

Relief formation in polished amalgam surfaces

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The relief produced in the surface of dental amalgam as a result of polishing was studied by scanning electron microscopy in traditional low-copper amalgams, high-copper dispersant-type amalgams, and high-copper single-composition amalgams. Specimens were polished metallographically in two planes at right angles to each other. Micrographs were taken of the edge between the planes; the profile of one of the polished planes could be traced and the microstructural phases recognized. The traced lines were analyzed by a computer that calculated the mean levels of the phases and the mean deviation (roughness) of all the phases along the scanned distance. Recesses were seen in the surface of the gamma-2 phase. The gamma-1 phase attained the highest level, protruding above the phases of the alloy particles. The results indicate that well-polished amalgam surfaces have a structural relief that contributes to the roughness and limits the degree of smoothness that can be obtained in an amalgam surface. □ *Amalgam phases; dental materials; roughness*

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For the clinical success of dental amalgam restorations, a smooth surface is required. The smoothness of the surface of dental amalgam is not only a function of the polishing technique; it also depends on structural characteristics of the material (1). Even the best finishing method can only improve the smoothness to a certain limit, beyond which nothing more can be accomplished by continued polishing. At that stage it is the heterogeneity of the amalgam microstructure that restricts further improvement in surface smoothness. It has been shown (2) that porosity is one of the structural features that severely limit the polishability of dental amalgam. Furthermore, it has been shown that the ability to generate porosity varies among amalgam products (2) and is also influenced by operator variables such as the amount of precondensation mercury used (3).

Even though the porosity or void content is important for the polishability of amalgam, it only occupies a fraction of the total surface. In the technique of relief polishing of amalgam (4) the tendency of the gamma-2 phase to form recesses during polishing is utilized to bring out this phase in microphotographs. It might be expected that other phases of the

amalgam structure also to some extent contribute to the formation of a relief and roughness of the surface.

The present study was undertaken with the objective of examining the profile of phases of the amalgam surface in metallographically polished specimens by scanning electron microscopy (SEM).

Materials and methods

The amalgam products used in the study are presented in Table 1. Conditions of specimen preparation—that is, the alloy to mercury ratio, trituration, condensation, the sectioning of the cylindrical specimens, embedding, grinding, and polishing—were as explained in a previous paper (2). After the final polishing the specimens were placed in resin with their square-sectioned surfaces polished. The specimens were then carefully taken out of the resin, rotated 90°, placed on their semicircular base, and reembedded in Epofix resin (Struers, Denmark). After polymerization of the resin, grinding and polishing were again done in the same manner as previously. In this way it was feasible to observe one of the polished surfaces in

Table 1. Amalgam alloys used in the study

Alloy	Code	Batch no.	Manufacturer
New True Dentalloy®	NTD	937707	S. S. White Ltd., England
Hi-Atomic®	HIA	KB 25	G.-C. Dental Industrial Corp., Japan
Dispersalloy®	DIS	HRI 8137-002822	Johnson & Johnson Dental Products Co., USA
Amalcap Non Gamma 2®	AMA	308544	Ivoclar A.G., Liechtenstein
Indiloy®	IND	437701	Shofu Dental Corp., Japan
Sybraloy®	SYB	1027752289	Sybron/Kerr Europe, Italy
Dialloy®	DIA	JM 30	G.-C. Dental Industrial Corp., Japan

profile and to characterize the relief produced by the protrusions and recesses of the microstructures. The final polishing was carried out immediately before the carbon coating and the electron microscopic procedures (5). Four specimens were made from each product.

The identification of amalgam phases and porosity was done on SEM micrographs of the polished surface. By this method major phases (Table 2) such as gamma, gamma-1, and gamma-2 and spherical alloy particles could be identified by virtue of atomic number contrast and also by location and morphology (6). Scanning electronic microscopic pictures, operating on a backscattered mode, were taken of the semicircular bases of the specimens (Jeol, JSM 35, Japan) using an accelerating potential of 25 kV and a magnification of $\times 800$. To make the identification easier, both normal (Fig. 1) and reversed pictures were obtained. The pho-

tographs were taken with Verichrome Pan film (VP 120 Kodak, ASA 125). The images were projected onto white paper, and the profile of the edge defined by the two polished planes was traced at a total magnification of $\times 4200$. During the tracing the structural phases were identified, and the intersections between their boundaries and the edge were marked. The paper containing the profile line was then placed on the measuring table of a digitizer (Hipad Digitizer, Houston Instruments, USA) connected to a computer (ABC 80, Sweden). As the sensor was moved along the line, the computer was programmed to measure the vertical deviation from a base line and the horizontal extension of the various phases. It calculated the mean level for each phase and the mean deviation along the total scanned distance, which really expresses the arithmetic roughness value Ra (7).

The horizontal extensions of the phases

Table 2. Amalgam phases measured

Product	Phase
New True Dentalloy and Hi-Atomic	Gamma Gamma-1 Gamma-2
Dispersalloy and Amalcap Non Gamma 2	Gamma Gamma-1 Spherical dispersant particle center Spherical dispersant particle periphery
Sybraloy, Dialloy, and Indiloy	Gamma-1 Spherical particle center Spherical particle periphery

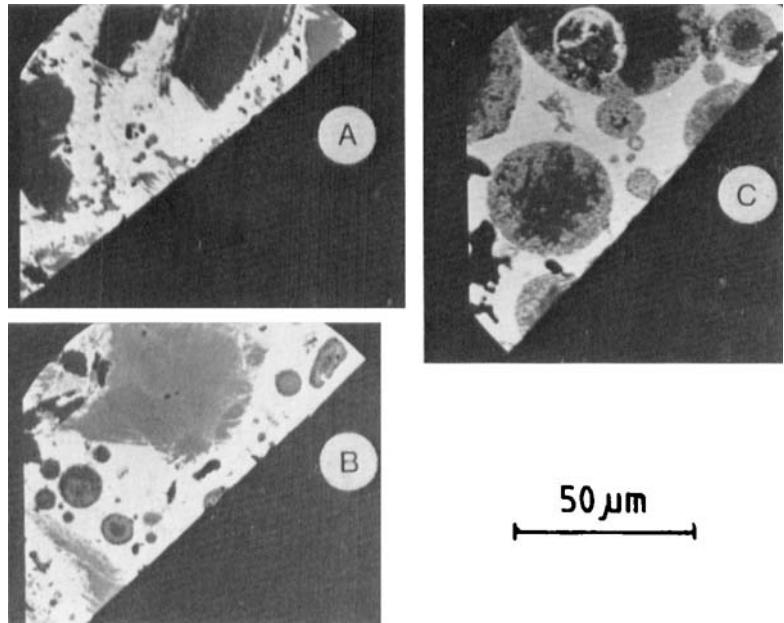


Fig. 1. Back-scattered SEM pictures of the edge between polished amalgam surfaces at a right angle to each other. A. New True Dentalloy; B. Amalcap Non Gamma 2; C. Dialloy.

and voids were used to calculate weighted arithmetic mean values for their vertical deviations. For each product 16–18 micrographs were traced, giving a total length of the examined edges of 400 cm on the paper, corresponding to approximately 1 mm on the amalgam surface.

A study of the error of the method was done in the following manner: the product New True Dentalloy, in which the identification of phases was somewhat more difficult than it was for the other products, was measured twice. The second series of measurements was taken several months after the first, and the operator no longer had any recollection of the results obtained the first time. This study comprised errors in connection with the identification of phases, measurement of their deviation from base line, and measurement of their horizontal extension. The two series of measurements were compared by the paired *t* test. No differences between the two series were found (for gamma, $p = 0.70$; for gamma-1, $p = 0.12$; for gamma-2, $p = 0.18$).

Statistical methods

Possible differences between the phases

in their vertical extension pattern were evaluated by the use of one-way analysis of variance.

Results

The results of the measurements are presented in Fig. 2 and indicate the differences in vertical levels of the amalgam phases and, by the horizontal extension of each line, the relative amount of the phases, excluding voids. The results of the statistical analyses are also given. The levels of the various phases in most cases showed statistically significant differences; only for Dispersalloy and Indiloy were the differences between the phases barely significant. The most conspicuous finding was the prominence of the gamma-1 phase relative to the others for all products except Hi-Atomic. The traditional amalgams New True Dentalloy and Hi-Atomic were also characterized by having the gamma-2 phase at the lowest level. In the high-copper dispersant products Dispersalloy and Amalcap Non Gamma 2 the gamma particles were less prominent than the gamma-1 phase. The spherical Ag-Cu eutectic particles exhibited an unclear pat-

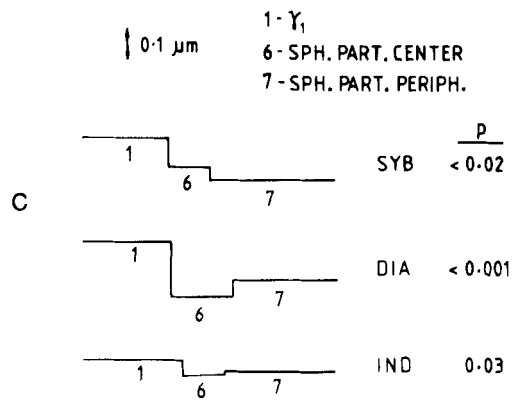
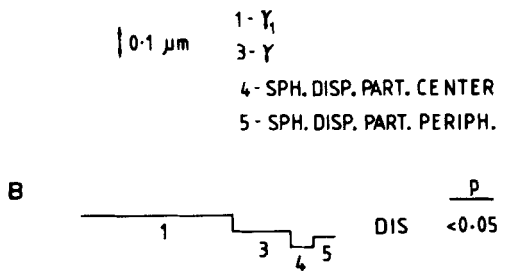
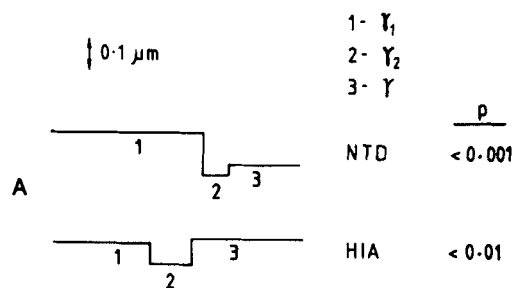


Fig. 2. Schematic presentation of the vertical levels and horizontal extensions of the examined phases. A. Low-copper (traditional) amalgams; B. High-copper dispersant amalgams; C. High-copper single-composition amalgams.

tern, varying for the two products. In the high-copper single-composition products Sybraloy, Dialloy, and Indiloy too the differences between particle center and periphery did not show a uniform pattern, but the

Table 3. Mean deviation of phases from base line, corresponding to R_a

Product	Mean deviation, μm
New True Dentalloy	0.13
Hi-Atomic	0.17
Dispersalloy	0.21
Amalcap Non Gamma 2	0.11
Sybraloy	0.16
Dialloy	0.17
Indiloy	0.11

particles were in all cases less prominent than the gamma-1 phase.

In Table 3 the mean deviations of the phases, or roughness values, between the voids are presented. These values ranged between 0.11 and 0.21 μm .

Discussion

A well-cast and well-polished gold alloy can attain a smooth surface that can be expressed by an R_a value of 0.01 μm (Leitão J. Unpublished observations, 1982). Dental amalgams, on the other hand, will under the same conditions of polishing and roughness measurement score higher R_a values (2). One reason for the limited smoothness obtainable in amalgam surfaces is the porosity, which also is reported to account for some of the variations in roughness of amalgams (2, 3).

The present experiment has focused on surface microstructures too small to be studied with conventional techniques of roughness determination. Consequently, these samples of surface area had to be so minute and the techniques so different from those used previously that comparisons with earlier results (2, 3) cannot be made. Still, the present findings do indicate that a relief is formed on polishing. The relief seems to be sufficiently pronounced to influence the roughness value of the amalgam.

Furthermore, the results give some suggestions with regard to the contribution to the relief of the various phases. Thus, in traditional amalgams the well-known tendency of the gamma-2 phase to wear away

during polishing (4, 8) was verified. Another striking feature was the gamma-1 phase protruding above the other phases. An explanation of this finding cannot be offered at present. With regard to hardness the gamma-1 phase is known to be inferior to the phases of the alloy particles (9). The general pattern of this phase projecting above even the alloy particles is remarkable.

The relief observed was most probably formed during the final stage of polishing—that is, when the 3- μ m diamond paste and the soft NAP cloth were used. When assessing the present results, therefore, it should be borne in mind that the relief depends on the technique of polishing, and thus amalgam surfaces after a clinical finishing may appear quite different from the specimens studied in this experiment. Whatever the method, the smoothness obtainable when polishing amalgam is usually limited by the scratches produced by the final abrasive and by the porosity of the surface. If the polishing procedure is continued by the use of soft and fine-grained means, then the formation of a structural relief may set the limit for further improvements. The polishability of dental amalgam, therefore, seems to be limited both by porosity and by relief formation.

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References

1. Wing G. The polished amalgam surface. *J Dent Res* 1965;44:1411.
2. Leitão J. Surface roughness and porosity of dental amalgam. *Acta Odontol Scand* 1982;40:9–16.
3. Leitão J. Polishability of dental amalgam as influenced by condensation pressure and primary mercury content. *Acta Odontol Scand* 1983;41:327–31.
4. Jørgensen KD. Structure study of amalgam. III. The marginal structure of class II amalgam fillings. *Acta Odontol Scand* 1967;25:85–104.
5. Mahler DB, Adey JD, Van Eysden J. Microprobe analysis of amalgam. I. Effect of surface preparation. *J Dent Res* 1973;52:74–8.
6. Mahler DB, Adey JD, Van Eysden J. Quantitative microprobe analysis of amalgam. *J Dent Res* 1975;54:218–26.
7. Leitão J, Hegdahl T. On the measuring of roughness. *Acta Odontol Scand* 1981;39:379–84.
8. Allan FC, Asgar K, Peyton FA. Microstructure of dental amalgam. *J Dent Res* 1965;44:1002–12.
9. Greener EH, Harcourt JK, Lautenschlager EP. *Materials science in dentistry*. Baltimore: The Williams & Wilkins Co., 1972;187.