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PHYSICAL PROPERTIES OF A PLASTIC FILLING MATERIAL

(ADDENT®)

by

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INTRODUCTION

Although silicate cement and acrylic resins are commonly used for anterior fillings, the properties of neither of these materials approach the ideal. Silicate cements are soluble, particularly in an acid environment, whilst the coefficient of thermal expansion and low abrasion resistance of acrylic resins make them unsuitable for a permanent restoration. Among the more recent synthetic polymers, several may be found which have one or more of the desired properties of an anterior tooth filling material. In recent years, attempts have been made to find a polymer or mixture of polymers which possesses as many as possible of the required properties. These should include:

Insignificant dimensional changes on setting
A coefficient of thermal expansion equal to that of the tooth substance
Adhesion to dentine and enamel
Chemical inertness
Insoluble in mouth fluids, dimensional stability, mechanical properties equal to tooth substance
Good colour matching and colour stability
No pulp reaction
Easy manipulation.

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Bowen (1956, 1962, 1963, 1964) investigated resins reinforced with glass particles and found that surface treatment of the glass particles with vinyl silane established a chemical bond between filler and resin. The resulting material had properties which rendered it more suitable as a filling material than resin reinforced with particles which were not surface treated.

In 1961, the *Minnesota Mining and Manufacturing Co.* (*3M*) developed and marketed a filling material, Addent 35, composed of 70 % surface treated glass particles and 30 % organic binder which was a copolymer of an epoxy compound and an acrylate. The material was for class III and V cavities. Later Addent 12 was marketed. This newer material was for class I cavities in molars and for class I and II cavities in premolars and deciduous molars.

Roydhouse (1966) explained the origin of the material and suggested the presence of a certain degree of adhesion to tooth substance. More than 10,000 fillings of Addent were made, and at the time of publication these were still under observation. The results of these clinical investigations have not yet been published. *Hollenback* (1966) did not agree with *Roydhouse* (1966) as to the adherent properties of Addent, and stated that Addent did not adhere to tooth substance.

In a survey on improvements in dental materials, *Phillips* (1966) commented that lasting adhesion under mouth conditions had not been demonstrated.

Peterson et al. (1966) compared Addent with three acrylic resins and found that Addent was harder and had greater abrasion resistance than the acrylic resins. Penetration of Ca_{45} along the margins of fillings occurred with all four materials.

Going & Sawinskii (1966) investigated nine different filling materials for sealing ability by means of Ca_{45}, and found that Addent was as good as, or better than, other polymers and at first better than silver amalgam and silicate cement.

Pothmann (1967) investigated color stability and discoloration of 38 Addent anterior fillings. After six months the marginal adaptation, surface and colour were satisfactory.

Schulman (1965) checked fillings of Addent at one, three and six months after they had been made and found that the material was better than both silicate cement and acrylic resin as far as adaptation, colour stability, contraction and solubility were concerned.

The aim of this study has been to evaluate the material by subjecting it to laboratory tests.

MATERIALS AND METHODS

Batches. The experiments were carried out on

Addent 12 batch no. 6353/03

Addent 35 batch no. 6335/03

Sevriton® batch no. K,7z,K3 (powder) and B, 10p,K3 (liquid).

All specimens, except those used for measuring dimensional change upon setting, were covered by tinfoil and stored for 24 hours at 37°C prior to testing.

Setting contraction. The linear dimensional changes upon polymerization were measured at room temperature ($24 \pm 1°C$) by the mercury bath technique (*Docking et al.*, 1948). The specimen, about 20 mm in length, was floated on a bath of mercury and fastened at one end to the wall of the bath. On the other end a small lump of compressed tinfoil was placed. Apart from the fixing point the specimen was placed far from the other walls of the bath, and thus it was free to move unrestricted. With the bath on the stage of a travelling microscope a well-defined measuring point on the surface of the tinfoil was chosen. The position of this point was determined at half-minute intervals from 1½—7 minutes after starting the mix, and then at increasing intervals until 24 hours after starting the mix. The accuracy of measurements with the microscope was 1μ. For each type of material six series of measurements were carried out.

It was also attempted to measure the setting contraction in cavities. In extracted, intact teeth which had been stored wet since extraction, oval cavities were prepared under water spray. The cavities were about 2 mm in depth and about 4.0×2.5 mm in area. Then the teeth were dried by an air blast and stored at room temperature ($24 \pm 1°C$) for 24 hours before the fillings were made. Fillings were made according to the manufacturer's instructions. Some amalgam alloy particles were placed in the surface of these fillings near opposite edges. With the tooth secured on the stage of a travelling microscope an alloy particle near each end of the filling was chosen as a measuring point. The positions of these points were determined from 2 minutes after starting the mix until no further movements of the points could be demonstrated. Eleven cavities were underfilled to make sure that both the cavity margins and the unprepared surface were free from filling material. Seven cavities were filled flush. One cavity was overfilled.

Compressive strength. The compressive strength was measured on cylindrical specimens, 6.0 mm in diameter and 11.8 mm high. Half the specimens of each type were crushed in a »Losenhausen» compressive strength testing machine with a rate of loading of 10 kg per second. The remaining

specimens were weighed and subjected to vacuum-vibration in distilled water for 30 minutes and weighed again, because these specimens were used also for the water absorption experiments reported below. After this the specimens were stored for 5 months at 37°C in distilled water, which was renewed after 1, 2 and 3 months. After 5 months the specimens were crushed as described above.

Hardness. The surface hardness of the two types of materials was measured using an Alpha-Durometer (Type D) mounted with 1/8″ steel ball and a major load of 44.4 kg (modified Rockwell test). The specimens were loaded with the minor load (10 kg) for 10 seconds. Immediately thereafter the major load was applied and maintained for 8 seconds. The dial scale B was read 45 seconds after replacing the minor load. The disc-shaped specimens had parallel flat surfaces and a thickness of 2 mm. The surfaces were polished with fine emery paper. Each series comprised 12 specimens and 3 readings were taken on each surface at room temperature (24 ± 1°C). The specimens were stored for 5 months in distilled water at 37°C and then tested again.

Abrasion resistance. The abrasion resistance of Addent 12, Addent 35 and Sevriton was tested using a motor-driven tooth brushing machine. Twenty-four disk specimens were made with a diameter of 16 mm and a thickness of 2 mm. After polishing with emery paper no. 600 the specimens were divided into three groups each comprising four specimens of each of two materials. The machine was mounted with four heads of tooth brushes (Tandex no. 19), each loaded with 500 g. The brushes were moved to and fro at 55 cycles per minute. As an abrasive, »Macs» fluorine toothpaste suspended in glycerol (ratio 1:4) was used. Four specimens from each group were subjected to brushing for five hours, while the four remaining specimens were kept in the abrasion suspension as a control. For each of the three groups new brushes were used with a fresh suspension of toothpaste. All specimens were weighed before and after brushing.

Thermal expansion. The coefficient of thermal expansion by volumen was measured in a mercury dilatometer in the temperature range 25—45°C on five box-shaped specimens ($3.5 \times 3.5 \times 25$ mm) of each type of material. Each specimen was measured twice. To complete the polymerization each specimen was heated slowly to 55°C and then cooled to room temperature (22 ± 1°C) before the measurements were carried out. To avoid errors due to the low thermal conductivity of the specimens the temperature was maintained until three consecutive readings at 15 minute intervals gave the same values for expansion. The temperature was read with an accuracy of 0.1°C and the expansion was recorded to 0.05 mm[3].

Water absorption. Six disk specimens with a diameter of 15 mm and a thickness of 1.75—2.00 mm were used together with the cylindrical specimens also used for determining compressive strength. Two pieces of 0.2 mm brass wire were embedded in two diametrically opposite places near the border in the disk-shaped specimens, so that the end of the wire was level with the surface after the specimen was polished. The ends of the wires were used as measuring points in determining linear change due to storage in water. The cylindrical specimens were polished flat in both ends. All specimens were weighed every day until the weight on three consecutive days was constant. Then the distance between the measuring points in the disk shaped specimens were measured by a travelling microscope, and the length of the cylindrical specimens was determined by a micrometer gauge. To find out if a vacuum treatment in water had any effect on weight and dimension and to standardize the material the specimens were vacuum-vibrated in distilled water for 30 minutes and then weighed and measured. The vacuum treatment had no detectable effect on the cylindrical specimens. The disk shaped ones showed a slight increase in weight ($0.7\ ^0/_{00}$) and a slight reduction of the distance between the measuring points ($0.9\ ^0/_{00}$). The values found after vacuum treatment were used as a base for calculating changes in weight and dimensions by storage in distilled water at 37°C for five months. The water was renewed after one, two and three months, and weight and length were measured at the same time and at the end of the experiment after five months.

Discoloration. Ten disk shaped specimens with a diameter of 10 mm and a thickness of 2 mm of each of the two types of material were polished on one surface with emery paper no. 600 and alternately dipped into two baths with 1 % aqueous solution of methylene blue. The temperatures of the two solutions were 45°C and room temperature (24 ± 1°C). The purpose of using two baths was to subject the specimens to a temperature change, which might increase the discoloration. The stay in each bath was 15 seconds. The experiment was continued with interruptions until 5,500 immersions in each bath were attained.

Colour stability. Three disk shaped specimens of both Addent 12 and Addent 35 were exposed to the radiation of a lamp as defined in A.D.A. specification no. 12.

RESULTS

Setting contraction. The results from measurement on the mercury bath appear in Table I and Figs. 1a and b. The difference between the contrac-

tion figures after 24 hours is statistically significant for $P < 0.005$. The figures, but not the table, include all intermediate readings.

The results from measuring contraction in cavities are given in Table II. The table does not include intermediate readings as there was random movement of the reference points in relation to each other which not achieved a state of stability until the material had set.

Compressive strength. The measured compressive strength values are listed in Table III. In both dry and wet conditions Addent 35 is 10—20 % weaker than Addent 12, and Addent 35 loses more of its strength (20 %) than Addent 12 (10 %) on storage in water.

Hardness. The hardness numbers appear in Table IV. Storage in water causes a reduction in hardness of about 9 % for Addent 12 and about 20 % for Addent 35. In a dry condition Addent 35 is about 5 % less hard than Addent 12. In a wet condition the difference is about 15 %. Addent 12 is almost twice as hard as Sevriton.

Abrasion resistance. None of the control specimens showed any change in weight after 5 hours in the suspension. The weight loss of the abraded specimens is shown in Table V. The two Addent materials turned out to have an abrasion resistance about ten times as great as Sevriton, whereas no definite

Table I.

Setting contraction at room temperature (24±1°C) of Addent 12 and Addent 35 measured on mercury bath during the first 24 hours after starting the mix. The figures are averages from six series of readings. One series of readings of each type of material was continued until three days after the mix.

minutes after starting the mix	2	5	10	20	60	1440	4320
				Addent 12			
linear contraction in %	0.16	0.48	0.62	0.73	0.85	0.98	1.00
standard deviation	0.071	0.061	0.071	0.069	0.068	0.083	—
variation coefficient %	45	13	11	9	8	8	—
				Addent 35			
linear contraction in %	0.14	0.42	0.52	0.50	0.67	0.77	0.85
standard deviation	0.058	0.065	0.073	0.078	0.084	0.090	—
variation coefficient %	41	15	15	13	13	12	—

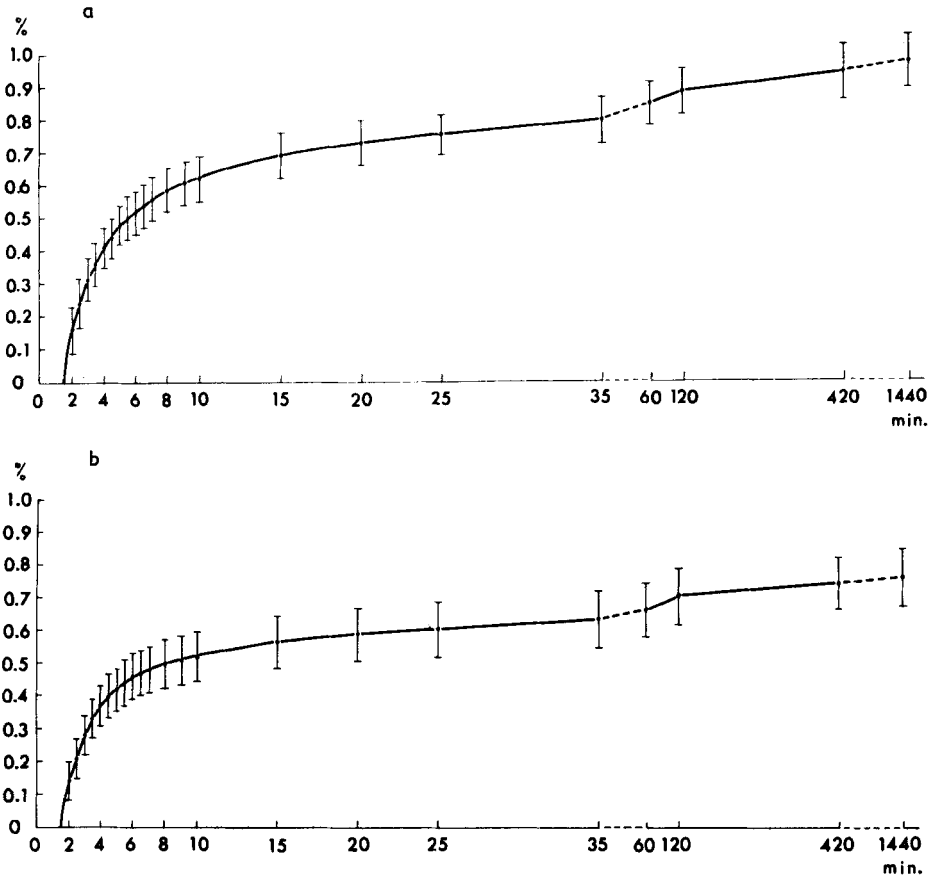

Fig. 1. a. Addent 12. b. Addent 35. Linear setting contraction in per cent in relation to time passed after starting the mix measured on mercury bath at room temperature (24±1°C). The figures are averages from six readings. The vertical lines in the points have a length corresponding to twice the standard deviation in the point.

difference between Addent 12 and Addent 35 could be demonstrated. While it was very difficult to detect any abrasion of the Addent specimens, the acrylic specimens showed distinct traces of abrasion as shown in Fig. 2.

Coefficient of thermal expansion. The calculated coefficient of linear thermal expansion was $(35 \pm 4) \times 10^{-6}$ cm/cm/°C for Addent 12 and $(27 \pm 2) \times 10^{-6}$ cm/cm°C for Addent 35.

Water absorption. The results from water absorption experiments are shown in Table VI and presented in the diagrams in Fig. 3 and 4. In Table VI the increments are given in per cent and the weight increments are con-

Table II.

Addent 35: Linear change upon setting measured in cavities at room temperature (24±1°C)

	% linear change									
A	0	0	—0.26	—0.30	—0.30	—0.37	—0.58	—0.80	—0.29	—0.40	+0.20
B	+0.39	+0.15	+0.10	+0.48	+0.19	+0.11	0				
C	+0.15										

A: 11 cavities underfilled.
B: 7 cavities filled flush. Enamel surface around the cavity cleaned by scraping.
C: 1 cavity overfilled.
All the cavities were coated with cavity liner before filling according to the manufacturer's instructions.

Table III.

Comparison of values for compressive strength measured on cylindrical specimens: diameter 6.0 mm, height 11.8 mm

	compressive strength kp/cm²	difference	difference in %
Addent 12 dry	2221 ± 117	+++	100
Addent 35 dry	1961 ± 126		88
Addent 12 wet	2016 ± 184	+++	100
Addent 35 wet	1554 ± 56		77
Addent 12 dry	2221 ± 117	++	100
Addent 12 wet	2016 ± 184		91
Addent 35 dry	1961 ± 126	+++	100
Addent 35 wet	1554 ± 56		79

dry: specimens stored for 24 hours after starting the mix at 37°C.
wet: specimens stored in destilled water at 37°C for five months.
The readings were taken at room temperature (24±1°C).
In each group the higher value is equaled to 100 and the lower value calculated in per cent from this.
+++ : highly significant, $P<0.001$.
++ : significant, $P<0.01$.

Table IV.

Rockwell hardness numbers

		mean hardness	max / min
Addent 12	dry	113.17	114 / 112
	wet	103.36	105 / 100
Addent 35	dry	107.72	110 / 103
	wet	86.19	90 / 83
Sevriton	dry	65.39	70 / 61
	wet	54.53	59 / 49

1/8 inch steel ball. Major load 44.4 kg.
The results are averages from three readings on each of twelve specimens.
The specimens were polished with emery paper no. 600.
dry: (see table III).
wet: (see table III).
The readings were taken at room temperature (24±1°C).
The impressions by major load were for Sevriton about 0.25 mm, and for Addent about 0.10 mm deeper than those by minor load.
The specimens were 2 mm in thickness.

Table V.

Loss in weight caused by tooth brushing under conditions mentioned in the text

	mean loss in weight mg	standard deviation	mean error	relative difference (2.25 = 100)
Addent 12	2.25	0.45	0.23	100
Addent 35	2.30	0.32	0.16	102
Sevriton	21.18	1.02	0.51	941

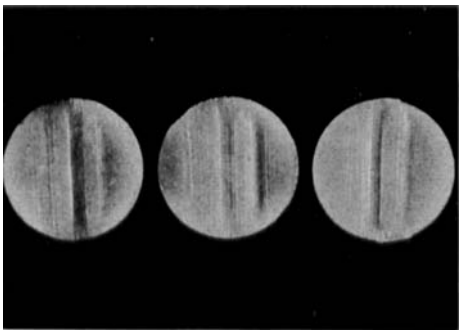

Fig. 2. Acrylic resin specimens abraded by tooth-brushing under conditions described in the text.

Table VI.

Increase in weight and length after storing in destilled water at 37°C for one, two, three, and five months, respectively

	Addent 12							
	increase in weight %				increase in length %			
disk shaped	1.23	1.45	1.75	1.88	0.44	0.58	0.65	0.71
cylindrical	0.88	1.18	1.38	1.60	0.24	0.37	0.45	0.51
average	1.06	1.32	1.52	1.74	0.34	0.48	0.55	0.61
average converted to mg/cm²	1.85	2.34	2.78	3.12				

	Addent 35							
	increase in weight %				increase in length %			
disk shaped	1.96	2.63	3.22	3.68	0.51	0.62	0.70	0.75
cylindrical	1.36	1.95	2.32	2.75	0.30	0.48	0.56	0.63
average	1.66	2.29	2.77	3.22	0.41	0.55	0.63	0.69
average converted to mg/cm²	2.79	3.89	4.69	5.47				

disk shaped: circular specimens. Diameter 15 mm. Thickness 1.75—2.00 mm. Polished on both sides with emery paper no. 600.

cylindrical: cylindrical specimens. Diameter 6 mm. Height 11.8 mm. Both end surfaces were polished flat with emery paper no. 600.

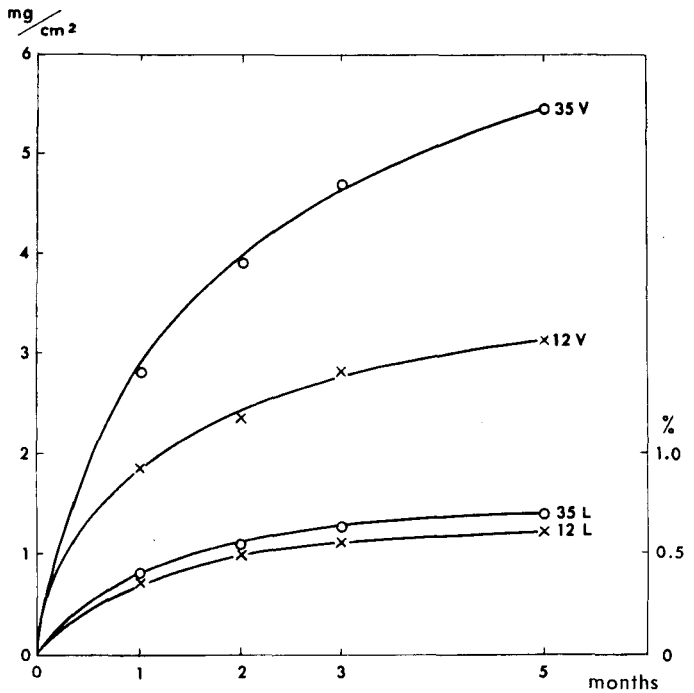

Fig. 3. Increase in weight and length of Addent 12 and Addent 35 after storing in destilled water at 37°C. V: increase in weight in mg/cm² (left ordinate). L: increase in length in per cent (right ordinate).

verted into mg per cm² of the surface of the specimens. The increments of the disk shaped specimens are about one fifth bigger than those of the cylindrical specimens. It is seen from Fig. 3 that the increase in weight for Addent 35 is twice as big as for Addent 12, while the difference in expansion is only moderate (0.69 % and 0.61 % respectively). Most of the expansion takes place during the first two to three months, whereafter it continues at a lower rate. In Fig. 4 the results are reproduced in a semi-logarithmic scale with logarithm of time on the abscissa. Although the curve apparently becomes a straight line, an estimate of the magnitude of the expansion beyond the period investigated will be rather uncertain, as the water absorption takes place by diffusion, which ceases when saturation is reached.

Discoloration. All surfaces showed heavy discoloration, and vigorous brushing with soap and nailbrush removed only a small part of the staining. No difference in tendency of discoloration between the two types of material or between polished and unpolished surfaces could be demonstrated.

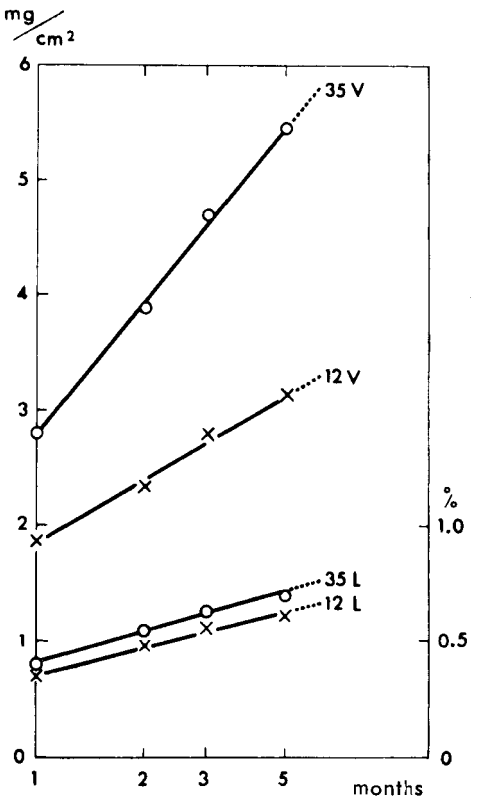

Fig. 4. Same experiment as in Fig. 3 but now with logarithmic abscissa.

Examination in a microscope (×240) revealed no traces of dye having entered the body of the specimens. The superficial discoloration was polished away from those surfaces earlier polished. In places where the first polishing had opened air bubbles, a heavy discoloration was seen entering the specimen to a depth of about 0.5 mm. The discolored spots were soft and could be removed with an instrument.

Colour stability. After exposure to ultraviolet light for 24 hours all specimens showed a very easily perceptible change in colour. The exposed surfaces were yellowed.

DISCUSSION

Setting contraction. The reason why Addent 12 showed more contraction (1.0 %) than did Addent 35 (0.85 %) is probably the difference in shape of the filling particles as shown in Fig. 5. Ball-shaped particles yield greater

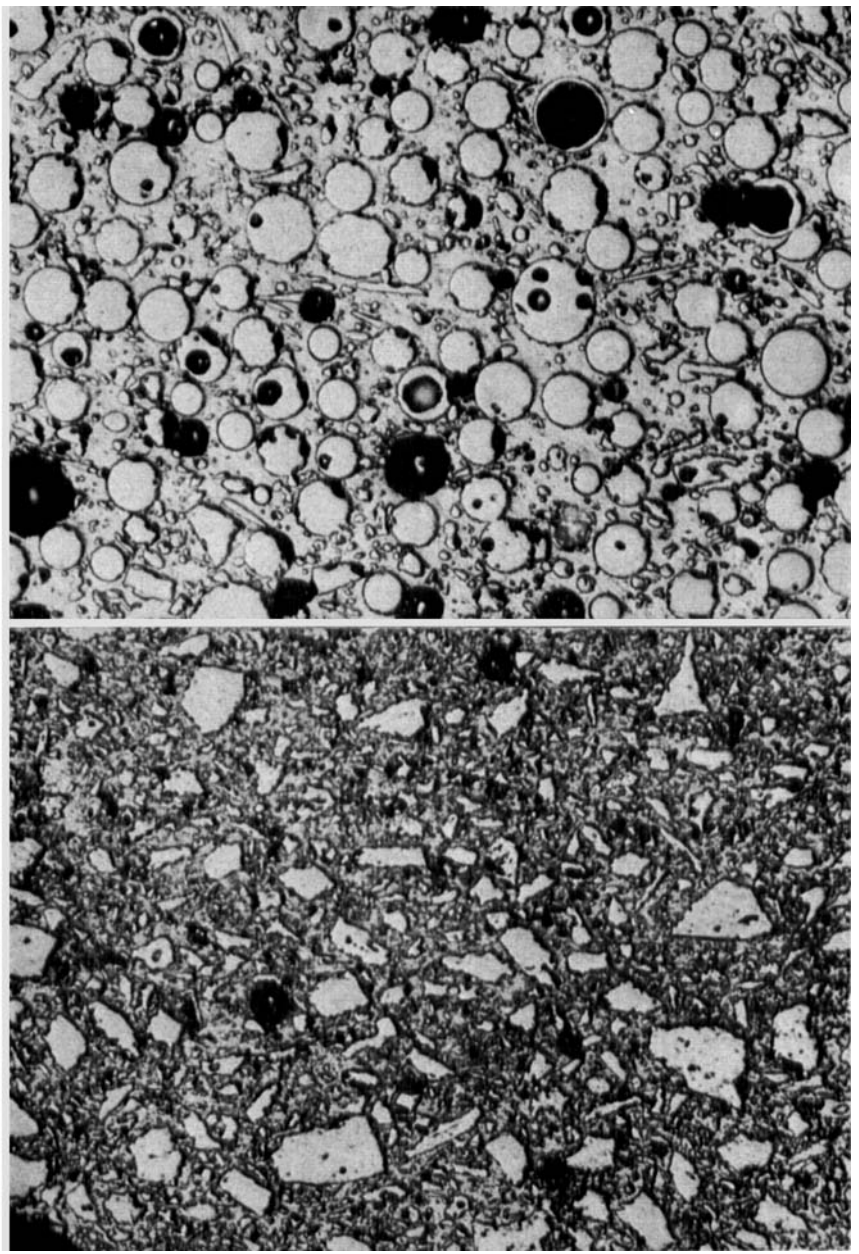

Fig. 5. Microphotographs of set Addent material, ×240, reflected light. a. Addent 35 with ball shaped particles. b. Addent 12 with irregularly shaped particles. The black spots represent air bubbles.

reinforcement and less need of organic binder (resin) than do particles of random, irregular shape (*Bowen*, 1964). In a resin composed approximately like Addent, *Bowen* (1963) has found a volumetric setting contraction of 2.7 % after 60 minutes which is in good accordance with the linear contraction values of 0.6—0.7 % after 60 minutes found here.

No conclusion as to the behaviour of the material in cavities could be drawn from the results of measurements on fillings. Negative values (contractions) seem most likely when the cavities are underfilled, and positive values (expansion) when the cavities are filled completely. Tensile forces will develop in a filling material setting in a cavity, if an adhesive bond occurs between filling material and cavity walls. The strength of the adhesive bond must exceed the tensile stresses that develop upon setting of the material for the sealing of the cavity to remain intact. (*Bowen*, 1967). Thus the positive figures in Table II do not reflect an expansion but indicate that the bond of the material to the cavity walls has been able to resist the stresses developed in the material. The large variations between the measurements might be explained if the bond between material and cavity wall has been able to resist the tensile stresses in the material only for a limited period. A measuring point would move towards the point on the cavity wall where the bond is strongest.

Compressive strength. The manufacturer (*3M*, 1966) gives compressive strength values of 1900 kp/cm² for Addent 12 and 1500 kp/cm² for Addent 35 with a reduction of 1 % and 3 % respectively after storage in water for three weeks. *Bowen* (1963) gave the value of 1600 kp/cm² for a material which largely corresponded with Addent 35. *Hollenback et al.* (1966) reported values of 1820 and 1540 kp/cm² for Addent 12 and Addent 35 respectively. Thus there is fair agreement between the values stated in the literature and those found here. Addent is two to three times as strong as acrylic resin (700—1000 kp/cm²), of about the same strength as silicate cement (1700—2300 kp/cm²) and about half as strong as amalgam (3500—4000 kp/cm²) according to *Skinner & Phillips* (1967).

Hardness. Chang et al. (1965) found that Addent 35 had a Rockwell hardness of H-100 for a dry specimen and H-88 after three weeks' storage in water at 37°C. For Addent 12, *3M* (1966) gave the numbers H-102 and H-101 respectively. Rockwell test H (60 kg major load) gives numbers which are about 10 units smaller than the numbers from the modified Rockwell test (44.4 kg major load) used here. *Bowen* (1963) compared Rockwell hardness numbers for a material like Addent 35 with those for silicate cement and acrylic resin and found that this material was twice as hard as acrylic resin and about 30 % harder than silicate cement. *Peterson et al.* (1966) mea-

sured Knoop hardness on Addent and acrylic resin and found too that Addent was at least twice as hard as acrylic resin. Thus there are no major discrepancies between the values in the literature and those found here.

Abrasion resistance. Shell et al. (1966) have found that Addent had an abrasion resistance almost as great as that of amalgam and considerably greater than that of other resins and silicate cement. The same difference in abrasion resistance between Addent and acrylic resin was found by *Phillips* (1966), *Peterson et al.* (1966), *Shell et al.* (1966) and *Hollenback et al.* (1966), Furthermore *Hollenback et al.* (1966) were able to demonstrate that the abrasion resistance of Addent 12 was about 50 % greater than that of Addent 35, and that Addent 35 and silicate cement had approximately equal abrasion resistance. *Shell et al.* (1966) stated that the abrasion resistance of Addent 35 was almost equal to that of amalgam, and that the abrasion resistance of Addent 12 was 50 % greater than both that of Addent 35 and amalgam. Contrarily *Nishii et al.* (1967) have found that the abrasion resistance of Addent is inferior to that of reinforced acrylic resin, and *Buonocore et al.* (1966) found the same abrasion resistance of Addent and silicate cement, but only half that size of abrasion resistance for acrylic resin and amalgam.

The results found here are in agreement with those quoted from the literature as to Addent compared with acrylic resin while no difference between Addent 12 and 35 could be demonstrated.

Coefficient of thermal expansion. Chang et al. (1965) reported values of 19.2×10^{-6} (0—30°C) and $45.0\times10^{6-}$ (30—50°C) for Addent 35. The corresponding numbers for Addent 12 from *3M* (1967) are 14.9×10^{-6} (0—30°C) and 53.8×10^{-6} (30—50°C). There is little difference between the values referred to and those found here. *Skinner & Phillips* (1967) stated the following coefficients: tooth substance 11.4; silicate cement 7.6; amalgam 25.0; acrylic resin 81.0. As the base in Addent has a coefficient of thermal expansion of a magnitude like acrylic resin, these values are a measure of the ability of the filler to lower the coefficient.

Water absorption. Peterson et al. (1966) found that the increased weight of Addent 35 after 150 days of storage in water was about 4.7 mg/cm² in disk shaped specimens. The increments found here are of the same magnitude. Most of the water absorption and the attendant expansion take place in two to three months, but the specimens continued to gain water over the entire test period. The influence of water absorption is discussed below.

Discoloration and colour stability. On the basis of the observations made on colour stability and discoloration and on the results of *Peterson et al.* (1966) and *Bowen* (1963) it can be stated that Addent shows a change

in colour when exposed to ultraviolet light, probably due to the amine in the catalyst system. It is not known whether the observed change in colour will influence the ability of the material to match tooth colour. If porosities have been cut when polishing, a discoloration in spots occurs. The body of the filling is not susceptible to discoloration, and normal oral hygiene should prevent discoloration of the surface except that due to porosity. Discoloration along the margins may occur due to a colour change in the cavity liner (e.g., by eugenol) or due to coloured particles of debris trapped in a gap between filling and cavity wall.

The ability of the material to seal the cavity. The ability of a tooth filling material to seal the cavity is of fundamental importance in making a permanent restoration. The initial seal is determined partly by dimensional change upon setting and partly by the adhesion of the material to the cavity walls. The ideal material is expected to adhere to tooth substance and to show a slight expansion upon setting. If the material contracts during setting, it may still seal the cavity if the material adheres strongly enough to the cavity walls (*Bowen*, 1967). If, by a matrix, pressure is applied to a contraction material, this pressure can prevent part of the setting contraction from manifesting itself, especially that part of the contraction which takes place while the material is still plastic. Addent contracts about 0.5 % while it is still partially plastic, and less than 0.5 % after it has hardened (Table I).

After setting, the sealing ability is determined mainly by the coefficients of thermal expansion. When the coefficient of thermal expansion of the filling material differs essentially from that of tooth substance, temperature changes from eating hot and cold food produce a space between cavity wall and filling. If the material expands in the cavity due to water absorption, this might increase the sealing ability, since a possible setting contraction is compensated completely or partially. Provided this late expansion is bigger than the setting contraction, compressive stresses may develop in the material and reduce the effect of temperature changes. The thermal conductivity of the material also plays a role so that temperature changes of short duration, as they occur in the mouth, do not bring about a corresponding change in volume if the thermal conductivity is low.

Whilst no clinical testing has been done, the setting contraction values, especially the values of contraction in fillings made without a matrix, the coefficient of thermal expansion and the expansion when stored in water, do not exclude a favourable interaction between the individual factors as mentioned above.

The thermal conductivity of Addent has not been measured, but it is estimated to be about 0.002 cal/sec/cm^2/°C (*Bowen*, 1967). This is about the

same as those of silicate cement and tooth substance. The conductivity is so low that one can suppose the aforementioned delay of thermal contraction and expansion to be valid.

The findings of *Peterson et al.* (1966) and *Going & Sawinski* (1966) that the sealing ability of Addent, both initially and in the long run, was as good as that of silicate cement and substantially better than that of acrylic resin, may be explained by the favourable interaction between setting contraction, expansion due to water absorption and thermal conductivity.

CONCLUSIONS

1. Addent 35 has such mechanical and physical properties that it can be characterised as a promising material for anterior fillings.
2. Because of insufficient mechanical properties it is questionable if Addent 12 can be considered usable for fillings exposed to biting forces.
3. The polymerization shrinkage, the water absorption and the coefficient of thermal expansion are less, while hardness, compressive strength, abrasion resistance and other mechanical properties are better than an acrylic filling resin.
4. The adhesion of the material to the cavity walls during setting may prevent part of the setting contraction from manifesting itself.
5. The set material contains air bubbles, the walls of which are incompletely polymerized. Discoloration of the surface of the filling occurs if such porosites are cut when polishing.
6. Addent is a better material than acrylic. Only clinical investigations can determine if it is better than silicate cement and amalgam too.
7. If a more effective cavity liner and/or a biologically inactive polymer can be found, such a material might be able to replace silicate cement.

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SUMMARY

The aim was to investigate the plastic filling materials Addent 12 and Addent 35. The dimensional changes upon setting were measured on a mercury bath and in fillings made in extracted teeth. The compressive strength

of cylindrical specimens was measured in a »Losenhausen» compressive testing machine. Rockwell hardness values for Addent and an acrylic filling material (Sevriton) were measured by means of a Durometer on disk shaped specimens. The abrasion resistance was indicated by loss in weight after tooth brushing. The coefficient of thermal expansion was measured on box shaped specimens in a mercury dilatometer. Dimensional change and increase in weight due to water absorption of both cylindrical and disk shaped specimens were also determined. Finally, discoloration and colour stability of the material were investigated.

When the material set freely, it contracted linearly 0.7—1.0 % (Table I and Fig. 1). When setting in a cavity part of this contraction was prevented by adhesion of the setting material to the cavity walls (Table II). The compressive strength of Addent was 1500—2000 kp/cm² which is almost the same as that of silicate cement, but only half of that of amalgam (Table III). The coefficient of linear thermal expansion was about 30×10^{-6} cm/cm/°C in the temperature range 25—45°C and it is of the same magnitude as that of amalgam. Addent 12 was 10—20 % harder than Addent 35 and Sevriton was about half as hard as Addent 12 (Table IV). The abrasion resistance of Addent was about ten times that of Sevriton (Table V, Fig. 2). Expansion of 0.6 % due to water absorption may contribute to sealing of the cavity (Table VI and Figs. 3 and 4). Apart from discolouring in air bubbles cut during polishing, the risk of discolouring of Addent fillings is small.

Addent 35 is a promising anterior filling material which is better than acrylic. Because of poor mechanical properties Addent 12 is not considered usable for fillings exposed to biting forces.

If Addent shall be able to replace silicate cement a more effective cavity liner and a biologically inactive base must be found.

RÉSUMÉ

PROPRIÉTÉS PHYSIQUES D'UNE RÉSINE D'OBTURATION (ADDENT®)

Le but a été d'examiner les résines d'obturation Addent 12 et Addent 35. Les changements de dimensions au cours de la polymérisation ont été mesurés par la méthode du bain de mercure et à l'aide d'obturations exécutées sur des dents extraites. La résistance à la compression a été déterminée à l'aide d'une machine »Losenhausen» à éprouver la compression sur des éprouvettes cylindriques. La dureté Rockwell pour Addent 12, Addent 35 et un matériau d'obturation acrylique (Sévriton) a été déterminée à l'aide d'un Duromètre sur des éprouvettes en forme de disque. La résistance à l'usure, représentée par la perte de poids due au brossage des dents, a été

déterminée pour les deux sortes d'Addent et pour Sévriton. Le coefficient d'expansion thermique a été mesuré sur des éprouvettes en forme de caisse dans un dilatomètre à mercure. Les changements de dimensions et l'accroissement du poids à cause de l'absorption d'eau ont été mesurés sur des éprouvettes soit cylindriques soit en forme de disque. Enfin la tendance aux changements de teinte et la stabilité de la couleur du matériau ont été examinées.

Quand le matériau se polymérise, flottant sur une surface de mercure, il se contracte de 0,7—1,0 % linéairement (Tabl. I et Fig. 1). Pendant la polymérisation dans des cavités, cette contraction est partiellement empêchée à cause de l'adhésion du matériau aux parois des cavités au cours de la solidification (Tabl. II). La résistance à la compression est de 1500—2000 kp/cm^2, environ comme celle du ciment aux silicates, mais seulement la moitié de celle de l'amalgame (Tabl. III). Le coefficient d'expansion thermique, d'environ 30×10^{-6} cm/cm/°C dans l'intervalle 25—45°C, est du même ordre de grandeur que celui de l'amalgame. Addent 12 était de 10—20 % plus dur qu'Addent 35, et la dureté du Sévriton était environ la moitié de celle d'Addent 12 (Tabl. IV). La résistance à l'usure d'Addent était près de 10 fois plus grande que celle du Sévriton (Tabl V et Fig. 2). L'expansion de près de 0,6 % due à l'absorption d'eau (Tabl. VI et Fig. 3 et 4) est supposée contribuer à un meilleur scellement de la cavité. A part un changement de teinte au niveau de bulles d'air ouvertes pendant le polissage, le risque de changements de teinte des obturations d'Addent est faible.

Addent 35 est un matériau d'obturation pour les regions antérieures qui semble prometteur, et qui est meilleur que les résines acryliques. A cause de ses propriétés mécaniques insuffisantes Addent 12 ne peut être utilisé pour des obturations exposées à la pression de la mastication. Une condition pour qu'Addent puisse remplacer les ciments aux silicates est que l'on trouve un isolant plus efficace et une base inactive du point de vue biologique.

ZUSAMMENFASSUNG

PHYSIKALISCHE EIGENSCHAFTEN EINES KUNSTSTOFF-FÜLLUNGSMATERIALS (ADDENT®)

Der Zweck dieser Arbeit war die Kunststoff-Füllungsmaterialien Addent 12 und Addent 35 zu untersuchen. Nach einem Durchgang der Litteratur wird eine allgemeine Beschreibung des Materials gegeben.

Die dimensionellen Veränderungen wärend des Abbindevorganges wurden nach der Quecksilberbadmethode gemessen, und ferner auf Füllungen,

die zu diesem Zweck in extrahierten Zähnen ausgeführt waren. Die Druckfestigkeit wurde mittels einer »Losenhausen» Druckprobemaschine auf zylinderförmigen Prüfkörpern gemessen. Die Rockwellhärte für Addent 12, Addent 35 und ein Acrylat-Füllungsmaterial (Sevriton) wurden mittels eines Durometers auf scheibenförmigen Prüfkörpern festgelegt. Die Abnutzungsfestigkeit, durch den Gewichtsverlust infolge der Zahnreinigung ausgedrückt, wurde für beide Typen von Addent und Sevriton festgelegt. Der Wärmeausdehnungskoeffizient wurde auf kastenförmigen Prüfkörpern gemessen. Dimensionelle Änderungen und Gewichtszunahme infolge Wasserabsorption wurden auf sowohl zylindrischen als auch scheibenförmigen Prüfkörpern festgelegt. Schliesslich wurden Verfärbungstendenz und Farbbeständigkeit geprüft.

Wenn das Material, während des Abbindens auf einer Quecksilberoberfläche schwimmt, erfährt es eine lineäre Schrumpfung, die etwa 0,7—1,0 % beträgt, (Tab, I und Abb. 1). Sofern diese Abbindung in Kavitäten stattfindet, wird die Manifestation dieser Kontraktion, wegen der Adhäsion des abbindenden Materials an den Kavitätswänden, ganz oder teilweise verhindert (Tab. II), welches einen besseren Abschluss der Kavität herbeifürht. Die Druckfestigkeit ist 1500—2000 kp/cm², welches ungefähr dasselbe ist als für Silikatzement, aber nur die Hälfte von der des Amalgams (Tab. III). Der Wärmeausdehnungskoeffizient, der etwa 30×10^{-6} cm/cm/°C in Intervalle 25 bis 45°C beträgt, ist von derselben Grössenordnung als der des Amalgams. Addent 12 erweis sich als 10—12 % härter als Addent 35, während Sevriton nur ungefähr die Hälfte erreichen konnte (Tab. IV). Die Abnutzungsfestigkeit war ca. zehnmal grösser für Addent als für Sevriton (Tab. V und Abb. 2). Eine Ausdehnung von etwa 0,6 % wegen einer Wasserabsorption wurde nachgeweisen (Tab. VI und Abb. 3 und 4). Diese wird wahrscheinlich dazu beitragen sowohl ein weiteres Versiegeln der Kavität als auch eine Hemmung von einer möglichen Percolation herbeizuführen. Abgesehen von stellenweiser Verfärbungen in Luftblasen, die während des Polierens geöffnet worden sind, kommt die Gefahr einer Verfärbung der Addentfüllungen sehr gering vor.

Addent 35 ist ein versprechendes Füllungsmaterial für Frontzähne, das besser ist als Acrylstoff. Nur klinische Untersuchungen können entscheiden, ob es auch besser ist als Silikatzement. Wegen ungenügenden mechanischen Eigenschaften kann Addent 12 nicht mit Sicherheit für Füllungen, die für den Kaudruck ausgesetzt sind, verwendet werden. Eine Voraussetzung dafür, dass Silikatzement durch Addent ersetzt werden kann, ist, dass ein noch effektiverer Lack und/oder ein biologisch inaktiver Plast gefunden werden können.

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