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THE STRENGTH OF CORRODED AMALGAM

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Investigations have been made into the effect of selective total dissolution of the γ_2 phase in dental amalgams on the tensile strength of the amalgams. The mean reduction in strength for four brands with a relatively low mercury content was 16.4 %. The mercury content of the amalgams was positively correlated with the percentage reduction in strength. The results indicate that corrosive dissolution of the γ_2 phase in margins of amalgam fillings with a relatively high content of mercury may reduce their durability significantly.

Previous investigations (references, see *Jørgensen & Saito*, 1970) have shown that the characteristic feature of corrosion of dental amalgam is an anodic attack on the tin-mercury phase of the amalgam, the so-called γ_2 phase. As a result of corrosion the γ_2 phase decomposes as tin ions and metallic mercury. The tin ions are frequently deposited as heavy soluble compounds on or adjacent to the anode, whereas the metallic mercury diffuses into the amalgam, causing mercuroscopic expansion.

At the margins of amalgam fillings the surfaces facing the cavity wall frequently act as the anode, apparently because of the relatively low concentration of oxygen in the microgap between the filling and the cavity wall. Unilateral mercuroscopic expansion of an amalgam margin less than 90° will cause this margin to deflect away from the cavity wall and become unsupported (*Jørgensen*, 1965). If deflection is sufficiently great, the margin will fracture under the influence of masticatory forces; the minimum degree of deflection necessary to cause fracture under such forces is directly proportional to the flexural strength or tensile strength of the amalgam margin.

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During the course of the anodic corrosion the γ_2 phase is eliminated completely from the corroded marginal areas (see *Jørgensen & Saito*, 1970), and it must be assumed that the strength of the amalgam is reduced accordingly. The purpose of the present work is to investigate the effect of total dissolution of the γ_2 phase on the tensile strength of the amalgam.

MATERIALS AND METHODS

The brands of dental amalgam alloy stated in Table I were employed in the investigation; all alloys complied with the composition and property requirements of F.D.I. specification no. 1.

Cylindrical specimens with a diameter of 5.00 mm and a length of 5.0 ± 0.1 mm were made by means of a method described elsewhere (*Jørgensen & Saito*, 1970). Brands A and B, which are pre-amalgamated, were triturated with 55 % mercury, whereas brands C and D were triturated with 60 % mercury. The mercury content in the final specimens was determined by gravimetric means as the difference between the weight of the specimen and the weight of the alloy used to manufacture the specimen.

Four groups of specimens, 20 in each group, were prepared of each brand of alloy. The respective groups were treated in different ways, as indicated in Table II, before the tensile strength was measured; the treatment in all cases was conducted at a temperature of 37°C.

The specimens in groups II and IV were subjected to a thorough vacuum treatment in distilled water immediately prior to immersion in the sodium

Table I.
Brands of alloy employed in the investigation

No.	Name	Batch	Manufacturer
A	Argos Non-Zinc	4036	A.B. Svenska Dental Instrument, Sweden
B	STA 68	1400	Guldsmeds Aktiebolaget i Stockholm GAB, Sweden
C	True Dentalloy	356944	S.S. White Dental Mfg. Co., England
D	True Dentalloy Zinc-Free	196413	S.S. White Dental Mfg. Co., England.

Table II.

Treatment of the individual groups of specimens before measurement of the tensile strength

Group	1st week	2nd—33rd week	34th—37th week
I	In air		
II	In air	In 10 % sodium citrate solution	
III	In air	In air	
IV	In air	In 10 % sodium citrate solution	In air

citrate solution in order to ensure the best possible contact between the amalgam and the citrate solution. At the end of the 33rd week the specimens in group IV were vacuum-treated in distilled water to remove all traces of citrate solution from the amalgam.

Previous investigations (*Jørgensen & Saito*, 1970) have shown that all the γ_2 phase in amalgam made from various alloys was dissolved after 32 weeks in a 10 % solution of sodium citrate at 37°C. A check of specimens from groups II and IV during the present investigation confirmed this observation.

Since there is a possibility that unreacted mercury may remain in the amalgam and reduce the latter's mechanical properties immediately after treatment with sodium citrate solution, the specimens in group IV — after cleansing by vacuum treatment in distilled water — were stored for a further four-week period in air at 37°C. It was assumed that any free mercury would react during this period with remaining γ phase.

The tensile strength was calculated on the basis of the specimens' diametrical compressive strength in accordance with the formula:

$$M = \frac{P}{\pi \cdot r \cdot l}$$

where P is the registered force exerted by the testing apparatus at the moment the specimen fractures, and r and l are the radius and length of the specimen respectively. Testing was conducted at the rate of 1 mm per minute.

RESULTS

The mercury content of the groups investigated is shown in Table III; the values for tensile strength are shown in Table IV and in the diagram Fig. 1.

Table III.

Percentage mercury content of investigated specimens

Group	A		B		C		D	
	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.
I	46.0	0.5	38.9	0.5	44.2	0.3	45.2	0.3
II	45.8	0.5	39.0	0.3	44.1	0.3	45.2	0.3
III	45.8	0.4	39.2	0.3	44.1	0.3	45.0	0.4
IV	45.9	0.5	39.0	0.4	44.0	0.3	44.9	0.3

n = 20

The reduction in tensile strength as a result of dissolution of the γ_2 phase in specimens of the same age is illustrated by comparing groups II and III. For brands A—D the reduction is 18.8 %, 12.4 %, 16.3 % and 18.2 % repecstively; in all cases differences are strongly significant. The mean value for strength reduction for the four brands is 16.4 %.

The difference between groups II and IV does not indicate a general tendency. In the case of brand A the strength increases by 12.0 % (this increase is statistical significant) whereas in the case of the other brands it reduces slightly, by 3.2 %, 1.8 % and 4.3 % respectively.

Table IV.

Tensile strength of investigated specimens in kp/mm²

Group	A		B		C		D	
	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.
I	4.71	0.39	5.48	0.26	5.51	0.28	5.28	0.25
II	3.75	0.40	4.71	0.41	4.47	0.17	4.44	0.12
III	4.62	0.35	5.38	0.42	5.34	0.33	5.43	0.32
IV	4.20	0.62	4.56	0.36	4.39	0.19	4.25	0.13

n = 20

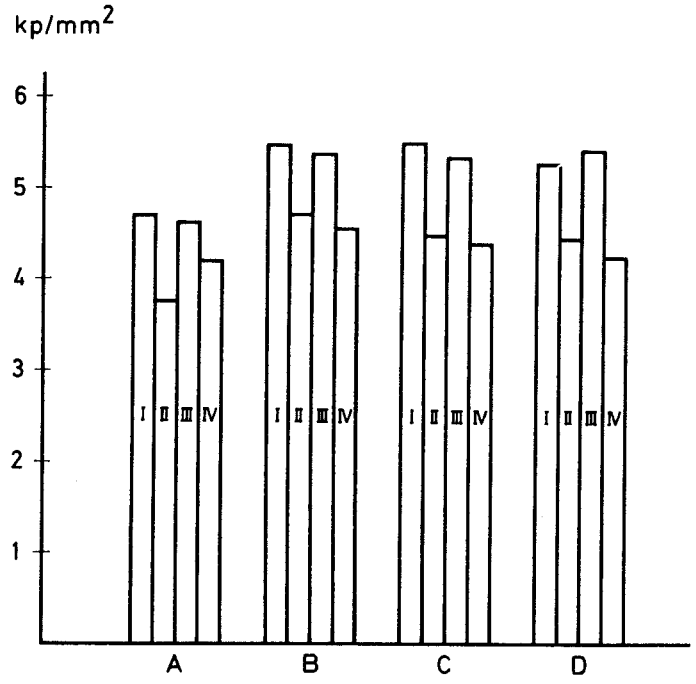

Fig. 1. Diagrammatic listing of the investigation results for the four brands A—D. The column headings I—IV indicate the pre-treatment of specimens (see Table II) before measurement of the tensile strength.

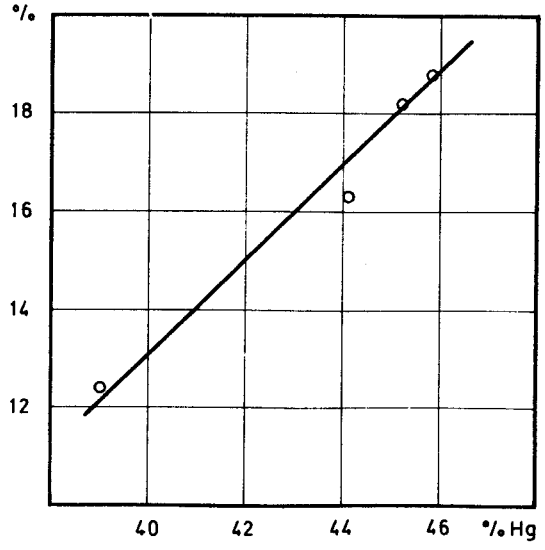

Fig. 2. Relationship between the mercury content of the hardened amalgam (abscissa) and the reduction in strength in percentage as a consequence of total dissolution of the γ_2 phase.

DISCUSSION

It seems obvious that selective total dissolution of one of the three main phases, viz. the γ_2 phase, in dental amalgam must result in a weakening of the amalgam. This assumption has been confirmed by the present investigation; the mean tensile strength for the four amalgams studied was reduced by 16.4 %. The percentage reduction in strength is proportional to the mercury content of the set amalgam, viz. approx. 1 % reduction in strength per 1 % increase in the content of mercury (Fig. 2). In effect this correlation is no source of surprise, as earlier investigations (*Otani & Jørgensen*, 1967) have shown that the mercury content of hardened amalgam is directly proportional to the volume of the γ_2 phase. Despite the fact that the reduction in strength of the amalgams examined in the present work after total dissolution of the γ_2 phase may be termed moderate, the results indicate that corrosive dissolution of the γ_2 phase in amalgam fillings with a relatively high content of mercury can reduce their durability considerably.

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