Original Article

Contemporary curing profiles: Study of effectiveness of cure and polymerization shrinkage of composite resins: An *in vitro* study

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Abstract

Aims: This study was undertaken to determine the effect of step-curing, ramp curing, single intensity on the effectiveness of cure and polymerization shrinkage of composite resin. The influence of filler loading on the effectiveness of cure and polymerization shrinkage of composite resin was investigated.

Materials and Methods: In this study, a total of 80 specimens divided into four groups were used. Group I – specimens cured with the step-cure mode. Group II – specimens cured with single high intensity. Group III – specimens cured with the ramp-cure mode. Group IV – specimens cured with single low intensity. Each group had two subgroups based on the composite resins used for making the specimen. The effectiveness of cure was determined from surface hardness values obtained from Rockwell hardness testing. A mathematical volumetric method was used to assess the volumetric shrinkage.

Results: Group III showed the best effectiveness of cure followed by group I and II. Group IV showed the least. Polymerization shrinkage was highest with group III and group II, were as was lowest for group I and IV. Charisma showed better effectiveness of cure and low polymerization shrinkage compared to Durafill VS.

Conclusion: This study emphasizes on the fact that, the soft–start polymerization modes (step curing and ramp curing) should be preferentially used over the conventional single (high or low light) intensities to cure composite resins, as its use results in optimal properties.

Keywords: Effectiveness of cure; hardness ratio; polymerization shrinkage

INTRODUCTION

Light activated resin composites, introduced in 1970s, revolutionized clinical dentistry by maximizing working time and minimizing setting time and has evolved as the foundation of modern dentistry. An inherent disadvantage of resin composites is the polymerization shrinkage. Since the introduction of light cured resin-based composites, the problem of polymerization shrinkage and the methods used to overcome this have concerned clinicians and researchers.[1] Though polymerization shrinkage is unavoidable, the shrinkage stresses generated, can be reduced by various ways.

The most recent approach, designed to allow the restoration some freedom of movement between the cavity wall and the centre of contraction, consists of initially reduced conversions of the resin material.[2] This soft-start polymerization involves a step-wise modulation of light energy and has been shown to result in lesser marginal gap and better marginal integrity.

The polymerization shrinkage and effectiveness of cure of composites have been extensively investigated. Yap *et al*. conducted a study on soft-start polymerization, its effect on effectiveness of cure, and post gel shrinkage of a visible light cured resin composite.[3] Results showed that effectiveness of cure generally increased with increased cure time and modulation of light energy intensity resulted in lower shrinkage compared to high intensity. Fan PL *et al*. conducted a study on curing light intensity and depth of cure of resin-based composites, listed according to international standards.[4] The results showed that, curing lights with an intensity of 300 mw/cm^2 appear to effectively cure most resins when appropriate curing

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times are used. Stanford C *et al*. conducted a study on polymerization of composites by sequential and continuous irradiation with visible lights.[5] The results showed that composites activated by visible light, when irradiated continuously or sequentially for the same total exposure polymerize to a similar extend, when the time of irradiation is adequate.

However, few studies have been conducted on the effectiveness of cure and polymerization shrinkage, in view of the latest curing profiles. This study was undertaken to determine the effect of step-curing, ramp curing, and single intensity on the effectiveness of cure and polymerization shrinkage of two different composite resins. The influence of filler loading on the effectiveness of cure and polymerization shrinkage of composite resin was also investigated.

MATERIALS AND METHODS

A stainless steel ring of 10.69 mm inner diameter and 2 mm height was used as the mold to confine the light cured composite resin during the polymerization process. Two types of composite resins were used [a microfilled composite (Durafill VS) and a hybrid composite (Charisma).

The ring was first mounted on a glass slide of 2 mm in thickness, and the ring was filled with the resin, till the brim of the ring. Two cover slips were used to cover the ring. The light curing tip was placed directly over the cover slips and the resin was cured for 40 s.

The product details of the various curing units used in this study are as follows [Table 1].

A total of 80 specimens were divided into four groups in this study.
Group I – specimens cured with *step-cure mode* using ELIPAR curing light (n-20) Unit (100 mW/cm^2 for 20 s and 400 mW/cm^2 for 20 s).
Group II – specimens cured with single intensity of light – *High intensity* (n-20) (700 mW/cm^2 using Kulzer TRASLUX ENERGY for 40 s).
Group III – specimens cured with *ramp-curing mode* using Kulzer (n-20) TRASLUX ENERGY (0–700 mW/cm^2 for 20 s and at 700 for next 20 s).
Group IV – specimens cured with single intensity of light – *low intensity* (n-20) (350 mW/cm^2 using Kulzer TRASLUX CL curing unit 40s).
Each group had two subgroups based on the composite resin used for making the specimens.
(i) Group A – microhybrid composite (n-10) (Charisma was used)
(ii) Group B – microfilled composite (n-10) (Durafill VS was used)

The effectiveness of cure was assessed by means of surface hardness testing. The superficial rockwell hardness method was used to compute the hardness gradient between the top and bottom surfaces of composite specimens after light curing for 40 s. Hardness ratio was calculated using the formula:

$$\text{Hardness ratio} = \frac{\text{Bottom RHN}}{\text{Top RHN}}$$

The polymerization shrinkage associated with curing of composites with each curing mode was determined by a mathematical volumetric method. A vernier precision digital micrometer was used to measure the dimensions of the mold and the cured specimens.

The mean height and mean diameter was obtained and the volume of the ring was first calculated using the formula:
$V_R = \pi r^2_R h_R$
Were V_R = volume of the ring
π = 3.14
r_R = radius of the ring
h_R = height of the ring.

Similarly, the volume of the cylindrical specimen was calculated by the same formula:
$V_S = \pi r^2_S h_S$
Were V_S = volume of the specimen
r_S = radius of the specimen
h_S = height of the specimen.

The percentage of volumetric shrinkage was calculated by using the formula:

$$\text{Percentage of volumetric shrinkage} = \frac{\Delta v}{V} \times 100$$

Where Δv = refers to change or difference in volume ($V_R - V_S$)
V = original volume of the mold.

Table 1: Product details of the curing units

Brand	Type	Modes of curing	Manufacturer
Translux CL	Quartz Tungsten halogen(QTH)	Low intensity	Heraeus Kulzer
Translux Energy	QTH- fast halogen	High intensity and Soft start mode	Heraeus Kulzer
Elipar Highlight	QTH	Step cure	3M ESPE

The effect of filler loading on the effectiveness of cure and polymerization shrinkage was assessed by comparing the hardness ratios and volumetric shrinkage values of the two composite resins use (hybrid resin - Charisma and microfilled resin - Durafill VS).

Comparison of the top and bottom hardness of Charisma and Durafill in all the four groups were done using the one-way ANOVA test. The statistically significant bottom hardness values of all the groups for both Charisma and Durafill were then subjected to independent sample T-test.

Comparison of hardness ratios, between different groups, was done using independent sample T-test and the intra group comparison of hardness ratios for each group were carried out by paired samples T-test.

The comparison of volumetric shrinkage values of Charisma and Durafill between all the groups were done using one-way ANOVA. The significantly different volumetric shrinkage values of all the four groups were then subjected to Scheffe's Post HOC test.

The intragroup variability was then assessed using paired sample T-test.

The comparison of the effect of filler loading on the effectiveness of cure and polymerization shrinkage for both the composites was done using paired sample T-test.

RESULTS

The results showed that

- There was statistically no significant difference between the top hardness values of all the groups for Charisma and Durafill. Group III showed the highest bottom hardness values and Group IV showed the lowest value.
- Group III showed the highest hardness ratios whereas Group IV showed the lowest hardness ratios.
- The percentage of volumetric shrinkage of all the groups of Durafill VS was significantly greater than Charisma.
- Charisma has higher filler loading (64% by volume) than Durafill VS (40% volume) and has better effectiveness of cure (gauged by hardness ratio) and lower polymerization shrinkage values, when compared to that of Durafill VS [Tables 2-5].

DISCUSSION

In this study, two different composite resins, (a hybrid composite - CHARISMA and a microfilled composite - DURAFILL VS) were used to determine the effect of filler loading on the effectiveness of cure and polymerization shrinkage of the resin. Low intensity was taken as 350 mW/cm^2 because; the I. S. O recommended, minimum intensity for curing a composite of 2 mm thickness increment, was 300 mW/cm^2. 700 mW/cm^2 was taken as the high intensity in this study; as it is more than double the recommended intensity value for curing composites resins.

The superficial rockwell hardness testing was used in this study, because it was relatively simple, accurate and gave directly hardness values.[6] In this study, a mathematical, volumetric method of assessing polymerization shrinkage was chosen because of its simplicity and accuracy to 0.001% when measured using the vernier precision micrometer.

The results of the study showed that there was no significant difference in the top surface hardness, between the groups. The duration of exposure is the most important factor for polymerization of the top surface and is less dependent on light intensity used for curing.[7] Group three showed the highest bottom hardness values. This is because, the bottom hardness is directly related to the intensity of light used. The higher the intensity of light used, the better is the bottom hardness.[8]

Table 2: Mean top and bottom RHN values and mean hardness ratio

Cure mode	Light intensity in mw/cm^2	Top RHN values (S.D)		Bottom RHN values (S.D)		Hardness ratio (S.D)	
		Charisma	Durafill	Charisma	Durafill	Charisma	Durafill
Step curing (group-I)	100 for 20 s and 400 for 20 s	64.96 (3.67)	35.43 (2.23)	57.33 (3.44)	28.22 (2.07)	0.88 (0.06)	0.79 (0.06)
High intensity (group-II)	700 for 40 s	67.33 (2.49)	36.10 (2.24)	60.48 (4.03)	29.14 (0.50)	0.89 (0.07)	0.81 (0.05)
Ramp curing (group-III)	0–700 over 20 s and at 700 for 20 s	68.24 (4.24)	37.23 (2.74)	66.37 (0.69)	34.24 (0.62)	0.96 (0.04)	0.90 (0.06)
Low-intensity (group-IV)	350 for 40 Sec	64.87 (2.76)	34.93 (2.39)	51.76 (0.56)	23.13 (0.84)	0.80 (0.04)	0.66 (0.06)

Table 3: Mean percentage of volumetric shrinkage for each groups

Cure mode	% of volumetric shrinkage (S.D) Charisma (hybrid)	% of volumetric shrinkage (S.D) Durafill VS
Step-curing (group I)	1.723% (0.286)	2.457% (0.251)
Highintensity (group II)	2.774% (0.303)	3.804% (0.249)
Ramp-curing (group III)	2.457% (0.365)	3.311% (0.343)
Lowintensity (group IV)	1.567% (0.471)	2.618% (0.602)

Table 4: Results of statistical analysis of RHN and Hardness ratio

Factor	Difference	
	Charisma (Hybrid)	Durafill VS (Microfilled)
RHN Top	No statistically significant difference. Grp1 = Grp2 = Grp3 = Grp4.	No statistically significant difference. Grp1 = Grp2 = Grp3 = Grp4.
RHN Bottom	Ramp curing> High intensity = Step curing>Low intensity. (Grp3 > Grp2 = Grp1> Grp4)	Ramp curing > high intensity= step curing > low intensity. (Grp3 > Grp2 = Grp1 > Grp4)
Hardness Ratio	Ramp curing > high intensity= step curing > low intensity (Grp3 > Grp2 = Grp1 > Grp4)	Ramp curing > high intensity= step curing > low intensity (Grp3 > Grp2 = Grp1 > Grp4)

Table 5: Results of statistical analysis of polymerization shrinkage

Factor	Difference	
	Intergroup variability	Intragroup variability
Polymerization shrinkage	For both Charisma and Durafill VS 1. There is no significant difference in percentage of volumetric shrinkage between ramp curing and high-intensity curing. 2. No significant difference in percentage of volumetric shrinkage between low-intensity and step curing. 3. Percentage of volumetric shrinkage is significantly higher for ramp and high-intensity than low intensity and step curing. (ramp/high> low intensity/step curing).	In all the four groups Percentage of volumetric shrinkage of Durafill VS is significantly greater than Charisma.

The results of this study showed that the highest hardness ratio was obtained for group III. This is because, the hardness ratio is more dependent on the bottom surface hardness, that is, better the bottom hardness, the higher the hardness ratio.[9]

The polymerization shrinkage has a linear relationship with the light energy density (intensity x time), that is, for a fixed time of exposure the higher intensity brought about higher polymerization shrinkage.[10]

Higher the filler loading, the less volume of resin matrix is available for polymerization and hence, low polymerization shrinkage results.[11] The higher the filler loading, the better the hardness and higher the hardness ratio.

CONCLUSIONS

Under the conditions of this *in vitro* study

- The effectiveness of cure of composite resins , polymerized using the ramp–curing mode was the best. The second best, was when high intensity curing mode was used, step-curing mode was as good as the high-intensity mode. The effectiveness of cure was lowest, when polymerization was done with the low-intensity curing mode.
- The polymerization shrinkage of the composite resins were highest, when the ramp-curing mode and high-intensity curing modes were used. Lower polymerization shrinkage values were obtained when step-curing and low-intensity modes were used.
- In all the four groups; the hybrid composite (Charisma) which had higher filler loading (64%), showed lower polymerization shrinkage and better effectiveness of cure; when compared to that of the microfilled composite (Durafill VS) of filler loading 40 vol%; which showed a lower effectiveness of cure and high polymerization shrinkage.

The step-curing mode and the ramp-curing mode fall under the category of soft-start polymerization. Hence, this study emphasizes on the fact that, the soft-start polymerization modes should be preferentially used over the conventional single (high or low) light intensities to cure composite resins, as its use results in optimal properties.

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