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INVESTIGATIONS ON THE HARDNESS AND COMPRESSIBILITY OF MODEL PLASTER

by

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The purpose of the empirical laboratory tests referred to in this paper has been to demonstrate the influence of various factors on the hardness and compressibility of the model plaster (dental stone) used in dentistry, and on the basis hereof to set up an optimum norm for the manipulation of this important auxiliary material.

Among the properties that must be required of a good model plaster are:

- (1) Considerable hardness and strength, low compressibility.
- (2) Small changes in volume during and after the setting.

These are essential requirements for a stable model, which determines the accuracy of the dental work (dentures, crowns, inlays etc.) constructed on the models.

The properties mentioned under point (1) will be considered below. A further examination of the properties mentioned under (2) has been commenced and will be dealt with in a subsequent paper.

METHODS AND MATERIALS

The hardness of a material may be defined as its ability to resist the penetration of its surface by a harder material.

The method for hardness testing used here is based on that evolved by *Brinell* (1900), in which a ball of some material harder than that under test is pressed against its surface. The hardness is then expressed as the ratio of the pressure applied (in kg) to the area of the ball impression (in mm²).

Where D is the diameter of the ball and d the diameter of the impression (see Fig. 1) it is required by "Deutsche Verband für die Materialprüfungen der Technik" (cf. *Memmler*, 1930: 90), that $0.2 \cdot D \leq d < 0.5 \cdot D$. In Fig. 2 the importance of this requirement is represented graphically by means of curves, which show the relationship between the hardness (H) and d . It will be seen that slight changes in d , where $d < 0.2 D$, correspond to large changes in H . Conversely, where $d > 0.5 D$ even large changes in d result only in small changes in H . As d is not usually measured to a greater accuracy than ± 0.01 mm, it is readily seen when $d < 0.2 D$ the accuracy of the determination of H is low, and the accuracy decreases the greater the pressure applied. With $d > 0.5 D$ the accuracy of the determination of H would be fairly high, but in this range the testing conditions are essentially different from those on which Brinell's testing theory is based, the discrepancy being greatest for small pressures and increasing d .

In the tests referred to here d was in most cases kept within the above-mentioned limits, and in each case $d > 0.2 \cdot D$.

All the specimens had a minimum size of $4 \times 4 \times 1$ cm. The pressures in the hardness tests were applied at right angles to plane surfaces.

Dry hardness means the hardness of the plaster after storage in ordinary laboratory air (relative humidity during the experimental period 50 ± 5 , temperature $20 \pm 1^\circ\text{C}$) for a period of at least 5 days, in which did not decrease in weight; that is, about one week after the preparation of the specimens.

Wet hardness is the hardness of the specimens when they are saturated with water. In this connection a specimen may be regarded as water saturated when it has been immersed in water for 10 minutes after having been dried.

All the hardness tests were made on a *Vicker* Hardness Tester with a steel ball having a diameter of 5.00 mm. After a number of experiments the period during which the pressure was maintained was fixed at 10 secs., as it was found that the size of the ball impression did not increase measurably on continuing the pressure beyond this.

Measurements and calculations of the relationship between the diameter d and the depth H of the impression have shown that

the deformation of the plaster surface caused by the hardness test is permanent; that is, the impression retains its size and shape for an unlimited period after the test.

d was read and measured by means of a measuring microscope to an accuracy of ± 0.01 mm.

Fig. 2 shows the pressures applied to the various specimens. H was read directly from *G. Jensch's* tables (1928).

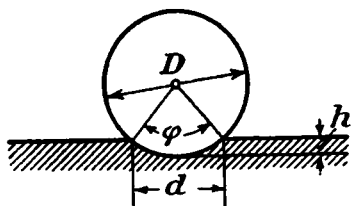


Fig. 1. The principle of *Brinell's* hardness test. A steel ball is pressed against the surface of the material with a known force to form a concave impression, the area of which is determined. (*Memmler*, 1930: 88, Fig. 35).

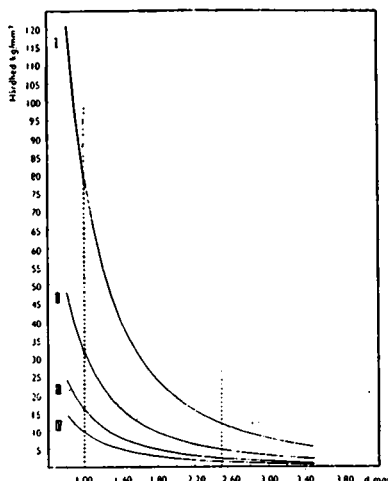


Fig. 2. The relation between the *Brinell* hardness H , expressed in kg/mm^2 , and the diameter d of the impression of the ball, for the pressures applied in the tests performed. $D = 5.00$ mm. Curve I: $62\frac{1}{2}$ kg, II: 25 kg, III: $12\frac{1}{2}$ kg, IV: $7\frac{1}{2}$ kg. The vertical dotted lines correspond to $d = 0.2 \cdot D$ and $d = 0.5 \cdot D$.

If a soft metal such as copper is tested for hardness by the method described, it will be found that the rim round the impression is raised above the level of the surrounding plane surface; in other words, the defect in the surface is not caused by compression alone. A similar deformity could not be found in the plaster specimens, even though the level changes round the surface defect were measured to an accuracy of ± 0.005 mm (cf. Fig. 3).

This must mean that the hardness of the plaster — with reference to the material and hardness-test technique described — is also a measure of its compressibility; that is, the harder the plaster the less will it be compressed.

Voellmy (1941: p. 628) states that the breaking strength for ordinary plaster is about $\frac{2}{3}$ of the Brinell hardness.

Except when otherwise stated the plaster material used in the tests was a model plaster (dental stone) made in this country, and mixed with ordinary tap water. The water was left to stand in a bottle until it had assumed air temperature ($20 \pm 1^\circ\text{C}$). The powder was taken from one tin container which was practically air-tight, it being closed with a tight-fitting cover between the individual tests.

All the specimens were prepared by sprinkling the plaster powder into the water (about 15 sec.), and by manual spatulation. The spatulation took place rather slowly — at the rate of 110 ± 5 turns per minute, the same spatula and plaster bowls of the same shape and size being used in all the tests.

All the experimental results referred to here were checked at least twice. Only results where the deviation of the control tests from the original tests was negligible are given below.

RESULTS

Increase in hardness in relation to the time elapsing after spatulation

It is a familiar fact that the hardness of plaster increases comparatively quickly in the first minutes after the initial set but continuous tests giving details of this increase do not seem to have been conducted.

The experiments aimed at showing the influence of the chemical and crystallization processes on the increase in hardness after the initial set, and were carried out as follows.

The water/powder ratio = 0.30, mixing time 60 seconds. The specimen was cast as a circular plate between two flat, parallel glass plates, the diameter was approx. 7 cm and the thickness 1 cm. Immediately after the initial set the specimen was soaked and kept thoroughly wet throughout the experiment. Hardness tests were applied every second minute in the first half hour, every fifth in the following half hour, every tenth in the subse-

quent hours, and at considerably longer intervals in the remaining period of the experiment which ran for 30 hours in all.

The results of a typical experiment are represented in Fig. 4. The hardness curve is very steep in the first 30 min. and less steep in the following 90 min., while its rise is very slight during the subsequent hours.

This finding is of practical importance in showing that a plaster model, prepared from the material used here, should not

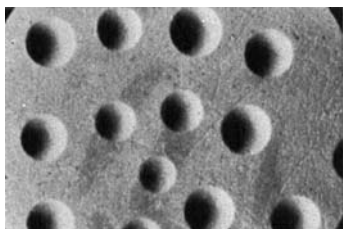


Fig. 3. Cup-shaped impressions in a very heterogeneous plaster surface. It may be observed that there is no macroscopic elevation of the rims round the impressions. The largest impression has a diameter of 2.57 mm. The small impressions correspond to lumps of insufficiently spatulated plaster powder, the pressure k is constant for all the impressions. — Water/powder ratio = 0.60. Mixing time 30 seconds.

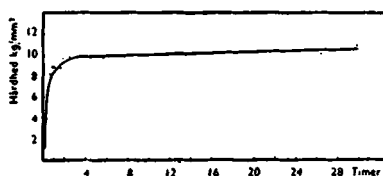


Fig. 4. The relation between the hardness of the plaster (H in kg/mm^2) and the time elapsing after the beginning of stirring. Only a few of the readings taken have been plotted.

be separated from the impression until half an hour after the stirring is begun, and that the model attains its maximum *wet* hardness about 4 hours after spatulation.

In their specifications relating to the hardness and strength of model plaster many manufacturers state that the time for the plaster to have acquired these properties is "30 min. after spatulation". As many factors such as the temperature of the water, the rate of spatulation and the storage conditions of the plaster have an appreciable influence on the setting time, it will be seen that such statements can only be an inadequate and inaccurate expression of the mechanical properties of the plaster. It would be much more important to know the wet hardness after, say,

24 hours, where the hardness curve runs almost parallel to the axis of abscissa and characterizes the product with sufficient accuracy.

The relationship between the water content and the hardness of the model

The specimens were prepared as described in the preceding section and left in water for about a week, when they were wiped

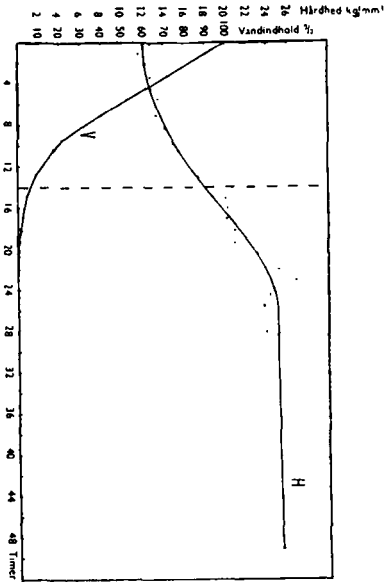


Fig. 5. Curve *H* shows the relationship between the hardness of the plaster (*H* in kg/mm²) and the time of drying (in hours). Curve *V* shows the relationship between the percentage water content and the drying time. The points to the left and right of the vertical dashed line correspond to the specimens A and B, respectively.

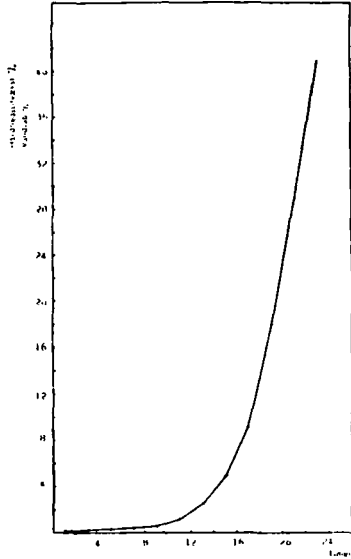


Fig. 6. The relationship between the percentage hardness increase and the percentage loss of water during the drying of a plaster specimen is plotted against time (in hours).

with a towel and allowed to dry freely in the laboratory air, at the same time being subjected to hardness tests. As they had to be tested at relatively short intervals over a period exceeding 24 hours it was for practical reasons necessary to combine the results from two specimens (A and B). They were prepared in the same way and had the same wet hardness after a week's immer-

sion in a water bath, but one was taken out of the bath and allowed to dry 15 hours before the other (see Fig. 5). For each hardness test the loss of water due to evaporation was determined as a percentage of the original water content.

From curve H in Fig. 5 it is at once apparent that the hardness increases very considerably during drying. Further experiments showed that the hardness of the dry plaster specimen momentarily falls to the original wet hardness value when it is soaked, but that the hardness is recovered by renewed drying. In the completely set plaster specimen the relationship between the water content and the hardness is further illustrated by the curve in Fig. 6. The hardness increase was read on the hardness curve in Fig. 5.

It is interesting to note that very small amounts of water reduced the hardness of the completely air-dried plaster specimen to a very high degree, while the removal of comparatively large amounts of water from the wet specimen improved its mechanical properties only very slightly.

A model should therefore be kept perfectly dry. Even very slight moistening will significantly reduce its resistance to damage.

Knowledge of the wet hardness (compressibility) is of special importance in estimating the dimensional stability of the plaster model while the denture materials are being pressed in the flasks, as the plaster is practically always wet during this stage of the work, or at least it becomes wet when the flask is immersed in water for polymerization or vulcanization.

*Influence of the water/plaster ratio and the time of spatulation
on the hardness*

All the specimens in this experimental series were prepared on the same day to ensure the greatest accuracy of the results. The plaster was allowed to set in the bowl, and about two hours after spatulation it was ground to the dimensions $4 \times 4 \times 1$ cm in such a way that the surface to be tested for hardness in all the specimens was lying at the same level in relation to the bottom of the bowl; this was done in order to prevent the sedimentation — which occurred before setting in the thin mixes — from influencing the hardness of the specimens in any way. The hard-

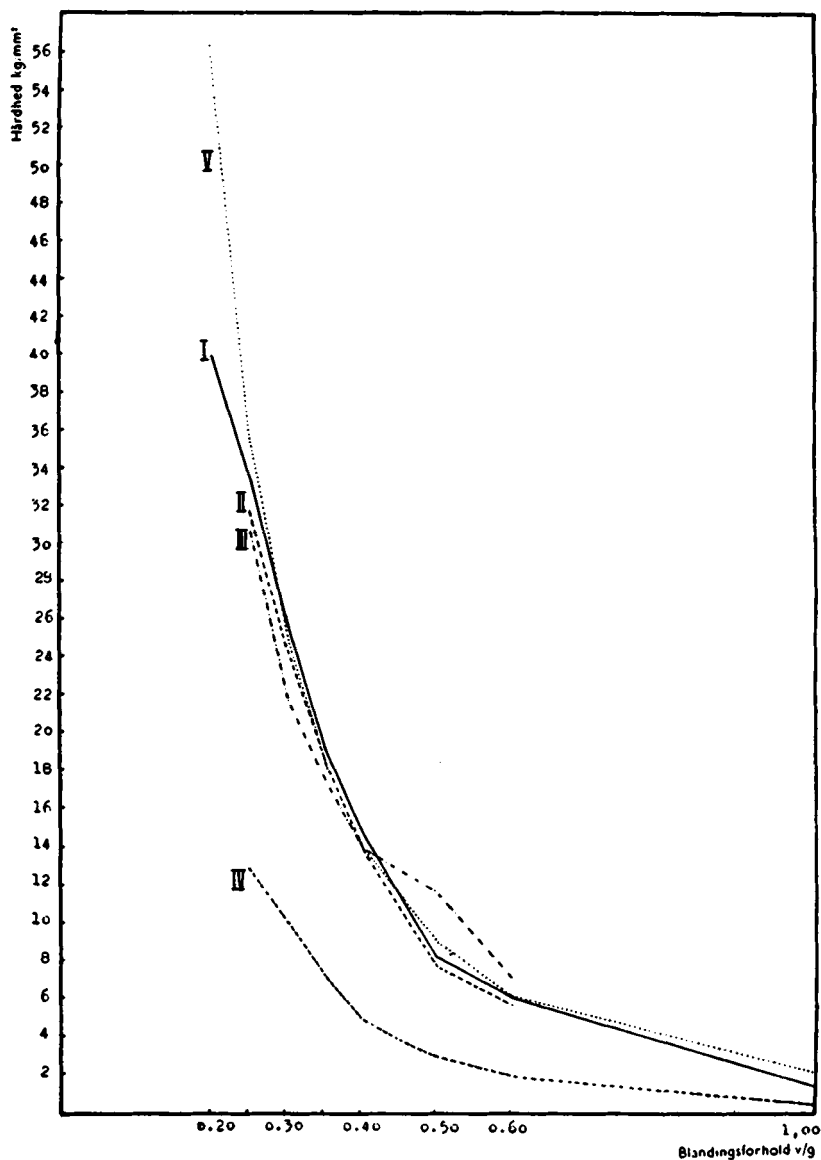


Fig. 7. The relation between dry hardness (H in kg/mm^2) and the w/p ratio for different mixing times. I: 120 secs. II: 60 secs. III: 30 secs. Curve IV represents the wet hardness for the same specimens, the dry hardness of which is represented by Curve II. Curve V is the "ideal curve", constructed according to the formula

$$H = k \cdot \left(\frac{p}{w}\right)^2 \text{ with } k = 2.25.$$

ness tests were applied 8 days after the preparation of the specimens; that is, about one week after any loss of water by evaporation could be shown.

In order to obtain a reasonably reliable average result 30 readings were taken for each specimen.

The results of the experiments are represented in Fig. 7 for the mixing times 120, 60 and 30 seconds. The curves for the two first periods are regular and are almost hyperbolas; the irregular course of the 30 seconds curve, with greater hardness than expected in the mixing range 0.40—0.60, is due to sedimentation of insufficiently spatulated lumps of plaster powder (*cf.* Fig. 3).

It is noteworthy that the hardness increased somewhat with the period of spatulation. Prolonged spatulation is known to reduce the setting time in consequence of the increased number of centres of crystallization, and the grain of the set product will be finer. It is not improbable that the increase in hardness is due to this reduction in the grain size.

For the mixing time of 120 seconds the following hardnesses were found in the various test specimens:

W/P ratio	0.20	0.25	0.30	0.35	0.40	0.50	0.60	1.00
Hardness kg/mm ²	40.2	33.7	25.9	19.3	14.9	8.27	6.16	1.51
<i>k</i> · 10	(16)	21	23	24	24	21	22	(15)

The symbol *k* represents a constant in the formula

$$H = k \cdot \left(\frac{p}{w} \right)^2 \text{ kg/mm}^2,$$

where *H* is the hardness of the plaster, *p/w* is the ratio between the weights of plaster and water. It will be seen that the hardness curve for model plaster in this experiment follows the formula fairly closely, with a mean value for *k* of 2.25 — *cf.* Fig. 7.

The actual hardness numbers for low values of *w/p* are slightly lower than the hardness numbers given by the formula, due no doubt to the fact that the hardness is reduced by the relatively large number of small air-bubbles present in these specimens. At the other end of the curve are deviations of the same quality,

which may be due to the slower setting rate of the plaster (change in crystal form and size).

These deviations are, however, of little interest in practice where such proportions are rarely used; but it is of importance that the hardness curve for the water/plaster ratios used in actual dental practice follows the "ideal" curve, the formula for which was given above.

All the types of plaster products tested have hardness curves of the same fundamental form as the one described here. This means that the hardness property of any of these types of plaster may be characterized by a certain water/plaster ratio and the constant k , which refers to dry test specimens prepared from mixes stirred to a homogeneous consistency and made up in the proportions used in practice. Later in this paper k is computed for a number of dental stones used in this country.

Influence of the water/plaster ratio and spatulation on the homogeneity of the plaster

It is of essential importance to our knowledge of the dimensional stability of plaster models to know whether their deformation under pressure is uniform, that is, whether they are of the same percentage magnitude throughout the model. The numerous hardness tests which have been made give valuable information in this respect.

Fig. 8 is a graphical representation of the percentage deviation from the calculated mean hardness for a number of hardness tests on specimens prepared with varying w/p ratios and mixing times. The following points may be observed.

Mixing time 30 seconds: a w/p ratio of only 0.35 results in a fairly homogeneous paste, but owing to the relatively high water content this proportion results in too weak models.

Mixing time 60 seconds: the proportions 0.35 and 0.30 produce homogeneous models. The proportion 0.30 in most cases gives the optimum consistency and sufficient hardness; proportions approaching the value 0.25, which can be used in case of robust impressions, will affect the homogeneity adversely.

Mixing time 120 seconds: all the proportions used in practice give mixes of good homogeneity.

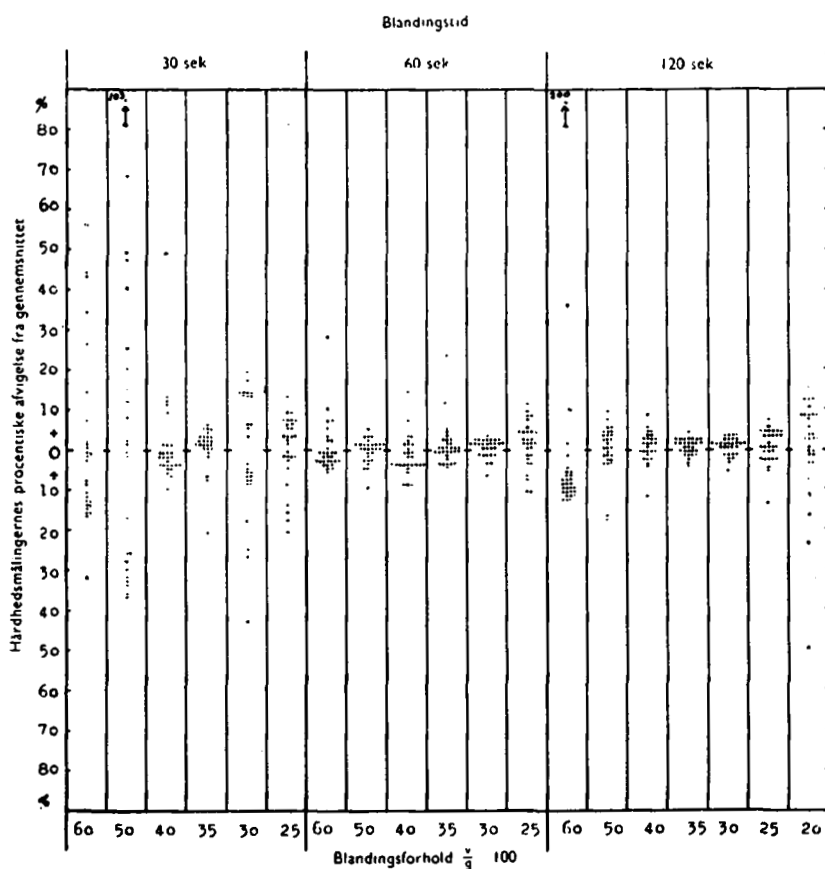


Fig. 8. Graphical representation of hardness determination on specimens of model plaster prepared with varying w/p ratio and mixing time. Each specimen was subjected to 30 hardness tests. The broken zero line corresponds to the average hardness for each specimen; the points show the percentage deviation of the individual hardness determination from the average.

The influence of various liquids on the hardness of the plaster

Water. The influence of this liquid on the hardness of plaster that is completely set has already been mentioned and is further illustrated below. The wet and dry hardness of test specimens mixed for 60 seconds and made up in various w/p ratios were examined with the following result:

W/p ratio	0.25	0.30	0.35	0.40	0.50	0.60	1.00
Hardness, wet (kg/mm ²)	13.1	10.2	7.16	4.90	2.97	2.00	0.46
Hardness, dry (kg/mm ²)	32.0	24.4	18.5	13.9	7.76	5.75	1.51
Increase wet-dry (%)	144	139	158	184	161	188	228
Loss dry-wet (%)	59.1	58.2	61.3	64.8	61.7	65.4	69.6

Stellon alginate separative: same effect as water, but only to a depth on about 5 mm below the surface. The hardness test was applied after the separating medium had dried out and formed a film; that is, 5—8 min. after being applied.

Acrylic monomer: the reduction in hardness after being soaked for 3 minutes amounted to about 15 % of the dry hardness.

Liquid wax, vaseline and paraffin oil: no clear changes in the hardness could be shown.

The hardness of various commercial model plasters

The manufacturers of various model plasters usually state an optimum w/p ratio for their products. An examination of these figures shows, however, that the manufacturers have widely different ideas of what is to be considered as the optimum.

In order to arrive at a uniform estimate of the hardness properties of the various brands the author has, on the basis of practical experience, fixed a normal consistency for a certain brand of dental stone, and examined the hardness of this brand and of other brands mixed to produce the same normal consistency.

Normal consistency is a property characterizing the freshly spatulated water/plaster mix, and is an expression of the viscosity of this mix.

The consistency was determined by a modified Vicat apparatus (Fig. 9), according to the principle stated by Am. Soc. Test. Mat. The diameter of the cylinder C (Fig. 9) used by the author was 10.0 mm, the weight of the vertically movable rod CBD 255 g. The normal consistency chosen here corresponded to an immersion of the cylinder C of 20 ± 2 mm into the plaster mass. The freshly spatulated mix was placed in a standard mould below C, and the movement of C read on the scale F.

The experiment showed that the consistency of the mix is not only dependent on the proportion of water and plaster but

also on the vibration effect. It was found that certain mixes spatulated to a normal consistency were very viscous during the stirring, but at the same time became rather thin under slight vibration. As a plaster model is always cast under vibration, the normal consistency was in all cases established for freshly vibrated mixes. Other plaster types were much less viscous

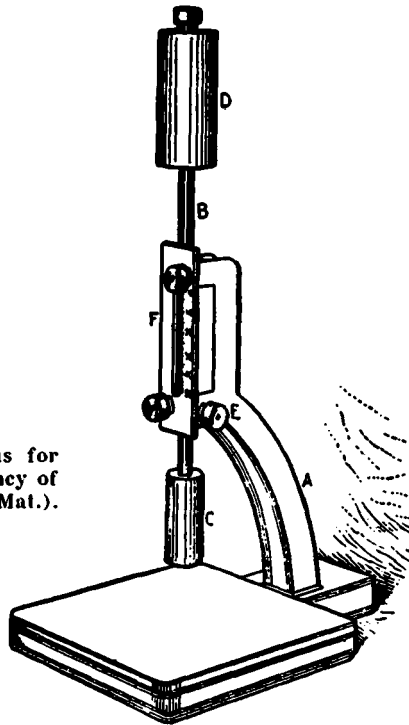


Fig. 9. Modified Vicat apparatus for determining the normal consistency of the plaster paste. (Am. Soc. Test. Mat.).

during spatulation, but on the other hand their viscosity was only slightly affected by vibration.

This difference in the vibration effect from brand to brand demonstrates that the proper w/p ratio for a certain plaster cannot be determined on the basis of the spatulation consistency alone, and that certain types of plaster may be stirred to essentially greater viscosity than others, and yet, merely by slight vibration, be made to flow out in the mould.

The list below shows the dental stones tested and their respective w/p ratios at normal consistency. It is pointed out that all

the test specimens were prepared from the contents of freshly opened packets, and that the results were reproduced several times.

The brands are listed alphabetically.

Brand	<i>m/p</i> ratio at normal consistency	Vibration effect
Calestone	0.30	medium
Diamantine	0.275	great
E. P. 1.....	0.29	slight
Kemcal	0.29	slight
Moldano, Bayer	0.29	slight
Moldano, Danish	0.29	medium
Mouledur	0.35	great
Nybro	0.31	great
Odus, blue	0.33	great
Odus, yellow	0.35	great

When using these products it must be remembered that a brand with great vibration effect *must* be mixed with less water than a brand with medium or slight vibration effect.

It should be added that the determination of the highly varying vibration effect is based on an estimate made by observing the change in the consistency of the freshly spatulated mix when vibrated with a spatula.

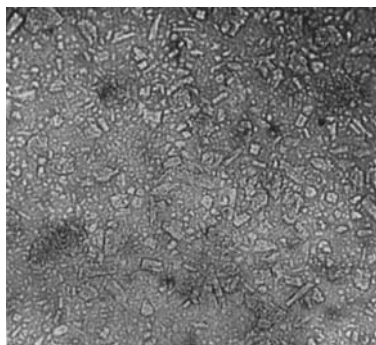
After the preparation of test specimens spatulated to a normal consistency the dry hardness of the various stones was examined. The data are given below. The numbers do *not* represent the brands in the order they are enumerated in the alphabetical list.

Brand	I	II	III	IV	V	VI	VII	VIII	IX	X
Hardness at normal consistency.....	26.2	25.1	23.4	22.2	21.2	20.7	20.3	17.0	16.9	15.5
<i>k</i> · 10	22.0	21.1	17.7	18.6	17.8	18.6	19.5	18.5	20.7	18.9

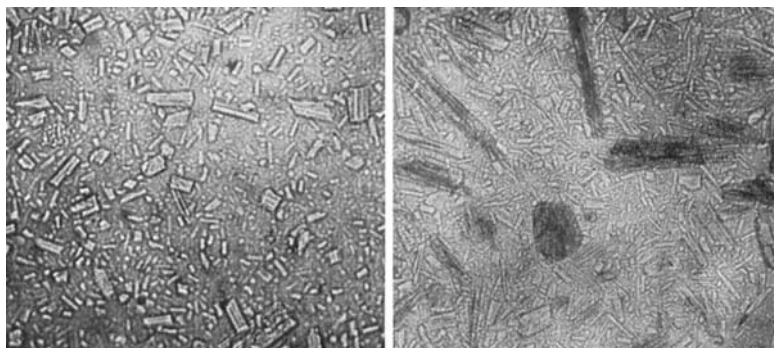
The great difference in the hardness of the various brands is noteworthy. Brand No. X is only slightly harder than ordinary white plaster of Paris. A test specimen of the plaster of Paris generally used at the Dental College, mixed to the same normal consistency as the above stones, had a dry hardness of 14.2. Further it was found that there is little relationship between the quality and the price of the various brands.

The comparatively slight variation of the constant k shows that the hardness of the various brands is chiefly governed by the water/powder ratio.

The vibration effect which, as above mentioned, is of importance to the normal consistency, and consequently for the



A



B

C

Fig. 10. Microphotos of powder preparations of three of the commercial stones mentioned. (a) small, almost isometric particles; slight vibration effect. (b) larger, more elongated particles; medium vibration effect. (c) many large, rod-shaped and irregular particles; great vibration effect. The mineralogical picture in preparation (c) signifies insufficient calcination of the plaster.

hardness of the models, is largely determined by the form and size of the hemihydrate particles (see Fig. 10). Small, isometric particles give a definitely lower vibration effect than large, rod-shaped particles.

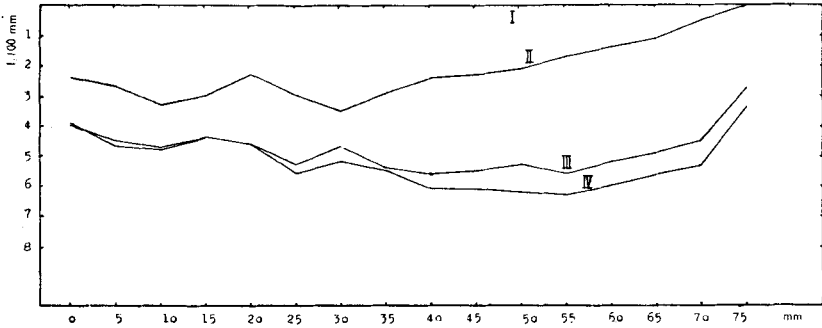


Fig. 11. Level changes in a plane plaster surface due to pressure. The experimental conditions are described in the text. Curve I represents the original surface of the plaster which — though slightly uneven — is drawn plane. Curve II shows the changes in level of the surface after the first compression with an acrylic material; the changes for each point of measurement on the horizontal axis were determined to an accuracy of ± 0.003 mm. Curve III and IV have been obtained in the same way. The distance from the extreme left and right reference points to the vertical wall of the flask was about 2 mm.

On the other hand it is known that particles of the latter form cannot be packed so closely as the former. The empirical experiments show that plaster materials with a slight vibration effect, which are composed of small, isometric particles, usually assume considerably greater hardness than types with a great vibration effect and coarse, rod-shaped particles.

The compressibility of model plaster in the denture flask

The lower half of a denture flask, cylinder-shaped and 40 mm deep, was filled with a Danish model plaster — made up in the proportion 0.30 and mixed for 60 seconds — so that the top surface of the plaster was plane. After the setting and separation of the plaster the upper half of the flask was filled with the same plaster.

After the setting and drying of the plaster at room conditions a lump of acrylic the size of a walnut and ready for packing was placed between the two halves of the flask which were closed together under a pressure equal to that applied to the flask in the construction of a denture; that is, about 2 kg/mm². Immediately after the closure of the flask the changes in level of the plaster surface were measured with an instrument designed for the purpose, the accuracy of which was ± 0.003

nim (curve II, Fig. 11). After being measured the plaster was soaked and compression repeated with another acrylate; the result of the measurement of the plaster surface is represented by curve IV, Fig. 11. The flask was allowed to stand for 26 hours, after which the plaster surface was measured again for possible elastic after effects in the compressed mass. The result is shown in Fig. 11, curve III.

The experiment was repeated for w/p ratios of 0.25, 0.35 and 0.50 and the relative values thus obtained were almost equal to those found for the hardness of the plaster by the Brinell method.

The maximal compression for these plaster mixes, compressed when wet and measured immediately after the compression test, were:

w/p ratio	max. compression 1/100 mm
0.25	2.6
0.30	6.3
0.35	5.9
0.50	23.0

Similar values were obtained by control tests. The numbers given above show the magnitude of the compression; it will be seen that the compressibility of the plaster may be a factor of appreciable influence on the accuracy of the technical work. It must however be borne in mind that the plaster used in this test is one of the hardest available on the market. Corresponding measurements on softer types would probably reveal an appreciably greater compression.

The lowest compression and greatest hardness are obtained by selection of the proper commercial product and by proper manipulation, especially in respect of the proportion of water and powder. Several of the dental commercial stones must be regarded as rather unsuitable for the construction of denture models owing to the risk of raising the bite.

The inaccuracy due to compression of the plaster may be further reduced by making the models — and the upper and lower casts in the flask — as low as possible. It would no doubt be an advantage to press and boil the acrylic material on dry plaster; but this is hardly possible with the technique at present practised.

SUMMARY

The experiments referred to above, by means of which the hardness and compressibility of various model plaster were tested, have yielded the following results:

1. The stability of shape of model plasters is determined primarily by its hardness and by the dimensional changes due to expansion.
2. The hardness of the plaster is an expression of its tendency for permanent deformation. Elastic after-effects can be shown only to a slight degree, and not at all if the plaster is compressed locally with a steel ball, as in the hardness test.
3. The hardness of the plaster is also an expression of its compressibility. The greater the hardness the lower the compressibility.
4. The increase in the hardness of the plaster (varying with the brand) due to the setting processes is very great during the first 30—45 minutes after spatulation, somewhat lower during the next 90 minutes, and almost zero at the end of this period. It would therefore be best not to separate a model from the impression until at least 30 minutes after casting.
5. The hardness of dry plaster is reduced by about 60 % when it is soaked, but is recovered by drying. Even very small amounts of moisture cause a considerable reduction in the hardness.
6. Working models must be kept completely dry if they are to possess the greatest possible resistance to physical damage. It is much easier to crush the plaster or to carve off excess when it is wet than dry.
7. The hardness of the plaster increases very much with a decrease in the amount of water used in the mix. The hardness is greatest if it is thoroughly stirred.
8. Homogeneous plaster is only obtained by thorough spatulation. The heterogeneity resulting from insufficient spatulation is very considerable.
9. The surface hardness of the plaster falls by about 60 % if it is painted with Stellan alginate separative, and by about

- 15 % if it is moistened with acrylic monomer. Liquid wax, vaseline and paraffin oil do not affect the hardness of the set plaster.
10. In many cases the water/plaster ratio indicated by the manufacturers do not give the optimum consistency.
 11. Some brands become essentially thinner under vibration (great vibration effect), while the consistency of other brands is only slightly changed by vibration. The former must be stirred to a consistency of essentially greater viscosity than the latter.
 12. There is a very great difference between the hardness of the various brands mixed to the optimum consistency.
 13. There is little relation between the price and the hardness properties of the brands.
 14. During the pressing of an acrylic denture the plaster is definitely compressed and changes its form permanently. The hardest plaster is least compressed.
 15. Denture models should be made as low as possible and cast in the lowest possible flask to reduce to a minimum the risk of raising the bite.
 16. Several brands of dental stone are of little value for denture models and investing.

ZUSAMMENFASSUNG

HÄRTE UND KOMPRESSIBILITÄT VERSCHIEDENER MODELLGIPSE

Die oben referierten Untersuchungen über die *Härte und Kompressibilität verschiedener Modellgipse* haben zu folgenden Resultaten geführt:

1. Die Formfestigkeit des Modellgipses hängt vor allem von seiner Härte und von den expansionsbedingten Änderungen des Volumens ab.
2. Die Härte des Gipses ist gleichzeitig ein Ausdruck für seine Fähigkeit zu plastischer Formveränderung. Eine elastische Nachwirkung kann nur in geringem Mass nachgewiesen werden, und gar nicht, wenn der Gips lokal mit der bei der Härteprobe angewendeten Stahlkugel komprimiert wird.
3. Die Härte des Gipses drückt auch seine Kompressibilität aus. Je grösser die Härte, desto geringer die Kompressibilität.

4. Die Zunahme der Härte des Gipses infolge der Abbindungs-vorgänge ist je nach dem Fabrikat die ersten 30—40 Minuten nach dem Anrühren sehr kräftig, die folgenden 90 Minuten etwas schwächer und dann fast null. Ein Modell darf also nicht gern vor mindestens $\frac{1}{2}$ Stunde nach dem Guss vom Abdruck getrennt werden.
5. Der trockene Gips verliert ca. 60 % seiner Härte, wenn er befeuchtet wird. Die Härte wird durch Trocknen wiederhergestellt. Selbst ganz kleine Mengen von Feuchtigkeit setzen die Härte bedeutend herab.
6. Arbeitsmodelle müssen vollständig trocken gehalten werden, um ein möglichst grosses Widerstandsvermögen gegen mechanische Beschädigung zu besitzen. — Will man den Gips zerschlagen oder den überschüssigen Gips wegschneiden, ist dies viel leichter bei feuchtem als bei trockenem Zustand des Gipses zu bewerkstelligen.
7. Die Härte des Gipses nimmt bei fallender Wassermenge im Mischverhältnis Wasser/Gips sehr stark zu. Die Härte des Gipses ist am grössten, wenn er gründlich angerührt wird.
8. Der Gips wird nur bei gründlichem Anrühren homogen. Bei schlechtem Anrühren ist die Inhomogenität erheblich.
9. Die Oberflächenhärte des Gipses fällt bei Bepinseln mit einem Stellon-Alginat-Separationsmittel um ca. 60 % und bei Befeuchtung mit Akrylmonomer um ca. 15 %. Flüssige Wachs, Vaseline und Paraffinöl üben keinen Einfluss auf die Härte des abgebundenen Gipses aus.
10. Was mehrere Gipsfabrikanten über das Mischverhältnis Wasser/Gips anführen, entspricht nicht dem optimalen.
11. Gewisse Fabrikate werden bei Vibrieren wesentlich dünnflüssiger (grosser Vibrationseffekt), andere verändern ihre Konsistenz nur in geringem Mass. Die ersteren müssen zu einer wesentlich zäheren Konsistenz angerührt werden als die letzteren.
12. Es besteht ein sehr grosser Unterschied zwischen der Härte der verschiedenen Fabrikate, wenn sie zur optimalen Konsistenz angerührt sind.
13. Die Preise und die Härte der einzelnen Fabrikate stehen selten im entsprechenden Verhältnis zueinander.

14. Der Gips wird beim Pressen einer Akrylprothese deutlich komprimiert und verändert bleibend seine Form. Der härteste Gips wird am wenigsten komprimiert.
15. Man soll die Prothesenmodelle so niedrig wie möglich machen und sie in eine möglichst niedrige Küvette eingiessen, wenn man eine möglichst geringe Bisserrhöhung bekommen will.
16. Mehrere Hartgipsfabrikate sind für Prothesenmodelle und zum Eingiessen in die Küvette weniger gut geeignet.

RÉSUMÉ

LA DURETÉ ET LA COMPRESSIBILITÉ DE DIFFÉRENTS PLÂTRES
POUR MODÈLES

Les études ci-dessus rapportées sur *la dureté et la compressibilité de différents plâtres pour modèles* ont donné les résultats suivants:

1. La stabilité de forme du plâtre à modèle est déterminée, en premier lieu, par sa dureté et les modifications de volume dues à l'expansion.
2. La dureté du plâtre est en même temps une expression de sa faculté de déformation plastique. La déformation élastique subséquente ne peut être constatée qu'à un degré faible, et pas du tout si le plâtre est exposé à une compression locale par une bille d'acier dont on se sert pour l'essai de dureté.
3. La dureté du plâtre est aussi une expression de sa compressibilité. Grande dureté, faible compressibilité.
4. La croissance de dureté du plâtre, par suite des processus de la prise, est très forte pendant les premières 30 à 40 minutes (selon les produits) après le délayage, un peu plus faible pendant les 90 minutes qui suivent, après quoi elle devient presque nulle. Ainsi, il faut éviter de séparer un modèle de l'empreinte avant $\frac{1}{2}$ heure au moins après le moulage.
5. Le plâtre sec perd env. 60 % de sa dureté lorsqu'il est humecté. La dureté est récupérée par séchage. Même de très faibles quantités d'humidité réduisent sensiblement la dureté.
6. Les modèles de travail doivent être tenus complètement à

sec pour posséder un maximum de résistance aux efforts mécaniques. — Si l'on désire broyer le plâtre ou enlever des excédents de plâtre, ces opérations se font beaucoup plus facilement le plâtre étant humide que lorsqu'il est sec.

7. La dureté du plâtre augmente fortement avec la diminution de la quantité d'eau dans le rapport de mélange eau/plâtre. On obtient la plus grande dureté du plâtre en faisant soigneusement le délayage.
8. L'homogénéité du plâtre est subordonnée à un délayage soigneux. Le défaut d'homogénéité en cas de mauvais délayage est très prononcé.
9. La dureté superficielle du plâtre se trouve réduite d'env. 60 % par badigeonnage avec le moyen de séparation alginate Stellon, et d'env. 15 % par humectation avec méthacrylate de méthyle. La cire fluide, la vaseline et l'huile de paraffine n'exercent aucune influence sur la dureté du plâtre solidifié.
10. Les indications fournies par plusieurs fabricants sur le mélange eau/plâtre ne correspondent pas à la valeur optimum.
11. Certains produits deviennent essentiellement plus fluides par vibration (grand effet de vibration), d'autres ne changent qu'à un très faible degré leur consistance par vibration. Les premiers doivent être délayés pour avoir une consistance essentiellement plus visqueuse que ce n'est le cas pour les derniers.
12. Les différents produits présentent de très grandes variations de dureté lorsqu'ils sont délayés de sorte à avoir la consistance optimum.
13. Il y a peu de proportionnalité entre les prix des produits et leurs qualités de dureté.
14. Le plâtre se comprime visiblement et subit des déformations permanentes lorsqu'il est exposé à la pression exercée par une prothèse d'acryle. Le plâtre le plus dur se comprime le moins.
15. Il convient de faire ses modèles de prothèse aussi bas que possible et de les mouler dans la cuvette la plus basse possible, si l'on veut obtenir un minimum d'élevation de morsure.
16. Plusieurs produits de plâtre dur sont peu propres à la confection de modèles de prothèse et au moulage en cuvette.

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