Studies on Viscosity and Fluidity of Fluid Resins

by

Minoru NISHIYAMA*, Yoshiaki NAKAGAWA*, Atsushi KOHATA*, Tomokazu KODAKI*, Yoichi YAMAGUCHI* and Megumu YAMAGUCHI*

1. Introduction

The curing of fluid resins is performed by pouring the polymer-monomer mixture into molds made of hydrocolloid[1] or special plaster investment[2], before the fluidity of resin mixture disappears. Therefore, it can be said that the fluidity of resin mixture is an important factor which not only determines the pouring time but also is much related to the quality of the products.

The viscosity of fluid resins is extremely unstable; in the initial stage of the mixing process, it is presumably due to the mixture turning into non-homogeneous suspension composed of polymer and monomer, and then it rises, as time goes on, due to the swelling and solubility of polymer into monomer. Though it is very difficult to apprehend accurately the relationships between such non-equilibrium, non-homogeneous dispersion system viscosity and fluidity, the authors intend to examine the viscosity and fluidity at the pouring time from the viscosity rising and efflux of resin mixture to find fluidity suitable for pouring.

2. Materials and Methods

1. Materials

The experimental materials used are Shofu Dental Mfg. Co., Ltd.'s Cast Resin (A resin), Vernon Benshoff Company, Inc.'s Pront-II (B resin) and Coe Laboratories, Inc.'s Pour-n-Cure (C resin). Table 1 and Fig. 1 show the respective properties of the three materials.

2. Methods

1) Powder-Liquid Ratio

The polymer-monomer ratio (L/P) is determined according to the makers' directions as follows: 4 ml/7 g in the case of A resin, 2 ml/5 g in B resin and 1 ml/5 g in C resin. The temperature of monomer is 21–22°C.

2) Measurement of Viscosity Rising

The test materials are mixed at their respective powder-liquid ratios shown above and after being stirred for 30 seconds, the viscosity rising of resin mixture with the passage of time is measured by use of a rotary viscosimeter.

* 西山寛, 中川吉章, 木幡篤, 小澤祐一, 山口洋一, 山口メガム: Dept. of Dental Technology, Nihon University School of Dentistry, Tokyo (Director: Prof. Setsuo Higashi).
3) Measurement of the rate of efflux

Of the test materials mixed in the same way as shown in 2), the rate of efflux of resin mixture with the passage of time is measured by use of a measurement apparatus for rate of efflux of fluid resins[3].

The above-mentioned experiments are carried out under the condition of the room temperature $21 \pm 1^\circ\text{C}$ and humidity $50 \pm 1\%$.

### 3. Results

Fig. 2 shows the viscosity-time curves.

As it shows, difference can be seen in viscosity and viscosity rising among the test materials. That is, A resin is the lowest in viscosity, and then follow B resin and C resin in that order. As to the initial viscosity, B resin is approximately twice and C resin threefold as large as A resin, and at the final stage, B resin is approximately 1.5 times and C resin 4 times as large as A resin. While, in the viscosity rising, A and B resins are comparatively slow and C resin rapid.

The efflux of test materials per unit time and the coefficient of fluidity (1 rhe = 1/pois) obtained from the viscosity-time curves (Fig. 2) are shown in Figs. 3, 4 and 5.

That is, A resin, whose efflux and coefficient of fluidity are respectively 12.5 cm$^3$/sec. and 0.83 rhe at the period between 30 seconds and 60 seconds after mixing,
5.5cm³/sec. and 0.64 rhe after 90 seconds, 3.6cm³/sec. and 0.60 rhe after 120 seconds and 2.3cm³/sec. and 0.50 rhe after 150 seconds, shows most remarkable change in behavior of the three resins. B resin, whose efflux and coefficient of fluidity are 2.5cm³/sec. and 0.45 rhe from 30 seconds to 90 seconds after mixing, 2.2cm³/sec. and 0.42 rhe after 120 seconds and 1.65cm³/sec. and 0.38 rhe after 150 seconds, shows the least change of the three. C resin, whose efflux and coefficient of fluidity are 2.2cm³/sec. and 0.33 rhe after 30 seconds, 1.9cm³/sec. and 0.32 rhe after 60 seconds, 1.3cm³/sec. and 0.28 rhe after 90 seconds, 0.9cm³/sec. and 0.23 rhe after 120 seconds and 0.6cm³/sec. and 0.17 rhe after 150 seconds, shows the lowest values of them.

Fig. 6 is prepared from Figs. 3, 4 and 5 to examine the relationships between efflux and coefficient of fluidity of the test materials, with time used as parameter. As a result it is proved that in each case of the test materials they are proportionate.

Fig. 2. Relationships between viscosity and time
4. Discussion

The fluidity of fluid resin mixture is much affected by viscosity change due to the swelling and solubility of polymer into monomer in the mixing process. In general, the smaller the grain size and molecular weight are, the higher becomes the swelling and solubility into monomer and the faster the viscosity rising[4,5]. Contrarily, the
more crosslinking agents are included in monomer, the slower becomes the viscosity rising, the diffusibility of monomer into polymer being suppressed[4]. Again, it is a well-known fact that the smaller the powder-liquid ratio and the higher the environmental temperature is, the faster becomes the viscosity rising.

Then, the authors, of the test materials, examine the viscosity and fluidity at the pouring time, from the relationships between the viscosity rising and efflux and the properties of materials.
That is, A resin, whose molecular weight of polymer is approximately twice as large as those of B and C resins, with a great deal of polymer of large grain size included, is low in solubility, and is considered to show the lowest viscosity of the three in the initial stage of mixing. But, as the swelling and solubility of polymer goes on, because of its molecular weight being large, viscosity rises, and the viscosity rising and efflux consequently show remarkable changes on and after 60 seconds. Though efflux shows a large value in the initial stage of mixing, from the fact that the viscosity of resin mixture is low, it is considered that the mixing is insufficient and that if the mixture is poured in this stage, polymer separated from monomer, is sedimented, and the condensation becoming non-homogeneous, causes uneven curing, which cannot have any good effect on the physical properties of polymerized setting products. But from the fact that on and after 90 seconds, viscosity rises, and efflux decreases gradually, it is considered that pouring should be done quickly in the stage in which viscosity rises to some degree after mixing.

B resin, whose molecular weight of polymer is low, shows higher viscosity than A resin in the initial stage, but as it includes a great deal of polymer of large grain size, its solubility in the following stages is low, the viscosity rising slowest and the change of efflux is small. Consequently, in this case, comparatively a wide range of time for the pouring operation can be expected, and not only that, fluidity is also preferable.

In the case of C resin, whose molecular weight of polymer is low, and furthermore which includes a great deal of polymer of small grain size, smaller than 60 μ, the specific surface of polymer becoming large, in spite of its powder-liquid ratio being large as compared with that of A or B resin, its solubility increases and as a result, viscosity in the initial stage of mixing becomes highest, the viscosity rising abrupt and efflux shows the smallest value. Consequently, it is considered that pouring should be done quickly within 60 seconds after mixing.

Though the limit of viscosity and fluidity which makes it possible to pour the resin mixture into every detail of a mold cannot strictly be determined only from the fact above-mentioned, from the result of the present experiments, it is presumed that the ranges of coefficient of fluidity (poise) and efflux suitable for pouring are respectively 0.3~0.7rhe (3.3~1.4 poise) and 1.5~5cm³/sec.

V. Conclusion

The authors, of the three kinds of resins on the market, examine the viscosity and fluidity which make the pouring operation possible, from the changes of viscosity rising and efflux of resin mixture. The results are as follows:
1. A and B resin, whose initial viscosity is low, viscosity rising slow and efflux large, have a long time for pouring operation. While, C resin, whose initial viscosity is high, viscosity rising abrupt and efflux small, has a very short time for pouring operation.
2. In each case of test materials, the coefficient of fluidity and the average efflux prove to be proportionate.
3. The ranges of coefficient of fluidity and efflux suitable for pouring are 0.3~0.7rhe (3.3~1.4 poise) and 1.5~5cm³/sec. respectively.
References


