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THE INFLUENCE OF PRECONDENSATION MERCURY CONTENT ON THE TRANSVERSE STRENGTH OF AMALGAMS

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The purpose of this investigation was to study the influence of changing the precondensation mercury content (initial mercury content) on the early and final transverse strength of different amalgams. The material consisted of five conventional lathe cut alloys, two of which were zincfree, of one dispersion strengthened and one spherical alloy and of three lathe cut preamalgamated alloys. The amalgam was mixed with mercury using three different alloy-mercury ratios. Thus the precondensation mercury content of Mix I was about 50 per cent, of Mix II about 54 and of Mix III about 59 per cent for all amalgams except the spherical brand. Rectangular amalgam test pieces, measuring $2 \times 2 \times 12$ mm, were condensed by hand using a load of about 17 kg/cm^2. The transverse strength test was performed either after one hour or one week using three point loading. The results show that for some of the amalgams an increase of the precondensation mercury content resulted in a slight reduction of the early strength. Furthermore the results show that the early strength was lower for the preamalgamated amalgams than for the other amalgams. Increasing the precondensation mercury content did not significantly effect the final strength of six amalgam brands but increased the strength of three brands and reduced the strength of one brand. It was concluded that it is safer to use a moderate excess of initial mercury in clinical amalgam work than to try to reduce the initial mercury content as much as possible.

Dental silver-tin alloys have generally been triturated with mercury using initially as little mercury as possible or an excess of mercury. This excess was then removed by squeezing before condensation and by condensing. The advantages of the minimal mercury technique were first pointed out by *Eames* (1959). The method is based on the findings that increasing the residual mercury content of an amalgam decreases its strength (*Swartz & Phillips*, 1956), and that the residual mercury content increases proportionally with the mercury content in the original mix (*Skinner & Phillips*, 1967). There are, however, several studies showing no difference in strength or

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residual mercury content when different alloy/mercury ratios were used (*Sweeney & Burns*, 1961; *Mahler & Mitchem*, 1965; *Jørgensen*, 1967 and *Forsten*, 1970).

In addition to higher strength, the claimed advantages of the minimal mercury technique are simplier condensation procedures and greater safety against the dangers of handling mercury because little or no mercury has to be removed during the manipulation. A few years ago *Jørgensen* (1967) suggested the use of excess initial mercury which is to be removed by condensation only. He claimed that this technique offers several advantages over the minimal mercury technique, e.g. better adaptability, less porosity and easier condensation procedures, since the higher plasticity of the mix allows larger increments and condenser points and smaller condensing pressure.

In a prior study (*Forsten*, 1970), amalgams were manipulated using a »dry» technique or a mercury rich precondensation mix (Jørgensen's technique). The »dry» mix was prepared using a low initial mercury percentage or by expressing excess mercury prior to condensation. When the lathe cut amalgams were condensed by a high condensing pressure (90 kg/cm^2), no significant differences could be shown in the final strength* between amalgams made from the two different mixes. When, however, a low pressure (20 kg/cm^2) was used for all amalgams, the mix containing excess precondensation mercury resulted in higher strength values and lower scatter of the data.

In another work (*Forsten*, 1971), the one hour strength of the same amalgams also were studied using both techniques. When the lathe cut amalgams were condensed with 90 kg/cm^2 pressure and the spherical amalgams with 20 kg/cm^2 pressure, no differences in strength were found between the two manipulation techniques, except for one of the lathe cut amalgams. In comparing different brands, it was found that the early strength of the preamalgamated amalgams manufactured in Scandinavia was approximately one-half that of the other lathe cut and spherical amalgams.

The purpose of the present work was to study the effect of the precondensation mercury content on the early and final transverse strengths of amalgams by varying the initial mercury content only and by using a low condensing pressure (17 kg/cm^2). Another aim was to confirm the earlier finding that preamalgamated amalgams have generally lower early strength than other amalgams.

Part of this investigation was presented at the 49 Annual Meeting of the IADR, Chicago, Ill., March, 1971.

* The strength after one week.

MATERIAL AND METHODS

The alloys tested, types, forms and manufacturers are listed in Table I. The table also lists the code letters for the different alloys used in this and earlier studies of the present author. The same batch of each alloy was used throughout this study. The mercury complied with the requirements of the American Dental Association Specification No. 6 (*American Dental Association*, 1970—71). For proportioning the mercury, a Caulk dispenser was used with all alloys except the alloy P, with which the Kerr proportioner was employed. Mixes with three different alloy/mercury ratios were made for each alloy by changing the plunger of the Caulk dispenser. Plunger E was used for Mix I, C for Mix II and B for Mix III. With the alloy P, three different readings were used with the Kerr proportioner.

For each mix of the pellet alloys one 6 grain pellet and one spill of mercury were dispensed except for alloy P, for which two 4 grain pellets and 2 mercury spills were dispensed. To estimate the initial mercury content of each mix made from each alloy in pellet form, 80 pellets of each alloy were weighed separately on an analytical balance (Mettler, accuracy 0.02 mg) and the mean weight was calculated. 10 separate spills from the Caulk dispenser using each of the three plungers and from the Kerr proportioner using each of the three readings were also weighed and the mean weights were calculated. The resulting initial mercury contents for each alloy and mix are shown in Table II. The table also shows the initial mercury contents for the prea-

Table I.

The tested amalgam alloys

Code	Brand Name	Form	Manufacturer
S	Caulk fine cut®	pellet	L. D. Caulk Co., U.S.A.
T	Velvalloy®	pellet	S. S. White Co., U.S.A.
$T_{Zn\text{-}f}$	Velvalloy zinc-free®	pellet	S. S. White Co., U.S.A.
H2	New True Dentalloy®	pellet	S. S. White Co., U.S.A.
$H_{Zn\text{-}f}$	True Dentalloy zinc-free®	pellet	S. S. White Co., U.S.A.
U	Dispersalloy®	pellet	Unitek Co., U.S.A.
P	Kerr Spheraloy®	pellet	Kerr Mfg. Co., U.S.A.
E*)	Abedent®	filing	AB Bååths Dental Industry, Sweden
$E_{Zn\text{-}f}$*)	Abedent zinc-free®	filing	AB Bååths Dental Industry, Sweden
D*)	Sterling®	filing	OY Dental Depot AB, Finland

*) Preamalgamated filings (brands E, $E_{Zn\text{-}f}$ and D) were washed with a mercury salt solution during the manufacturing process, and are claimed to contain a maximum of 3 % Hg.

Table II.

Percentages of initial mercury and type of pestle used with the different alloys

Alloy	Initial Hg % by Mixes I	II	III	Pestle*)
S	52.1	56.3	61.0	b
T	51.1	55.3	60.0	a
T_{Zn-f}	50.6	54.8	59.6	a
H2	49.6	53.8	58.6	a
H_{Zn-f}	49.4	53.6	58.4	a
U	50.6	54.5	59.9	d
P	48.3	50.3	52.2	a
E	50.0	54.2	59.0	a
E_{Zn-f}	50.0	54.2	59.0	a
D	50.0	54.2	59.0	a

*) Pestles: a = small plastic: 1.004 gm, diameter 5.00 mm, length 16.4 mm
b = large plastic: 0.940 gm, diameter 7.75 mm, length 15.1 mm
d = small metal: 1.303 gm, diameter 4.39 mm, length 12.1 mm

malgamated filing alloys E, E_{Zn-f} and D. For each mix 0.41 grams of alloy was weighed and one spill from the Caulk dispenser was used with plungers E, C or B. In addition, two more mixes were prepared with the preamalgamated filing alloys, one with 45 and one with 47.5 per cent initial mercury content.

The amalgam was triturated for 6 seconds in an ultra-high speed device (Silamat®, Ivoclar AG) with a pestle in the capsule (See Table II). Since *Jørgensen* and *Okuda* (1970) recently pointed out that mercury may leak from capsules during the trituration, the capsules used in this study were checked using tape as recommended in that study.

The mixed amalgam was formed into a »rope» using a squeeze cloth and divided into four increments. Each increment was condensed by hand with a flat-ended rectangular condenser measuring 1.62×1.79 mm into a mold cavity (Fig. 1A) using 30 thrusts. The mold was fixed to a scale which was adjusted to react to loads exceeding 0.5 kg. Thus, the resulting condensing pressure was about 17 kg/cm^2. When the cavity had been overfilled, a »dry» portion of amalgam squeezed by hand was placed on the top and condensed using 15 thrusts of a metal plate which covered the entire surface of the specimen. The excess was carved away using a sharp, stiff razor blade. No excess mercury was removed prior to condensation in any case before using the »dry» excess.

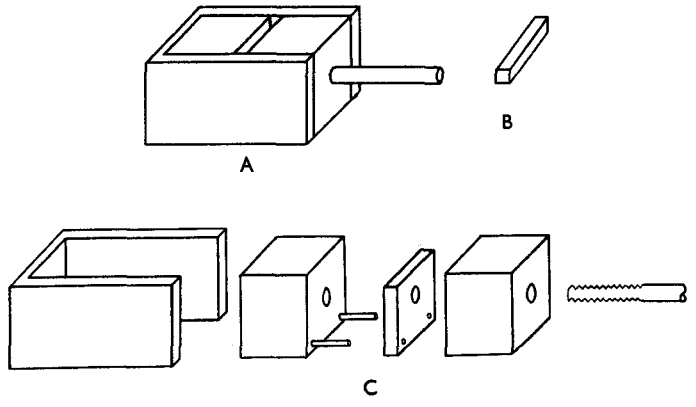

Fig. 1. Sample mold and amalgam specimen.
A = assembled mold, B = amalgam specimen, C = exploded view of mold

The rectangular specimen (Fig. 1B) measuring $2.04 \times 2.05 \times 12$ mm was removed immediately from the split mold, and stored in air for 1 hour at $23 \pm 2°C$ or for 7 days at $37 \pm 2°C$. The transverse strength was tested parallel to the direction of condensation using an Instron testing machine and a fixture of the same type as has been described by *Mahler* and *Mitchem* (1964). The crosshead speed was 0.005 cm/min. The transverse strength (S_T) was calculated using the formula:

$$S_T = \frac{3\ L}{2b\ h^2} \times P$$ where:

L = sample length between supports (10 mm)
b = sample width (2 mm)
h = sample thickness (2 mm)
P = fracture load

Six samples were prepared and tested for each condition at room temperature ($23 \pm 2°$ C).

RESULTS

Fig. 2 A and B shows the one hour and Fig. 3 A and B the one week transverse strengths of the various amalgams using the three mixes having different mercury contents. The variance of the data is shown as the standard deviation (vertical lines). The results were analyzed using an analysis of variance and Duncan's multiple range test (*Duncan*, 1955). Different num-

bers inside the bars indicate that there was a significant difference between the values at the 99 per cent confidence level.

From Fig. 2 it can be seen that for amalgams S and T there were no significant differences between the early strength values of the different mixes. For five of the amalgams ($T_{Zn\text{-}f}$, H2, $H_{Zn\text{-}f}$, E and $E_{Zn\text{-}f}$) the strength for the »dry» mix (Mix I) and the intermediate mix (Mix II) were the same but higher than those for the »wet» mix (Mix III). For amalgam D the intermediate mix demonstrated the highest strength and for the dispersion amalgam U and the spherical amalgam P the »dry» mix resulted in the highest strength value.

The results reveal, furthermore, that the one hour strength of the preamalgamated amalgams (E, $E_{Zn\text{-}f}$ and D) was only between one third and one-half that of the other amalgams. The strength of the dispersion amalgam U and the spherical amalgam P was about the same as the strength of the conventional amalgams (S, T, $T_{Zn\text{-}f}$, H2 and $H_{Zn\text{-}f}$).

The results in Fig. 3 A and B reveals no significant differences in the one week strength between the three mixes for amalgams S, H2, $H_{Zn\text{-}f}$, U, E and D. For amalgams T, $T_{Zn\text{-}f}$ and P the »dry» mix resulted in lower strength values than the two other mixes. Only amalgam $E_{Zn\text{-}f}$ showed a reduction in strength with increasing precondensation mercury content.

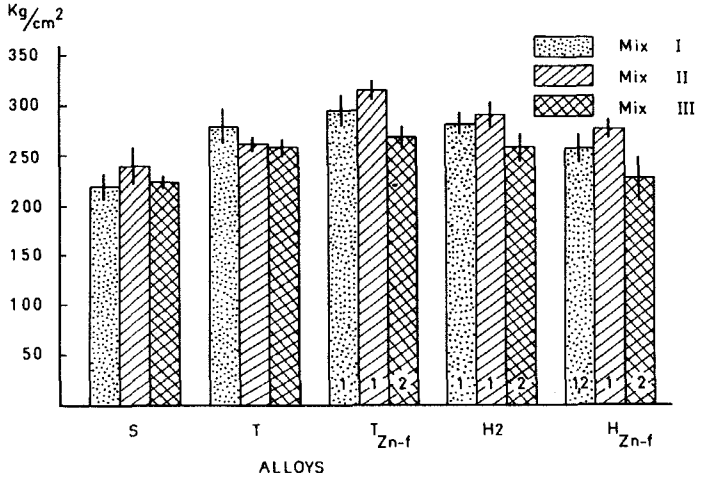

Fig. 2 A. One hour transverse strength of amalgams S, T, $T_{Zn\text{-}f}$, H2 and $H_{Zn\text{-}f}$ when three mixes with different precondensation mercury content were used. The vertical lines represent the standard deviation ($\pm$ 1 × S.D.)

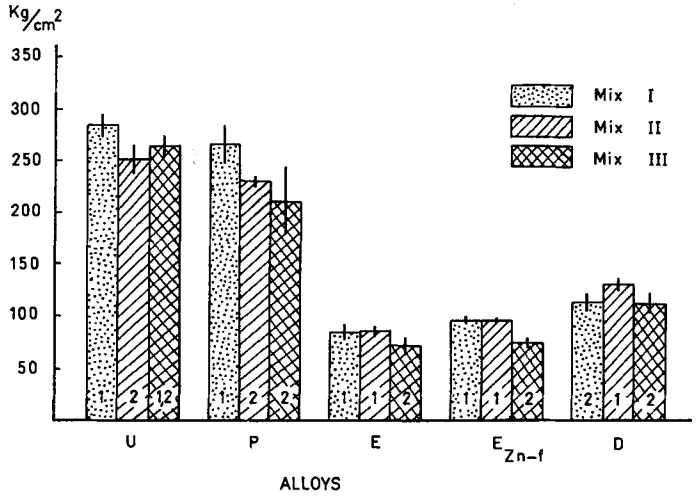

Fig. 2 B. One hour transverse strength of amalgams U, P, E, E_{Zn-f} and D when three mixes with different precondensation mercury content were used. For vertical lines, see Fig. 2 A.

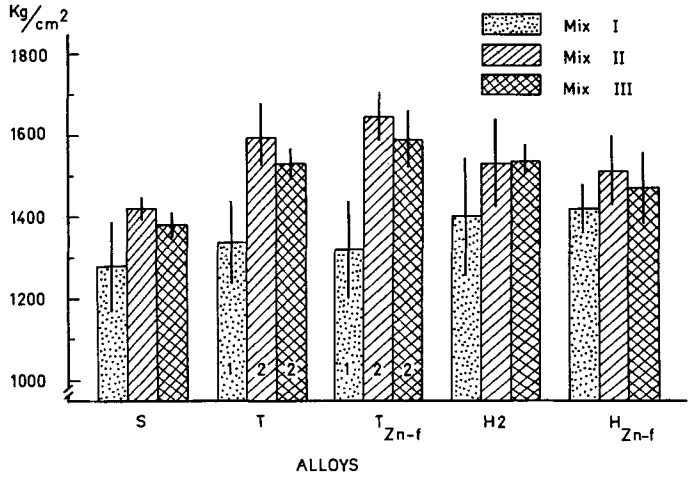

Fig. 3 A. One week transverse strength of amalgams S, T, T_{Zn-f}, H2 and H_{Zn-f} when three mixes with different precondensation mercury content were used. For vertical lines, see Fig. 2 A.

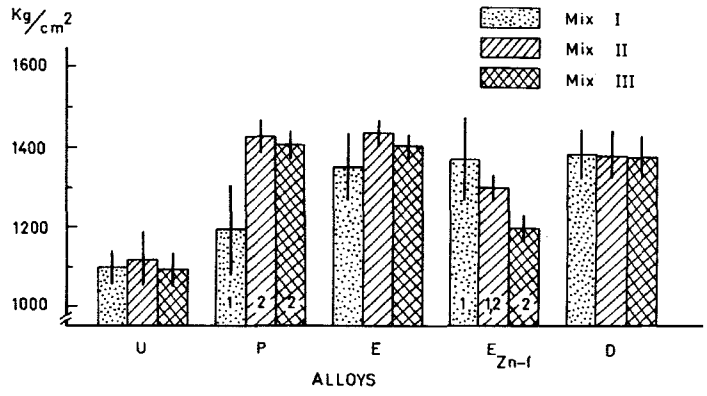

Fig. 3 B. One week transverse strength of amalgams U, P, E, $E_{Zn\text{-}f}$ and D when three mixes with different precondensation mercury content were used. For vertical lines, see Fig. 2 A.

These results also showed that the scatter of data was significantly greater when using the mix with the lowest mercury content. The mean variance for Mix I for the ten amalgams was 100 kg/cm², for Mix II 68 kg/cm² and for Mix III 50 kg/cm². The difference was statistically significant between the variances of mixes I and II and I and III but not between mixes II and III.

Table III, showing the results when two additional ratios were used for the preamalgamated alloys, reveals that precondensation mercury content of less than 50 per cent caused a decrease in strength for all three amalgams.

Table III.

Transverse strengths (kg/cm²) of preamalgamated amalgams using five different precondensation mercury contents

Mix	Alloy E		Alloy $E_{Zn\text{-}f}$		Alloy D	
	Mean	S D	Mean	S D	Mean	S D
00*)	1051 (2)	56	1122 (3,4)	143	1060 (2)	109
0**)	1059 (2)	45	1070 (4)	116	1110 (2)	59
I	1347 (1)	86	1368 (1)	107	1382 (1)	63
II	1432 (1)	36	1296 (1,2)	34	1380 (1)	63
III	1404 (1)	29	1194 (2,3)	34	1376 (1)	51

*) Precond. Hg = 45.0 %
**) Precond. Hg = 47.5 %

NOTE: Numbers in parentheses indicate ranking at the 99 % confidence level.

DISCUSSION

The condensing pressure used in the present study was low compared with the pressure (almost 150 kg/cm²) recommended in the revised A.D.A. Specification No. 1 (*American Dental Association*, 1970—71) for preparation of test specimens. According to *Jørgensen* (1967), a high condensing pressure, such as the latter, will generally result in an amalgam with optimum properties. Studies evaluating the condensing loads used in clinical work have shown that the load is usually rather low. *Mahler* and *Mitchem* (1965) reported loads between 1.5 and 2 kg and *Moffa* and *Jenkins* (1971) reported loads between 0.5 and 1.5 kg. Judging from personal clinical experience, condensers with a diameter of about 2 mm are often used. To attain a condensing pressure of 150 kg/cm² with such a condenser, a load of 4.5 kg must be applied. Even if such a load can be used in clinical work, it is definitely higher than the averages reported in the above mentioned studies (*Mahler & Mitchem*, 1965 and *Moffa & Jenkins*, 1971). Clinical problems are apt to arise when the amalgam is condensed by too low a condensing pressure. In a laboratory study of manipulation techniques, it is, therefore, desirable to use low condensing pressures in order to detect differences, which may be of clinical significance.

A three point loading transverse test was used in the present study as an index of the strength for the following reasons: (1) The »clinical» fracture of amalgam is due to a complicated mechanism including different types of stresses which also is the case when the transverse test sample breaks; (2) the test is easy to perform, comparatively fast and almost independent of the crosshead speed; (3) the specimen can be of »clinical» size and shape; and (4) as the width and depth of the cavity mold are close to those of »clinical» cavities, the condensing procedures can be very similar to clinical conditions.

In this study there were no significant differences in one hour strengths between the »dry» and the intermediate mixes of the lathe cut amalgams. Lower strength resulted, however, for most of these amalgams when the »wet» mix was used. This was not in full agreement with the results of a prior study (*Forsten*, 1971), in which a significant difference in early strength between the »dry» and Jørgensen's »wet» technique was shown for only one of the six lathe cut amalgams studied. The conflicting results of these two studies may have been due to the difference in condensing pressure. If this was the case, it speaks in favor for using low condensing pressures in laboratory studies.

The results showed, furthermore, that the spherical amalgam had about the same early strength as the conventional lathe cut amalgams tested. This was in agreement with the prior study (*Forsten*, 1971), but not with the findings of *Boyer et al.* (1968) who reported the one hour strength of lathe cut amalgams to be only half that of spherical amalgams, when determined by a four point transverse strength test.

The low one hour strengths of the preamalgamated amalgams was in agreement with earlier findings (*Forsten*, 1971) although the preamalgamated alloy brands tested in that study were not the same as in the present study. The difference between the preamalgamated and the other amalgams was even greater in the present investigation which again may have been a result of the lower condensing pressure.

According to present theories the difference in the final strength between the amalgam specimens made from the three mixes could be due to two factors, difference in residual mercury content and/or the amount of porosity. Using a lower percentage of precondensation mercury usually resulted in lower strength. Since lower precondensation mercury should result in lower residual mercury content and thus higher strength (*Swartz & Phillips*, 1956 and *Skinner & Phillips*, 1967), it is unlikely that the higher residual mercury content could have been the cause of the lower strength. It is, therefore, likely that the lower strength when using the minimal mercury technique, was due to higher porosity. Residual mercury contents will be checked later by analysis and attempts will also be made to measure the porosity by estimating the density of the test specimens. Even if the transverse strength may not have direct application to clinical performance (*Mahler et al.*, 1970), the present results suggest that decreasing the precondensation mercury content increases the porosity, which certainly is of clinical significance (*Jørgensen*, 1967).

The higher variance of data with the »dry» mix indicates that when using this technique the strength of the amalgam is more sensitive to human variables during the condensation procedures.

With the three preamalgamated brands in this study two »higher» and two »lower» alloy/mercury ratios were used in addition to the recommended ratio when the final strength was studied. The results showed that the strength was significantly lower, at least in connection with the zinc-containing brands, when less mercury than recommended was used compared with the strength when the recommended ratio or excess mercury was used. The preamalgamated alloys are usually dispensed in bulk form and most manufacturers recommend only the fifty-fifty ratio. In clinical work, the accuracy of dispensing alloy filings and mercury in the proper proportions is often

questionable. Because of this and the results of this study, it is recommended to use slightly more than 50 per cent initial mercury with preamalgamated alloys.

The results of this study show that a moderate excess of precondensation mercury does not seem to decrease the early strength of amalgams, but does tend to increase the final strength. Thus, the claim of gaining higher final strength by using the minimal mercury technique cannot be justified. In fact, there is a greater risk that a filling made using the minimal mercury technique will have lower strength, especially since this technique produced a higher variance of the test results. Thus, it is suggested that clinically, excess precondensation mercury should be used.

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