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THE INFLUENCE OF PRECONDENSATION MERCURY CONTENT AND MULLING ON THE TRANSVERSE STRENGTH OF AMALGAMS CONDENSED AFTER A DELAY

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The purpose of this study was to investigate the influence of changing the precondensation mercury content (initial mercury content) on the final strength of amalgams when the condensation was delayed. Another purpose was to study the effect on the transverse strength of mulling the amalgam mix after the delay. The material consisted of ten different brands of alloy. Three different alloy-mercury ratios were used with each alloy brand; Mix I about 50 % Hg, Mix II about 54 % Hg and Mix III about 59 % Hg. Rectangular amalgam test pieces, measuring $2 \times 2 \times 12$ mm, were condensed after a 5 minutes delay by hand using a load of about 17 kg/cm^2. The transverse strength test was performed after one week using three point loading. The five minutes delay of the condensation reduced the strength of the amalgams by 1 to 42 per cent depending on the brand of alloy and precondensation mercury content. The three preamalgamated amalgams were affected less by the delay than the other amalgams. Increasing the precondensation mercury content reduced the effect of the delay on the final strength. The »mulling» of the amalgam mix also decreased the effect of the delay. It was concluded that a moderate excess of initial mercury gives the dentist a longer condensing time thus allowing him to perform the condensing procedure with care.

Clinical success of dental amalgam depends mainly on two manipulative factors. The condensation should not take too long, because the strength decreases with increased condensing time (*Skinner & Phillips*, 1967). According to *Phillips et al.* (1969), a loss of strength of 10 to 20 per cent will result if the condensation is delayed 1 to 3 minutes and after 5 minutes the decrease will be 40 per cent. The second factor, perhaps even more important, is the care with which the condensation is performed. These two factors are in partial conflict. A compromise has to be made by using slow setting amalgams or by making the amalgam mix less sensitive to prolonged condensation. Another way is to triturate separately small portions of amal-

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gam so that each portion can be condensed carefully in less than two minutes. This procedure, however, is impractical, especially with large restorations.

It has been shown (*Jørgensen*, 1965) that a delay in condensation of 5 to 10 minutes decreases the compressive strength slightly, when an excess of precondensation mercury is used. In another study (*Forsten*, 1970) the present author came to a similar conclusion. When using a »wet» mix, with a moderate (5 to 10 %) excess of precondensation mercury, a delay of 5 or 10 minutes reduced only slightly the transverse strength of four of the six amalgams studied. When a »dry» mix was used, there was a definite reduction in strength for all the amalgams. Furthermore, one of the two spherical alloys studied was much more sensitive to a delay in condensation than the lathe cut alloys.

It has been assumed that there is a relationship between the setting rate of an amalgam and the amount of reduction in strength caused by a delay in condensation (*Skinner & Phillips*, 1967). Since an early strength test has been considered a good index of the setting rate (*American Dental Association*), in a prior study (*Forsten*, 1971) the one hour early strengths were compared with the amount of reduction in final strength caused by delayed condensation. However, no clear relationship was found between those two properties. A 90 kg/cm^2 condensing pressure was used for the lathe cut amalgams and a 20 kg/cm^2 pressure for the spherical amalgams in these studies (*Forsten*, 1970, 1971).

The purpose of the present study was to investigate the effect of three different precondensation mercury contents on the final transverse strength when the condensation was delayed and when a low condensing pressure of 17 kg/cm^2 was used. Some dentists restore the plasticity of an amalgam mix by mulling or kneading if it shows signs of stiffening during prolonged condensation. Another aim of the investigation was to study the effect of this procedure.

MATERIAL AND METHODS

The ten alloys investigated, the precondensation mercury contents and the test methods utilized have been described before (*Forsten*, 1972). In this study, however, the amalgams were not condensed immediately, but after a delay of 5 minutes. In addition, amalgam mixes of four of the ten alloys (T, H2, $H_{Zn\text{-}f}$ and P) were triturated again, for 6 seconds without a pestle

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in the capsule, after the 5 minute delay, but before beginning the condensation. To act as a control, samples of these four alloys were triturated for an additional six seconds without a pestle in the capsule immediately after the initial mixing and were then condensed without delay.

Six specimens were prepared and tested for each condition at room temperature ($23\pm2°C$).

RESULTS

Table I shows the mean transverse strengths with standard deviations for the ten amalgams condensed immediately and after a delay of 5 minutes. The values for the immediately condensed specimens have been presented previously (*Forsten,* 1972). The results were analyzed using an analysis of variance and Duncan's multiple range test at the 99 per cent confidence level. Solid lines indicate that there was no significant difference between values. Fig. 1 shows the per cent reduction in strength caused by delayed condensation. The mean strength after a delay of 5 minutes was significantly lower for all amalgams. From Table I and Fig. 1, it also can be seen that the minimal mercury technique (Mix I) gave lower strengths when the condensation was delayed than mixes with excess mercury. This was significant for all amalgams except brand U. Even for this amalgam, the strength increased with increasing mercury content, but the difference was significant only between Mixes II and III. For two amalgams (S and $T_{Zn\text{-}f}$) there was a significant difference between the strengths of all three mixes (Table I). It also can be seen that when the condensation was delayed and the »wet» mix was used, the strength of amalgams S, $T_{Zn\text{-}f}$, U, P, E and D was about the same as that of samples condensed immediately using the minimal mercury technique.

Table II demonstrates the percentage decrease of the final strength caused by a 5 minute delay in condensation and the one hour strengths expressed in terms of a percentage of the final strengths without a delay. The percentage values of one hour strength were calculated using mean strength values from an earlier study (*Forsten,* 1972). The table shows that the relative one hour strengths of the preamalgamated materials (E, $E_{Zn\text{-}f}$ and D) were less than half that of the other amalgams, while the reduction of the one week strength was less than five per cent for these amalgams when Mix III was used. Thus Table II reveals a relationship between low one hour strength and low sensitivity to delayed condensation, i.e. the group of preamalgamated amalgams (E, $E_{Zn\text{-}f}$ and D), and high one hour strength and high sensitivity to delayed condensation, i.e. the other amalgams (S, T, $T_{Zn\text{-}f}$,

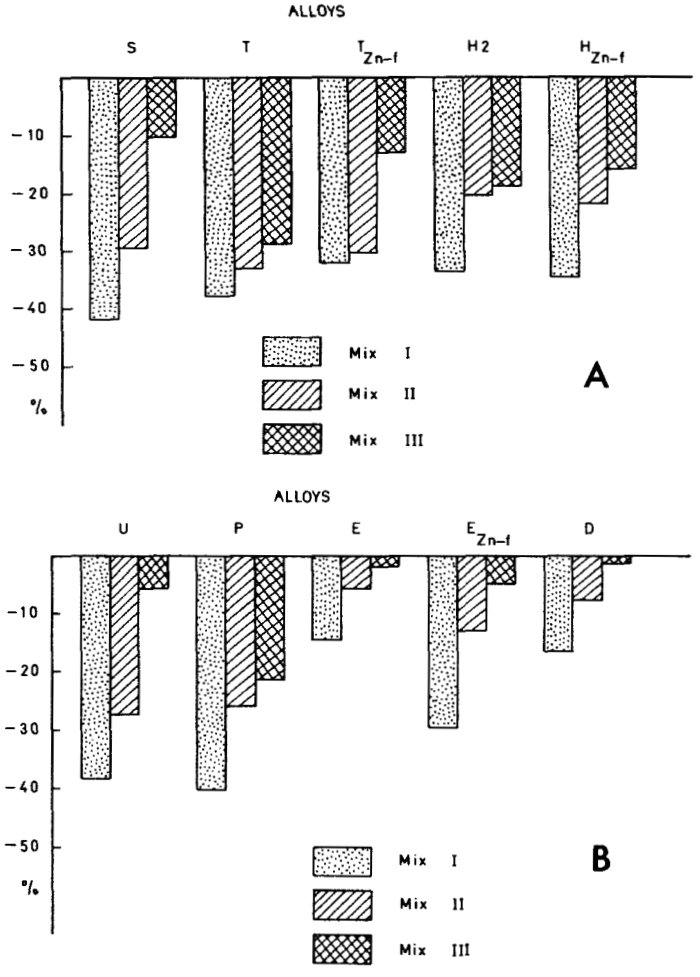

Fig. 1. Percentage decrease of one week transverse strength when the condensation was delayed by 5 minutes and when three mixes with different precondensation mercury contents were used.
A. Amalgams S, T, T_{Zn-f}, H2 and H_{Zn-f}
B. Amalgams U, P, E, E_{Zn-f} and D

H2, H_{Zn-f} and P). The dispersion amalgam U was an exception since Mix III resulted in an amalgam with high early strength but showed little reduction in final strength when the condensation was delayed.

Table III shows the transverse strength values and standard deviations for amalgams T, H2, H_{Zn-f}, and P when condensed immediately and after a delay of 5 minutes when the amalgams were (B) or were not (A) triturated

Table I

One week transverse strengths (kg/cm²) of amalgams condensed immediately and after 5 min. delay using three mixes with different precondensation mercury contents (about 50 %, about 54 % and about 59 % Hg)

Alloy	Mix*	Immediate condensation*		5 Min. delayed condensation	
		Mean	S D	Mean	S D
S	I	1278	112	740	99
	II	1421	27	1047	87
	III	1381	33	1236	52
T	I	1338	103	857	79
	II	1600	85	1064	80
	III	1533	39	1086	52
$T_{Zn\text{-}f}$	I	1318	121	896	134
	II	1651	64	1151	79
	III	1594	72	1382	112
H2	I	1403	148	932	157
	II	1536	113	1224	149
	III	1542	41	1254	86
$H_{Zn\text{-}f}$	I	1421	63	926	122
	II	1515	89	1186	66
	III	1471	89	1238	71
U	I	1095	43	676	114
	II	1114	70	807	57
	III	1090	43	1028	56
P	I	1192	115	709	132
	II	1425	43	1056	103
	III	1408	35	1107	111
E	I	1347	86	1146	138
	II	1432	36	1354	137
	III	1404	29	1378	63
$E_{Zn\text{-}f}$	I	1368	107	964	66
	II	1296	34	1128	109
	III	1194	34	1138	33
D	I	1382	63	1152	166
	II	1380	63	1273	118
	III	1376	51	1360	73

* See *Forsten*, 1972.

NOTE: Solid lines indicate no significant difference between mean values at the 99 % confidence level.

Table II.

Per cent decrease of one week transverse strength of amalgams after 5 min. delay of condensation and percentages of one week transverse strength at one hour

Alloy	Mix	One week strength	One hour strength
		% decrease-delayed condensation	% of one week strength
S	I	42.1	17.1
	II	26.4	16.9
	III	10.5	16.1
T	I	37.8	20.3
	II	33.5	16.4
	III	29.2	16.9
$T_{Zn\text{-}f}$	I	32.1	22.4
	II	30.3	19.1
	III	13.3	16.9
H2	I	33.6	20.1
	II	20.3	19.0
	III	18.7	16.8
$H_{Zn\text{-}f}$	I	34.8	18.1
	II	21.7	18.4
	III	15.8	15.5
U	I	38.3	25.8
	II	27.6	22.4
	III	5.7	24.1
P	I	40.5	22.2
	II	25.9	16.1
	III	21.4	14.9
E	I	14.9	6.5
	II	5.4	5.8
	III	1.9	5.0
$E_{Zn\text{-}f}$	I	29.5	6.8
	II	13.0	7.2
	III	4.7	6.1
D	I	16.6	8.1
	II	7.8	9.4
	III	1.2	8.1

Table III.

Transverse strength (kg/cm²) of amalgams T, H2, $H_{Zn\text{-}f}$ and P condensed immediately and after 5 min. delay using two different precondensation mercury contents with or without additional trituration prior to condensation

Alloy	Mix		Immediate condensation		Delayed condensation	
			Mean	S D	Mean	S D
T	I	A*)	1338	103	857	79
		B**)	1427	81	1161	185
	II	A	1600	85	1064	80
		B	1536	112	1430	185
H2	I	A	1403	63	932	157
		B	1270	98	1128	85
	II	A	1536	113	1224	149
		B	1534	32	1471	120
$H_{Zn\text{-}f}$	I	A	1421	63	926	122
		B	1354	104	1039	154
	II	A	1515	89	1186	66
		B	1418	27	1336	79
P	I	A	1192	115	709	132
		B	1333	124	1075	151
	III	A	1408	35	1107	111
		B	1385	70	1365	86

*) A = no additional trituration.
**) B = additional trituration for 6 sec. without a pestle prior to the condensation.
NOTE: For solid lines, see Table I.

for 6 additional seconds before the condensation. Mixes I and II (III with alloy P) which had a precondensation mercury content difference of about 4 %, were used. Differences between »standard» trituration (A) and trituration with additional »mulling» (B) were analyzed using a two-sided t-test at the 99 per cent confidence level. Solid lines indicate that there was no significant difference between the respective values. When the amalgams were condensed immediately, there were no significant differences in strength between the two methods of trituration. When the condensation was delayed by 5 minutes, additional »mulling» increased the strength for two amalgams (T and P)

significantly when using Mix I and for all amalgams when using Mix II (or III for alloy P).

DISCUSSION

The results of this study showed that using the minimal mercury technique without additional mulling, the loss in strength after a 5 minute delay in the condensation was nearly 40 per cent for about half of the amalgams studied. This agrees with the percentage loss reported by *Phillips et al.* (1965).

It has been suggested that the decrease in strength due to delayed condensation is caused partially by disrupting the crystaline structure. (*Skinner & Phillips*, 1967). The results of this study do not support that assumption since »mulling» the amalgam mix after a delay of 5 minutes decreased the influence of the delay. The »mulling» would be expected to increase the breakdown of the crystaline structure and consequently reduce the strength of the amalgam even more. An increase in residual mercury content has been reported to cause strength reduction (*Phillips et al.*, 1969). However, this study showed that mercury decreased the influence of the delay, although it might be expected that the excess mercury would result in increased residual mercury. Internal voids have also been reported after delayed condensation (*Phillips et al.*, 1969). In the opinion of the present author, one of the main causes for the decrease in strength is increased porosity. Increasing the plasticity of the amalgam mix by initially using an excess of mercury or additional »mulling» 5 minutes after the trituration reduced the detrimetral effect of the delayed condensation. The correlation between high plasticity of the amalgam mix and low porosity of the restoration has been reported by *Jørgensen* (1967).

The results confirmed the findings (*Forsten*, 1970) that the strength loss caused by a delay of condensation diminished significantly with increased precondensation mercury content. Clinically, the dentist wishes to use more than two minutes for condensing each mix without decreased final strength. This can be accomplished by using slow setting amalgam brands, i.e. pre-amalgamated material or by using fast setting brands with an excess of precondensation mercury. In the first case, however, the early strength will be low since the condensed restoration will harden slowly. However, when fast setting brands with an excess of precondensation mercury are used, only the setting of the mix is retarded and not the hardening of the restoration. The results showed that there even was a significant difference

between the »dry» and the intermediate mix. This indicated that it is not necessary to use a large excess of mercury, but a moderate excess will decrease the influence of delayed condensation enough to allow the dentist sufficient time to condense with care. During non-typical working conditions, e.g. dentists without assistants, there may be occasions when unusually long condensing times are needed. Under these circumstances, the use of fast setting amalgam with an initial mercury content exceeding 60 per cent or even preamalgamated amalgams with more than 55 per cent initial mercury content may be advisable. The routine use of too large an excess of initial mercury in clinical practice should be avoided because of the inconvenience of handling a »sloppy» mix and because of the danger of contaminating the office with mercury. Furthermore, an amalgam mix which has lost sufficient plasticity should never be condensed.

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REFERENCES

American Dental Association: Guide to dental materials and devices, ed. 5, Chicago, Ill., 1970—71.

Forsten, L., 1970: Inverkan av försenad kondensering på böjhållfastheten hos dentala amalgam (English summary). Suom. Hammaslääk. Toim. *66:* 28—35.

Forsten, L., 1971: Influence of manipulation technique on early strengths of different amalgams. Suom. Hammaslääk. Toim., *67:* 211—218.

Forsten, L., 1972: Influence of precondensation mercury content on the transverse strength of amalgams. Acta odont. scand. *30:* 441—452.

Jørgensen, K. D., 1965: The effect of delayed condensation upon the crushing strength of amalgam. Acta odont. scand. *23:* 271—275.

Jørgensen, K. D., 1967: Dentale amalgamer, Danmark 1967, Odontologisk Bokhandels Forlag.

Phillips, R. W., M. L. Swartz & R. D. Norman, 1969: Materials for the practicing dentist, St. Louis, The C. V. Mosby Co.

Skinner, E. W. & R. W. Phillips, 1967: The science of dental materials, ed. 6, Philadelphia and London, W. B. Saunders Company.

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