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ADAPTABILITY OF DENTAL AMALGAMS

by

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By adaptability of a material is understood its ability, under plastic deformation, to reproduce the surface details of a solid. Adaptability is a macroscopic as well as a microscopic and submicroscopic phenomenon, i.e. it concerns reproduction of surface details which can be observed with the naked eye or under the microscope or which are invisible in the optical microscope.

The ability of a plastic, mechanically homogeneous material to reproduce surface detail depends exclusively on its viscosity, on the pressure with which it is forced against the solid surface, and on the length of time the pressure is applied. By using sufficient pressure and sufficient time complete adaptability can be achieved between such a material and a solid surface with any degree of macroscopic or microscopic surface roughness.

The situation is somewhat different with mechanically homogeneous materials of the elastic-plastic type. After adaptation under pressure to a solid surface these materials will show some elastic relaxation when the pressure is removed. Consequently, they can never attain complete adaptability.

Viscous mixes of powder and liquid where the liquid wholly or partly is disappearing during the setting process, will present quite special conditions with regard to adaptability, somewhat depending upon, e.g., the nature of the setting process. If the properties of the powder undergo little or no change during the

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setting process, the adaptability of the mix will be determined to a considerable degree by the properties of the particular powder used. Grain size and grain size distribution of the powder, particle shape and surface, and the elastic-plastic properties of the powder material will all be able to influence the adaptability of the mix. As regards silver amalgam, it should be pointed out that the superficial softening of the powder particles during amalgamation will contribute to better adaptability.

The importance of good adaptability in certain dental materials is often self-evident. For amalgams good adaptability means good retention and diminished risk of penetration of saliva, food debris, bacteria, etc. In addition, good adaptability means a more perfect support of the filling margin, a factor which is undoubtedly of essential importance to the duration of this margin. (In a theoretical and experimental study which is being made on the durability of amalgam margins, this question will be dealt with in detail.) It should be added that a prerequisite for evaluating the adaptability of an amalgam is, of course, that the amalgam does not pull away from the cavity wall as a result of the hardening process, delayed expansion, thermal expansion or contraction, plastic deformation or other factors.

METHODS

Observation of amalgam surfaces which have been condensed and set in contact with a polished, plane steel plate provided with regular scratches (Figures 1 and 2) will reveal the characteristic differences between amalgam with good and less good adaptability. Poor adaptability, unlike good adaptability, gives defective, rough amalgam surfaces, and it is immediately apparent that these surface defects are responsible for the failure of the material to reproduce in detail the scratches in the steel surface, i.e. for the poor adaptability of the amalgam. This relationship provides a basis for metric expression of the adaptability, since the degree of surface roughness can be expressed by standardized roughness measurement of an amalgam surface which has been sought adapted to a flat, polished, non-scratched steel surface. The greater roughness such a measurement shows, the less adaptability has the amalgam, and *vice versa*.

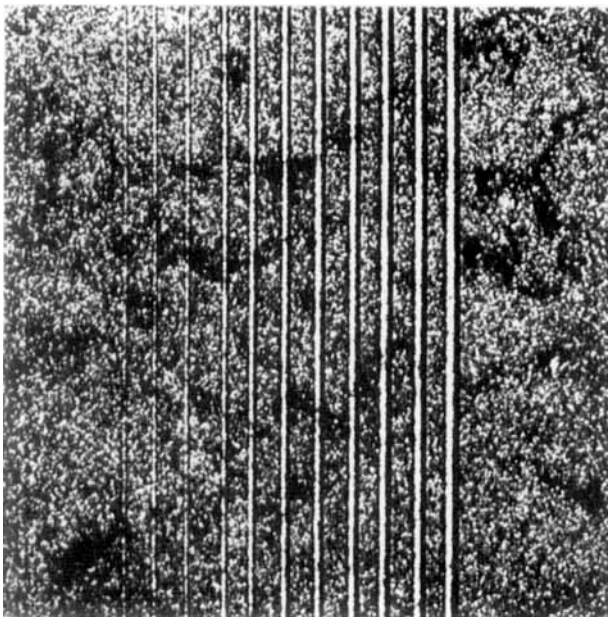


Fig. 1. Amalgam surface condensed and set in contact with a plane, polished steel surface with parallel scratches (cf. Fig. 2). 20 ×.

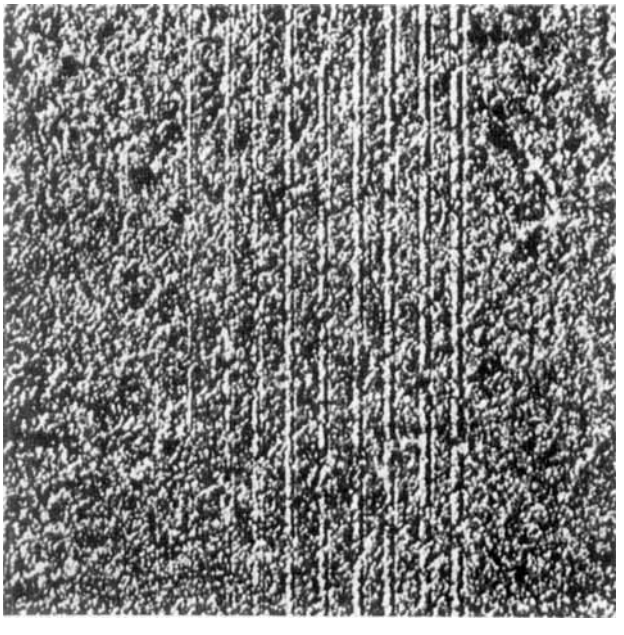
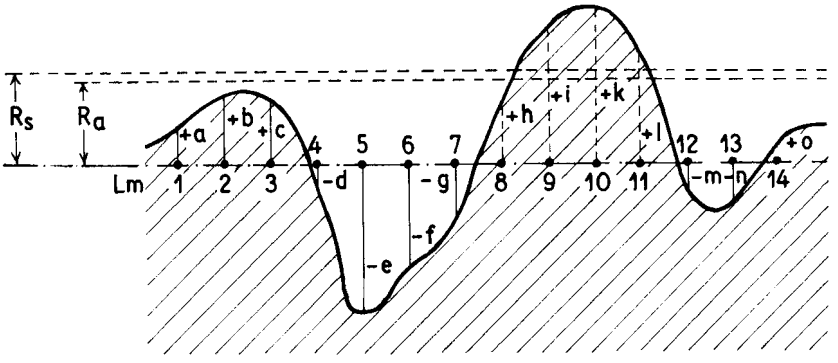


Fig. 2. As Fig. 1. The amalgam in Fig. 1 has only slight surface roughness, and for this reason reproduces the finest scratches in the steel surface, i. e. it has good adaptability. In Fig. 2 the high degree of roughness results in poor ability of reproduction, i. e. poor adaptability. 20 ×.



$$Ra = \frac{|a|+|b|+|c|+|d|+|e|+\ldots}{Z}$$

$$Rs = \sqrt{\frac{a^2+b^2+c^2+\ldots}{Z}}$$

Fig. 3. The geometrical and mathematical meaning of the arithmetical and geometrical mean roughness, R_a and R_s, respectively. L_m is the midline of the profile curve, i. e. a straight line so placed that the sum of the areas between the profile curve and the mid-line, when calculated with plus and minus signs, equals zero. Further, the mid-line is so placed that the sum of the positive and negative areas, taken separately, is minimum.

The roughness of a surface may be defined in different ways; definitions with a view to mathematical expression of roughness are contained in the various national and international standards. In measuring the roughness of amalgams in this investigation both the arithmetical and the geometrical mean values were determined and designated R_a and R_s, respectively. The significance of these expressions can be seen in Figure 3. As all measurements showed a fairly constant relation between R_a and R_s only one of these values, viz. R_a, will be considered below. The metric unit for roughness is one thousandth of a millimeter.

The roughness was measured by means of a Perth-O-Meter, type V1Bc (see Figures 4 and 5) with graph recorder, type R 120-n. Both instruments were kindly placed at our disposal

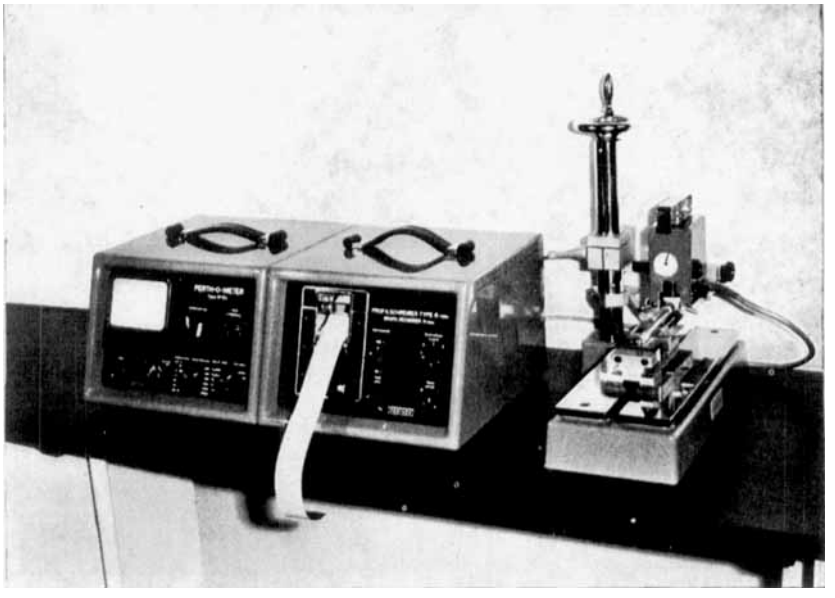


Fig. 4. Perth-O-Meter, type W1Bc, with graph recorder, type R 120-n.

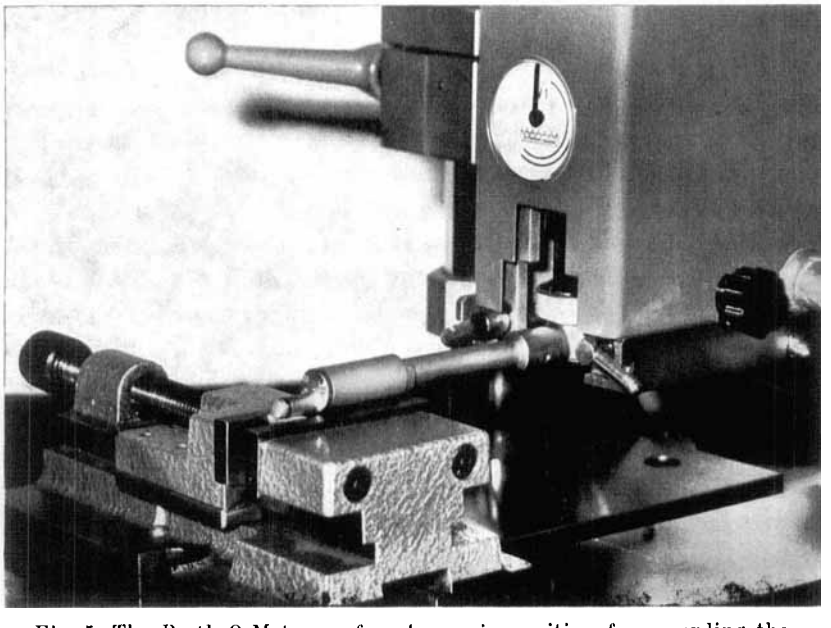


Fig. 5. The Perth-O-Meter surface tracer in position for recording the roughness of an amalgam specimen.

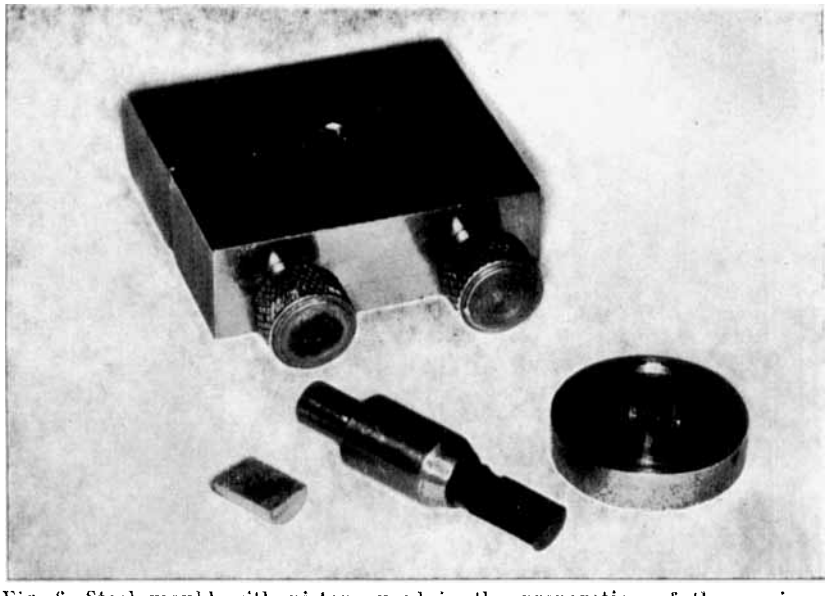


Fig. 6. Steel mould with pistons used in the preparation of the semi-cylindrical specimens. A specimen is seen in front to the left.

by the firm of *V. Løwener,* Copenhagen. In testing the surface roughness with this instrument a pick-up diamond cone is drawn across the surface of the material, and its vertical movements registered electronically by means of a pointer on the scale of the instrument. Each measurement covered a length of 5 mm. The pick-up (type HT 25/6) was able to measure depths not exceeding 25 μ, which was sufficient for the greater number of the test specimens. The point of the diamond cone had a radius of 10 μ and the measuring pressure was 80 mg. The graph recorder made it possible to trace the measured surface profile with horizontal magnifications of 20 or 100 times and vertical magnifications of 1,000, 4,000, 10,000, 40,000, or 100,000 times. In most of the graphic registrations the horizontal magnification was 20 or 100 and the vertical magnification 1,000.

The test specimens were prepared in a semi-cylindrical steel mould 7 mm in diameter (Figure 6), and under a continuous pressure by an upper and a lower piston; during condensation only the upper piston could be moved. The flat side of the mold

Table 1

Brands of dental amalgams studied

Brands	Designation	Manufacturer	Notes
True Dentalloy	A	The S.S. White Co. of Great Britain, Ltd., England	Medium-grained
New True Dentalloy	B	The S.S. White Co. of Great Britain, Ltd., England	Fine-grained
Standard	C	A.B. Svenska Dental Instrument, Sweden	Coarse-grained
Standalloy	D	Degussa, West Germany	Preamalgamated
Argos	E	A.B. Svenska Dental Instrument, Sweden	Preamalgamated
Argos Non-Zink	F	A.B. Svenska Dental Instrument, Sweden	Preamalgamated
STA 68	G	Guldsmeds Aktiebolaget in Stockholm G.A.B., Sweden	Preamalgamated
Ardent	H	Bååths Dentalindustri, Sweden	Preamalgamated
Splitter 70 non zinc	I	Dr. Walter u. Schmitt GMBH, West Germany	Preamalgamated
True Dentalloy Zinc-Free	K	The S.S. White Co. of Great Britain, Ltd., England	
Cupro-Muc	L	Merz & Co., West Germany	Copper amalgam
Neo-Silbrin	M	Dentalchemie Bad Nauheim, West Germany	Copper amalgam
Globe	N	Amalgamated Dental Co., England	Copper amalgam

was highly polished and had an R_a value of only 0.03, so that its roughness was too slight to influence the findings for the roughness of the various amalgams.

The amalgam alloys were mixed with mercury in the proportions stated by the manufacturers. Mixing was carried out in a

Wig-L-Bug mechanical mixer for so many seconds that all the particles appeared well moistened with mercury. The condensation was started one minute after finishing the mix. In the standard tests the condensation time was usually 3 minutes, and the pressure was 40 kg (about 1 kg per mm^2). The amalgam specimens were not removed from the mould before they had developed sufficient strength to resist damage, i.e. normally ½—1 hours after condensation. Measurement of the surface roughness was made at the earliest when the amalgam had gained so much strength that the diamond point of the pick-up failed to produce any detectable change in the relief, i.e. when repeated measurements of the same profile gave the same results. Generally, about 24 hours passed between preparation and measurement of the specimens.

All the specimens were 10 ± 0.5 mm long, and a total of 9 measurements were made on each. The measured profile lines were lying at right angles to the long axis of the cylinder; the first line was 1.0 mm from the top surface of the specimen, the others respectively 1.5, 2.0, 4.0, 4.5, 5.0, 7.0, 7.5, and 8.0 mm from the top face. This placed the profile lines in three zones, viz. an upper, a middle, and a lower zone.

The brands used in the investigation are listed in Table 1.

RESULTS

Before preparation of the amalgam specimens used in the final measurements, rather extensive experiments were carried out to establish how far it was possible to produce surfaces which were representative of given combinations of variables. The microscopic as well as a stereomicroscopic examination gave favourable results in this respect. Specimens obtained with the same technique and material were in all cases extremely uniform, and they were often clearly different from those made by another technique or from another material. Least consistency was found for specimens from relatively coarse-cut, non-preamalgamated alloys, and where the mixing and condensation times were abnormally short and the condensing pressure low. As an example, it may be mentioned that product A showed — as the mean of the three top measurements on five specimens in all — an R_a value of 2.33

and a standard deviation of 0.72, while the corresponding figures for a relatively fine-cut, preamalgamated alloy (D) were 1.13 ± 0.32, and for copper amalgam M 0.61 ± 0.14.

Following these preliminary experiments, amalgam specimens which must be considered representative of the various brands and preparation techniques were made. The specimens were measured in the abovementioned nine profile lines, and the mean R_a value was calculated.

With the standard technique (normal proportioning and mixing time, 40 kg condensation pressure applied for 3 minutes) the various brands (A—N) gave the results shown in Table 2, column I.

Table 2

Mean roughness values for the different brands and techniques

Technique	Column	A	B	C	D	E	F	G	H	I	K	L	M	N
Standard	I	2.3	1.2	3.1	1.1	0 6	1.3	1.1	1.0	2.5	1.7	0.6	0.6	0.8
½ min., 15.6 kg	II	2.9	2.3	4.6	1.7	2.3	1.6	2.7	1.8	3.4	3.0	1.5	1.3	1.1
Undermix	III	2.4		3.1		0.9					2.9			0.8
Overmix	IV	0.8		1.7		0.6					0.9			0.6
Reduced Hg ratio	V	2.5				1.5	2.3				2.8			
Hand condensation	VI	1.9			1.0						1.7			0.8
Vibration	VII	1.3			0.7						1.4			0.8

The standard technique was varied in different ways. It was thus examined how the roughness was affected by a reduction of condensation pressure and time. It was found that the pressure was of essential importance (the load was reduced from 40 to 15.6 kg), while the condensation time (reduced from 3 to ½ min.) was a less important factor. The effect of a combined reduction of both these factors is shown in Table 2, column II.

Variation in mixing time was carried out with five alloys, and represented different degrees of both undermix and overmix. The results for the shortest and longest mixing times appear in Table 2, columns III and IV. The times in seconds for shortest undermix, normal mix, and longest overmix were as follows: A (6, 11, 52), C (8, 14, 52), E (7, 12, 52), K (4, 7, 52), and N (4, 7, 52).

Mixing the alloy with more mercury than recommended by the

manufacturer did not alter the surface roughness, even if an excess of 50 % or more was used. It was different with a reduction, since a relatively moderate reduction of the mercury content increased the roughness. The results for four brands tested appear in Table 2, column V. Normal alloy-mercury ratio, and ratios with reduced mercury content were as follows: A (5/7.5, 5/6), E (5/5, 5/4), F (5/6, 5/4), and K (5/7, 5/6).

As a further modification of the standard technique, tests were run with specimens condensed by hand and by vibration. The hand condensation corresponded to careful clinical procedure, and was done with a 2 kg pressure on a Black plugger having a diameter of 1.75 mm. The mould was overfilled and the excess removed by scraping with a glass plate. Condensation was finished 3—4 minutes after trituration. Other specimens were prepared in a similar way using a Bergendal vibrator. The condensing pressure was not measured, but was materially lower than on the hand condenser. The vibrator point was 1.5 mm in diameter. The results of the tests with four brands appear in Table 2, columns VI and VII.

DISCUSSION

It is evident from the data presented in Table 2 that the different alloy products give amalgam surfaces with markedly different roughness. The graph in Figure 7 illustrates the geometrical significance of the numerical values in the table. Curve 1 represents brand A treated according to the standard technique, and with an R_a value of 1.9. Curve 2 shows the same brand prepared by reduced condensation time and pressure, and with an R_a value of 3.2, while curve 3 shows the effect of prolonged trituration with an R_a value of 0.8. Curves 4 and 5 are obtained with alloys E and N by the standard technique, and the R_a values are 0.6 and 0.8, respectively.

Thus, there can be no doubt that for example brand C gives appreciably rougher surfaces than A, which again is rougher than B. It is characteristic that small particles result in smoother surfaces than large particles, and that pre-amalgamation will reduce the roughness, while absence of zinc will increase it. All three copper amalgams exhibit very little surface roughness.

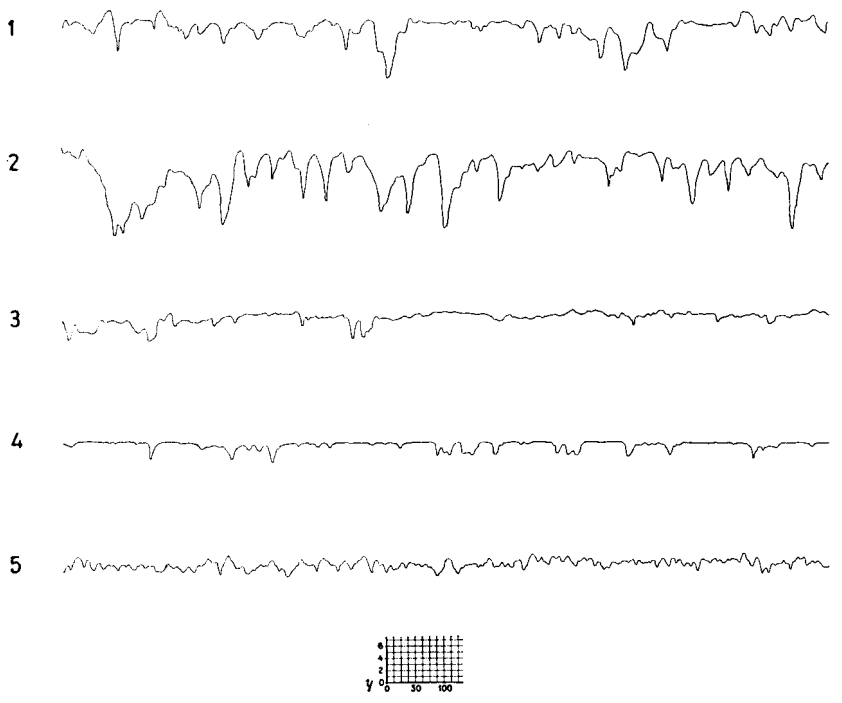


Fig. 7. Profile curves for various amalgam specimens. (1) Brand A, standard technique, R_a 1.9. (2) Brand A, ½ min. condensation time, 15.6 kg pressure, R_a 3.2 (3) Brand A, mixing time 52 sec., R_a 0.8. (4) Brand E, standard technique, R_a 0.6. (5) Brand N, standard technique, R_a 0.8. Minima represent depressions in the amalgam surfaces.

The experiments further demonstrate that reduced pressure consistently results in greater roughness, while the period the pressure is exerted is of minor importance in this connection. Prolonged trituration is another important factor in the reduction of roughness, unless the amalgam is very little rough even by the standard technique; the fact that a reduction in mixing time with clearly insufficient amalgamation only in a moderate degree increases the roughness, suggests that generally the times given in the directions must be regarded as minimum times.

An increase in the recommended mercury ratio does not perceptibly alter the roughness, while a rather moderate reduction

in the amount of mercury in the original mix definitely increases the roughness.

Careful hand condensation gives about the same roughness values as condensation by the standard technique. Vibration reduces the roughness quite clearly for amalgams which have medium or high R_a values by the standard technique.

The choice for maximum adaptability is therefore a pre-amalgamated, fine-grained, zinc-content alloy, which should be mixed with at least as much mercury, and somewhat longer, than directed in the instructions.

SUMMARY

The main purpose of the present work is a presentation of apparature and technique for objective registration of the adaptability of dental amalgams. It is demonstrated that adaptability finds expression in the roughness of the amalgam surfaces when these have been condensed and set against a plane, polished steel surface with a roughness appreciably smaller than that of the amalgam (Figures 1 and 2). Large roughness corresponds with poor adaptability. A Perth-O-Meter with graph-recorder (Figures 4 and 5) was used in measuring the roughness of the amalgam surfaces. This instrument will record the roughness directly in various standard units; as unit was chosen the R_a value, i.e. the arithmetical mean roughness (Figure 3).

The experimental results show (Table 2) that the roughness values are essentially different for different brands; fine grains, pre-amalgamation, and perhaps zinc content reduce R_a. Prolonged mixing, high condensing pressure, and mechanical condensation will also reduce R_a, especially when the properties of the alloys predispose to a relatively rough surface. All copper amalgams showed low R_a values under the present experimental conditions.

It is assumed that good adaptability increases retention of the amalgam in the cavities and leads to better resistance of the margins towards mechanical and electrochemical attacks, provided that no other factors will compromise the contact between amalgam and cavity walls.

RÉSUMÉ

L'ADAPTABILITÉ DES AMALGAMES DENTAIRES

Le but principal de la présente étude est de présenter une instrumentation et une technique pour l'enregistrement objectif de l'adaptabilité des amalgames dentaires. Le fait que l'adaptabilité se trouve exprimée par la rugosité de surfaces d'amalgame condensées et solidifiées sur une surface plane d'acier poli de rugosité sensiblement moindre que celle de l'amalgame est démontré. (Fig. 1 et 2.) A une rugosité importante correspond une mauvaise adaptabilité. Un "Perth-O-Meter" avec dispositif d'enregistrement graphique (fig. 4 et 5) a servi à la mesure de la rugosité des surfaces d'amalgame. Cet appareil peut effectuer l'enregistrement de la rugosité directement en diverses unités standard; l'unité choisie a été la valeur R_a, c'est-à-dire la moyenne arithmétique de la rugosité (fig. 3).

Les résultats montrent (tableau 2) que les valeurs de la rugosité diffèrent essentiellement d'une marque à l'autre; la finesse du grain, la préamalgamation et peut-être la présence de zinc réduisent R_a. Un malaxage prolongé, une pression de condensation élevée et une condensation mécanique réduisent aussi R_a, en particulier lorsque les propriétés des alliages prédisposent à une rugosité relative de surface. Tous les amalgames de cuivre présentaient des valeurs R_a peu élevées dans les conditions de la présente expérience.

Il est vraisemblable qu'une bonne adaptabilité augmente la rétention de l'amalgame dans les cavités et conduit à une amélioration de la résistance des bords envers les attaques mécaniques et électrochimiques, pourvu que le contact entre l'amalgame et les parois des cavités ne soit pas compromis par d'autres facteurs.

ZUSAMMENFASSUNG

DIE ADAPTÄBILITÄT VON AMALGAM

Der Hauptzweck der vorliegenden Arbeit ist die Beschreibung von Apparatur und Technik zur objektiven Feststellung der Adaptäbilität dentaler Amalgame. Es wird gezeigt, dass die Adaptäbilität ein Ausdruck für die Rauheit der Amalgamober-

flächen ist, wenn diese gegen eine ebene, polierte Stahloberfläche mit einer wesentlich geringeren Rauheit als der des Amalgams gestopft und abgebunden sind (Abb. 1 und 2). Grosse Rauheit entspricht geringer Adaptäbilität. Zur Messung der Rauheit der Amalgamoberflächen wurde ein Perth-O-Meter mit Graph-recorder benutzt (Abb. 4 und 5), der die Rauheit direkt in Standardeinheiten registriert; als Standard wurde der sogenannte R_a-Wert, die arithmetische Mittelrauheit, gewählt (Abb. 3).

Die Versuchsergebnisse zeigen (s. Tabelle II), dass die Rauheit verschiedener Fabrikate wesentlich verschieden ist; Feinkörnigkeit, Voramalgamierung und vieleicht Zinkgehalt vermindern den R_a. Auch die Verarbeitung ist für die Rauheit von wesentlicher Bedeutung; verlängertes Anrühren, kräftiges Stopfen und Vibrieren vermindern alle den R_a, insbesondere, wenn die materialmässigen Eigenschaften eine relativ rauhe Oberfläche bedingen. Kupferamalgame wiesen bei allen Versuchsverhältnissen relativ geringe Rauheit auf.

Es ist offensichtlich, dass gute Adaptäbilität den Halt des Amalgams in den Kavitäten steigert und eine grössere Kantfestigkeit gegen sowohl mechanische als elektrochemische Angriffe bewirkt. Eine Voraussetzung hierfür ist jedoch, dass andere Faktoren das Kontaktverhältnis zwischen Amalgam und Kavitätswand nicht ungünstig beeinflussen.