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E D I T O R I A L

Declining Enrollment in Dental Schools

The decline in the number of applicants for dental schools continues. What has happened to discourage prospective students from embarking on careers in dentistry? Primarily it is the relatively high ratio of dentists to population that has resulted from the expanded capacity of dental schools. This expansion was initiated and subsidized by the government, which, in addition to providing the usual subsidy for the tuition of students, provided the funds to enlarge the physical facilities of dental schools and support the increased expense of their operation.

The economy always reacts to an intervention that upsets the normal tendency of the supply of a commodity and its demand to approach an equilibrium. This is a game that sooner or later the economy always wins.

The effect of the artificially stimulated increase in the number of dentists is now upon us. Established dentists are no longer always fully employed and newly graduated dentists are encountering increasing difficulty in establishing practices. These are the circumstances that discourage young students from entering the profession and that is mainly why enrollment in dental schools is declining.

Adjusting to overexpansion, be it of a profession or an industry, is always painful because the contraction that is needed to correct the misapplication of resources leads to underemployment of both labor and capital. Contrived expansion represents a costly interference with the automatic regulation of the economy whereby adjustments to changing conditions are continuous and smooth rather than precipitate and convulsive.

One of the consequences of overexpansion has been an increase in the cost of dental education because a significant portion of the money paid has gone to administrators and bureaucrats, few of whom teach students. The public, through its taxes, and students, through tuition, have thus been paying more for dental education but getting less; any continuation of the artificial stimulus to increase the supply of dentists is a cost the public should no longer be asked to pay.

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ORIGINAL ARTICLES

Effect of Delayed Trituration on Compressive Strength and Microstructure of Two High-Copper Dental Amalgams

Delaying the trituration of alloy and mercury once they have been placed in contact reduced the compressive strength of the amalgam.

JOHN K JONES • CHIAYI SHEN • CLAIR D REITZ

Summary

Exposing tablets of Dispersalloy and Tytin to mercury for various periods of time before trituration showed that after 30 minutes for Dispersalloy and 1 hour for Tytin a significant reduction of the 7-day compressive strengths resulted.

Examination of the microstructure of the amalgam showed the amount of imperfection increased as the contact time of the mercury with the tablets was extended.

Therefore, we recommend that trituration should be done as soon as possible after the mercury has come in contact with the alloy.

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Introduction

A dentist may unknowingly handle materials improperly, a practice that could deleteriously affect the physical properties and thus the performance of the material. One such questionable practice is dispensing mercury into the mixing capsule with the amalgam alloy and, for various reasons, not triturating for minutes, hours, or perhaps days. The tablets or powder of alloy are then lying in contact with or floating on the mercury. Some change in the alloy may occur as a result of this contact with mercury, the extent of change depending on the duration of contact before trituration. Unfortunately, any change in the amalgamation of the alloy may be too subtle to detect during the eventual manipulation and placement of the amalgam. If the changes cannot be detected, presumably the amalgam may be used regardless of the duration of the contact of the alloy with the mercury. Changes in the physical properties from delayed trituration may lead to premature failure such as corrosion, marginal fracture, or excessive creep, but the cause of these failures may not be readily determined.

This investigation sought to determine the effect, if any, on the compressive strength and microstructure of high-copper dental amalgams produced by delayed trituration of tablets of amalgam alloy that have been in contact with mercury.

Materials and Methods

The two alloys chosen as representative of high-copper amalgam alloys were Dispersalloy (Johnson & Johnson, East Windsor, NJ 08520, USA), a mixture of lathe-cut particles of conventional formula and spherical particles of the eutectic phase of silver and copper, and Tytin (S S White, Philadelphia, PA 19102, USA), a spherical alloy of single composition.

Tablets of the alloys were dispensed into reusable capsules, made by the respective manufacturers, with the amount of mercury specified by the manufacturers (50% for Dispersalloy; 45% for Tytin). The tablets were allowed to remain in contact with mercury, before trituration, for eight different times of exposure, namely, 0 minutes (control), 30 minutes; 1, 2, and 4 hours; and 1, 3, and 6 days. The appearance of the tablets was observed daily for up to a week.

The amalgam was triturated according to the manufacturers' recommendations (10 s with a pestle of 0.675 g for Dispersalloy; 4 s with a pestle of 1.43 g for Tytin) on a Vari-Mix Model VM-A amalgamator (L D Caulk Co, Milford, DE 19963, USA). The specimens were prepared according to Specification No 1 of the American Dental Association for testing the compressive strength of dental amalgam and were stored in air at 37 °C for 1 hour, 1 day, or 7 days. These intervals were chosen so that the results of the control could be compared with previous studies (Malhotra & Asgar, 1978; Clark & others, 1981). Five replicas were made for both brands at each of the eight durations of contact with mercury.

Compressive strength was tested on an Instron Model 1125 (Instron Corp, Canton, MA 02021, USA) using a crosshead speed of 0.2 mm $\cdot$ min^{-1} for specimens stored for 1 hour and 0.5 mm $\cdot$ min^{-1} for specimens stored for 1 day and 7 days. The results were analyzed statistically by a two-way analysis of variance and Duncan multiple range testing ($\alpha = 1\%$).

Metallographic procedures were followed in mounting and polishing the fragments of all the fractured specimens. Final polish was done with 0.05 μm aluminous particles for 2 hours. The mounted specimens were then cleaned ultrasonically in distilled water for 15 minutes. Most specimens of Dispersalloy revealed excellent microstructure and required no further treatment. All specimens of Tytin were etched for 5 to 10 seconds with 4% iodine in ethyl alcohol and immersed for 1 to 2 minutes in hypo cleaning solution (Abbott & Makinson, 1978). After they were rinsed with distilled water and dried with compressed air, photomicrographs were made of representative areas in each specimen at a magnification of 400X.

Photomicrographs were also made of untriturated tablets and of untriturated tablets left in contact with mercury to react for approximately 6 weeks. The microstructure of the experimental specimens was compared with that of the controls, as well as with the microstructure of the untriturated unreacted and untriturated reacted tablets.

Results

During the period of exposure to mercury, the tablets of alloy showed several changes. The mercury diffused completely into the Dispersalloy tablets after 1 week and the tablets were swollen and had fractured. After only 2 days the mercury had diffused

Effect of Delayed Trituration on the Compressive Strength of Two Amalgams at 1 Hour and 7 Days

Duration of Delay	Compressive Strength MPa 1 Hour Dispersalloy Mean ± S D	1 Hour Tytin Mean ± S D	7 Days Dispersalloy Mean ± S D	7 Days Tytin Mean ± S D
0 minutes (control)	118.87 ± 11.99	144.46 ± 16.00	424.00 ± 16.46	478.92 ± 28.23
30 minutes	129.48 ± 16.19	169.26 ± 13.75	359.58 ± 81.68	450.53 ± 12.58
1 hour	111.85 ± 8.81	135.10 ± 19.40	367.38 ± 23.54	417.92 ± 57.90
2 hours	111.23 ± 7.39	139.78 ± 14.50	366.91 ± 22.08	379.08 ± 62.99
4 hours	119.50 ± 15.11	111.85 ± 18.76	367.85 ± 24.74	321.52 ± 26.98
1 day	109.50 ± 17.33	39.31 ± 16.15	292.81 ± 30.85	154.53 ± 15.75
3 days	58.66 ± 8.51	No data	191.41 ± 37.91	No data
6 days	35.57 ± 13.85	No data	114.19 ± 28.01	No data

Solid line: means of groups that are not significantly different at 1% level by Duncan's multiple range test.
Dotted line: connects subgroups of a group.

completely into the Tytin tablets, and they also appeared swollen but remained intact.

Compressive strengths of the amalgams, along with the results of the Duncan multiple range test ($\alpha = 1\%$), are shown in the table. The tablets of Tytin exposed for 3 and 6 days had reacted so much that trituration would not give a workable amalgam; therefore there are no data for Tytin at these durations. Strengths at 24 hours for both brands at all durations of mercury contact did not differ significantly from those at 7 days, so they are not shown in the table. Analysis of variance indicated significant differences ($P < 0.001$) among data.

The table shows that the 1-hour compressive strengths of the two brands were the highest when trituration was delayed 30 minutes. No significant reduction was observed for Dispersalloy until trituration was delayed more than 4 hours. For Tytin, a significant reduction in strength was observed in control samples and in other samples in which trituration was delayed longer than 30 minutes.

The controls of the two brands exhibited the highest 7-day compressive strength. For Dispersalloy, significant reduction was observed as soon as trituration was delayed 30 minutes, and no further significant reduction was observed up to 4 hours of delay. Further reduction was significant as delay increased to 1, 3, and 6 days. For Tytin, the 7-day compressive strength when trituration was delayed 30 minutes was less than that of the control but was not statistically significant. At any period of delay of 1 hour or longer, the specimen became progressively weaker until at 3 and 6 days it was impossible to amalgamate the mercury diffused tablets.

DISPERSALLOY

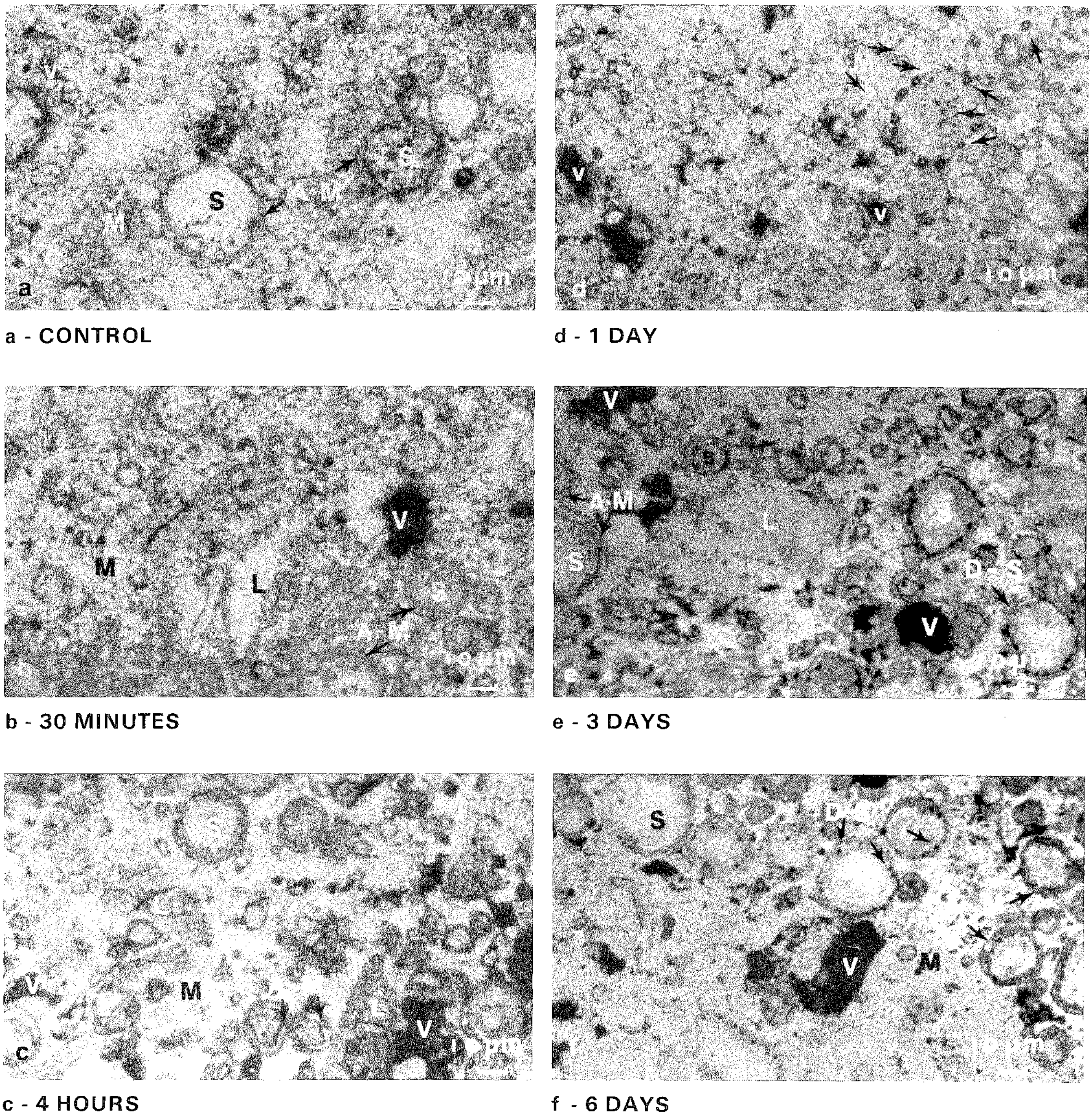
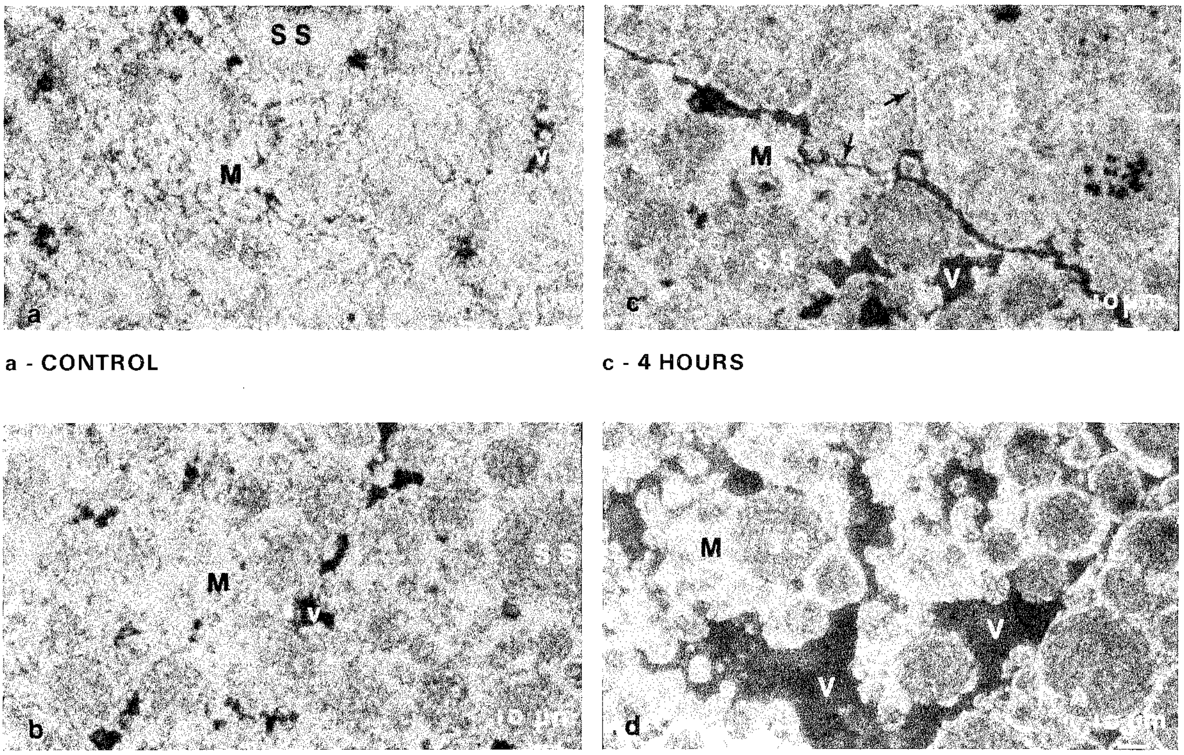


FIG 1. *Microstructure of Dispersalloy with increasing delay of trituration. 400X*

L:	*Lathe-cut particles*	M:	*Matrix phase*	D-S:	*Drop-shaped area*
S:	*Silver-copper spheres*	V:	*Voids*	A-M:	*Asgar-Mahler zone*

The microstructure of Dispersalloy specimens fractured at 7 days can be seen in Figure 1. As the delay of trituration increased, the quantity of matrix phases (M) increased, as well as the size and number of voids (V), and also the area of Asgar-Mahler (A-M) zone of reaction (Okabe & others, 1977), which surrounds the sphere

TYTIN



a - CONTROL

c - 4 HOURS

b - 30 MINUTES

d - 1 DAY

FIG 2. *Microstructure of Tytin with increasing delay of trituration. 400X*

SS: *Single phase sphere* V: *Voids*
M: *Matrix phase* P-A: *Set amalgam*
F: *Fracture*

of silver-copper (S) eutectic. The small drop-shaped area (D-S) spread over the entire surface and seemed to decrease in overall quantity as delay increased but showed preferential accumulation at the interface of the spheres and the Asgar-Mahler zone of reaction. Particles of set amalgam (P-A), the granular area similar to that seen in Figure 3b, that survived trituration were first seen in the specimens delayed for 1 day and continued to exist as the delay of trituration increased.

As trituration was increasingly delayed in Tytin (Fig 2), the quantity of matrix phases (M) and the number and size of voids (V) increased as they did in Dispersalloy. However, there was no Asgar-Mahler zone of reaction in any of the specimens. Particles of set amalgam (P-A) that survived trituration were present first in the specimens delayed for 4 hours and seen in increasing number and size as delay was increased. When these particles were seen, they were often accompanied by a fracture (F) along their border, or into the particles themselves (Fig 2c & 2d), indicating some propensity for propagation of fractures.

DISPERSALLOY TYTIN

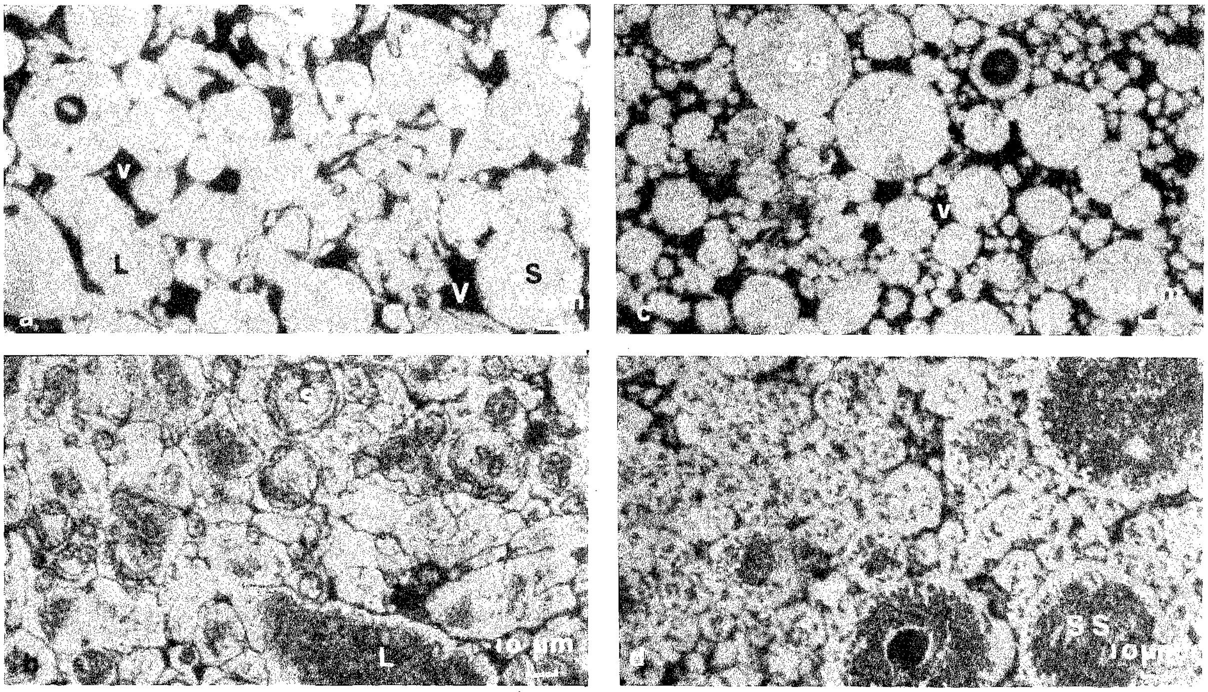


FIG 3: *Comparison of unreacted specimens in contact with mercury longer than 6 weeks. Dispersalloy (on left), a, b; Tytin (right), c, d.*

L: *Lathe-cut particles* V: *Voids*
S: *Silver-copper spheres* SS: *Single phase spheres*

Examination of the microstructure of the untriturated tablets at 6-weeks exposure to mercury (Fig 3) indicated that the particles (S,L & SS) reacted with mercury and grew bigger to occupy most of the void space. The triturated control specimen (Fig 1a & 2a), on the other hand, showed a matrix phase (M) continually surrounding the particles.

Discussion

Presumably amalgamation begins as soon as mercury contacts the alloy. The rate of reaction depends on several factors, most of which affect the degree of wetting of the alloy by mercury. Factors that affect wetting or contact angle are types and amounts of oxides formed, tin content, surface energy of the particles, size and shape of particles, and ratio of surface to volume of the particles (Baran & O'Brien, 1977). Of these variables, size of particle appears to be most significant, and dynamic analysis of the setting reaction of amalgam (Kusy, Greenberg & Taylor, 1980) disclosed that spherical alloys set faster than dispersed-phase alloys due to smaller average size of the particles (Fig 3), and these alloys gain a higher 1-hour compressive strength. Apparently, a 30-minute delay in trituration allows formation of more matrix than in control specimens, so that an increase in 1-hour compressive strength is observed with a 30-minute delay in trituration. However, longer trituration will also increase the amount of set amalgam which is deleterious to the strength. The compressive strengths obtained at 1 hour do not show statistical difference until 1 day for Dispersalloy and 4 hours for Tytin.

The reasons for the decrease of 7-day compressive strength with increasing delay of trituration may be found in the microstructure of the fractured specimens. Younis, Asgar & Powers (1975), and Asgar and Sutfin (1965) found that the formation of cracks induced by bending stresses goes through, in decreasing order of frequency, voids, γ_2 phase, grain boundary of γ_1 phase, around γ_1 phase, and finally γ_1 phase. Observations of the microstructure of specimens revealed that the frequency of propagation of cracks along the boundary of amalgamated particles formed before trituration seems to be greater than through voids. This finding suggests that repair of a fractured amalgam filling with new amalgam may actually create an area prone to fracture at the interface of old and new amalgam even though initially the bond may appear to be perfect. This conclusion may be confirmed by a previous finding (Reitz & Mateer, 1966) that crack propagation occurred at the junction of the repair after a period of thermocycling. The formation of set amalgam before trituration consumed a significant portion of the mercury to be used for later trituration and hindered the flow of the amalgam during condensation, resulting in more and larger voids. This phenomenon is confirmed by the fact that gradual decrease in 7-day compressive strength of Tytin is proportional to the particles of set amalgam and voids.

As with Dispersalloy, no obvious boundary of set amalgam and fracture lines was observed. Possibly the second solid state reaction, which occurs in Dispersalloy (Phillips, 1982), continues between the set amal gam and the triturated mass. The 7-day compressive strength decreases significantly at a delay of 30 minutes with no further significant decrease until a delay of 1 day. The reason for this pattern is not readily known. The microstructure (Fig 1) shows that voids and Asgar-Mahler reaction zones increase in number and size as delays extend. The main phase in the Asgar-Mahler reaction zone is known to be Cu_6Sn_5, which is a reinforcing agent of amalgam. Larger areas of such reaction zones will have more reinforcing powers, which may be the reason the reductions in compressive strength do not become significant until the delay of 1 day. Apparently, the formation of Cu_6Sn_5 reaches a plateau but the voids continue to increase further, which reduces the strength. Small drop-shaped areas, which are rich in mercury, have been documented for admixed amalgam and were also observed in the present study.

It has been suggested that the physical properties of amalgam alloys do not accurately predict marginal integrity (Laswell, Berry & Osborne, 1980), but it is generally believed that a decrease in compressive strength due to delayed trituration beyond critical durations determined for Dispersalloy and Tytin and the propagation of cracks around amalgamated particles is significant enough to warrant consideration of this variable when manipulating these amalgam alloys.

Conclusion

The compressive strength of Dispersalloy and Tytin at 7 days was significantly reduced when the tablets of alloy were exposed to mercury for various periods of time before trituration, 30 minutes or longer for Dispersalloy, and 1 hour or longer for Tytin. Even though the result may suggest there is an acceptable period of time during which trituration can be delayed, delay should be avoided.

Observation of the microstructure showed increasing quantities of imperfections in the set amalgam with increasing duration of contact with mercury. Accumulation of flaws is directly related to the rate of setting, which is faster for spherical alloys than for dispersed-phase alloys due to better wetting by mercury.

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Effect of Levels of Mercury in Amalgam Dispensers on Compressive Strength of Amalgam

The level of mercury in the reservoir of a dispenser for alloy and mercury may affect the compressive strength of the amalgam but mainly during the first 24 hours.

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C E CARROLL • J A von FRAUNHOFER

Summary

The compressive strength of amalgam made from Dispersalloy, Phasealloy, Sybraloy, and Tytin, dispensed with mercury at the full level and at the refill level in the reservoir of the dispenser, was found to vary—except for Sybraloy—at 1 hour and at 3 hours after mixing. At 24 hours, however, the differences were slight. The dispensers for Phasealloy and Sybraloy are accurate and consistent, but, even so, the amalgam of Phasealloy varied in compressive strength.

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Introduction

Certain brands of dispensers of mercury and alloy have been shown not to be consistent in the amount of mercury dispensed (Hamm, Currens & von Fraunhofer, 1981). In particular, the dispensers supplied for Dispersalloy and Tytin showed differences approaching 2% in the amount of mercury in amalgam mixes, depending upon whether the reservoir for mercury was at the full or refill level. Other dispensers, notably those supplied for Phasealloy and Sybraloy, showed minimal differences in the amount of mercury dispensed with variation in the level of mercury in the reservoir. This study was undertaken to determine whether such variations in the proportion of mercury would affect the strength of the amalgam.

Materials and Methods

The four high-copper amalgams and their respective dispensing systems that were used in this study are: Dispersalloy (Johnson & Johnson, East Windsor, NJ 08520, USA), Phasealloy (Phasealloy Inc, El Cajon, CA 92021), USA), Tytin (S S White/Pennwalt, Philadelphia, PA 19102, USA), and Sybraloy (Sybron/Kerr, Romulus, MI 48174, USA). All alloys were triturated at the recommended ratio of mercury to alloy with a mechanical mixer (Caulk Vari-Mix II-M, L D Caulk Co, Milford, DE 19963, USA) at the setting recommended by the manufacturer (Table 1).

Specimens of amalgam were prepared and tested in accordance with Specification No 1 for alloy for dental amalgam (American Dental Association, 1977). All tests for compressive strength were performed with a Unite-O-Matic Universal testing machine, the testing periods being 1, 3, and 24 hours after preparation of the specimens. A minimum of six specimens was prepared for each alloy for each of the three test periods at both the full and refill levels of the reservoirs for mercury in the dispensers.

Results

The mean compressive strengths, their standard deviations, and the levels of significance in Student's t tests between the full and refill levels of mercury are summarized in Table 2.

Table 1. Conditions of Preparation of Amalgam

Amalgam	Recommended Proportion of Mercury	Measured Proportion of Mercury Level		Setting on Amalgamator	Pellets per Mix	Trituration Time	Mulling Time
		Full	Refill				
	%	%	%		Number	s	s
Phasealloy	49.0	49.3	49.2	M2	2	10	2
Dispersalloy	50.0	50.2	49.1	M2	2	10	2
Tytin	45.0	46.5	44.7	M2	2	4	0
Sybraloy	43.0 - 51.0	46.0	45.9	M3	3	17	2

Table 2. Compressive Strength of Amalgam at 1, 3, and 24 Hours for Full and Refill Levels of Mercury in the Dispenser

Alloy	Compressive Strength kg · cm⁻² 1 Hour				3 Hours				24 Hours			
	Full		Refill		Full		Refill		Full		Refill	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Phasealloy	628.5	37.1	536.0	25.6	680.4	74.2	ns 735.4	61.9	2837.4	158.1	3204.7	238.6
Dispersalloy	1157.4	53.7	946.9	97.3	1922.1	113.5	ns 1803.0	165.2	3663.8	320.9	3357.4	170.0
Tytin	1035.0	78.0	ns 990.0	76.0	2163.0	92.0	2003.0	79.0	3408.0	375.0	2979.0	253.0
Sybraloy	1389.0	87.8	ns 1422.2	125.8	2245.7	197.4	ns 2155.8	241.3	3638.4	323.0	ns 3592.4	218.9

ns - not statistically significant

Sybraloy showed no statistically significant differences in the compressive strength of the amalgam at full and refill levels of mercury at any test period ($P > 0.05$).

Tytin showed no statistically significant difference in the compressive strength of amalgam at full and refill levels of mercury at 1 hour ($P > 0.05$), but statistically significant differences were found at 3 hours ($P < 0.01$) and 24 hours ($P < 0.05$), the amalgams from the full level of mercury being stronger.

Dispersalloy showed statistically significant differences in the compressive strength of the amalgam at full and refill levels of mercury at 1 hour ($P < 0.001$) and 24 hours ($P < 0.05$), the amalgams from the full level being stronger. No statistically significant difference was found at 3 hours ($P > 0.05$).

Phasealloy showed statistically significant differences in the compressive strength of amalgam at full and refill levels of mercury at 1 hour ($P < 0.001$), the full level being stronger, and at 24 hours ($P < 0.05$), the refill level being stronger. At 3 hours there was no statistically significant difference ($P > 0.05$).

Comparison of the four dental amalgams at the three test periods yielded some interesting results:

At 1 hour Sybraloy was the strongest, Phasealloy was considerably weaker than the other three alloys, and there was no difference between Dispersalloy and Tytin.

At 3 hours Phasealloy was much weaker than the other three alloys at both levels of mercury. There was no difference between Tytin and Sybraloy at either level of mercury. Both Tytin and Sybraloy were stronger than Dispersalloy at both levels of mercury ($P < 0.01$).

At 24 hours there was a pronounced increase in the strength of Phasealloy. At this stage there was no difference in strength between Phasealloy and Dispersalloy or between Phasealloy and Tytin at the refill level of mercury, though Phasealloy was weaker than Sybraloy ($P < 0.01$). Tytin was weaker than Dispersalloy and Sybraloy at the refill level of mercury and Dispersalloy was weaker than Sybraloy ($P < 0.05$). In contrast, at the full level of mercury there were no differences between Tytin, Dispersalloy, and Sybraloy, and all three were stronger than Phasealloy ($P < 0.01$ or 0.001).

Discussion

The data in Table 1 indicate that the dispensers for Sybraloy and Phasealloy deliver virtually identical amounts of mercury at the full and refill levels in the mercury reservoir as previously reported (Hamm & others, 1981). The dispensers for Dispersalloy and Tytin, however, showed a difference of 1.1 - 1.8% in the amount of mercury delivered at the full and refill levels.

Sybraloy showed no difference in the specimens prepared at the full and refill levels at all three test periods. Tytin showed a difference at 3 hours and 24 hours but no difference at 1 hour. Dispersalloy showed a difference at 1 hour and 24 hours but no difference at 3 hours. These findings suggest that level of mercury in the reservoir does affect the strength of the restoration, though there is no clear trend. Phasealloy, however, has a very accurate and reproducible dispenser but nevertheless showed differences in the strength of the amalgam at 1 and 24 hours, with no difference at 3 hours at the two levels in the reservoir.

These findings cannot be simply explained. The coefficients of variation for all sets of specimens under all conditions were comparable, lying within the range 4 - 11% and indicating similar precision for all measurements. The variations found with Tytin and Dispersalloy may be due to the dispensers but the variations observed with Phasealloy may be due to the alloy itself, this material showing the slowest rate of increase in strength of all the alloys tested.

Comparison of the four amalgams at the different test periods clearly showed that Phasealloy was the weakest and Sybraloy the strongest material at up to 3 hours at both levels of mercury. At 24 hours the compressive strengths of the four amalgams were more comparable though differences still existed. The differences in strength between Phasealloy and the other amalgams indicate a variability within Phasealloy itself.

The compressive strengths reported in

this study are lower than those obtained in a previous study (Leinfelder & others, 1980) at 1 hour, but the values at 24 hours here are approximately in between the values at 1 hour and 7 days reported by these workers. These differences in strength are difficult to account for but presumably reflect differences in preparation of specimens and techniques of testing. Nevertheless, the strengths reported in this study are a good comparative guide to the materials tested.

Conclusions

Variation in the level of mercury in the reservoirs of dispensers of mercury and alloy can affect the strength of the final amalgam, though these differences are largely eliminated after 24 hours. The variability of the compressive strength of Phasealloy was surprising in view of the accuracy and reproducibility of its dispenser, and the differences found with variation in the level of mercury must reflect an inherent characteristic of the alloy itself.

Dispersalloy and Tytin showed greater strengths at the high ratio of mercury to alloy, that is, when the reservoir was full, thus indicating that a ratio of mercury to alloy slightly above the recommended ratio gives a more coherent mass and therefore greater strength to the amalgam.

(Accepted 19 July 1982)

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OPERATIVE DENTISTRY, 1982, 7, 134-141.

Glass-Ionomer Restorative Cements: Clinical Implications of the Setting Reaction

Restorations of glass-ionomer cements need to be covered with a waterproof varnish to protect them from hydration and dehydration for the first hour.

G J MOUNT • O F MAKINSON

Summary

The glass-ionomer cements undergo a prolonged setting reaction. At four minutes the matrix can be removed without disturbing the restoration but it is approximately 60 minutes before the material is sufficiently resistant to hydration and dehydration to allow its exposure to the oral environment. During this time the restoration must be protected with a coat of waterproof varnish. An additional 24 hours should pass before it is contoured and polished. The clinical significance of these three stages in setting must be clearly understood.

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INTRODUCTION

Glass-ionomer restorative cements undergo a prolonged setting reaction when compared to other dental restorative cements (Smith, 1980). The reaction takes place in several overlapping stages. Metal ions are extracted from the particles of glass and form insoluble metal salts that lead to gelation. Subsequently hardening and hydration proceed. In the early stages the presence of crosslinks mainly of calcium ions results in a set material of low strength and stiffness and high plastic flow. At this time the material can be adversely affected by moisture because of the high sensitivity of the calcium polyacrylate to water. The aluminum ions appear to be bound to specific carboxyl groups so that over a period of time there is considerable improvement in strength and stiffness as well as in resistance to plastic deformation. Approximately 30 minutes are required for this initial process. The objective of this paper is to provide evidence of the need to protect the young cement from moisture for at least an hour to ensure good resistance to damage in the oral cavity. Similarly, the prevention of early dehydration will also be shown to be necessary for a satisfactory result.

The clinical implications of this prolonged reaction must be considered if optimum results are to be obtained from the restoration. The properties that must be safeguarded in particular include translucency, or at least an ability to reflect light, hardness of the surface, resistance to abrasion, resistance to stain, and the ability to withstand subsequent and repeated dehydration in the mouth breather.

Several published reports (Smales & Joyce, 1978; Smales, 1981; Flynn, 1979) have been critical of glass-ionomer cements in respect of several of these properties and acceptance of the glass ionomers as a restorative material by the profession has lagged because of the doubts expressed. Apart from some manufacturers' directions only one article has detailed the full clinical procedure for obtaining optimum results (Mount, 1981).

A series of laboratory experiments was designed to reproduce intraoral conditions for glass-ionomer restorations and to demonstrate the loss of desirable properties if the material was not retained in a controlled environment for 40 to 60 minutes after the commencement of mixing. The required stability of environment can be maintained either by leaving the matrix in place or applying a waterproof varnish immediately upon removal of the matrix.

MATERIALS AND METHODS

Four glass-ionomer cements are currently available on the market: Ketac (ESPE Fabrik Pharmazeutischer Praparate, GmbH, Seefeld/Oberbay, Federal Republic of Germany), Fuji Ionomer Type II (G C Dental Industrial Corporation, Tokyo, Japan), Chemfil (A D International Limited, Amalgamated Dental Company, London, W1, UK), Shofu Hi-Bond (Shofu Manufacturing Company, Kyoto, Japan).

All materials were subjected to the same tests. No attempt was made to define such properties as surface hardness in terms of Brinell numbers, but relative values for each material were sought as detailed below.

Specimens of each material 5.0 mm in diameter and 1.5 mm thick were fabricated in laminex templates, according to manufacturers' directions (Fig 1). Five specimens could be produced in each template from a single mix. They were allowed to set in standard conditions of 100% humidity at 27 °C under polyester strips.

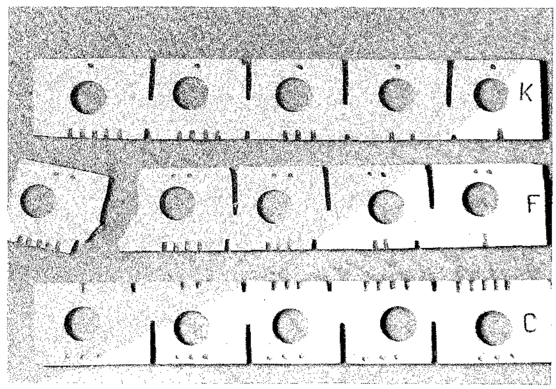

FIG 1. *Laminex templates used to produce standard specimens. One section has been broken off the center template for demonstration purposes.*

Surface Hardness

A Leitz Mini-load Tester with a 25 g load and a DPN point was used throughout. At four minutes after the commencement of mix specimens were coated on both sides with the varnish supplied with Fuji Type II. Beginning at 10 minutes they were tested at intervals of five minutes until there were three successive identical readings.

Further specimens were initially protected by mylar strips then exposed to water at 10 minutes, 20 minutes, and 40 minutes after commencement of mix, and tested after 48 hours. Other specimens were exposed to air 10 minutes after commencement of mix for a period of 10 minutes, then immersed in water for 48 hours prior to testing.

Translucency

Tests were carried out using a photometer (Photovolt, New York, NY, 10010, USA) set on number 1 range and the gauge regulated to read 100 for the most translucent material. Specimens were immersed in water at 10, 20, and 40 minutes after the commencement of mix and then tested at 48 hours.

Another series of specimens was exposed to air at 10 minutes after commencement of mix for 10 minutes then immersed in water for 48 hours prior to testing.

Control specimens were retained under mylar strips for 48 hours in an atmosphere of 100% humidity at 27 °C. All specimens were tested both wet and dry.

Staining

Red ink was used as the dye. Specimens were prepared as for each of the previous experiments and at 48 hours were gently dried before being immersed in the dye for 15 seconds. They were washed under running water for a further 15 seconds and the intensity of the uptake of the dye as well as the depth of penetration was noted.

RESULTS

The results of the tests for hardness are shown in the histogram (Fig 2) and the graph (Fig 3); the results of the tests for

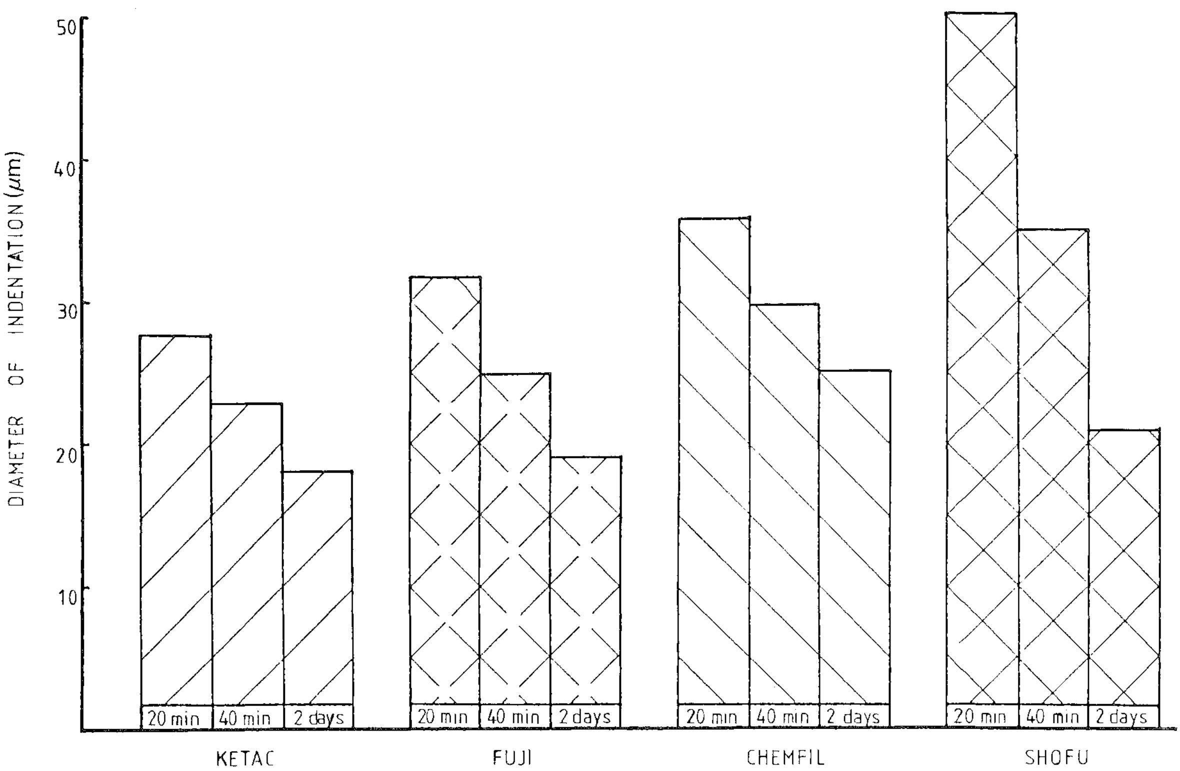

FIG 2. *Indentation tests 48 hours after contamination of the four materials at 20 minutes and 40 minutes after the commencement of mix. Tests on the 10-minute specimens were not readable.*

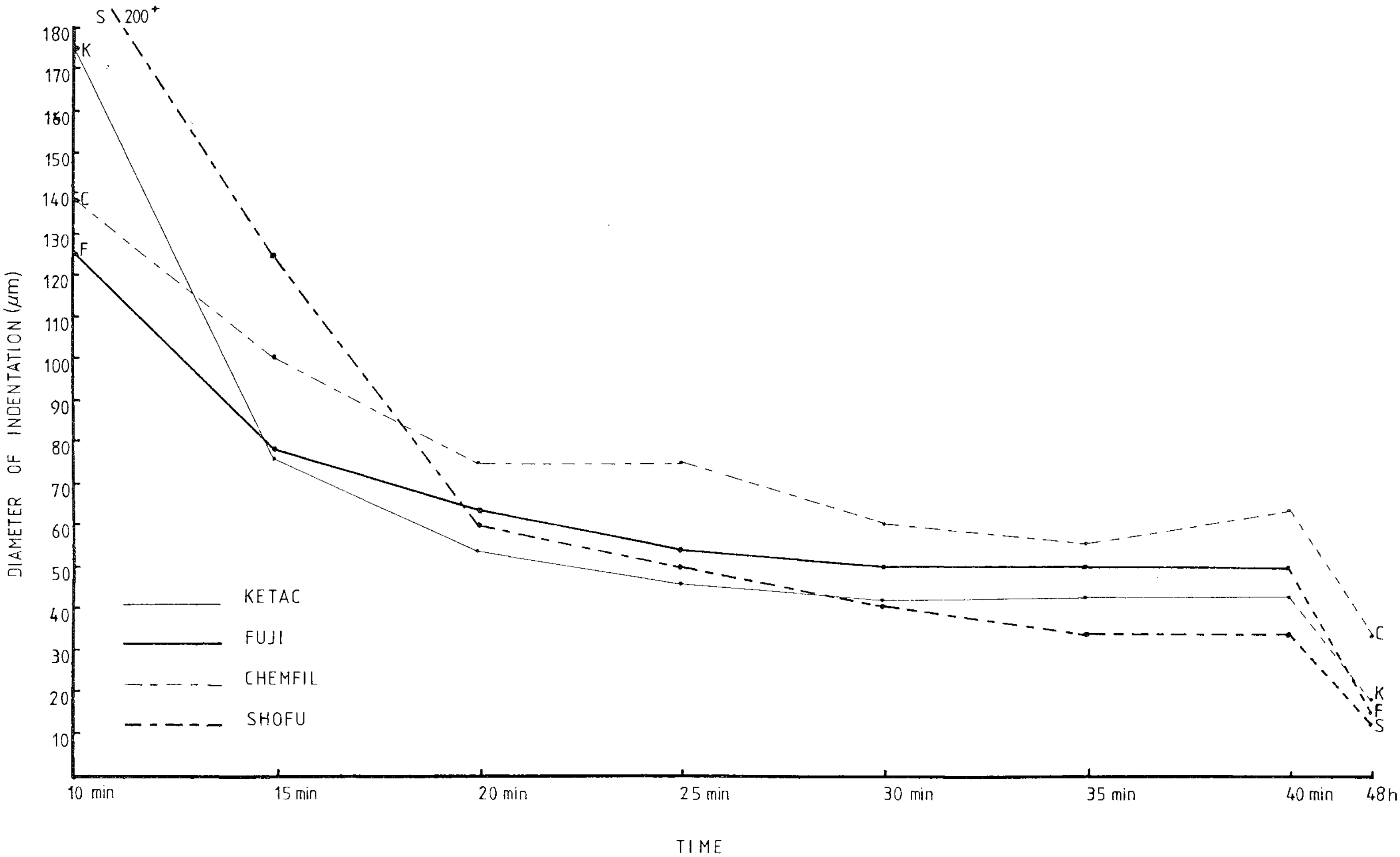

FIG 3. *Indentation tests reveal surface hardness stabilizing at approximately 30 minutes for all four glass-ionomer cements. However, there is still a slight increase over the subsequent 48 hours in surface hardness.*

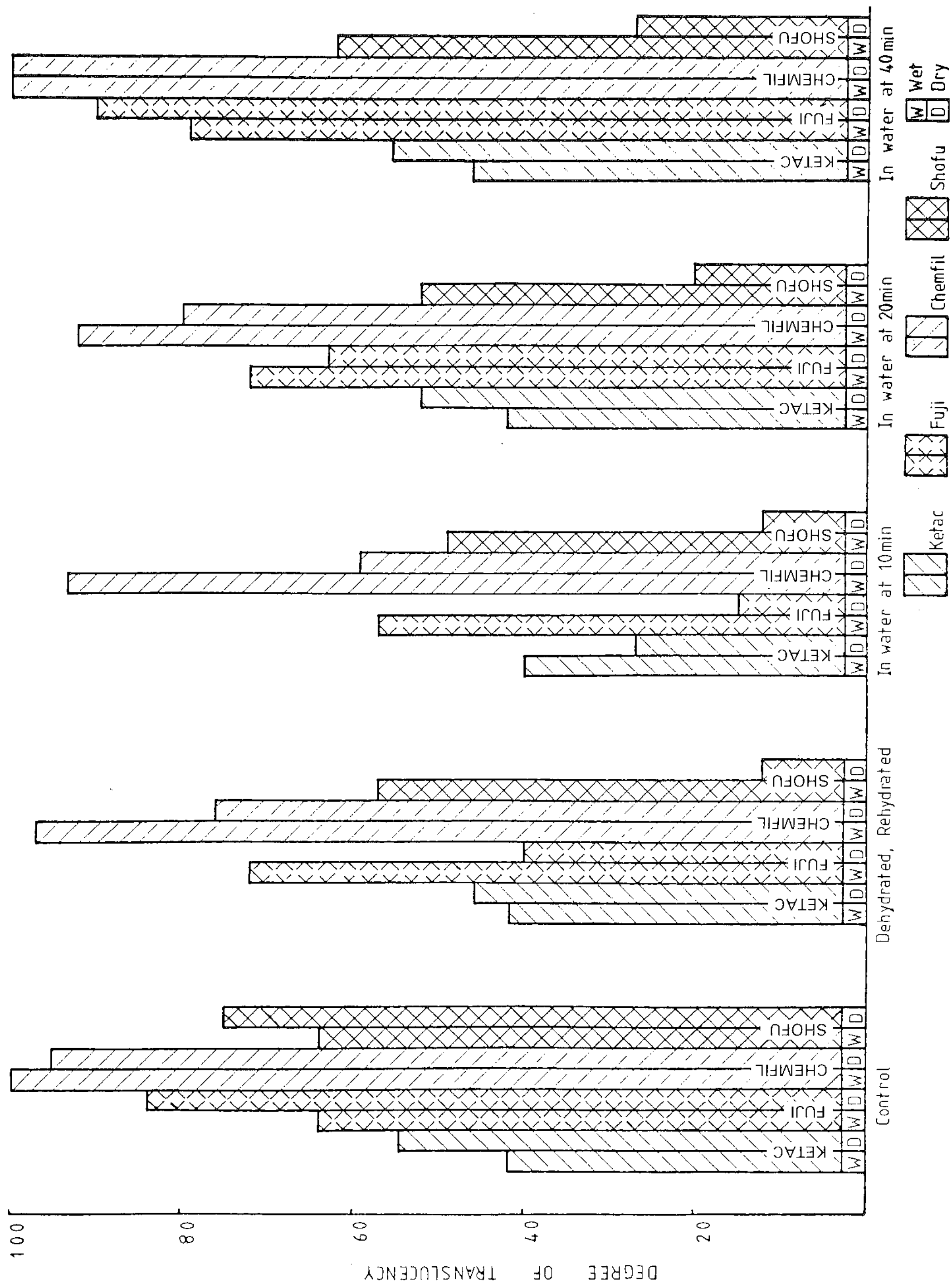

FIG 4. *Combined results of translucency tests on all four materials both wet and dry.*

translucency are shown in the histogram (Fig 4); and the results of the tests for staining are shown in Figs 5-8.

Ketac

Of the materials tested Ketac was the fastest to set as the surface hardness increased with reasonable speed but its lack of resistance to early hydration was similar to the others. Translucency was low but, probably because of its rapid set, this translucency did not vary greatly even after early hydration. Ketac dehydrated rapidly if left exposed to air and developed a distinct pattern of crazing within five minutes of removal of the matrix if the material was not protected immediately (Figs 5 & 6). These cracks will penetrate almost the entire thickness of the test specimens in 20 to 30 minutes (Fig 7).

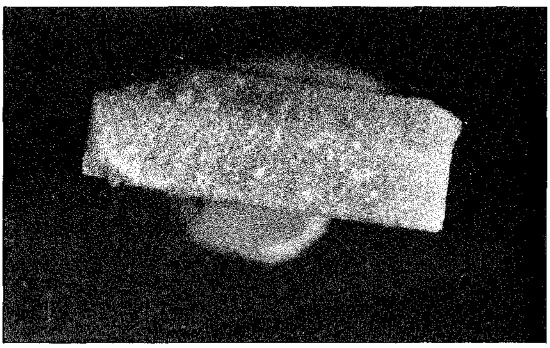

FIG 5. *Cross section of a specimen of Ketac glass-ionomer cement immersed in water at 10 minutes showing depth of penetration of red dye.*

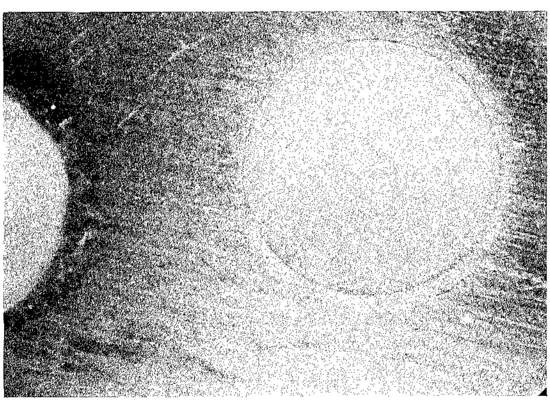

FIG 6. *Specimen of Ketac glass-ionomer cement. Top half protected with Fuji varnish and the bottom half exposed to air for 10 minutes, then stained with dye to reveal surface damage and craze pattern.*

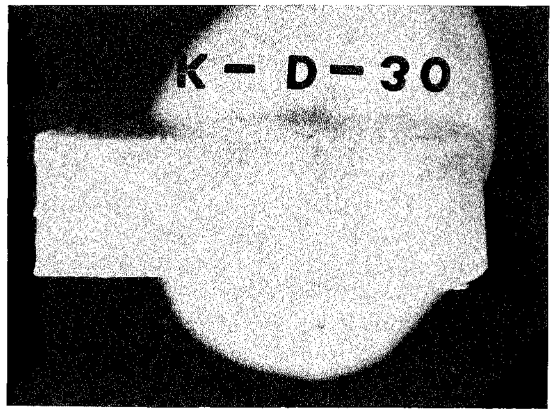

FIG 7. *Standard specimen of Ketac glass-ionomer cement dehydrated for 30 minutes. The crack penetrates ¾ of the way through the specimen. The reverse side was protected with varnish.*

Clinically the crazing will stain and the shrinkage, which has occurred, will stress the ionic bonding with tooth structure, possibly leading to leakage or loss of restoration. Providing it had not been allowed to dehydrate to the extent of developing crazing the resistance of Ketac to stain was good.

Fuji Type II

Fuji Type II material was a little slower in achieving its initial set but at one hour the surface resisted indentation well. In translucency it ranked slightly below Chemfil but the damage resulting from early hydration was quite severe. It did not readily craze but surface damage from early dehydration as well as hydration led to rapid penetration of the dye as well as to the early development of a white crystalline surface.

Chemfil

Chemfil was the slowest of the four materials to set and should be handled with care in its early stages. It was difficult to read indentation tests with this material because the hardness of its surface varied from one area to another throughout the setting cycle. The ultimate hardness of its surface was less than that of the other materials. When mixed, its high viscosity made it most difficult to handle clinically. However, Chemfil was the most translucent of the four cements and was reasonably resistant to damage from early hydration.

It should be noted, however, that it appeared to be less tolerant to variations in powder:liquid ratio than were the other materials. Reduction in content of powder led rapidly to a reduction in surface hardness and therefore probably in other properties as well. Uptake of dye was severe following early damage but early protection after the matrix was removed increased the resistance to penetration of the dye.

Shofu

Shofu was the most easily damaged by both hydration and dehydration. It was the softest of the four materials at 10 minutes but the hardest at 48 hours. Hardness of the surface developed only slowly and consequently it was most susceptible to early damage. Translucency was relatively low, and rapid and deep penetration of dye suggested that Shofu requires extra care in handling (Fig 8).

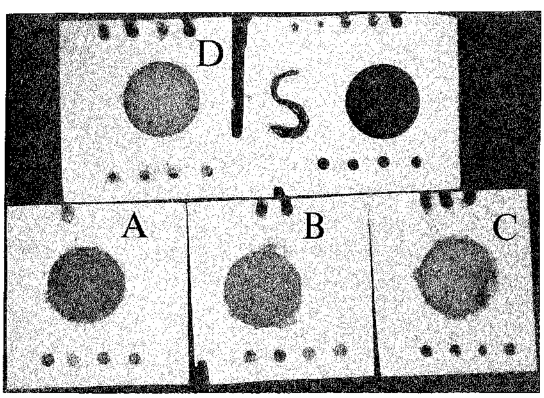

FIG 8. *Standard template with specimens of Shofu glass-ionomer cement showing variations in dye penetration.* A: *immersed in water at 10 minutes.* B: *immersed in water at 20 minutes.* C: *immersed in water at 40 minutes.* D: *control.*

DISCUSSION

Clinical success with glass-ionomer cements has been recorded sufficiently to suggest that the material has a valuable place in restorative dentistry (Mount & Makinson, 1978; Lawrence, 1979; Phillips, 1980; Garcia, Caffesse & Charbeneau, 1981) and the setting chemistry has been well documented (Wilson, 1978; Wilson & Prosser, 1980; McLean & Wilson, 1977; Belton & Stupp, 1979). Translation of this evidence into clinical action and experimental protocol has not always occurred. Lack of translucency, abrasion resistance, tissue tolerance, and the ability of the materials to gather plaque have all been criticized. However, it would seem that the full potential of the glass-ionomer cements has rarely been achieved in these experiments. Each of the tested materials if allowed to remain in a controlled environment undisturbed for 60 minutes is hard, translucent, and stable. The material can then be immersed in water or allowed to stand in air indefinitely with no apparent change. However, hydration or dehydration in the oral cavity during this initial period will reduce the physical properties to a marked degree.

Similarly there is sufficient evidence to suggest that a further 24 hours at least is desirable before attempting to obtain a final polished surface.

Subsequent polishing may remove the damaged surface but only at the expense of contour. The damaged material when hydrated in the mouth may look sound and this can be misleading. Dehydration for 30 seconds will reveal the affected relatively soft, white matte surface.

These tests show that material that is damaged by hydration or dehydration within 60 minutes of mixing is more susceptible to staining, abrasion, and perhaps plaque formation. In addition there is loss of translucency. This is more obvious when the restoration is in anterior teeth and particularly if there is intermittent dehydration such as occurs with a mouth breather.

The requirement is for a varnish or surface protector that will successfully control the environment of a newly placed restoration for at least 60 minutes after placement. For the class 5 lesion, abrasion or caries, a soft metal matrix can be left in place and removed by the patient after the required time. Other restorations, class 3 cavities for example, require removal of the matrix before the patient is dismissed. A waterproof varnish appears to be the simplest and most effective method, and current experiments suggest that the varnishes supplied with Fuji Type II, Chemfil, and Ketac are acceptable. It is suggested that the varnish be dried with a gentle stream of warm air for 15 seconds before being released to the oral environment. Copal varnish as used with amalgam is inadequate, and other materials such as cocoa butter and silicone grease are rapidly removed by the action of the tongue and lips.

CONCLUSION

Glass-ionomer cements set in three stages. At four minutes from the beginning of mix there is an initial set sufficient to allow safe removal of the matrix. After a further 40 to 60 minutes they will have progressed to a stage of setting sufficient to avoid damage from hydration or dehydration. Ionic exchange will continue thereafter for at least 24 hours and probably longer.

Therefore it is necessary to maintain control over the environment of the newly placed restoration for at least 60 minutes to achieve optimum results for esthetics and resistance to abrasion, staining, and plaque formation. The environment can be controlled by the immediate application of a waterproof varnish or, in the case of a class 5 restoration, by leaving the matrix in place for the minimum time required. In addition final contouring and polishing should not be attempted for at least one day to allow further maturation.

Acknowledgments

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 OPERATIVE DENTISTRY, 1982, 7, 142-144.

Change in Frequency of Oscillation of Amalgamators over Time

After five years the frequencies of oscillation of amalgamators increased substantially.

LINDA M DuBOIS • LARRY D HAISCH
VERNON W RINNE

Summary

The frequencies of oscillation of 40 amalgamators (Caulk Vari-Mix II) that had been in use for five years were found to have increased on the average from 3960 rev · min^{-1} to 5476 rev · min^{-1}, or about 38%, at the M2 setting with a capsule and contents weighing 4.6 g. Similar increases were found at other settings and for a capsule and contents weighing 3.7 g. The variation among amalgamators was substantial.

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Introduction

Variation in the trituration of amalgam has been found to alter both its working and physical properties. Depending upon the degree of variation, the alteration of these properties may be clinically significant. Increased time of trituration results in increased compressive strength, and both overtrituration and undertrituration increase the creep of amalgam (Osborne & others, 1977). In addition to time of trituration, the type of amalgamator, its frequency of oscillation, and the pressure of condensation all cause changes in creep, differences in condensing pressure being the most consistent cause of changes (Rehberg, Gramberg & Bayer, 1979). Although manufacturers of amalgam alloy recommend specific settings for different types of amalgamators, they also suggest that allowances be made for individual amalgamators and variations in line voltage (Johnson & Johnson, 1980; L D Caulk, 1981). Variance in the effectiveness of different amalgamators has been shown (Eames, 1969), but the performance over time has not been addressed. The purpose of this study was to evaluate variances in the frequency of oscillation of amalgamators that had been in use for five years.

Materials and Methods

The frequency of oscillation was measured on 40 amalgamators that had been in use for five years in the clinic of the University of Nebraska College of Dentistry. This clinic operates 20 hours a week for 41 weeks a year. The amalgamators were the Caulk Vari-Mix II (L D Caulk Co, Milford, DE 19963, USA). The Caulk Company recommends that the Vari-Mix II be recalibrated as necessary to maintain the proper frequency of oscillation. The amalgamators in this study had never been recalibrated. The Vari-Mix II is designed to operate at 3600 ± 200 revolutions per minute (rev · min^{-1}) on the M2 setting with a capsule and contents weighing 4.6 g and an alternating current of 115 V.

In this study, amalgamators operated on the normal line current of the clinic that was measured as 123 V by a Beckman Tech No 330 Digital Multimeter (Beckman Instruments Inc, Fullerton, CA 92634, USA). This additional voltage accounts for an increase of approximately 320 rev · min^{-1} above the recommended 3600. The frequency, after adjustment for the voltage, should therefore be 3920 ± 200 rev · min^{-1}.

The Caulk Company supplied the testing capsule that contained metal particles, which simulate amalgam alloy for use in this study. The combined weight of the capsule and metal particles was 4.6 g. This mass is relatively heavy when compared with the combined weight of the capsule, pestle, and alloy that is generally used. For this reason, data were also gathered on a capsule of 3.7 g.

Twelve measurements were made for each amalgamator. The frequency of oscillation was measured for capsules of each weight at six different settings of the amalgamator, three at low speeds and three at medium speeds. Accurate measurement at the high settings was prevented by mechanical interference of lateral movement of the arm in some units.

The measuring instrument was a Precision Stroboscope (Sargent-Welch Scientific Co, Skokie, IL 60076, USA). Means and standard deviations were calculated for the measurements.

Results

The means and standard deviations of the frequencies of oscillation and the number of amalgamators are shown in the table.

Frequency of Oscillation of Amalgamators Measured as Rev ·Min^{-1}

Setting	Capsule Alone Weight = 3.7 g N = 40		Capsule Containing Particles Weight = 4.6 g N = 39	
	Mean	SD	Mean	SD
L1	4452	314	4408	311
L2	4635	311	4571	310
L3	4836	304	4747	313
M1	5252	334	5105	342
M2	5476	334	5312	311
M3	5697	339	5514	328

The number of amalgamators decreased from 40 to 39 because the arm on one unit failed when the capsule weighing 4.6 g was triturated.

The mean frequency of oscillation at 5312 rev · min^{-1} at the M2 setting was greater than the expected frequency of 3920 rev · min^{-1}. Thus the frequency of oscillation increased with use over time. The standard deviations further indicate high variation in the performance of these instruments regardless of the mass of the capsule and contents or the presence of contained particles. The frequency of oscillation for this type of unit cannot be predicted accurately after five years of clinical operation.

Discussion

The design of this project might be criticized because it is restricted to one model of amalgamator, but it would be difficult to find another set of 40 amalgamators with the same history of use as exists in this study. Also, in this type of research, the publication of data on one model of equipment is significant in and of itself. Future documentation of other instruments from additional sources would complete the comparative model.

In support of the Caulk Company, the conclusion of this article confirms their literature on this product (L D Caulk Co, 1981), which states that the clinician's judgment is the best guide to the time of trituration. A properly mixed alloy is a smooth, plastic, homogeneous mass of material that may be readily inserted and condensed into a preparation. If the clinician feels uncomfortable with this method of controlling trituration, the amalgamator should be recalibrated as necessary.

The significance of the results of this study extends beyond the fact that any given amalgamator may perform optimally on a setting different from the manufacturer's recommendation. The variance in performance of instruments means that different units in the same clinic or office may operate most effectively at different settings.

Conclusion

Evaluation of amalgamators that had been used for five years indicates:

- The clinician's judgment is the best measure of the settings for trituration.
- If the manufacturer's recommendations are to be followed, amalgamators should be recalibrated as needed.
- Regardless of similar usage and environment, optimum settings for trituration may vary among amalgamators.

(Accepted 28 July 1982)

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POINT OF VIEW

Contributions welcomed

A Friendly Word of Advice to Authors (from an old-timer)

GERALD D STIBBS

When an editor receives a manuscript to consider for publication in his journal, he realizes that the author—be he neophyte or old hand—is as proud of his creation as is a new parent of a first child. At the same time, he must subject it to a number of criteria.

For example:

1. Is the topic new or timely?
2. Is the paper likely to appeal to the readers?
   (*Operative Dentistry* presently gives preference to papers that have a direct clinical application. As a second choice, it considers research reports. It periodically republishes papers by past giants in operative dentistry, so the present generation may profit from the thinking of those who have contributed so greatly to our phase of dentistry.)
3. Another consideration is that there should be a balance in the yearly coverage of the various facets of operative dentistry.
4. Does the paper tend to elevate the quality of restorative service?
5. Is the paper in good "written" language rather than being in conversational form?
6. Is the background of the topic documented properly, without being a ponderous recitation of the past literature? Is credit given to the principal past authors rather than to the one who has recently rehashed the subject?
7. Does the paper comply with the requisites of good English, sentence construction, and dental journalism? Does it use terminology that is generally acceptable, rather than being trendy or regional?

433 Medical Dental Building, Seattle, WA 98101

GERALD D STIBBS, BS, DMD, is an associate editor of *Operative Dentistry*

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Finally, be assured that countless numbers of you have material that, if published, could do much to elevate the quality of the service we are trying to deliver. Happy writing!

OPERATIVE DENTISTRY, 1982, 7, 146-149.

WIT AND WISDOM

The Economics of Brushing Teeth

ALAN S BLINDER

The ever-growing literature on human capital has long recognized that the scope of the theory extends well beyond the traditional analysis of schooling and on-the-job training. Migration, maintenance of health, crime and punishment, even marriage and suicide, are all decisions which can usefully be considered from the human capital point of view. Yet economists have ignored the analysis of an important class of activities which can and should be brought within the purview of the theory. A prime example of this class is brushing teeth.[1]

The conventional analysis of toothbrushing has centered on two basic models. The "bad taste in one's mouth" model is based on the notion that each person has a "taste for brushing," and the fact that brushing frequencies differ is "explained" by differences in tastes. Since any pattern of human behavior can be rationalized by such implicit theorizing, this model is devoid of empirically testable predictions, and hence uninteresting.

The "mother told me so" theory is based on differences in cultural upbringing. Here it is argued, for example, that thrice-a-day brushers brush three times daily because their mothers forced them to do so as children. Of course, this is hardly a complete explanation. Like most psychological theories, it leaves open the question of why mothers should want their children to brush after every meal. But it does at least have one testable implication: that individuals from higher social classes will brush more frequently.

In these pages I describe a new model which is firmly grounded in economic theory and which generates a large number of empirically testable hypotheses. I then show that the predictions of the model are supported by the data.

The basic assumption is common to all human capital theory: that individuals seek to maximize their incomes. It follows immediately that each individual does whatever amount of toothbrushing will maximize his income. The "mother told me so" model can be considered as a special case where the offspring only does as he or she is told, but the mother's decisions are governed by income maximization for the child. Thus, offspring will behave **as if** they maximized income.

An example will illustrate the usefulness of the model. Consider the toothbrushing decisions of chefs and waiters working in the same establishments. Since chefs generally come from higher socioeconomic strata, the "mother told me so" model predicts that they will brush more frequently than waiters. In fact, it has been shown that the reverse is true (Barnard & Smith, 1941). Of course, the human capital model predicts precisely this behavior. On the benefits side, chefs are rarely seen by

[1]The analysis to follow can also be applied to such important problems as combing hair, washing hands, and cutting fingernails, as I hope to show in a series of future papers.

ALAN S BLINDER, Princeton University

customers and work on straight salary. Waiters, by contrast, are in constant touch with the public and rely on tips for most of their income. Bad breath and/or yellow teeth could have deleterious effects on their earnings. On the cost side, since wages for chefs are higher, the opportunity cost of brushing is correspondingly higher. Thus, the theory predicts unambiguously that chefs will brush less. It is instructive to compare this rather tight theoretical deduction with Barnard & Smith's glib attribution of the observed differences to the different hygiene standards in the birthplaces of the individuals. (The chefs were born mostly in France, while the waiters were largely Brooklynites.)

I. Review of the Literature

A substantial literature on dental hygienics exists. It is ironic that economists are almost completely unaware of these studies, despite the fact that most economists brush their teeth.

The best empirical study was conducted by a team of researchers at the University of Chicago Medical Center in 1967. They compared toothbrushing habits of a scientifically selected sample of 27 sets of twins who had appeared in Wrigley's chewing gum commercials with a random sample of 54 longshoremen. The twins brushed their teeth an average of 3.17 times per day, while the longshoremen brushed only 0.76 times daily. The difference was significant at the 1 percent level. As noneconomists, the doctors advanced two possible explanations for this finding: either twins had a higher "taste for brushing" than nontwins, or the Wrigley Company deliberately set out to hire people with clean teeth. Further study, they concluded, would be needed to discriminate between these two hypotheses (Baker, Dooley, & Spock, 1968). The human capital viewpoint makes the true explanation clear enough. Earnings of models depend strongly on the whiteness of their teeth. On the other hand, no direct connection has ever been established between the income of longshoremen and the quality of their breath.

Another recent contribution was a survey of professors in a leading Eastern university. It was found that assistant professors brushed 2.14 times daily on average, while associate professors brushed only 1.89 times and full professors only 1.47 times daily. The author, a sociologist, mistakenly attributed this finding to the fact that the higher-ranking professors were older and that hygiene standards in America had advanced steadily over time (Persons, 1971). To a human capital theorist, of course, this pattern is exactly what would be expected from the higher wages received in the higher professorial ranks, and from the fact that younger professors, looking for promotions, cannot afford to have bad breath.

II. A Theoretical Model of Toothbrushing

Let w be the wage rate of an individual; let J be an index of his job; and let B be the time spent brushing his teeth. With no loss of generality, I can reorder the jobs so that jobs with higher J are the jobs where clean teeth are more important. The assumed wage function is therefore

$$w = w(J, B), \quad w_B \geq 0, \quad w_{BJ} = w_{JB} \geq 0. \quad (1)$$

Since jobs have been reordered, there is no a priori presumption about the sign of w_J. It is also assumed that $w(\cdot)$ is continuous, twice differentiable, and semistrictly quasi-concave in the nonnegative orthant.

Each individual is assumed to maximize his income:

$$Y = w(J, B)(T - B) + P, \quad (2)$$

where T is the fixed amount of time per period available for working or brushing[2] and P is the (exogenously determined) amount of unearned income.[3] That is, each

[2]It is assumed, for simplicity, that these are the only possible uses of time. The model can easily be extended to accommodate an arbitrary number of uses of time, as is not shown in an appendix.

[3]A more general model would allow for the possibility that cleaner teeth can lead to a larger inheritance, that is, $P(B)$ with $P'(B) > 0$. For evidence of this, see "Toothpaste Heir Disinherited for Having Bad Breath," *Wall Street Journal*, April 1, 1972, p. 1.

individual selects a value of B to maximize (2). The necessary condition for a maximum is:[4]

$$w_B(J, B)(T - B) - w(J, B) = 0. \quad (3)$$

Several important implications follow from (3). First, since both w and w_B are presumptively positive, (3) implies that $T - B$ must be positive. In words, the theory predicts that no person will spend every waking hour brushing his teeth—an empirically testable proposition not derivable from either the "bad taste" or "mother told me" models.

Second, (3) can be rewritten

$$\frac{B}{T - B} = \frac{Bw_B}{w} \quad (4)$$

In words, the ratio of brushing to non-brushing time is equated to the partial elasticity of the wage with respect to brushing time. So individuals in jobs where wages are highly sensitive to brushing will devote more time to brushing than will others—as indicated in the verbal discussion. Also, for any two jobs with equal w_B's but unequal w's, (3) implies that the higher-wage person will brush less due to his greater opportunity cost.

Finally, consider the important case where (1) is linear in B (though possibly nonlinear in J):

$$w = \alpha(J) + \beta(J)B, \quad \alpha \geq 0, \quad \beta \geq 0. \quad (1')$$

Substituting into (3) and solving yields

$$B = \frac{T}{2} - \frac{\alpha}{2\beta} \quad (5)$$

In jobs where brushing is immaterial to success, $\beta \rightarrow 0$, so (5) calls for a corner maximum with $B = 0$. Thus, we have a second strong prediction from the model: such persons will never brush. At the other extreme, as the ratio α/β approaches zero, (5) implies $B \rightarrow T/2$. In words, individuals whose wages depend almost exclusively on the whiteness of their teeth (MC's of television quiz shows are a good example) will spend approximately half their lives brushing. Again, no sociological theory can generate predictions as strong as this.

III. A Regression Model

The implications of the model can be put to an empirical test thanks to a recent cross-section study of American adults in the civilian labor force conducted by the Federal Brushing Institute. In its Survey of Brushing, the institute collected data on toothbrushing frequency and many socioeconomic characteristics of 17,684 adults in 1972. From these data, the following regression model was formulated:

$$NBRUSH = a_0 + a_1 AGE + a_2 WAGE + a_3 NTEETH + a_4 S + a_5 EXP + a_6 FDUM + a_7 Y + u. \quad (6)$$

The dependent variable is the number of times teeth were brushed during the year. *AGE* is included as a proxy for the number of years remaining before the individual's teeth fall out. Viewing brushing as a human investment clearly implies that $a_1 < 0$. *WAGE*, of course, measures the opportunity cost of time; so $a_2 < 0$. *NTEETH* is the number of teeth in the person's mouth. Since brushing time is nearly independent of the number of teeth brushed, having more teeth should certainly encourage more brushing. *S* and *EXP* are, respectively, years of schooling and work experience. They are included because this is a human capital model; although there are no a priori expectations about the signs of a_4 and a_5, both should have high t-ratios. *FDUM* is a dummy for persons who live in an area with fluoridated water supply, included since there is some substitution in the production function for good teeth between brushing and fluoridating the water. Finally, *Y* is nonlabor income, which enables us to estimate the income effect on toothbrushing frequency.

Since I have argued above that *WAGE* should depend on *NBRUSH*, equation (6) was estimated by the instrumental-variables technique. Denture wearers were included

[4]Since w is assumed semistrictly quasi-concave, this is also sufficient for a weak maximum.

in the sample, but 189 people with no teeth at all were omitted from the analysis. The empirical results are reported below, with standard errors in parentheses:

$$\underset{}{NBRUSH} = \underset{(0.63)}{2.04} - \underset{(0.001)}{0.006}\,AGE - \underset{(0.001)}{0.096}\,WAGE$$

$$+ \underset{(0.009)}{0.054}\,NTEETH + \underset{(0.0002)}{0.0043}\,S$$

$$- \underset{(0.0001)}{0.0022}\,EXP - \underset{(0.027)}{0.146}\,FDUM$$

$$+ \underset{(0.0002)}{0.0006}\,Y,\ R^2 = .79,\ SE = 0.056.$$

By any standards the results are very good. The R^2 is very high for cross-section work, indicating that the data have been successfully mined. All the variables suggested by the theoretical model are highly significant and, where the theory implied a priori sign restrictions, they are satisfied.

In summary, the survey data strikingly confirm the predictions of the theoretical model of toothbrushing presented here. Of course, this is only one of many possible tests of the theory. But it does point out the usefulness of human capital concepts in understanding dental hygiene. Hopefully, these results will stimulate renewed interest in such questions on the part of economists.

Acknowledgment

I wish to thank my dentist for filling in some important gaps in the analysis, and my colleague, Michael Rothschild, for insightful kibitzing. Support for this research is graciously solicited.

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DEPARTMENTS

Book Review

ETHICAL ISSUES OF INFORMED CONSENT IN DENTISTRY

By Richard Warner and Herman Segal

Published by Quintessence Publishing Co, Inc, Chicago, 1980. 120 pages. $12.00

The authors state that this book was written in the conviction that dentistry involves a complex and intricate psychological interaction between its practitioners and their patients, an interaction pervaded by difficult moral issues.

They emphasize that it is essential to take account of the fact that many dental procedures are elective, for there are often multiple methods of treating the same condition. An appreciation of the elective nature of dental procedures is essential to an adequate understanding of the relationship of dentist to patient for it means that patients have or often perceive themselves as having many options open to them.

The authors contend that patients are often denied the chance to choose among the options open to them, for dentists often act paternalistically toward their patients making the decisions thought best for the patient as a father makes decisions deemed best for his child. Children tend to respond negatively when they are overparented. Have dentists "overparented"? Is this why their "children" are angry? The writers think so and they substantiate this conclusion by quoting the dramatic increase in dental malpractice suits.

In northern California, for example, dental malpractice suits numbered 200 in 1950, 500 in 1970, and almost 1,900 in 1977.

Patients currently see the denial of choice involved in paternalism as overriding their rights, and they are demanding that such paternalism cease. This is why the mention of ethics and dentistry together provokes such anger. Patients do not want decisions taken out of their hands; they want to participate in the decision-making that occurs in dentistry, and they see such participation as their moral right.

The central issue of this book therefore addresses the question: "How should dentists tread the line between advising and imposing?"

The authors in addressing this question reveal the point of recognizing the right to give or withhold free and informed consent to dental treatment, for by recognizing this right, free rational choice is maximized. It is this concern which makes that right a moral ideal to be approximated in dental practice.

How can you best approximate in practice the ideal of truly free and informed consent? By combining effective treatment with respect for personal freedom, Warner and Segal contend.

Through a series of case presentations, the authors give examples and ask questions to elucidate the presence or absence of informed consent. This process involves explanation of the risks, "the inherent and potential hazards of the proposed treatment; the alternatives (and presumably the reasons for preferring the proposed treatment); and the risks of having no treatment at all."

The authors also address the theory of proxy consent in regard to children and disturbed patients. The power of giving or withholding consent is placed in the hands of the child's parents (or, legal guardian). However, this certainly does not make the child a nonperson. The child's wants and feelings must still be taken into account in making any decision about treatment.

The treatment of mentally disadvantaged patients raises the question of how to combine our respect for the individual with our concern to provide needed health care. Again, the authors contend that adequate health care must be combined with respect for individual freedom.

This is a provocative book concerned with patients' rights in relation to dentists' proposed treatment. It is a book whose content is somewhat verbose and repetitive but yet it brings into focus for discussion issues that are involved in dental practice. These issues, though present, have not always been addressed or elucidated even though they are very real. The book therefore has merit and value in bringing informed consent to the dentist's attention.

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Letters

On Low-gold Alloys in Operative Dentistry

I feel compelled to comment on a statement in the Spring issue contained in the article "Low-gold Alloys for Use in Operative Dentistry" by David C Sarrett and James S Richeson (Spring 1982, Vol 7, No 2, pp 63–74).

A paragraph on page 69 relates to the sale and apparent use by dentists of gold coins (South African Krugerrands or Canadian Mapleleaf) and either copper and silver coins or ingots, for the purpose of formulating dental casting alloys by melting these together. The practice of buying gold coins, in fact, constitutes a method of purchasing gold coins as a business expense for purposes of personal saving or for speculation in such coins. There is really no advantage to buy gold this way as pure gold can be obtained from refiners in many forms. In the meantime, the US Internal Revenue Service will have almost no way to verify whether the coins were really melted down or were hoarded. Of course, the tax savings can be substantial. I doubt very much if any such coins are actually melted down for dental restorations.

Furthermore, an alloy of gold, copper, and silver alone does not guarantee good mechanical performance, casting tolerance, or corrosion resistance. As pointed out in the article, even alloys with 75 wt % gold (18 karat) will tarnish without a small amount of palladium present. Iridium additions will reduce grain size, and zinc will improve castability. Attempting to be a metallurgist can be risky at best.

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ROBERTA MERRYMAN LEAVES *OPERATIVE DENTISTRY*

After over five years of dedicated service to *Operative Dentistry* Roberta Merryman has returned to her beloved Iowa where, at Lake Mills, she has joined her father in the operation of Graphic Publishing Company, Inc. Her boundless energy, infectious enthusiasm, and unswerving loyalty have contributed immensely to the success of *Operative Dentistry.* We thank her for her invaluable help and wish her every success in her new venture.

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American Academy of Gold Foil Operators

Annual Meeting: 29 and 30 September 1983
University of California
at Los Angeles
Los Angeles, California

Academy of Operative Dentistry

Annual Meeting: 16 and 17 February 1984
Chicago, Illinois

Press Digest

Effect of sealant placement on occlusal caries progression. Handelman, S L (1982) *Clinical Preventive Dentistry,* **4(5), 11-16.**

When carious fissures on the occlusal surfaces of teeth were sealed with either Nuva-Seal or Delton there was a 2000-fold decrease in the number of bacteria recovered from the carious lesions at the end of two years. By eliminating the source of nutrition for the bacteria in infected dentin, the sealant converted the active lesion to an arrested one. The author cautions that patients need to be examined periodically to ensure the integrity of the sealant, otherwise if the sealant is not intact caries is likely to progress.

Investigations of plaque accumulation on the teeth with ceramic restorations. Trifunović, M D and Kostić, D L-J (1982) *Stomatološki Glasnik Srbije,* **29, 177-181.**

When the accumulation of plaque on 60 teeth with ceramic crowns was assessed through the use of a disclosing solution (Alpha Plac) and the plaque index of Greene and Vermillion and compared with the data from 60 contralateral teeth, substantially less plaque was found on ceramic crowns. The highest index of plaque was found on approximal surfaces. The authors conclude that glazed porcelain is the most easily cleaned material in dentistry.

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OPERATIVE DENTISTRY

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I N D E X

Index to Volume 7 for 1982

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