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THE INFLUENCE OF THE CONDENSATION PRESSURE UPON CRUSHING STRENGTH AND MERCURY CONTENT OF AMALGAM

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In recent years the relation between condensation pressure, crushing strength, and mercury content of silver amalgam has been the object of studies which, to a certain extent, have given conflicting results. Thus *Crawford & Larson* (1954) showed for a single alloy that an increase of the condensation pressure from 1.4 kg up to 14 kg per mm² resulted in a continued increase of the crushing strength from 3710 kg to 4130 kg per cm² and a reduction of the mercury content from 48 to 35 %; their data are qualitatively in agreement with those reported by *Gray* (1919). *Swartz & Phillips* (1956) demonstrated a similar relationship between mercury content and crushing strength when the amount of mercury exceeded 53—55 %, while they found no correlation between these two factors at lower percentages of mercury. Unfortunately, the investigations made by these two authors are scarcely extensive enough to permit general conclusions. Likewise, it is doubtful whether any conclusions with regard to relationship between mercury content and crushing strength can be based on studies by *Rygge et al.* (1952) since they used specimens which possibly contained variables other than the mercury content.

Since the strength of amalgam is undoubtedly a factor of considerable clinical interest it is of importance to know whether packing methods by which the mercury content in the amalgam is brought down below 53–55 % will improve its crushing strength. The purpose of the work reported here was to examine this problem more closely.

METHODS

Alloy and mercury were weighed on a Dentatus amalgam balance in proportions as directed by the manufacturer, and in amounts to give the specimens made from the mix a length of 10 ± ½ mm. Trituration was done in a Wig-L-Bug mechanical mixer for so many seconds that all the alloy particles appeared well wetted. The amalgam was then transferred to a cylindrical test mold with an internal diameter of 5 mm, and an upper and lower piston of the same diameter as the mold. Condensation was carried out with a Durometer fitted with a dial gauge, which recorded the downward movement of the piston within the mold (see *Jørgensen et al.*, 1964). The condensation was started 2 minutes after finishing of the mix and lasted for 3 minutes. The amalgam specimens were then kept at room temperature for 72 hours, after which they were crushed at a rate of loading of 10 kg per sec. by means of a Losenhausen tester. For each variable 12 specimens were crushed.

The mercury content was determined in a number of preliminary experiments in the following way. Alloy and mercury were weighed first on the Dentatus balance, then on an analytical balance with a precision of 1 mg. When the amalgam specimen had been prepared, both the specimen and the expressed excess of mercury with alloy constituents were weighed. In a previous investigation an analysis by evaporation of this liquid phase had shown that its content of dissolved metals never exceeded 5 %, and rarely 3 %, by weight. Without introducing any appreciable error in calculating the percentage content of mercury, it could therefore be assumed (1) that the whole sample of weighed alloy was retained in the test specimens, and (2) that the amount of mercury in the specimen was the difference between weighed mercury and expressed liquid.

Ten experiments with weighing of alloy and mercury gave a mean value and a standard deviation of 1.136 ± 0.016 g and 1.675 ± 0.015 g, respectively. The calculated mercury content in ten specimens making up a corresponding series showed a value of 55.3 ± 0.37 %.

In view of the relatively small dispersion in these experiments for testing the accuracy of the method, it was decided to adopt simple calculation of averages in determining the mercury content of the amalgam specimens on which the investigation was to be based. As already mentioned, 12 specimens were made for each tested variable. Before and after preparation of such a series the containers with alloy and mercury were weighed. Besides the weight of the total amount of expressed mercury was determined. Based on these weighings it was possible to compute the average percentage of mercury for each series of 12 specimens.

In order to vary the mercury content of the specimens they were condensed under different pressures, viz. 0.8, 1.5, 2, 5, or 9.4 kg per mm^2. The first three of these pressures gave mercury contents corresponding to light, medium, and heavy hand condensation, while the pressures 5 and 9.4 kg per mm^2 gave more expressed mercury than it is possible to obtain by any clinical method used at present.

The investigation was carried out with six different alloys sold on the Danish market. Since the standard technique used does not ensure that differences between the products will occur in practical use as well, the trade names have been omitted.

RESULTS

The experimental results are shown in Tables 1 and 2, and in the graphs in Figures 1, 2, and 3. It can be seen that the crushing strength of all the amalgams increases with condensation pressure, at the same time as the mercury content decreases. The slope of the curves in Figures 1 and 2 gradually becomes less steep with increased condensation pressure. This shows that, within the

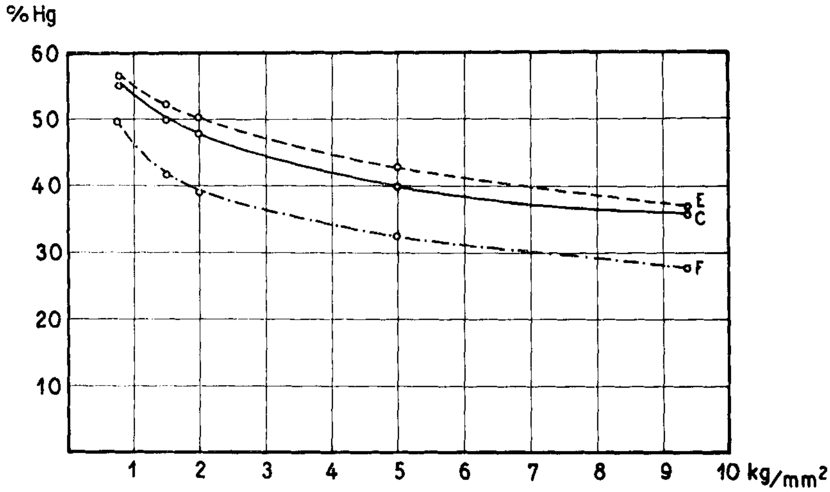

Fig. 1. The relation between condensation pressure and mercury content for amalgam from alloys E, C, and F.

range of pressures examined here, there is no critical limit beyond which an increase in crushing strength or a reduction in mercury content can no longer be obtained. The data (for example in Figure 3) also show that a reduction of the mercury content below 50 % results in an increase in crushing strength which can scarcely be characterized as unimportant. For amalgam obtained

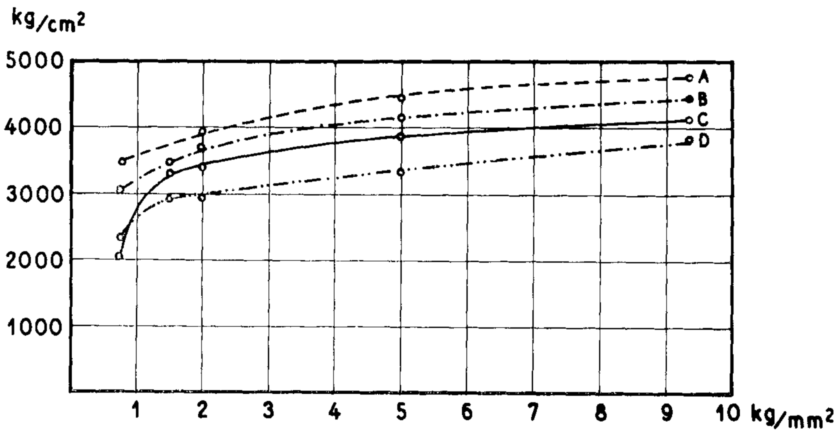

Fig. 2. The relation between condensation pressure and crushing strength for alloys A, B, C, and D.

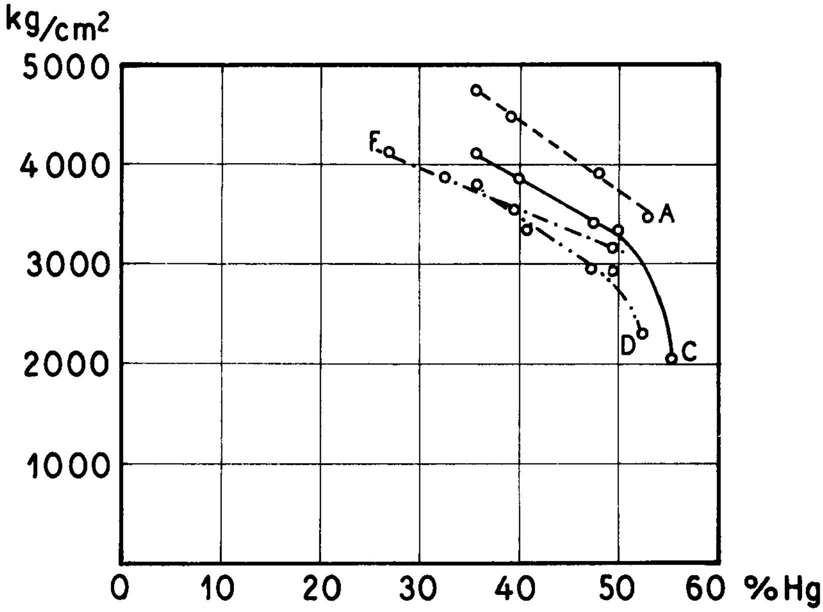

Fig. 3. The relation between mercury content and crushing strength for alloys A, C, D, and F.

with alloy A this increase is approximately 75 kg/cm²/%, while it is 42 kg/cm²/% for alloy F. The mercury content of an amalgam largely depends upon the type of alloy. For example, at a condensation pressure of 2 kg/mm² alloy E gives a mercury con-

Table 1

Crushing strength (kg/cm²) for amalgam specimens prepared with different condensation pressures (kg/mm²).

Condensation pressure	0.8	1.5	2.0	5.0	9.4
Alloy A	3490 ± 199	—	3934 ± 153	4475 ± 155	4750
» B	3055 ± 175	3465 ± 138	3695 ± 110	4160 ± 119	4455 ± 69
» C	2060 ± 152	3305 ± 76	3390 ± 98	3895 ± 114	4115 ± 149
» D	2300 ± 460	2920 ± 88	2920 + 36	3320 ± 111	3835 ± 75
» E	1870 ± 341	2920 ± 114	3160 ± 151	3715 ± 22	4275 ± 19
» F	3170 ± 147	—	3530 ± 40	3885 ± 88	4100 ± 83

Table 2

Mercury content (%) for amalgam specimens prepared under different condensation pressures (kg/mm²).

Condensation pressure	0.8	1.5	2.0	5.0	9.4
Alloy A	52.8	—	48.0	39.6	36.0
» B	52.9	49.2	47.9	41.3	36.3
» C	55.4	50.0	47.5	40.0	36.0
» D	52.2	49.1	47.2	40.9	35.9
» E	56.5	52.2	50.4	42.7	36.5
» F	49.8	41.3	39.4	32.6	27.7

tent of about 50 %, while alloy F gives a mercury content of about 39 %. The experiments further show that different amalgams with the same mercury content may have widely different crushing strength, and that different amalgams with the same crushing strength may differ considerably in mercury content.

SUMMARY

This is a study of the effect of condensation pressure upon crushing strength and mercury content af various amalgams, and of the relation between crushing strength and mercury content. The results are presented in Tables 1 and 2, and in Figures 1, 2, and 3. The experiments show that an increase of the condensation pressure from 0.8 to 9.4 kg/mm² results in a continued increase of the crushing strength and a reduction of the mercury content (Figures 1 and 2). The experiments also show (Figure 3) that a reduction of the mercury content of the amalgams below 50 % will result in an increase of the crushing strength from 40 to 75 kg/cm²/%.

RÉSUMÉ

INFLUENCE DE LA PRESSION APPLIQUÉE LORS DE LA CONDENSATION SUR LA RÉSISTANCE À L'ÉCRASEMENT ET SUR LA TENEUR EN MERCURE DE L'AMALGAME

Le présent travail est une étude de l'effet de la pression appliquée lors de la condensation sur la résistance à l'écrasement et sur la teneur en mercure de différents amalgames, et du rapport

entre la résistance à l'écrasement et la teneur en mercure. Les résultats sont présentés sur les tableaux 1 et 2, et sur les Figures 1, 2 et 3. Les expériences montrent qu'en augmentant la pression appliquée lors de la condensation de 0,8 à 9,4 kg/mm², on obtient une augmentation continue de la résistance à l'écrasement et une réduction de la teneur en mercure (Figures 1 et 2). Les expériences montrent aussi qu'une réduction de la teneur en mercure des amalgames jusqu'à des valeurs inférieures à 50 % résultera, pour la résistance à l'écrasement, en une augmentation allant de 40 à 75 kg/cm²/%.

ZUSAMMENFASSUNG

DIE EINWIRKUNG DES KONDENSATIONSDRUCKES AUF DIE DRUCKFESTIGKEIT UND DEN QUECKSILBERGEHALT DES AMALGAMS

Es wurden Untersuchungen angestellt darüber, in wie hohem Grad der Kondensationsdruck die Druckfestigkeit und den Quecksilbergehalt verschiedener Amalgame beeinflusst, sowie über den Zusammenhang zwischen Druckfestigkeit und Quecksilbergehalt. Die Ergebnisse sind in den Tabellen 1 und 2 und in den Abb. 1, 2 und 3 verzeichnet. Es ist zu erkennen, dass eine Erhöhung des Kondensationsdruckes von 0,8 auf 9,4 kg/mm² eine kontinuierliche Erhöhung der Druckfestigkeit und eine Minderung des Quecksilbergehalts mit sich führt (Abb. 1 und 2).

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