From:
The Department of Technology,
*Royal Dental College,*
Copenhagen, Denmark

# THE RELATIONSHIP BETWEEN TENSILE STRENGTH AND CARVABILITY OF DENTAL AMALGAMS

*by*
KNUD DREYER JØRGENSEN
KAZUYOSHI ISENOUMI

## INTRODUCTION

The Federation Dentaire Internationale specification No. 1 (points 3. 1. 3) for dental amalgam alloy requires that »The amalgam shall be susceptible to carving immediately after condensation and shall remain so for at least 15 minutes after amalgamation». Similar requirements are prescribed in other specifications for amalgam alloy. None of the specifications, however, contains any method for determination of the carvability of the amalgam, and so far no correlation seems to have been shown between an objectively measurable property of dental amalgams and their carvability. It is the purpose of this work to investigate whether the carvability of amalgam is correlated with its tensile strength.

## MATERIALS AND METHODS

The amalgam alloys used in the investigation are listed in Table I. Brands A—F complied with the requirements of the specification No. 1 for dental amalgam alloy, while brand G deviated from these requirements, both with regard to composition (silver content about 50 %) and to properties. The mercury fulfilled the requirements of F.D.I. specification No. 2 for dental mercury.

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Table I
*Brands of amalgam alloy*

| No. | Name | Batch No | Brand | Notes |
|---|---|---|---|---|
| A | True Dentalloy | 116719 | S. S. White Dent. Mfg. Co., G. B. | medium grained |
| B | New True Dentalloy | 996637 | S. S. White Dent. Mfg. Co., G. B. | fine-grained |
| C | Standard | 3717 | A.-B. Svenska Dentalinstrument | medium grained |
| D | Spherical amalgam alloy | — | Shofu Dental Mfg. Co. | very fine-grained |
| E | Sta 68 | 9257 | Guldsmeds Aktiebolaget, Stockholm | preamalgamated |
| F | Solila fine grain | 13 0 H3 | De Trey Frères S. A. | preamalgamated |
| G | Agestan 50 | 5768 | Bayer, Leverkusen | low silver content |

The alloy/mercury ratio by weight was 5:7 for brands A—D and 5:5 for the other brands. The mix contained sufficient alloy to give the test specimens described below a length of 10.0 ± 0.5 mm. Trituration took place in a Wig-L-Bug with pestle in the plastic capsule and was completed in 20 seconds.

The amalgam was condensed into a cylindrical steel mold with a diameter of 5.00 mm by means of pistons, about 0.01 mm smaller in diameter than the mold. The condensing pressure was held constant at 40 kp. Condensation was started two minutes after completion of the mix and continued for three minutes. The specimens were removed immediately after condensation.

The tensile strength was determined by the so-called cleavage test (*Carneiro & Barcellos*, 1953; *Krenchel*, 1962), in which the specimen is loaded at right angles to the long axis of the cylinder (diametrical compression). Loading was carried out in a Losenhausen compression and tensile testing machine at a rate of 1 kp per sec. The ultimate tensile strength was calculated from the formula

$$T = \frac{P}{\pi \cdot r \cdot l} \text{ kp/mm}^2,$$

where P is the breaking load in kp, r the radius of the specimen (2.50 mm), and l the measured length of the specimen in mm.

The carvability was measured in the following way. The specimen was placed with its cylindrical axis horizontally in a semi-cylindrical mold, which at the same time supported one of its end surfaces (Fig. 1). The carving instrument was made of hardened, stainless steel and had a sharp, thin blade with a straight cutting edge. During carving the blade was held at a constant angle (135°) in relation to the long axis of the specimen by means of a slit, which could be moved parallel to this axis (Fig. 1). The semi-cylindrical mold which held the specimen during carving was placed on a balance with a flat table (Fig. 2) so that it was possible to control the pressure of

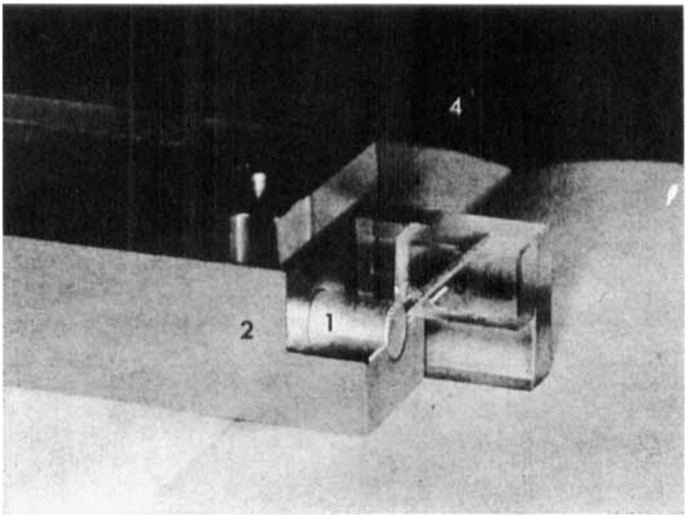


Fig. 1. Equipment for standardized carving of amalgam. 1, test specimen. 2, holder for specimen. 3, horizontally sliding slit for guidance of the carver. 4, table of the balance.

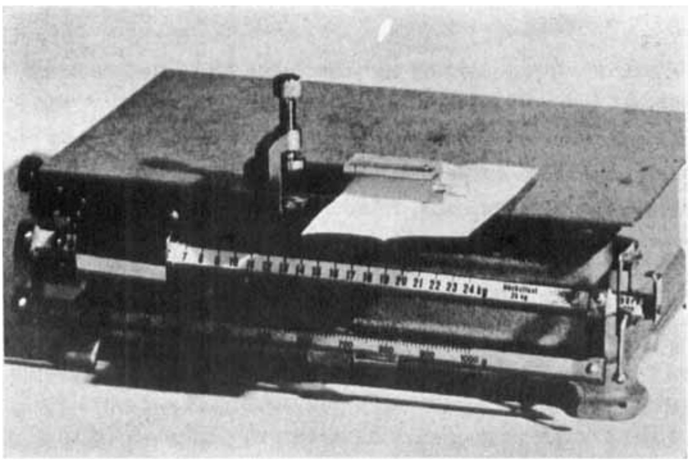

Fig. 2. Mounting of the carving apparatus on the balance.

the carver upon the specimen. The pressure was in all the experiments 200 p with a maximum deviation of 20 p.

Carving was started after different periods from condensation was finished. A given surface area of the specimen was carved with a single stroke and the removed amalgam was collected for subsequent weighing. The weight of the collected material was taken as a direct measure for the carvability at the given time. After each cut with the carver the specimen was rotated so much on its long axis that another, intact area was made accessible for carving. The time interval between each cut on a specimen was one minute, each carving movement occupied about two seconds, and the marks left by the carver had a length of $5.48 \pm 0.15$ mm (mean value and standard deviation of 50 marks).

Table II

*Control of carver*

*Carvability (mg) of alloy B at the beginning and the end of the tests*

N = 5

| Minutes after condensation | Start of tests $\bar{x}$ | S.D. | Completion of tests $\bar{x}$ | S.D. | t-values |
|---|---|---|---|---|---|
| 1 | 5.3 | 0.9 | 5.0 | 0.4 | 0.68 |
| 4 | 2.6 | 0.9 | 2.5 | 0.1 | 0.25 |
| 7 | 1.4 | 0.2 | 1.6 | 0.1 | 2.00 |
| 10 | 1.0 | 0.2 | 1.0 | 0.1 | 0.00 |
| 13 | 0.5 | 0.1 | 0.5 | 0.1 | 0.00 |

All the brands were measured for carvability five times each minute after condensation.

To find out whether the properties of the carver had altered during the experiments carving of the brand B that had been carved first was resumed after termination of all the tests. The results appear in Table II.

The low t-values show that the factor investigated remained unchanged during the tests.

## RESULTS

The values found for tensile strength and carvability are given in Tables III and IV, while the graph in Fig. 3 illustrates the influence of time upon the two properties for alloy F.

Table III

*Tensile strength (kp/mm²) for the various brands at different times after condensation was completed*
N = 5

| Minutes after | A | | B | | C | | D | | E | | F | | G | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| condensation | $\bar{x}$ | S.D. | $\bar{x}$ | S.D. | $\bar{x}$ | S.D. | $\bar{x}$ | S.D. | $\bar{x}$ | S.D. | $\bar{x}$ | S.D. | $\bar{x}$ | S.D. |
| 1 | 0.020 | 0.005 | 0.128 | 0.007 | 0.156 | 0.010 | 0.056 | 0.005 | 0.102 | 0.006 | 0.084 | 0.017 | 0.205 | 0.010 |
| 3 | 0.162 | 0.010 | 0.063 | 0.005 | 0.200 | 0.003 | 0.079 | 0.004 | 0.107 | 0.005 | 0.121 | 0.006 | 0.215 | 0.013 |
| 5 | 0.205 | 0.003 | 0.200 | 0.009 | 0.224 | 0.014 | 0.103 | 0.007 | 0.132 | 0.007 | 0.145 | 0.005 | 0.219 | 0.010 |
| 7 | 0.241 | 0.015 | 0.234 | 0.008 | 0.259 | 0.003 | 0.121 | 0.008 | 0.150 | 0.006 | 0.150 | 0.011 | 0.217 | 0.015 |
| 10 | 0.318 | 0.012 | 0.280 | 0.008 | 0.290 | 0.011 | 0.173 | 0.012 | 0.160 | 0.003 | 0.166 | 0.007 | 0.225 | 0.010 |
| 13 | 0.367 | 0.019 | 0.341 | 0.007 | 0.347 | 0.013 | 0.236 | 0.008 | 0.185 | 0.012 | 0.209 | 0.007 | 0.219 | 0.006 |
| 16 | | | | | | | 0.252 | 0.006 | 0.211 | 0.013 | 0.236 | 0.007 | 0.219 | 0.018 |
| 18 | | | | | | | | | 0.225 | 0.009 | | | 0.225 | 0.012 |
| 19 | | | | | | | 0.315 | 0.007 | | | 0.275 | 0.008 | | |
| 21 | | | | | | | | | 0.242 | 0.010 | | | 0.231 | 0.016 |
| 24 | | | | | | | | | 0.275 | 0.005 | | | 0.236 | 0.012 |

## DISCUSSION

The curve in Fig. 3 which illustrates the relation between age and tensile strength of the specimens is straight-lined, and its slope a measure for the mechanical setting rate of the amalgam. The other brands gave curves of similar shape. Their setting rates in kp/mm²/min. were for A: 0.021, B: 0.018, C: 0.016, D: 0.014, E: 0.008, F: 0.011, and G: 0.001. It has not been possible to demonstrate any connection between these values and the subjective assessment of the setting rate based on observing how soon the amalgam lose plasticity during condensation.

The curve in Fig. 3 which shows the relation between age and carvability of the specimens expresses an exponential function. In a co-ordinate system with logarithmic abscissa this curve is a straight line. The corresponding curves obtained with the other brands follow a similar pattern. An exception was however brand G with an almost constant carvability throughout the experimental period of 24 minutes.

The graph in Fig. 4 shows the relation between carvability and tensile strength for amalgams A—F. It is seen that these two properties were well correlated. Drawn in a coordinate system with logarithmic abscissa the curve in Fig. 4 becomes straight-lined. Product G falls outside this system.

Thus it is possible to measure and express the carvability of a standard amalgam indirectly by means of its tensile strength. This has the advantage that tensile strength is a property which is measurable by an international

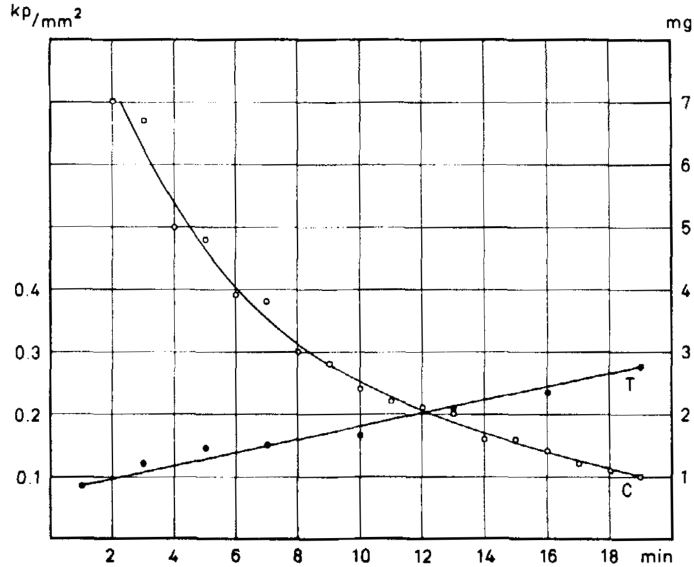


Fig. 3. The relation between age, tensile strength in kp/mm² (curve T), and carvability in mg (curve C) for brand F. The age is reckoned from the end of condensation.

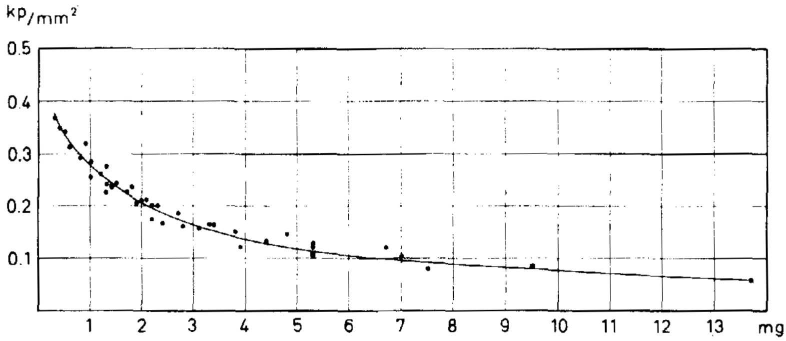


Fig. 4. The relation between carvability and tensile strength for brands A—F. From a practical point of view amalgam with a tensile strength exceeding 0.3 kp/mm² may be described as no more carvable.

standard technique with good accuracy of reproduction. A similar technique is not available for determination of carvability.

It is the impression of the present authors that an amalgam having a tensile strength of 0.3 kp/mm² or more is no longer clinically carvable. The

Table IV

*Carvability (mg) for the various brands at different times after condensation was completed*
N = 5

| Minutes after | A | | B | | C | | D | | E | | F | | G | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| condensation | $\bar{x}$ | S.D. | $\bar{x}$ | S.D. | $\bar{x}$ | S.D. | $\bar{x}$ | S.D. | $\bar{x}$ | S.D. | $\bar{x}$ | S.D. | $\bar{x}$ | S.D. |
| 1 | 5.3 | 1.5 | 5.3 | 0.9 | 3.1 | 0.8 | 13.7 | 3.3 | 7.0 | 0.8 | 9.5 | 2.6 | 0.6 | 0.1 |
| 2 | 3.7 | 0.6 | 4.2 | 1.2 | 2.3 | 0.4 | 10.1 | 0.5 | 6.5 | 0.5 | 7.0 | 1.6 | 0.4 | 0.1 |
| 3 | 3.4 | 0.9 | 3.3 | 0.7 | 2.2 | 0.4 | 7.5 | 1.8 | 5.3 | 0.6 | 6.7 | 1.6 | 0.4 | 0.1 |
| 4 | 2.5 | 0.2 | 2.6 | 0.9 | 1.7 | 0.3 | 6.6 | 1.6 | 4.7 | 0.9 | 5.0 | 0.8 | 0.4 | 0.1 |
| 5 | 1.9 | 0.4 | 2.3 | 0.6 | 1.3 | 0.3 | 5.3 | 0.4 | 4.4 | 0.9 | 4.8 | 1.0 | 0.3 | 0.1 |
| 6 | 1.8 | 0.5 | 1.6 | 0.3 | 1.2 | 0.1 | 4.4 | 0.8 | 4.0 | 0.4 | 3.9 | 0.4 | 0.3 | 0.1 |
| 7 | 1.3 | 0.3 | 1.4 | 0.2 | 1.2 | 0.2 | 3.9 | 1.0 | 3.8 | 0.6 | 3.8 | 0.6 | 0.3 | 0.1 |
| 8 | 1.2 | 0.3 | 1.4 | 0.2 | 0.9 | 0.2 | 2.8 | 0.3 | 3.4 | 0.3 | 3.0 | 0.5 | 0.3 | 0.1 |
| 9 | 0.9 | 0.2 | 1.2 | 0.2 | 0.9 | 0.1 | 2.8 | 0.7 | 3.2 | 0.4 | 2.8 | 0.2 | 0.3 | 0.1 |
| 10 | 0.8 | 0.2 | 1.0 | 0.2 | 0.8 | 0.1 | 2.2 | 1.1 | 2.8 | 0.6 | 2.4 | 0.7 | 0.3 | 0.1 |
| 11 | 0.6 | 0.2 | 0.8 | 0.2 | 0.7 | 0.1 | 2.4 | 0.7 | 2.7 | 0.6 | 2.2 | 0.5 | 0.3 | 0.1 |
| 12 | 0.5 | 0.2 | 0.7 | 0.2 | 0.6 | 0.1 | 1.9 | 0.5 | 2.6 | 0.4 | 2.1 | 0.5 | 0.3 | 0.1 |
| 13 | 0.3 | 0.1 | 0.5 | 0.1 | 0.4 | 0.1 | 1.8 | 0.5 | 2.7 | 0.6 | 2.0 | 0.4 | 0.3 | 0.1 |
| 14 | | | | | | | 1.6 | 0.5 | 2.7 | 0.3 | 1.6 | 0.3 | 0.3 | 0.1 |
| 15 | | | | | | | 1.6 | 1.6 | 2.2 | 0.3 | 1.6 | 0.4 | 0.3 | 0.1 |
| 16 | | | | | | | 1.0 | 0.3 | 2.1 | 0.3 | 1.4 | 0.4 | 0.4 | 0.1 |
| 17 | | | | | | | 1.1 | 0.2 | 1.6 | 0.2 | 1.2 | 0.2 | 0.5 | 0.1 |
| 18 | | | | | | | 0.6 | 0.3 | 1.7 | 0.2 | 1.1 | 0.2 | 0.4 | 0.1 |
| 19 | | | | | | | 0.6 | 0.3 | 1.7 | 0.1 | 1.0 | 0.2 | 0.4 | 0.1 |
| 20 | | | | | | | | | 1.5 | 0.1 | | | 0.3 | 0.1 |
| 21 | | | | | | | | | 1.5 | 0.1 | | | 0.3 | 0.1 |
| 22 | | | | | | | | | 1.3 | 0.1 | | | 0.3 | 0.1 |
| 23 | | | | | | | | | 1.2 | 0.2 | | | 0.3 | 0.1 |
| 24 | | | | | | | | | 1.3 | 0.3 | | | 0.3 | 0.1 |

standard amalgams under test passed this limit at the following times after amalgamation. A: 15 min., B: 16 min., C: 15 min., D: 23 min., E: more than 30 min., and F: 26 min. Brand G displayed no appreciable change in carvability or tensile strength during the first 30 minutes following amalgamation.

## SUMMARY

Investigations have been made on the relationship between the tensile strength and the carvability of dental amalgams. The results for six brands of amalgam alloy, all complying with the requirements in the F. D. I. specification No. 1, showed good correlation between the two properties investigated. An amalgam may be characterized as no more carvable, when its tensile strength has reached a value of 0.3 kp/mm$^2$ or more.

### RÉSUMÉ

### RAPPORT ENTRE LA RÉSISTANCE À LA TRACTION DES AMALGAMES DENTAIRES ET LEUR APTITUDE À ÊTRE SCULPTÉS

Des recherches ont été effectuées sur le rapport entre l'aptitude des amalgames dentaires à être modelés au moyen d'instruments tranchants et leur résistance à la traction; pour 6 produits remplissant les exigences de la spécification No 1 de la F. D. I., les résultats montrent qu'il existe une bonne corrélation entre ces deux propriétés. Lorsque la résistance à la traction des amalgames a atteint 0,3 kg/mm² ou plus, on peut, du point de vue pratique, considérer qu'ils ne sont plus en état d'être sculptés.



### ZUSAMMENFASSUNG

### DIE RELATION ZWISCHEN ZUGFESTIGKEIT UND KARVABILITÄT BEI DENTALEN AMALGAMEN

Es sind über die Relation zwischen Karvabilität und Zugfestigkeit dentaler Amalgame Untersuchungen ausgeführt worden; die Ergebnisse für 6 Fabrikate, die den Anforderungen der F. D. I. Spezifikation Nr. 1 entsprechen, zeigen, dass die beiden Eigenschaften wohlkorreliert sind. Wenn die Zugfestigkeit der Amalgame einen Wert von 0,3 kp/mm² oder mehr erreicht hat, sind sie von einem praktischen Gesichtspunkt aus als nicht länger schneidbar zu bezeichnen.


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Address:

*Department of Technology,*
*The Royal Dental College,*
*Copenhagen,*
*Denmark*