Polishability of dental amalgam as influenced by condensation pressure and primary mercury content

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The polishability of some amalgam products was studied by determining the roughness (Rs) of metallographically polished specimens. The surface porosity of the specimens was also measured and was found to be closely correlated with the roughness. Two manipulative variables, condensation pressure and primary (precondensation) mercury content, were examined with respect to their effect on porosity and polishability. For the condensation pressures 14 and 20 MPa no differences could be observed in the effect on the surface properties studied. The primary mercury content was varied in three steps—the normal, recommended level and 5% more and less than this. For those products having a recommended precondensation mercury content of 50% or less, the 5% decrease in mercury resulted in a pronounced increase in porosity and Rs. The results indicate that polishability is for some products markedly improved by avoiding a dry mix. □ *Amalgam surface; porosity; roughness*

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In a previous study (6) of surface roughness of dental amalgam it was observed that the polishability of different amalgam products varied considerably. It was also indicated that porosity was the factor that contributed significantly to the low polishability seen in some products.

The porosity of an amalgam filling is known to depend on manipulative variables. It has been demonstrated (2, 3) that the porosity content is lowered when a mercury-rich mix is used during condensation. The condensation pressure may also influence the polishability of an amalgam surface, since it has been shown that it affects the density of the structure (4).

The present study was undertaken with the objective of determining to what extent the polishability of an amalgam surface is influenced by variations of the condensation pressure and the primary mercury content.

Materials and methods

Four commercial amalgams, listed in Table 1, were used in the investigation. For each type of amalgam three different ratios of alloy and mercury were used: in addition to the normal ratio suggested by the manufacturer, a high ratio and a low ratio were used, each of them 5% off the normal ratio (Table 2). Alloy and mercury were weighed on an analytical balance. Trituration was done with a mechanical amalgamator (Silamat, Vivadent, Liechtenstein) for the time suggested by the manufacturers.

Table 1. Amalgam alloys used in the study

Alloy	Code	Batch no.	Manufacturer
New True Dentalloy® (traditional lathe-cut)	NTD	937707	S. S. White Ltd., England
Hi-Atomic® (traditional spherical)	HIA	KB 25	G-C. Dental Industrial Corp., Japan
Dispersalloy (non γ2, dispersion type)	DIS	HRI 8137-002822	Johnson & Johnson, Dental Products Co., USA
Sybraloy® (non γ2, spherical)	SYB	0219811346	Sybron/Kerr Europe, Italy

Table 2. Levels of primary mercury content (%)

	Low	Normal	High
New True Dentalloy®	55.4	58.3	61.2
Hi-Atomic®	40.8	42.9	45.0
Dispersalloy®	47.5	50.0	52.5
Sybraloy®	42.8	45.0	47.3

The amalgam was condensed into a cylindrical steel mold with a diameter of 4 mm. The condensation was carried out in accordance with ADA Specification No. 1, but using a condensation pressure of 14 MPa in one series and 20 MPa in a second series. Five amalgam specimens were made for each of the five conditions: two condensation pressures and three levels of mercury. The specimens were stored for 1 week at 37°C. The specimens were then embedded in resin blocks (Epofix, Struers, Denmark). Two cylinders of each product made with either of the two condensation pressures were included in each block. The cylinders were standing on their circular base.

The specimens were ground by hand on silicon carbide abrasive papers no. 220, 320, 400, 600, 1000, and 1200 under running water. The polishing was done by the use of a metallographic polishing machine (DAP-U, Struers, Denmark) and diamond pastes of 6 μm on a MOL cloth and 3 μm on a NAP cloth, using a 1:9 mixture of ethylene glycol and ethyl alcohol as a lubricant. Between each grinding and polishing step the specimens were cleansed in distilled water in an ultrasonic bath. At the end of the final polishing step the blocks were rotated on the NAP cloth until the scratches ran in all directions. Finally, the specimens were rinsed in alcohol, dried in a blast of warm air, and stored in a desiccator.

Porosity determination

The polished specimens were photographed in an incident light microscope (MEF, Reichert, Austria), using an objective lens of ×4 and an eye-piece of ×6.3. The film was the high-contrast Agfaortho 25, processed in Agfa Rodinal S. The negatives were projected onto a white paper covering the measuring table of a digitizer (Hipad Digitizer, Houston Instruments, USA), connected to a computer (ABC 80, Sweden). The total magnification was ×75.

Porosity content was determined by tracing the contour of all the voids seen within a 120° sector of the circular projected image. The areas of the voids were calculated by the computer. A peripheral zone of the image with a width corresponding to 50 μm on the specimen was excluded in the measuring of porosity. In this way an area of 3.98 mm^2 was examined in each specimen. Voids having a mean equivalent circle diameter of less than 20 μm were not measured. According to a previous study (6), the method error for this measurement of particle areas is negligible. The sum of the areas of all the measured voids in percentage of the total area examined was taken as the porosity value for each product.

Roughness determination

The surface roughness (Rs) (8) was determined with a roughness measuring instrument (Perthometer W5A, Perthen, FRG). The equipment was calibrated against a standard. The instrument was mounted in a profile projector (Nikon Profile Projector, Japan) so that the path of the profile trace could be chosen. Seven parallel scans 1.5 mm long, separated by a distance of 0.1 mm, were made within the sector of the specimen used in the porosity determinations. Thus, the mean roughness value for each specimen was based on a total scan length of 10.5 mm. A filtration was used corresponding to a cut-off value of 0.25 mm (8).

Statistical evaluation

Differences between mean values of series to be compared were evaluated by Student's *t* test (two-sided).

Results

Effect of condensation pressure

The porosity contents observed for condensation pressures of 14 and 20 MPa are

Table 3. Percentage porosity in amalgams for variations in condensation pressure and primary mercury content

	Concensation pressure, MPa	Mercury level					
		Low		Normal		High	
		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
New True Dentalloy®	14	1.2	0.4	2.5	2.0	2.2	1.7
	20	1.5	0.7	2.2	0.6	1.6	1.3
Hi-Atomic®	14	3.1	1.1	1.9	1.2	0.8	0.5
	20	3.7	0.9	1.7	0.6	0.8	0.9
Disperalloy®	14	5.2	2.0	2.5	1.0	0.6	0.4
	20	4.4	0.5	2.4	1.1	0.7	0.6
Sybraloy®	14	3.3	1.5	1.2	0.3	1.1	0.2
	20	3.8	1.1	1.1	0.4	0.8	0.1

listed in Table 3. It can be seen that for the various mercury levels the porosity percentage was sometimes higher for 14 MPa than for 20 MPa and sometimes lower. The standard deviation values were large, however, and the differences were not statistically discernible for any product ($0.69 < p < 0.97$).

The roughness data for the two condensation pressures are presented in Table 4. It can be seen that the mean values were not very different for the two conditions, and the *t* values are in all cases too low to indicate significant differences ($0.54 < p < 0.95$).

Effect of primary mercury content

The porosity values for the two condensation pressures were pooled and are presented graphically in Fig. 1 for the low, normal, and high levels of primary mercury content. For Hi-Atomic®, Sybraloy®, and Dispersalloy® a striking decrease in porosity was observed as the primary mercury content was increased. For New True Dentalloy® the lowest porosity content was encountered for the lowest mercury level.

Fig. 2 shows the relationship between roughness and primary mercury levels. An increase in mercury gave a decrease in roughness for all products except New True Dentalloy.

The *t* values for the differences in porosity content and roughness when low and high primary mercury levels were used indicate

Table 4. Rs values of amalgam surfaces for variations in condensation pressure and primary mercury content

	Concensation pressure, MPa	Mercury level					
		Low		Normal		High	
		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
New True Dentalloy®	14	0.14	0.04	0.23	0.15	0.24	0.12
	20	0.18	0.05	0.21	0.10	0.22	0.07
Hi-atomic®	14	0.23	0.09	0.13	0.04	0.11	0.03
	20	0.23	0.06	0.16	0.04	0.15	0.14
Dispersalloy®	14	0.39	0.11	0.18	0.07	0.17	0.05
	20	0.32	0.12	0.19	0.10	0.16	0.07
Sybraloy®	14	0.22	0.08	0.11	0.02	0.13	0.09
	20	0.26	0.11	0.11	0.05	0.13	0.03

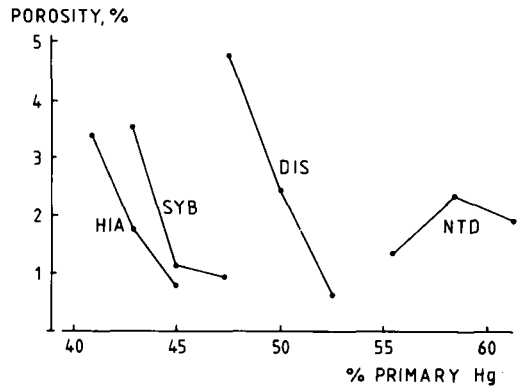

Fig. 1. Porosity contents of amalgams made with low, normal, and high levels of mercury content.

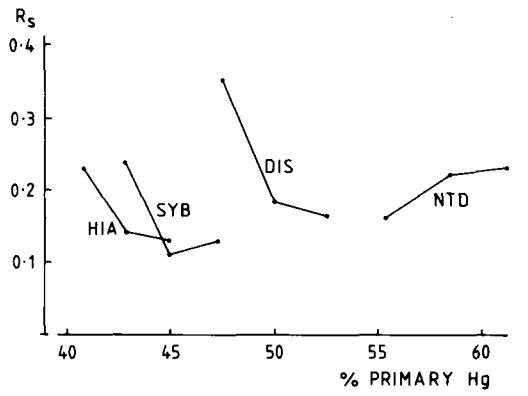

Fig. 2. The roughness of amalgams made with low, normal, and high levels of mercury content.

that the decrease in porosity and roughness resulting from the increase in mercury was significant for Hi-Atomic, Sybraloy, and Dispersalloy ($p < 0.02$). For New True Dentalloy the change in porosity was not statistically significant, while the increase in roughness accompanying the increase in mercury was significant at the 5% level.

Discussion

The roughness of the polished amalgam surfaces seemed to be highly dependent on the amount of porosity present. This was evident from the similarity of the porosity graphs (Fig. 1) and roughness graphs (Fig. 2). It follows that the porosity content is an important factor to control when seeking to improve polishability. These results confirm earlier data (6).

From the literature it is known that a high condensation pressure tends to enhance mechanical properties of amalgam (1, 5). The detrimental effect of porosity on strength is also well known (4). In the study mentioned (4) the condensation pressure, varying from 15 to 75 MPa, did not seem to affect the void content. In another report (1) the condensation pressures varied between 1.8 and 14 MPa. Under these conditions the porosity content, evaluated by light microscopy, was negatively influenced by the condensation pressure. These findings together could be taken to indicate that a porosity-reducing effect of condensation pressure exists for relatively low pressures. If so, the lack of correlation between condensation pressure and porosity content observed in the present study could be explained by the pressures being too high.

The present data suggest that a relatively high primary mercury content is beneficial for the polishability of amalgam. The question is whether the use of a high precondensation mercury level has any adverse effects on other properties. The consequences of a high residual mercury content for mechanical properties have been studied by several authors. It was observed (11) that amalgam suffered a serious loss in strength when the residual mercury percentage exceeded 55% but was barely affected when final mercury content was in the range of 50–55%. In a clinical study also (10), fillings containing 56–62% residual mercury showed more signs of surface roughness and general degradation than those containing about 42% mercury. Even though too much mercury may affect amalgam properties adversely, it has also been reported (9) that an increase in primary mercury is of advantage for transverse strength when low condensation pressures are used.

Over the past years amalgam products have appeared on the market which are to

be used with relatively small additions of mercury. For such products the residual mercury content is also low. It may be that the primary mercury content of these amalgams is more critical than it is for products requiring higher (>50%) precondensation mercury. The present results suggest this. There are also some data (7) for the products examined here which strongly indicate that strength is improved when the primary mercury is increased. This implies that by avoiding a too dry mix, a beneficial effect on polishability can be obtained without the risk of weakening the amalgam.

After the completion of the present study the author became aware of a similar investigation carried out by P. Biltoft, R. F. Hochman & M. Marek and abstracted in J. Dent Res., Vol. 60, 1981, Special Issue A, report No. 387.

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