Influence of different reinforcing materials on the rheology of provisional restorations.

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Citation

Abstract

The effects of adding different ratios (0.5, 1, 5, 10, 20 and 40%) of zirconium oxide powder (ZrO) and ultra high modulus polyethylene fibers (PE) (0.5, 1, 2 and 4%) on the rheology mean value of autopolymerizing acrylic resin was investigated using Rotary Viscometer. Also the effect of temperature on the rheology mean values of reinforced acrylic resin were studied and analyzed. Mean values, student t-test and paired sample t-test also was analyzed. From our results it is obvious that the rheology mean value of acrylic resin (group I) is increased by increasing the ratio of ZrO. There is no significant difference between acrylic resin and group II (zirconium oxide group) at 0.5, 1 and 5% ZrO, but at 10 and 20% ZrO there is significant difference. For PE group (group III), the rheology mean value of acrylic resin is increased by increasing the ratio of PE from 0.5 to 2% when measured at different temperatures 20, 25 and 30 ˚C. There is no significant difference between acrylic resin and group III at 0.5% PE, but at 1% and 2% PE there is a significant difference. In this study 40% ZrO and 4% PE had been eliminated from this study because the formed mixtures were friable and could not be molded. The rheology mean values were also affected by increasing the temperature from 20 to 30 ˚C.

INTRODUCTION

Rheological behavior is particularly readily observed in materials containing polymer molecules which typically contain thousands of atoms per molecule, although such properties are also exhibited in some experiments on metals, glasses, and gases. Rheology has important applications in engineering, geophysics, pharmaceutics and physiology. Rheology describes the interrelation between force, deformation and time. From a broad perspective, rheology includes almost every aspect and behavior that deals with the deformation of materials as a result of an applied stress.

Contemporary materials for the fabrication of provisional restorations are mainly resin based. There are many types according to methods of polymerization, filler composition and monomer type. Autopolymerizing acrylic resin is considered the material of choice for provisional restorations. However, it has several disadvantages as poor mechanical properties, poor durability, exothermic polymerization, polymerization shrinkage; poor wear resistance and pulpal irritation associated with excess free monomer [1,2,3]. Attempts have been made to strengthen acrylic resin materials with either chemical modification with grafted co-polymers and stronger cross linkage or by the use of various reinforcing materials as inclusion of metals, glass, carbon, polyester and rigid polyethylene and zirconium oxide. The effects of these materials on the modulus of elasticity, transverse strength, toughness, hardness and water sorption had been studied [4,5,6,7,8,9,10]. Fabricating provisional restorations directly on teeth using impression materials requires adequate flow of the material. A material that does not have enough flow yields an improperly seated crown and a nonuniform fitting surface. On the other hand, a material that has too much flow undergoes problematic movement onto the gingival [11]. Measurement of the flow properties during dough formation and the correct doughing and manipulation times is important since the material should be packed during the manipulation stage [12,13]. When the polymer and monomer components of acrylic resin material are mixed, the resultant material (dough) is at its lowest viscosity during the early period and that the viscosity increases gradually with respect to increase in time. This increase in viscosity depends on a number of factors that can be divided into factors that can be controlled by technicians in the laboratory during construction and factors that can be controlled by manufactures during the production of the material [14]. Among the factors that can be controlled by technicians in the laboratory are concentration of the polymer monomer mix, room temperature and technique. An increase in the polymer/monomer ratio reduces the dough

time. As the temperature is elevated the increasing in viscosity is more rapid. The viscosity of polymer/monomer mix can be sensitive to variations of the type and structure of polymer, such as powder particle size, molecular weight, glass transition temperature and copolymerization, and may be improved by modifying the powder component of the mix in several ways [1415].

The aim of this study was to evaluate the effect of adding different ratios of zirconium oxide powder and ultra high modulus polyethylene fibers (UHMPF) on the rheology mean value of provisional acrylic resin with studying the effect of temperature on the rheology mean values of reinforced acrylic resin.

MATERIALS AND METHODS

In this study we selected zirconium oxide powder and UHMPF as an example of the fiber and powder forms. Both of them are widely used in dentistry as they are biocompatible and produce adequate strength for provisional prosthesis, composite resin-reinforced prosthesis, composite resin crown, and provisional implant fixed partial dentures.

The materials used in this study were self-cured provisional acrylic resin (Duracryl) and reinforcing materials which are zirconium oxide powder (Promochem GmbH Postfach 10 09 55 46469 Wesel, Germany) and ultra high modulus polyethylene fibers (Good fellow, Ermine Business park, Huntingdon, PE 296 WR, England).

For (zirconium oxide) group II: weight different ratios (0.5, 1, 5, 10, 20 and 40%) of zirconium oxide powder, each one were used with the corresponding amount of self-cured acrylic resin. Thorough mixing of metal oxide powder with the polymer was done using porcelain mortar and pestle, then mixture was passed through a sieve to produce more homogenous mix, and the monomer was added to the mixture.

For (polyethylene fibers) group III: it was supplied as multifilament yarn. Cut fibers by sharp scissors. The length of the fibers was less than 6 mm. The short fiber length represented a convenient size for manipulation and inclusion into acrylic resin dough. Weight different ratios (0.5, 1, 2 and 4%) of polyethylene fibers, each one were used with the corresponding amount of self-cured acrylic resin. At first, the appropriate weight of fibers was added to the liquid monomer in the mixing jar prior to addition of polymer powder. The mixing procedure lasted 30 s each time.

The rheology for each mixture was done five times using Rotary Viscometer (Haake Inc., Germany). The mix was placed on the plate of Viscometer (with a diameter 2.9 cm) and Roto (cone with 2.8 cm in diameter). The plates are brought together and, after excess cement had been removed, the Viscometer was started. The time between the start of mixing and the beginning of measurements was about 60 s. The Rotary Viscometer was thermostatically controlled at 20, 25 and 30 ±0.5 ˚C. The rheology values were calculated using the following equation:

$$\square = G.S/N$$

Where $\square$ is the Viscosity in MPa.s (MPa.s = 1centipoise).

G is the Instrumental factor = 14200 (MPa.s/scalegrad.min).

S is the Torque (scalegrad).

N is the Speed (rpm).

The test was then terminated and the plates quickly cleaned before the acrylic had completely set.

Mean value, student t-test and paired sample t-test was analyzed. The significant levels were set at P≤0.05.

RESULTS AND DISCUSSION

The rheology mean value of provisional acrylic resin is increased by adding ZrO (group II) to it, however at 20% ZrO addition, the rheology was less than 10% ZrO. Also the rheology mean value of provisional acrylic resin is increased with increasing the temperature as shown in Fig. (1).

Student t-test was used to compare the rheology value of group I with the rheology values of group II at 20, 25, and 30˚C, it was found that there was no a significant difference between group I and group II at 0.5, 1, and 5% ZrO, but at 10 and 20% ZrO there was a significant difference as seen in Table I.

Paired sample t-test was used to compare the rheology values at 20 ˚C versus 25 ˚C, 20 ˚C versus 30 ˚C and 25 ˚C versus 30 ˚C; it was found that there was a significant difference among groups for all concentrations except at 20% ZrO where no a significant difference was found as seen in table II.

By adding PE from 0.5 to 2% (group III) to provisional acrylic resin (group I), the rheology mean value of it is increased. Also the rheology mean value is increased with increasing the temperature from 20 ˚C to 30˚C as shown in

Fig. 2.

Student t-test was used to compare the rheology value of group I with the rheology values of group III at 20, 25, and 30˚C, it was found that there was no a significant difference between group I and group III at 0.5% PE, but at 1% and 2% PE there was a significant difference as seen in Table I.

Paired sample t-test was used to compare the rheology values at 20 ˚C versus 25 ˚C, 20 ˚C versus 30 ˚C and 25 ˚C versus 30 ˚C; it was found that there was a significant difference among groups for all concentrations as seen in Table II.

Figure 1

Fig. (1): Viscosity of group II (different concentrations of ZrO in provisional acrylic resin) at different temperatures
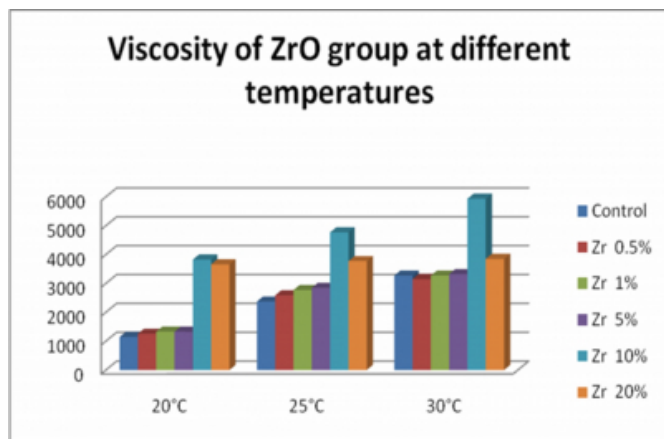

Figure 2

Table I: Student t-test, the rheology of different reinforcing materials

		Control x 20 ˚C		Control x 25 ˚C		Control x 30 ˚C	
		t	P	t	P	t	P
ZrO	0.5 %	1.36	0.21	1.73	0.11	0.81	0.44
	1 %	2.04	0.07	1.72	0.12	0.01	0.99
	5 %	1.55	0.16	0.17	0.86	0.29	0.78
	10%	19	<0.001***	11.8	<0.001***	13.09	<0.001***
	20 %	17.91	<0.001***	10.8	<0.001***	3.78	0.005**
PE	0.5 %	0.74	0.48	1.43	0.18	1.52	0.16
	1 %	2.46	0.039*	5.45	<0.001***	3.02	0.01**
	2 %	8.04	<0.001***	7.95	<0.001***	3.79	0.005**

Figure 3

Table II: Paired sample t-test of various groups

		20˚C x 25˚C		20˚C x 30˚C		25˚C x 30˚C	
		t	p	t	p	t	p
Control		12.3	<0.001***	16.12	<0.001***	6.16	<0.001***
ZrO	0.5%	12.04	<0.001***	4.29	0.002**	17.3	<0.001***
	1%	13.8	<0.001***	18.6	<0.001***	3.23	0.01**
	5%	4.04	0.003**	5.8	<0.001***	5.56	<0.001***
	10%	5.54	<0.001***	9.98	<0.001***	12.56	<0.001***
	20%	0.68	0.51	0.59	0.56	1.2	0.26
PE	0.5%	8.6	<0.001***	13.8	<0.001***	10.2	<0.001***
	1%	7.8	<0.001***	9.61	<0.001***	4.34	0.002
	2%	7.7	<0.001***	8.2	<0.001***	5.15	<0.001***

Figure 4

Fig. (2): Viscosity of group III (different concentrations of PE in provisional acrylic resin) at different temperatures.
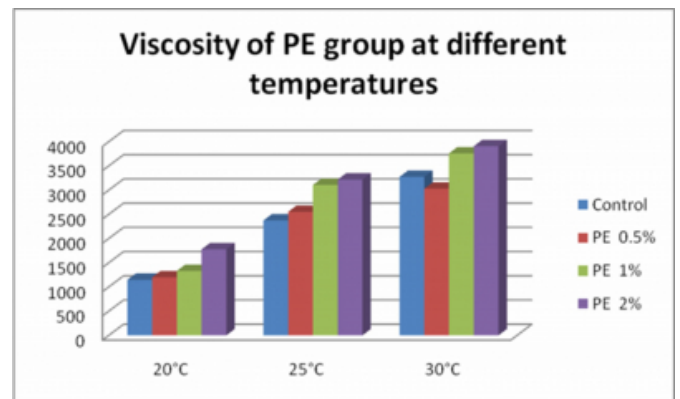
Adding (0.5, 1, 5, 10 and 20) ZrO and (0.5 to 2%) PE to provisional acrylic resin increased its rheology mean value. That is may be because, when ZrO and PE powder mixed with acrylic resin a two phase system is produced and small granules of polymer dispersed in a solvent. Swelling of the polymer granules and the subsequent entrapment of the monomer reduce the free volume, which leads to an increase in granule concentration, and hence viscosity. Also polymerization of the monomer also increases the viscosity.

Both swelling and polymerization are sensitive to temperature and this sensitivity may contribute to variation in working time. As the temperature is increased, the viscosity rises much more rapidly, and the manipulation period is reduced.

When the powder and monomer are mixed, a two-phase system is produced. It is composed of small granules of polymer dispersed in a solvent formed by the monomer. Hence the sample is dilatants. Two processes had been occurred as follows, swelling of the polymer granules and the subsequent entrapment of the monomer reduce the free volume, which leads to an increase in granule concentration,

and hence viscosity increased. Second is polymerization of the monomer also increases the viscosity. An increase of viscosity with increasing temperature has been demonstrated.

The effect of raising temperature will be to decrease the viscosity of the monomer (a small effect over this temperature range), through increasing the rate of swelling of the polymer in the monomer and the rate of polymerization. It is expected that the swelling process will initially dominate the change in viscosity and this is controlled by diffusion. Later, the rate of polymerization becomes more important and eventually will dominate. It is also observed that both swelling and polymerization are sensitive to temperature and this sensitivity may contribute to variation in working time [14,15]. As the temperature is increased, the viscosity rises much more rapidly, and the manipulation period is reduced [13]. For example the time to reach a given viscosity is approximately halved as the temperature increases from 19-25 ˚C [15]. The temperatures selected in this study 20, 25 and 30±0.5 ˚C may reflect a range of room temperature at which acrylic may be mixed.

CONCLUSIONS

Within the limitation of this study, the following conclusions were drawn:

The rheology of provisional acrylic resin is increased by adding ZrO to it. The increase in the rheology of provisional acrylic resin was not a significant at concentrations 0.5, 1 and 5% ZrO, but it is a significant at 10 and 20% ZrO.

The rheology of provisional acrylic resin is increased by adding the PE to it. There was a significant difference in the rheology of provisional acrylic resin by adding 1% and 2% PE.

The rheology values of provisional acrylic resin with/without reinforcing materials are increased with increasing temperature.

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