

# The Rheological Properties of Fluid Denture-Base Resins

S. G. VERMILYEA, J. M. POWERS, and A. KORAN

*Division of Dental Materials, U.S. Army Institute of Dental Research, Walter Reed Army Medical Center, Washington, D.C. 20012, USA, and Department of Dental Materials, University of Michigan, School of Dentistry, Ann Arbor, Michigan 48109, USA*

*The rheological properties of six commercial fluid denture resins were determined by rotational viscometry. Initial viscosity ranged from 67 to 575 centipoise at a rotational speed of 10 revolutions per minute. All resins showed initial non-Newtonian flow behavior and increased viscosity with time.*

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The use of pour-type (fluid) resins for the fabrication of denture bases has increased markedly over the past decade. Advantages offered by the fluid resins include: (1)

reduction of processing time; (2) simplification of flasking and deflasking procedures; and (3) reduction of time required for finishing and polishing the cured prostheses.<sup>1</sup>

Previous studies on fluid resins have been addressed to measurement of physical and mechanical properties, modification and refinement of processing procedures, and assessment of the effect of investment materials on the quality of the finished restoration.<sup>2-8</sup> Products made from pour-type resins often exhibit voids and other surface imperfections. It has been suggested that the defects may be the result of pouring a resin that is too viscous.<sup>5</sup> Unfortunately, sufficient information regarding the viscous properties of the pour resins is not available.

The present investigation was conducted to determine the apparent viscosity of several pour-type denture base resins as a

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Commercial materials and equipment are identified in this report to specify the experimental procedure. Such identification does not imply official recommendation or endorsement or that the equipment and materials are necessarily the best available for the purpose.

TABLE I  
MATERIALS EVALUATED IN THE STUDY

Code	Material	Batch Number		Powder/Liquid Ratio by Volume	Manufacturer
		Powder	Liquid		
A	Hyflo	061776	061776	2.5/1	Hygenic Dental Mfg. Co. Akron, Oh 44310
B	Pronto II	249106	069204	2.5/1	Vernon-Benshoff Co. Albany, NY 12201
C	Pro-Fit	084040	104013	2.5/1	Howmedica, Inc. Chicago, Il 60632
D	Porit	PO372J	MO475C	2.35/1	Product Research Laboratory Cambridge, Ma 02130
E	TruPour	74226	74275	2.15/1	Dentsply International, Inc. York, Pa 17404
F	Pour-n-Cure	040476	020176	2/1	Coe Laboratories, Inc. Chicago, Il 60658

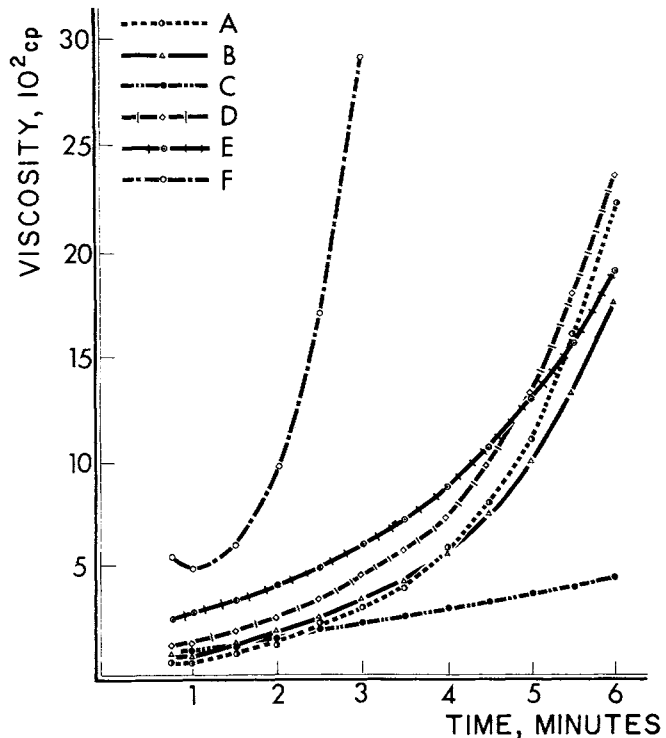


FIG 1. — The change in viscosity with time at 10 rpm.

function of time and rotational speed at a constant temperature.

#### Materials and Methods

Six pour-type denture base resins were obtained from proprietary sources. The manufacturers and batch numbers are listed in Table 1.

The polymer and monomer components of the materials were proportioned in accordance with manufacturer's recommended powder-liquid ratios to yield mixtures of approximately 40 cc. All mixtures and measurements were made within a constant temperature chamber maintained at  $23 \pm 0.05$  C.

Viscosity of the test resins was determined with a rotational viscometer.\*

\*Rheolog Model 1/4 RVT-RL-199, Brookfield Engineering Corp., Stoughton, Ma 02074.

†Spindle No. 5, Brookfield Engineering Corp., Stoughton, Ma 02074.

‡Pneumatic-Electric Converter, Brookfield Engineering Corp., Stoughton, Ma 02074.

§Model XY530TM, Esterline Angus, Unit of Esterline Corp., Indianapolis, In 46404.

+ Viscosity Standard No. N3500, Lot No. 72025p, Cannon Instrument Co., State College, Pa 16801.

Shearing was caused by the rotation of a disk (diameter 2.12 cm) and rod (diameter 0.45 cm) spindle assembly<sup>†</sup> at rates of 10, 20, and 50 revolutions per minute (rpm). Three trials were made with each material at each shear rate. The pneumatic output of the viscometer was converted to an electrical signal by a pneumatic-electric converter<sup>‡</sup> and recorded on a y-time recorder.<sup>§</sup> Data were obtained as viscosities in centipoise (cp) by calibration of the spindle with a Newtonian standard.<sup>+</sup> Recording of the viscosities of five materials (A, B, D, E, F) was begun 45 seconds after the start of mixing. The long mixing time required for material C necessitated initial viscosity measurement 90 seconds after commencement of sample preparation. The viscosity of each material was recorded continuously for a period of six minutes following the initiation of mixing or until the viscosity of the mix exceeded the range of the recorder.

All data were evaluated statistically by analysis of variance and means compared using Scheffé's method at the 95% level of confidence.<sup>9</sup>

### Results

The viscosity of each material increased markedly with time. The changes in the viscosities of the resins with time at 10 rpm are shown in Figure 1. Initial viscosity values ranged from 67 cp for material A to 575 cp for material F. The mean values of the initial viscosity at 10 rpm of C and D were equivalent (Table 2). The mean values of the viscosity of A, B, D, and F were statistically different from each other and from those of the other materials at this rotational speed. The Scheffé interval was 21 cp.

Subsequent values were recorded at times when comparable amounts of shear had occurred in each material (3 minutes for A, B, D, E, and F and 3½ minutes for C). At this time, the viscosity of F had increased to 2,900 cp (Table 2). The viscosities of the other materials had increased to values only slightly above (625 cp, E) or markedly below (283 cp, C) the initial viscosity of F (575 cp). The mean values of the viscosity of A, B, and C were statistically equivalent at the 95% level of confidence. The viscosities of B and D were also equivalent at this confidence level. The Scheffé interval was 129 cp.

The effect of rotational speed on the initial viscosity of the resins is shown in Figure 2. Materials A, B, C, D, and E demonstrated significant increases in viscosity with increased rotational speeds. Material F ex-

hibited shear thinning over the range of rotational speeds employed. The Scheffé interval was 11 cp. As the time from the start of mixing increased, the effect of rotational speed on the viscosity of all but one of the resins (F) decreased. The changes in viscosity with rotational speed at 3 minutes after the start of mixing are shown in Figure 3. Materials A, B, C, and D behaved as Newtonian liquids with no increase in viscosity with increased rotational speed, whereas materials E and F exhibited shear thinning. The Scheffé interval was 66 cp.

### Discussion

The viscosity of a polymerizing monomer-polymer mixture is affected by many factors. The particle size, molecular weight, and initiator content of the polymer as well as the molecular weight, and presence of cross-linking agents, inhibitor and accelerator in the monomer influence the rate of polymerization and contribute to the viscous properties of the mixed resins.

A range of viscosities for the optimal clinical use of the pour resins has not been established. However, the viscosity of the mixed resins as the time from the start of mixing increases would appear to be an important factor in the clinical handling of these materials. A resin possessing a low viscosity for a suitable period of time would be convenient when multiple molds are to be poured from a single mix.

TABLE 2  
APPARENT VISCOSITY OF THE FLUID RESINS AT 10 RPM

Material	Initial Viscosity (cp)*	Subsequent Viscosity (cp)†
A	67 (14)‡	342 (29)‡
B	104 (7)	371 (8)
C	133 (14)	283 (38)
D	133 (14)	475 (25)
E	267 (29)	625 (43)
F	575 (0)	2,900 (260)

\*Values for A, B, D, E, and F at 45 seconds after addition of polymer powder to monomer. Value for C obtained 90 seconds after polymer to monomer addition.

†Values for A, B, D, E, and F at 3 minutes after addition of polymer powder to monomer. Value for C obtained at 3½ minutes after polymer to monomer addition.

‡Means with standard deviations in parentheses are based on three trials. Scheffé intervals were 21 cp and 129 cp for initial viscosities and subsequent viscosities respectively. The standard deviation of material F is much different from those of the other materials. The inclusion of this material in the analysis of variance results in a calculated Scheffé interval that is much larger than would be expected if material F were excluded from the statistical treatment. Hence the calculated Scheffé interval does not discriminate small differences between materials.

FIG 2. — The initial viscosity of each material as a function of rotational speed.

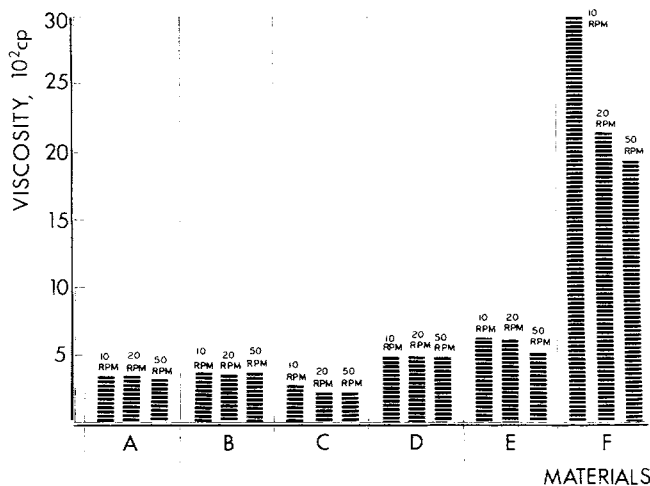
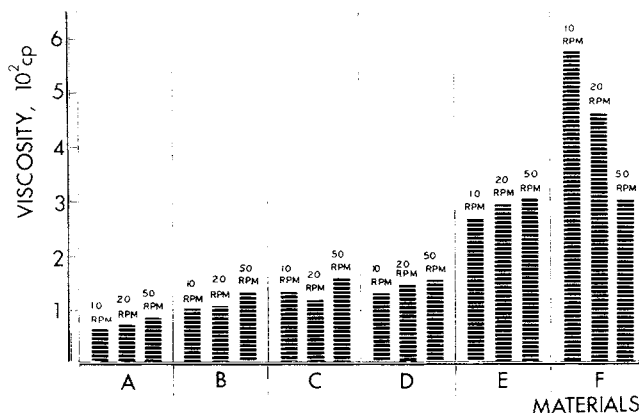


FIG 3. — The viscosity of each material at 3 minutes after the beginning of mixing as a function of rotational speed.

The initial shear thickening behavior of the fluid resins A, B, C, D, and E suggests that the introduction of the mixed resin into the mold should be accomplished slowly. Rapid pouring or injection of these materials may create high shear rates and increase the viscosity such that flow into the fine details of the mold is prohibited.

On the other hand, the shear thinning observed with material F suggests rapid pouring of the resin may enhance the flow into the fine details of the mold. The clinical significance of the shear rate effect is unclear. To date, sufficient information on the rates of shear employed in the clinical handling of these materials is unavailable. Further research into the magnitude of these shear rates and their effects on the detail reproduction and mechanical properties of the fluid resins would be invaluable in establishing guidelines for the use of these materials.

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#### Conclusion

Variation in the initial viscosity of six fluid denture base resins was demonstrated by rotational viscometry. All materials showed increases in viscosity with time; however, one material increased at a markedly faster rate.

Five materials exhibited increases in viscosity with increased rotational speed.

Early introduction of the mixed materials into the prepared mold may help minimize the presence of voids and the loss of fine detail in the final restoration.

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## References

1. WINKLER, SHELDON: Construction of Denture Bases from Pour Resins, *Dent Clin N A*, 19:243-254, 1975.
2. CIVJAN, S.; HUGET, E. F.; and DE SIMON, L. B.: Modifications of the Fluid Resin Technique, *JADA*, 85:109-112, 1972.
3. GOODEND, R. J., and SCHUELTE, R. C.: Dimensional Accuracy of Pour Acrylic Resin and Conventional Processing of Cold-Curing Acrylic Resin Bases, *J Prosthet Dent*, 24:662-668, 1970.
4. MIRZA, F. D.: Dimensional Stability of Acrylic Resin Dentures, *J Prosthet Dent*, 11:848-857, 1961.
5. WINKLER, S.; ORTMAN, H. R.; MORRIS, H. F.; and PLEZIA, R. A.: Processing Changes in Complete Dentures Constructed from Pour Resins, *JADA*, 82:349-353, 1971.
6. SHEPARD, W. L.: Denture Bases Processed from a Fluid Resin, *J Prosthet Dent*, 19:561-572, 1968.
7. WINKLER, S.; MORRIS, H. F.; THONGTHAMMACHAT, S.; and SHORR, J. H.: Investing Mediums for Pour Resins, *JADA*, 83:848-851, 1971.
8. KOBLITZ, F. F.; SMITH, R. A.; and WOLFE, H. E.: Fluid Denture Resin Processing in a Rigid Mold, *J Prosthet Dent*, 30:339-346, 1973.
9. GUENTHER, W. C.: *Analysis of Variance*. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1964, p 141.