Original Article

The effect on indirect tensile mechanical properties of light polymerized composites by polymerization under pressure

N. S. Murarka, B. K. Motwani, N. Vaidya

Department of Prosthodontics, Sharad Pawar Dental College, Sawangi, Wardha, India

For correspondence

Dr. Nitu Murarka, Department of Prosthodontics, Sharad Pawar Dental College, Sawangi (Meghe), Wardha - 442004, Maharashtra, India

Flaws developed during the polymerization of composites cause weakness in the final product with a decrease in the value of its mechanical properties [dimetral tensile strength (DTS)]. Therefore, reducing the flaws within the material may improve its mechanical performance. The aim of this study is to determine the effect of polymerization under pressure on the indirect tensile mechanical properties (stiffness and DTS) of light polymerized composite. As composite is a brittle material and failure occurs because of low resistance to tensile stresses, comparison between materials and their failure probability should be based on tensile properties. A special mold is prepared that enables polymerization under pressure. Stiffness (N/mm) and DTS (MPa) are analysed while loading the specimen to failure with an Instron testing machine. Thus, the effect of polymerization under pressure on properties is studied.

Key words: Polymerization under pressure, pores, tensile strength

Composite restorations have become the mainstay in dentistry because of the superior esthetics provided by them. But the esthetic property of composite has to be compounded by strength for clinical durability of the restorations. Failure of composite restorations has been vastly documented in the literature. Various reasons have been attributed for this failure, one of them is due to flaws (such as voids, pores, micro cracks, etc.) developed during the polymerization of composites. They cause weakness in the final product, with a decrease in the values of their mechanical properties (dimetral tensile strength and fatigue compressive limit).

Pores caused by entrapped air are common in dental restorations of composite resins. Previous studies of anterior composite resins demonstrated porosities ranging from 0.03 to 28.3%. Possible adverse effects of porosity are increased water sorption, decreased degree of conversion due to oxygen inhibition from entrapped air, and reduced abrasion resistance, increased surface roughness with increased surface discoloration and plaque accumulation. Therefore, reducing the flaws within the material may improve its mechanical performance.

Composite is a brittle material and failure occurs because of low resistance to tensile stresses.[1] Therefore, comparison between materials and their failure probability should be based on tensile properties. Light cured composites are characterized by a high compressive and low tensile strength. High compressive strength cannot predict the ability of materials to withstand tensile stresses. When tensile stresses develop in a restoration, opening or sliding of cracks, flaws within the material occurs, resulting in catastrophic failure. Therefore, as brittle materials do not fail under compressive stresses, the importance of a relatively high compressive strength value for restorative brittle materials in clinical use is limited.

Although the dimetral tensile strength value represents failure of indirect tensile stress, it does not provide information related to the behaviour of the material in function. Properties such as elastic modulus or stiffness enable a better understanding of a restorative material behaviour during functioning. Stiffness was found to be more sensitive to material type than dimetral tensile strength (DTS). Elastic modulus of a material or stiffness values of similar specimens made out of different materials indicate the amount of deformations a material undergoes during loading as opposed to strength value which indicates the ultimate stress a material can withstand without failure.[2]

However, strength is a conditional material property for comparison purposes only, and the strength values are more valuable when indicating the flaw distribution that will cause failure.[3] This information can be obtained by adopting the Weibull analysis on strength values. The most significant parameter obtained by this analysis is the Weibull modulus, m, when comparing different materials which indicates the distribution of flaws and cracks in the specimen: the narrower the distribution, the more reproducible the materials strength value.

The aim of this study was to determine the effect of polymerization under pressure of three light-polymerized composite materials on stiffness (elastic modulus related) and DTS. The null hypothesis was that these mechanical properties could be changed by the procedure of polymerization of these materials.

MATERIAL AND METHODS

A four-part system [Figure 1] was fabricated to allow loading of the composite resin material during polymerization. This was assembled to create cylindrical composite specimens, 6 mm in diameter and 2 mm in height. Briefly, the system included a piston assembled in a mold through aluminium U-plate that served as a spacer [Figure 2]. This created a compartment with the above dimensions [Figure 3]. The composite was packed against the piston, a polymethyl methacrylate (PMMA) plate was connected to the mold and the whole system was reversed. The spacer removed from the system allowed the piston to rest directly on the specimen. Loads were applied on the piston while the material was polymerized from the bottom through the translucent PMMA plate [Figure 4]. This was polymerized under a light source: Cu 100 (Appozo, Taiwan, ROC).

A total of 20 specimens ($n = 5$ per group) were prepared from each material. Four loads created surface pressures of 0, 0.35, 0.71 and 1.06 MPa (with weights of 0, 1, 2 and 3 kg) were tested. This selection was performed in relation to previous studies that showed that mechanical properties improved when materials were loaded in 0.68 MPa during setting. Therefore, lower and higher pressures were selected. Specimens were stored in 100% humidity at 37°C for 7 days. Specimens were tested for DTS by use of a universal testing machine (Instron testing machine) with a crosshead speed of 0.5 mm / min up to failure.

Load *vs* deflection data while compressing the discs during crosshead movement were automatically recorded. Stiffness value was calculated using the slope of the linear portion of the curve. The DTS value was calculated by the equation:

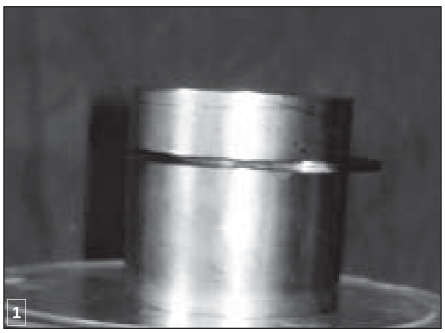
$$DTS = 2P\Pi \times D \times T$$

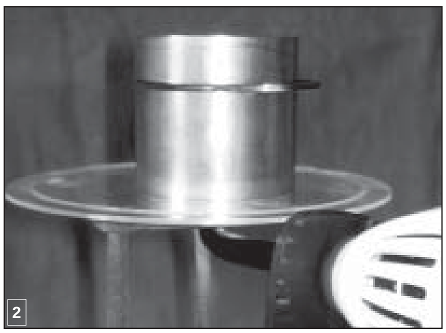
where P is the failure load, D the specimen diameter (6 mm) and T is the specimen thickness (2 mm).

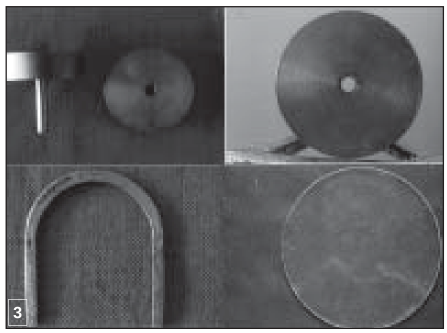
RESULTS

Table 1 presents the mean stiffness and DTS values and their related standard deviations (SD). Table 2 presents the Weibull statistic parameters for DTS.

A two-way analysis of variance was performed on the results obtained and it was found that material type had a statistically significant influence on both stiffness and DTS ($P < 0.05$). Loading also had a significant influence on stiffness and DTS ($P < 0.05$). For each material property, an interaction was found


1


2


3


4

Figure 1: From top to bottom-piston, U-plate, mold, PMMA plate. **Figure 2:** Area for the placement of composite specimen. Dimensions are: 6-mm diameter and 2-mm depth. **Figure 3:** Top left: piston and mold. Top right: cross-sectional view of mold. Bottom left: U-plate as spacer. Bottom right: PMMA plate of 2 mm. **Figure 4:** Polymerization of composite specimen under 0 Kg pressure by keeping spacer bar (U-plate) in the set-up. When polymerization under 1, 2 and 3 kg is done, spacer bar is removed and weight is applied on the piston from the top to load the composite specimen

Table 1: Mean stiffness and DTS values

Material	PUP (MPa)	Stiffness (N/mm)	SD	DTS (MPa)	SD
Z 100	0	4781	224	50.1	5.9
	0.35	4495	384	55.8	6.7
	0.71	4632	260	54.9	6.4
	1.06	4410	227	55.1	6.2
Charisma	0	3945	276	48.7	6.9
	0.35	3860	161	54.9	7.3
	0.71	3829	218	55.8	5.5
	1.06	4113	195	56.3	6.5
TPH Spectrum	0	3324	283	51.2	5.6
	0.35	3449	364	53.0	7.0
	0.71	3598	255	53.8	8.0
	1.06	3261	237	53.7	7.3

PUP, polymerization under pressure; DTS, dimetral tensile strength; SD, standard deviation.

Table 2: Weibull statstic parameters for DTS

Materials	*M*	σ	$\sigma_{0.05}$	R^2
Z 100	6.87	35.20	25.40	0.29
	8.79	98.70	41.80	0.03
	726	47.20	35.40	0.89
	6.94	84.42	27.50	0.71
Charisma	6.65	46.43	35.40	0.38
	6.30	46.79	35.40	0.25
	8.45	34.65	26.00	0.09
	10.50	93.03	41.80	0.75
TPH Spectrum	6.56	58.90	27.50	0.53
	8.42	62.60	31.20	0.14
	9.92	81.61	32.50	0.02
	9.98	94.47	26.01	0.11

m is the Weibull modulus, σ the normalized parameter, $\sigma_{0.05}$ the DTS value of 5% probability for all combinations of PUP and materials and R^2 is the linear correlation coefficient for Weibull distribution.

between the materials and loadings ($P < 0.05$).

Stiffness values of *Z* 100 were significantly higher than the values of other materials.

The TPH spectrum had significantly lower stiffness value compared with other materials. For Charisma, highest stiffness value was recorded with maximum loading during polymerization under pressure (PUP).

DISCUSSION

The effect of loading on some of the mechanical properties of three composites showed that improvement of mean values occurred though limited. However, application of PUP had different effects on the three different materials. The PUP of 0.35 MPa increased *Z* 100 DTS values by 12%. A further increase in PUP did not improve the mechanical properties. On the contrary, high loadings during PUP resulted in a decrease in *Z* 100 DTS values. The influence of PUP on TPH spectrum was related to an increase in its DTS values almost similar for both PUP of 0.71 and 1.06 MPa. For Charisma, a significant increase in DTS values for PUP of 1.06 MPa about 14% was observed. Higher loadings during polymerization resulted in a subsequent increase in DTS values, respectively.

This study questioned whether PUP improves the indirect tensile properties of composites. The Weibull distribution statistical test provided additional information because this test determines the sensitivity of a material to failure. A high value of '*m*' implies a narrow distribution of strength values and a small chance of low strength. This value increased to more than 25% for each material compared to THAT obtained with null PUP.

High '*m*' values and their related high $\sigma_{0.05}$ were obtained when:

- *Z* 100 was polymerized under 0.35 MPa,
- charisma was polymerized under 1.06 MPa,
- TPH spectrum was polymerized under 0.71 and 1.06 MPa.

This indicated that these conditions provided less chance for cracks or defects to develop in the material and improved the strength value for which there is less than 5% chance of failure.

It can be assumed that the ability to reduce flaws in material is probably related to homogeneity / heterogeneity of particles. When materials are similar in particle size and shape, more flaws develop during setting compared with a material with a high range of particle size and shape. When dissimilarity occurs in particles, their arrangement within the matrix during condensation is better, leaving smaller spaces for the resin and fewer chances for flaws to develop. When voids are present in the resin, its DTS values are lower. The amount of voids is reduced by loading the material before polymerization.[4]

The highest DTS value was obtained with Charisma and the lowest with *Z* 100. The *Z* 100 has the highest percentage of filler in volume. Stiffness and modulus are increased by increasing the percentage of filler. The *Z* 100 also has a high elastic modulus. These results are in agreement with this study. However, there is a significant positive correlation between the percentage filler volume and DTS.

CONCLUSION

Polymerizing light-polymerized composites under pressure improves their dimetral tensile strength and stiffness and reduces the probability of failure. The amount of applied pressure is material dependent.

REFERENCES

1. Brosh T, Ferstand N, Cardash H, Baharav H. Effect of polymerization under pressure on indirect tensile properties of light polymerized composites. J Prosthet Dent 2002:88:381-7.
2. Brosh T, Baharav H, Gross O, Laufer B. Influence of

surface loading and irradiation time during curing on mechanical properties of a composite. J Prosthet Dent 1997:77:573-7.
3. Brosh T, Ganar Y, Belov I, Pilo R. Analysis of strength properties of light cured composites. Dent Mater 1999:15:174-9.
4. Dijken JW, Ruyter IE, Holland RI. Porosity in posterior composite resins. Scan J Den Res 1986:94:471-8.