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

STANDARD CONSISTENCY OF DENTAL STONE

by
KNUD DREYER JØRGENSEN
ATSUSHI KONO

INTRODUCTION

The draft for The American Dental Association's specification for dental gypsum products states that the standard consistency of standard artificial stone and high-strength artificial stone must be determined by means of a cone penetration method as described in ASTM standard C 472-66 (Fig. 2) and on plaster mixed with a 4 % sodium citrate solution.

The purpose in determining standard consistency must be to form a basis for comparison of the properties of different brands in circumstances resembling as closely as possible the practical application of these products. Since the artificial stones are normally employed under some form of vibration, the static penetration method suggested cannot be applied without considerable caution. It is a recognised fact that the rheological properties of concentrated suspensions may differ radically whether subject to static or dynamic forces.

The purpose of the present project is to introduce a method for determining the standard consistency of dental stone under vibration corresponding as closely as possible to the practical application of the material, and also to compare the results of this method with the method suggested by the A.D.A. specification.

Received for publication, January 22, 1971.

MATERIALS AND METHODS

The brands of artificial stone shown in Table I were used in the study. Brands A, B, D and F may be described as standard artificial stones requiring a moderate quantity of gauging water, whereas brands C, E, G and H are high-strength artificial stones requiring only small amounts of gauging water. At least 4 kg was purchased of each brand. The contents of each package were mixed carefully to ensure homogeneity before tests were conducted. Room temperature during all tests was 23° ± 2° C, and relative humidity was 25 % ± 5 %.

Table I
Tested brands of artificial stone

No.	Name	Batch no.	Manufacturer
A	Calestone	—	Amalgamated Dental Trade Distributors Ltd., England
B	Hard Plaster	—	Chemident, Denmark
C	Duroc	8HC	The Ransom & Randolph Co., U.S.A.
D	EP1	TL-82	Amalgamated Dental Trade Distributors Ltd., England
E	Glastone	8GA	The Ransom & Randolph Co., U.S.A.
F	Moldano	10C549	Bayer Leverkusen, W. Germany
G	Surstone	RO6	The G-C Chemical Mfg. Co. Ltd., Japan
H	Vel-mix	735 C848	Kerr Europ S.p.A., Italy

The apparatus for measuring the standard consistency of the stone during vibration is illustrated in Fig. 1; its primary component is a horizontal, semi-cylindrical trough (A) with a diameter and length of 10 mm. One vertical end of the trough is closed by a square plexiglass plate (B), secured by a screw (C); the top edge of the plexiglass plate is at the same level as the upward-facing base surface of the trough. The free end of the trough opens onto a 30-mm wide incline (D) of polished brass. The incline has a 60° gradient, and a millimeter scale is engraved on the side; the length of the incline is 48 mm. The free end of the trough can be closed by means of a plexiglass plate (E) whose bottom edge rests on the base plate (F) of the apparatus; the upper end of the plexiglass plate has a 5-mm high vertical surface which closes the free end of the trough, and the top edge of the plate lies on the same plane as the upward-facing base surface of the trough.

The apparatus is screwed on a dental, electromagnetic gypsum vibrator which in the basic tests was the large model manufactured by Dipl.-Ing. E. u. H. Renfert, Singen/Htwl., W. Germany (no. 1048/93); in the following

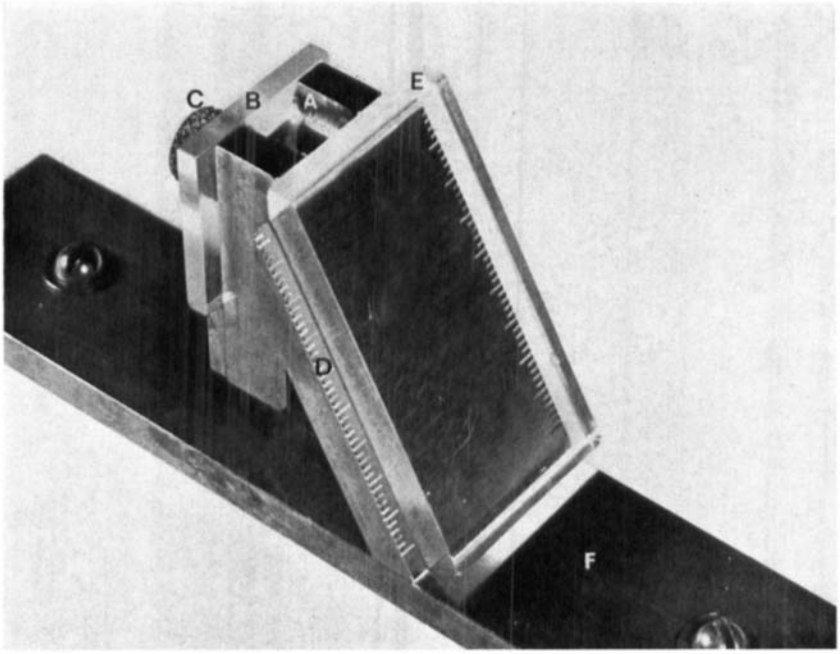

Fig. 1. Apparatus for measuring consistency of water/powder mixes by vibration. Operation of the apparatus is described in the accompanying text, page 450.

report this vibrator will be referred to as Porex I. In supplementary tests, which will be discussed below, a smaller model of the same manufacture (no. 1720) was also used — referred to as Porex II — in addition to a Croform vibrator (no. 416) manufactured by Croform Techniques Ltd., England, with a circular table having a diameter of 10 cm. The vibrators were connected to an A.C. supply, 220 volts $\pm$ 1 volt, 50 cycles.

The intensity of vibrations produced by Porex I can be varied by means of a rotary resistor, adjustable to values 0—10. The setting was kept at 10 for all tests — representing maximum intensity.

The consistency of the gypsum was determined in the following manner. A given quantity of demineralised water was drawn off by means of a pipette (accuracy: $\pm$ 0.05 ml) into a plaster bowl of plastics with a rounded bottom; diameter of the bowl was 75 mm. A 25 g charge of hemihydrate powder was weighed (accuracy: $\pm$ 25 mg) and poured into the water in the plaster bowl. Ten seconds later mixing was commenced with a stiff-bladed, stainless steel spatula with rounded contours and a width of 15 mm. Mixing lasted for 20 seconds with approximately two rotations per second; in the case of highly

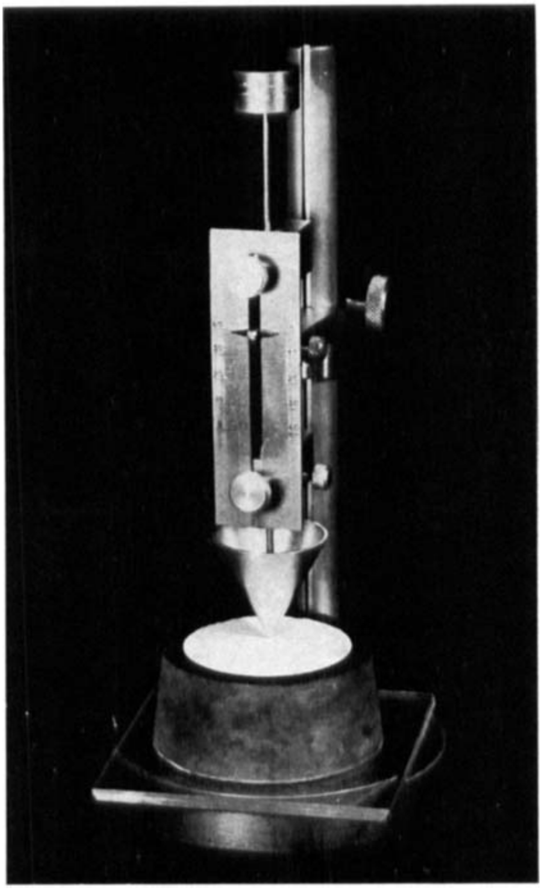

Fig. 2. Modified Vicat apparatus in accordance with ASTM C472-66 for determining consistency of W/P mixes according to cone penetration method.

viscous mixtures a spatulation movement was employed in addition to the rotary movement. In all cases the mixtures had a homogenous appearance when stirring was completed. Immediately afterwards the semi-cylindrical trough on the consistency apparatus was filled with the gypsum mixture with the aid of a cement spatula; the surplus gypsum was scraped off with the straight edge of the spatula. Forty seconds after mixing, the plexiglass plate (E) was removed with a horizontal movement parallel with incline (D), and in the same instant the vibrator was started. Vibration lasted for 20 seconds. The length of the stone tongue on the incline was then measured with the aid of a ruler and the engraved millimeter scale; measurement was accurate to within 0.5 mm. The length of the stone tongue was taken as a measure of the consistency of the dental stone.

The water/plaster ratio was varied in a series of different tests. For brands A, B, D and F the range varied from 0.24 to 0.32, and for brands C, E, G and H the range was from 0.19 to 0.26. Five tests were conducted with each mix ratio. It is the opinion of the authors that a length of 10 ± 2 mm of the stone tongue on the incline corresponds to optimum consistency, i.e. the thickest possible consistency which still permits convenient application of the mixture in the dental laboratory. It is submitted that this consistency should be adopted as the standard consistency.

RESULTS

The relationship between water/plaster ratio and the length of the plaster tongue in the consistency apparatus is shown in Table II, and in the case of brands D and H additionally in Fig. 3.

In order to compare the standard consistency of the vibration method described above with the standard consistency according to the A.D.A. specification, the latter was measured in accordance with the directions in the specification, except that the penetration depth of the cone was measured five times instead of three, at 7, 8 and 9 minutes after mixing commenced. The mean value of the total of 15 measurements made for each mix ratio was then calculated. The results are seen in Tables III and IV.

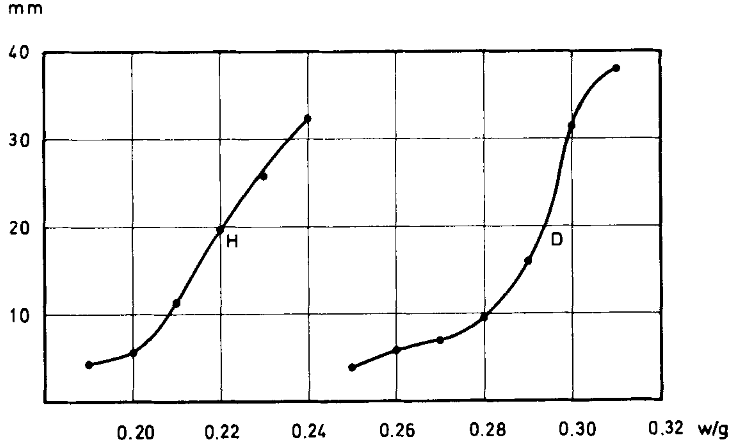

Fig. 3. Relationship between W/P ratio and length of plaster tongue on the apparatus in Fig. 1 for a high-strength artificial stone (brand H) and a standard artificial stone (brand D).

Table II

Effect of water/plaster ratio on length in mm of stone tongue on the incline of the consistency apparatus for brands A—H

W/P	A		B		C		D		E		F		G		H	
	$\bar{x}$	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.	$\bar{x}$	S.D.
0.19					7.1	1.02							6.8	0.75	4.3	0.88
0.20					9.8	1.33			4.5	0.45			10.3	1.01	5.6	0.80
0.21					17.5	2.28			6.3	0.60			13.9	1.02	11.2	1.17
0.22					24.2	2.01			11.8	1.83			24.5	1.42	19.8	2.27
0.23					31.1	1.62			14.6	1.50			27.1	1.80	25.9	1.11
0.24	1.8	0.93			41.4	2.45			27.8	1.54			38.3	2.82	32.4	1.36
0.25	2.4	0.49					3.9	0.66	33.1	1.63						
0.26	5.8	1.03	5.1	1.11			5.8	0.68	38.4	1.53						
0.27	6.4	0.86	7.5	0.63			6.9	1.36								
0.28	8.3	1.08	10.9	1.40			9.3	1.44			4.1	0.20				
0.29	22.2	2.04	16.8	1.46			16.0	0.63			8.1	1.02				
0.30	33.6	3.22	22.3	1.63			31.4	1.63			23.8	2.30				
0.31	38.0	2.00	24.1	1.60			38.1	1.74			30.6	1.16				
0.32			29.7	1.60							36.5	1.55				

n = 5

Table III

Depth of penetration by A.D.A. cone method in plaster mixed to standard consistency according to vibration method

Brand	W/P ratio for standard consistency according to vibration method	Depth of penetration (mm) $\bar{x}$	S.D.
A	0.28	19.8	1.14
B	0.28	10.2	0.75
C	0.20	20.7	0.75
E	0.22	21.4	1.00
F	0.29	26.6	0.52
H	0.21	14.6	0.64

To study the accuracy of the vibration method, the mixing time was varied for one of the brands (H), as was the period between the conclusion of mixing and the commencement of vibration, and the vibration time itself. The results are seen in Tables V, VI and VII.

As the consistency apparatus could be mounted in two different positions on the vibrator table, with the incline facing either right (position 1) or left (position 2), a study was also conducted to see what significance this factor might have for the measurement of consistency. The results are shown in Table VIII.

A test was also made of the significance of placing the vibrator on either an ordinary wooden laboratory table or a 5-cm thick terrazzo (Table IX).

Table IV

Length of plaster tongue according to vibration method for plaster mixed to standard consistency stipulated by the A.D.A. cone penetration method

Brand	W/P ratio according to A.D.A. cone penetration method	Length of plaster tongue (mm) $\bar{x}$	S.D.
A	0.31	38.0	2.00
B	0.38	>48	
C	0.26	37.3	2.56
E	0.28	>48	
F	0.31	30.6	1.16
H	0.28	>48	

Table V

Effect of mixing time on length of plaster tongue. Brand H mixed to standard consistency of vibration method

Mixing time (secs.)	Length of plaster tongue (mm) $\bar{x}$	S.D.
20	11.2	1.17
30	10.6	2.58
45	9.1	1.96
60	8.5	1.95
90	5.8	0.81

n = 5

Table VI

Effect on length of plaster tongue of various pauses between conclusion of mixing and commencement of vibration

Pause (secs.)	Length of plaster tongue (mm) $\bar{x}$	S.D.
20	15.0	1.12
40	10.2	0.84
60	12.8	0.95
90	14.5	1.08

Brand H mixed to standard consistency of vibration method. n = 5

Table VII

Effect of vibration time on length of plaster tongue

Vibration time (secs.)	Length of plaster tongue (mm) $\bar{x}$	S.D.
10	6.8	0.46
15	8.5	0.72
20	10.2	0.84
30	15.8	1.18

Brand H mixed to standard consistency of vibration method. n = 5

Table VIII

Effect on length (mm) of plaster tongue of the position of the consistency apparatus on the vibrator table

W/P	Position 1		Position 2	
	$\bar{x}$	S.D.	$\bar{x}$	S.D.
0.21	10.3	1.47	14.8	0.75
0.22	13.2	0.98	20.9	2.20
0.23	16.5	1.90	28.1	1.02

Brand H n = 5

Vibrators Porex II and Croform demonstrated considerably greater effect than Porex I; with the consistency apparatus mounted on the former two vibrators the gypsum flowed much further down the incline than on the Porex I. By introducing a voltage regulator to lower the voltage to these two vibrators, it proved possible to reduce their intensity so that the standard technique developed for Porex I produced the same flow of gypsum on the inclines of all three vibrators (Table X).

DISCUSSION

The vibration method described in this work makes it possible with a high degree of accuracy to measure the consistency of mixtures of water and artificial-stone powder; differences in consistency depending on variations in the mix ratio are very clear (Table II and Fig. 3). The vibration method for determining the standard consistency of artificial stone must be regarded as more relevant than the cone penetration method; as the results of the two methods scarcely correlate, it would seem reasonable to describe the penetration method as less suitable.

Table IX

Effect of vibration underlay on length (mm) of plaster tongue

W/P	Wooden table		Stone table	
	$\bar{x}$	S.D.	$\bar{x}$	S.D.
0.20	6.2	0.72	11.4	1.17
0.21	10.7	1.71	14.4	1.12
0.22	21.5	1.58	23.5	1.36

Brand H n = 5

Table X

Voltage necessary on different vibrators to produce the same result in measurement of consistency

Porex I	Porex II	Croform
218—222	127—133	91—95
Brand H	W/P = 0.21	

The vibration method is based on the use of a dental, electromagnetic vibrator; one possible disadvantage of this method may be that the effect transferred from the vibrator to the W/P mix via the consistency apparatus cannot be standardised mechanically. The effect depends partly on the position of the apparatus on the vibrator table (Table VIII), partly on the underlay on which the vibrator rests (Table IX), and partly on the type of vibrator and the voltage supplied (Table X). All these factors can be held constant without any difficulty for a given vibrator; but if the vibration method for determining the standard consistency of artificial stone were to be used not only in a single research or control laboratory but also as part of a national or international standard, every single vibrator used for this purpose would require to be adjusted. This adjustment can be performed in the traditional manner by the issue of plaster samples from a central laboratory to all interested parties.

Other variables involved in the vibration method (voltage, mixing time, vibration time, etc.) appear to have such a moderate effect on the results of the method that they can be kept sufficiently constant without great difficulty.

SUMMARY

Prompted by a method for determining the standard consistency of dental stone by means of a method of cone penetration described in a proposed American Dental Association Specification for Gypsum Materials, the authors have studied an alternative method which tests the standard consistency by means of vibration. The results of the two methods were poorly correlated. As the vibration method can be presumed to provide in practice a more satisfactory expression of standard consistency, it is suggested that this be used instead of the penetration method. The vibration method presents no difficulties in checking variable factors but it requires adjustment of the individual vibrator with fitted consistency apparatus; such an adjustment can

be performed with the aid of plaster samples issued by a central laboratory to all interested parties.

RÉSUMÉ

CONSISTANCE STANDARD DES PLÂTRES DURS POUR USAGE DENTAIRE

Après qu'une spécification concernant les matériaux à base de plâtre proposée par l'American Dental Association ait donné la description d'une méthode destinée à la détermination de la consistance standard des plâtres durs pour usage dentaire en utilisant la pénétration d'un cône, les auteurs du présent article ont effectué l'étude d'une méthode différente, dans laquelle l'essai de la consistance standard se fait en vibrant. Les résultats des deux méthodes présentaient une mauvaise corrélation. Etant donné que la méthode vibratoire fournit vraisemblablement une expression de la consistance standard répondant mieux aux conditions pratiques, les auteurs proposent qu'elle soit employée à la place de la méthode par pénétration. La méthode vibratoire ne comporte pas de variables difficilement contrôlables, mais elle exige le réglage du vibra- teur utilisé avec un appareil monté pour la détermination de la consistance; un réglage de cette nature peut être réalisé en utilisant des échantillons de plâtres fournis aux parties intéressées par un laboratoire central.

ZUSAMMENFASSUNG

DIE STANDARDKONSISTENZ DENTALER HARTGIPSE

Auf Veranlassung eines Verfahrens zur Bestimmung der Standardkonsistenz dentaler Hartgipse mittels einer Kegel-Penetrations-Methode, die in einer vorgeschlagenen »American Dental Association Specification for Gypsum Materials» beschrieben ist, haben die Verfasser dieses Berichtes ein alternatives Verfahren untersucht, das die Standardkonsistenz bei Vibration prüft. Es zeigt sich, dass die Ergebnisse der beiden Verfahren voneinander abweichen. Da das Vibrationsverfahren vermutlich einen für die Praxis zweckmässigeren Ausdruck der Standardkonsistenz vermittelt, wird die Anwendung desselben anstatt des Penetrationsverfahrens vorgeschlagen. Das Vibrationsverfahren ist mit keinen schwer kontrollierbaren Variablen behaftet, es setzt jedoch die Justierung des einzelnen Vibrators mit anmontiertem Konsistenzgerät voraus; eine solche Justierung liesse sich durch den Versand von Gipsproben von einem zentralen Laboratorium and die Interessenten vornehmen.

REFERENCES

American Society for Testing Materials. C 472.66. Physical testing of Gypsum plasters and gypsum concrete.

American Dental Association: Proposed specification for gypsum materials, June 2, 1969.

Address:
Department of Technology,
The Royal Dental College,
160 Jagtvej, 2100 Copenhagen Ø,
Denmark