the future by other authors. The highlight of the chapter on "Principles" is the comprehensive review of the numerous in vitro research investigations into factors influencing dowel retention: length, type, diameter, and surface configuration. Discussion of each of these factors is exhaustively referenced and accompanied with excellent line drawings, graphs, or tables. For example, dowel length is reviewed in detail with several different recommenda-

tions summarized from no less than 75 authors. Shillingburg and Kessler pose the question "what then should be the length of the dowel? Simply stated it should be as long as possible. A dowel length equal to that of the crown or two-thirds that of the root is a good rule of thumb."

The chapter on "Principles" concludes with an excellent table giving specifications and dimensions of 13 manufactured, prefabricated dowels or rotary instruments used to prepare dowel channels. The degree of taper, dowel material, plastic burnout availability, surface configuration, and diameter are clearly presented for comparative evaluation. This table presents the specifications of armamentaria referred to in succeeding chapters and provides a convenient basis for the practitioner to select a system to meet specific clinical circumstances. In this chapter and throughout the book, the authors are to be commended for identifying conflicting opinions found in clinical articles or research reports. The avoidance of such issues can produce a false impression of simplicity that can mislead the reader who is seeking an accurate representation of the subject. The comprehensive review of the apparently disparate findings on whether dowels "reinforce" roots is an example of such an issue.

A chapter is devoted to each of 12 different methods of placing a core prior to the restorations of a tooth with a complete crown. These methods have been grouped and presented in generic categories with the applicable manufacturers of systems, instruments, or materials cited for each group. Three variations of the custom dowel-core are described: the directly, indirectly, and two-piece fabricated foundation. Prefabricated dowel-core systems, both metal dowels and plastic burnout pattern dowels, are the topics of four chapters. Those dowels that obtain significant retention from threads tapped into the sides of a dowel channel are grouped for description into pretapped or self-threading and parallel or tapered categories. A chapter each is devoted to pin-retained amalgam and composite resin cores. Two means are presented for providing a foundation beneath an existing cast restoration. The chapters on the "Dowel-Core Under a Crown" and the "Dowel-Inlay Crown Repair" describe useful techniques to increase the longevity of restorations through which an access opening for endodontics has removed significant supportive dentin.

The format of this hard-cover textbook allows for unstrained, enjoyable reading. The type is large and contrasts well with the opaque white paper for which Quintessence Publishing Company has become renowned. The text is very well referenced and contains suggestions for additional reading or specific topics. Each chapter contains superb line drawings that are highlighted with several colors. The instructions for each technique are also complemented with photographic plates of dentoform and clinical restorations. Color renditions of intraoral tissues is excellent. In an otherwise outstanding collection of illustrations, the radiographs included in some line drawings are unfortunately of poor clarity.

The only significant criticism of this book is a deficiency in providing guidelines for selecting a specific restorative system when faced with particular clinical conditions. Although in many circumstances the selection would not be of significance, in certain cases the anatomical considerations would favor one system over others. The deficiency of treatment planning in this book will necessitate the teacher of restorative dentistry or the clinician to make the decision as to the type of restoration for a particular pulpless tooth. Having made that decision, one could not wish for a better instructional reference than *Restoration of the Endodontically Treated Tooth.*

This book represents an outstanding contribution to the dental literature. It is the first comprehensive reference devoted entirely to the restoration of pulpless teeth, and as such it should belong on the shelf of every serious student of restorative dentistry.

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Announcements

NEWS OF THE ACADEMIES

CERTIFICATION PROGRAM

The American Board of Operative Dentistry

In recent months there have been considerable discussion and a few heated words concerning the Certification Program of the American Board of Operative Dentistry. Much of the concern is based on myth and misconception.

Although this Academy parented and sponsored the Board, we presently are in an advisory and supportive capacity. The Board proper developed its own operational philosophy and examination procedures.

Since its inception in 1981, the single purpose of the Certification Program has been, and remains, to elevate the art and science of operative dentistry by encouraging scientific study and improving its therapeutic efforts.

Another rumor would have the members of the Academy Council and the members of the Founding Board "grandfathered" into certification. Nothing could be further from the truth. There are **no** exceptions to Certification. In fact, a member of the examining Board must **resign** before he or she can qualify as a candidate.

Departments of operative dentistry have been the poor kids on the block long enough. A certified faculty, so ordained, would be able to stand on its own merits and implement programs with the same amount of authority as "specialty" departments.

The thrust of the program and its expected impact on dental education is to provide an excellent credential for recruitment of faculty. By virtue of its very being, it will induce other faculty members to seek a similar level of attainment. Having created a market, it should entice dental schools to develop good programs in operative dentistry.

Lastly and perhaps most important, it will expose students to a faculty improved in skills, knowledge, and judgment. It will also provide graduates who desire to be recognized for superior achievement as continuing students in the art and science of operative dentistry with an opportunity to be so certified by their peers. The ultimate winners: Our profession . . . and, God bless 'em, our patients.

WILLIAM N GAGNON, DMD
President, Academy of
Operative Dentistry

NOTICE OF MEETINGS

American Academy of Gold Foil Operators

Annual Meeting: 18 and 19 October 1984
Emory University
Atlanta, Georgia

Academy of Operative Dentistry

Annual Meeting: 18 and 19 February 1985
Westin Hotel
Chicago, Illinois

Membership in the Academies

Inquiries about membership in the academies should be directed to the respective secretary.

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NEWS OF THE STUDY CLUBS

Course on Gold Foil

The Associated Ferrier Study Clubs will sponsor a two-week course on gold foil beginning 17 September 1984 at the University of Washington in Seattle. This course is a requirement for active membership in any of the Associated Ferrier Study Clubs but is open to nonmembers. Registration will be limited to 12. Participants will be responsible for furnishing their own assistants and patients, but a special effort will be made to assist participants not living in the area. The instructors for the course will be Dr Bruce B Smith and Dr J Martin Anderson. For further information contact:

Dr Bruce B Smith
1110 Cobb Medical Center
Seattle, WA 98101
(206) 623-8545

Press Digest

Airpolishing effects on enamel, dentine, cement and bone. Boyde, A (1984) *British Dental Journal,* 156, 287–291.

Airpolishing with a Dentsply-Cavitron Prophy-Jet Airpolishing Prophylaxis Unit and Prophy-Jet cleaning powder has no effect on the surface of sound enamel when used for times in excess of those likely to be used for clinical treatment. Prismatic enamel exposed by cutting, fracturing, attrition, or erosion, however, is eroded by airpolishing. Dentine, cementum, and calculus are eroded rapidly. Airpolishing is safe to use in removing plaque, stains, and calculus from sound enamel but is not recommended for cleaning cementum or dentine. It is suggested that airpolishing might be useful in cleaning enamel surfaces before etching and the application of sealants; in cleaning the surface of the tooth before applying fluoride; in removing the smeared layers of enamel and dentine from the walls of cavities; in placing retention in cavities; and in removing carious dentine.

Curing depth of visible light-activated composites. Forsten, L (1984) *Acta Ondontologica Scandinavica,* 42, 23–28.

A macrofilled composite (Prisma-Fil) cured to twice the depth of microfilled composites (Heliosit and Silux) for the same times of exposure. The depth of cure of Heliosit was lower than that given by the manufacturer, Silux about the same, and Prisma-Fil higher. Doubling the exposure time increased the depth of cure of Silux and Prisma-Fil by about a third and affected Heliosit only slightly. Darker shades of Prisma-Fil reduced depth of cure but it was affected little by darker shades of Heliosit and Silux. Exposure through a layer 0.8 mm thick of dentin and enamel reduced the depth of cure by about 1 mm. The Prisma-Lite was slightly more effective in curing than either the Heliomat or the 3M unit.

INSTRUCTIONS TO CONTRIBUTORS

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Send manuscripts and correspondence about manuscripts to the Editor, Professor A Ian Hamilton, at the editorial office: OPERATIVE DENTISTRY, University of Washington, School of Dentistry SM-57, Seattle, WA 98195, USA.

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Submit the original manuscript and one copy; authors should keep another copy for reference. Type double spaced, including references, and leave margins of at least 3 cm (one inch). Supply a short title for running headlines. Spelling should conform to *Webster's Third New International Dictionary,* unabridged edition, 1971. Nomenclature used in descriptive human anatomy should conform to *Nomina Anatomica,* 5th ed, 1983; the terms 'canine', 'premolar', and 'facial' are preferred but 'cuspid', 'bicuspid', and 'labial' and 'buccal' are acceptable. SI (Système International) units are preferred for scientific measurement but traditional units are acceptable. Proprietary names of equipment, instruments, and materials should be followed in parentheses by the name and address of the source or manufacturer. The editor reserves the right to make literary corrections.

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