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ORIGINAL RESEARCH

The Effect of Different Shades, Voltages and Increment Thickness on the Polymerization Depth of a Microhybrid Composite

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ABSTRACT

Aim: Electric fluctuations in the developing world are common and may affect dental composite curing. We determined the effect of variable voltage and increasing thickness of different shades of composite on its depth-of-cure.

Materials and methods: ISO scrapping method was used on 14 commonly used shades of Esthet-X HD composites. Student's t-test and ANOVA were applied to compare the mean depth-of-cure and a linear regression model was developed using variables voltage (180 V and 220 V), material thickness (2, 4 and 6 mm) and shades (n = 14).

Results: The mean curing depth of samples was significantly reduced at 180 volts compared to 220 volts (p-value <0.002). At thickness of 2 mm, all samples were fully cured but when it was raised to 4 mm, the depth-of-cure reduced to 1.86 mm ± 0.06; while at 6 mm thickness, it reached to 1.96 mm ± 0.06 (p-value < 0.001).

Conclusion: Around 82% variation in the depth-of-cure is explained by voltage, thickness and shade of composite material (p-value <0.001).

Clinical significance: Electric fluctuations are prevalent in the developing world and thus poor voltage flow is responsible for dental composite's inadequate polymerization.

Keywords: Composite, Depth-of-cure, Polymerization, Increment thickness, Voltage, Laboratory experiment.

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INTRODUCTION

For maximum polymerization of an increment of resin composite, an efficient curing light is required. In order to maintain the efficiency of curing light unit, it is important that the electric current flow and the voltage are maintained properly. Fan et al had reported that, at low voltage, the curability of resin composite is significantly reduced.[1] A low curing unit's intensity on radiometer does not merely suggest a fading bulb; rather it may also inform the clinician about the poor voltage flow. Variations in the voltage flow are prevalent in all parts of the world, but its incidence is higher in the developing countries, such as Pakistan. This may have a significant effect on the resin composite curability.

Furthermore, inadequate curing of composite is associated with a reduction in its mechanical properties, high tendency to surface staining and possibility of marginal leakage.[2-6] Therefore, the clinicians working with composite materials at unidentified variable voltages need to have a clear understanding of its physics which may affect the resin composite chemistry.

Composition of material, presence of dark pigments, distance of light tip to the material, type of photoinitiators, thickness of the material used, wave length/bandwidth, curing time are just a few of the factors that affect the depth of curability of composite material.[7] Consequently, there is little information available on the composites' curability, ideal increment size for individual shades at variable voltages.

The ideal voltage for resin composite polymerization in South Asian region is 220 volts. In our settings, this voltage is seldom maintained. The usual fluctuation is between 220 and 190 volts (as evaluated by us through a digital voltmeter before conducting the experiment). In order to check the material curability (the depth-of-cure) at this varied voltage flow, we designed this study. The experiment was expanded in terms of curability of different shades and increased material thickness at different voltages. Our objectives were as follows:

1. To determine the effect of variable voltage and increasing thickness of material with different shades on depth-of-cure of a microhybrid composite material.
2. To evaluate the minimum depth-of-cure of the same composite by using the ISO scraping method.

MATERIALS AND METHODS

A total of 14 commonly used shades (A1, A2, A3, A3.5, A4, B1, B2, B3, C1, C2, C3, C4, CE (Clear enamel) and UNIV (Universal) of Esthet-X HD material were tested for the depth-of-cure. We used two voltage levels; first an ideal of 220 V and the second a dropped down voltage of 180 volts.

All the samples were tested using the ISO scrapping method. In this technique, 50% of the total cured sample length is measured after scraping away of uncured portion with a spatula.[8,9] Each sample reading was taken three times through which a mean value was derived as the final half depth-of-cure. Factors, such as light intensity, curing time and the distance of light guide were kept constant during the experiment. All the experiments were conducted in a dark room. A voltage convertor was used that maintained the constant voltage of 220 V. The composite material was first packed in the 2 mm mold (Dentsply, USA) and flattened to remove any residual space within the mould. A halogen curing light (Hilux 250, FirstMed, USA) with a polymerization intensity of 600 to 800 mW/cm^2 was employed. The light tip was kept approximated to the resin composite surface while curing. This experiment was repeated with various shades at 4 and 6 mm increments at 220 V. Similarly, a new series of same batch of shades at 2, 4 and 6 mm increments were tested at a dropped voltage of 180 V.

SUMMARY OF EXPERIMENT AND OBSERVATIONS

- Composite material used: Esthet-X HD (Dentsply, USA)
- Curing light: Hilux 250, USA
- Total number of shades tested: 14
- Thickness used: Three (2, 4 and 6 mm)
- Voltages applied: Two (180 and 220 V)
- Observations per experiment: 3
- Total experiments conducted: 84
- Total number of observations generated: 252.

RESULTS

There was a statistically significant difference between the mean curing depths of composite sample at 180 V compared to 220 V. All the samples cured better at 220 V as shown in Table 1.

Table 2 shows the individual effect of effect of voltage, material thickness and material shade. It was found that voltage independently was responsible for 44%, material thickness accounts for 58% while composite shade contributes 15% observed variations on the depth-of-cure of composite material.

The combined effect of voltage, material thickness and material shade on the depth-of-cure show that these three variables cumulatively account for 82% observed variations on the depth-of-cure of composite as shown in Table 3.

Figure 1 shows that the mean depth-of-cure at the dropped voltage of 180 V was 1.68 mm but at an optimal voltage of 220 V, the depth-of-cure rose to 1.87 mm. Both values were above the ISO cutoff of 1.5 mm.

Although, the 2 mm molds were fully cured while the maximum curing depth achieved in 6 mm mold was 1.96 mm (Fig. 2).

Shades A3, B1, B3, C2 and C4 showed shallower curing depth than the shade A1 (reference category) while the other shades were cured deeper than A1 (Fig. 3).

Figures 4A to G shows all the equipments and the armamentarium used in the study.

Table 1: Comparison of depth-of-cure at two different voltages (n = 252)

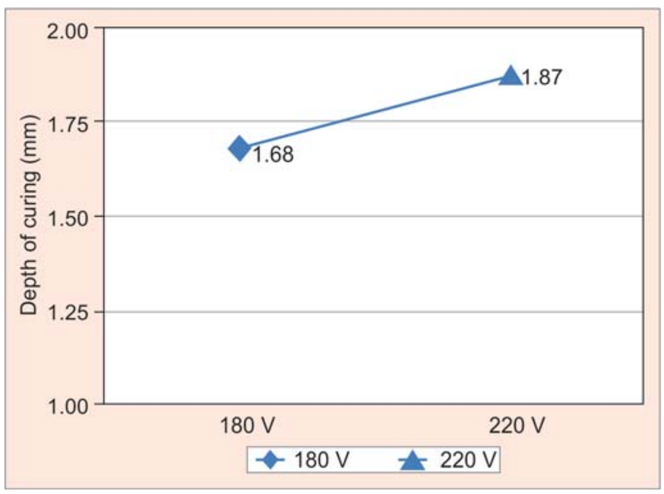
Composite shade	*180 V mean (SD)*	*220 V mean (SD)*	*Overall mean (SD)*	*p-value*
A1	1.58 (0.26)	1.94 (0.44)	1.59 (0.50)	
A2	1.52 (0.45)	1.56 (0.50)	1.54 (0.43)	
A3	1.26 (0.23)	1.45 (0.38)	1.35 (0.30)	
A3.5	1.45 (0.39)	1.61 (0.52)	1.53 (0.42)	
A4	1.59 (0.52)	1.69 (0.60)	1.64 (0.50)	
B1	1.47 (0.40)	1.63 (0.54)	1.55 (0.44)	
B2	1.56 (0.49)	1.63 (0.54)	1.59 (0.46)	0.002
B3	1.32 (0.29)	1.51(0.44)	1.41 (0.35)	
C1	1.68 (0.59)	1.82 (0.76)	1.75 (0.61)	
C2	1.44 (0.385)	1.61 (0.52)	1.53 (0.42)	
C3	1.63 (0.55)	1.76 (0.68)	1.70 (0.56)	
C4	1.47 (0.40)	1.59 (0.52)	1.53 (0.42)	
CE	1.99 (0.99)	1.99 (0.99)	1.99 (0.88)	
UNIV	1.61 (0.53)	1.74 (0.65)	1.67 (0.54)	
Total	1.68 (0.39)	1.87 (0.42)	1.60 (0.49)	

Table 2: Individual effect of voltage, increment thickness and shade on depth-of-cure

Model	*Adjusted R^2*	*Std. error*	*p-value*
Voltage	0.44	0.41	0.002
Material thickness	0.58	0.27	<0.001
Shades	0.15	0.39	<0.001

DISCUSSION

The resin composite curing depth was measured using the ISO standardized scraping test.[8] This test is fairly easy to perform in a clinical setting as no special equipment is required and is inexpensive to conduct. The ISO scraping test is also considered as quantitative in nature as compared to other tests which are qualitative.[10]



The mean curing at:
- 220 V was 1.87 (±0.042)
- 180 V was 1.68 (±0.039)

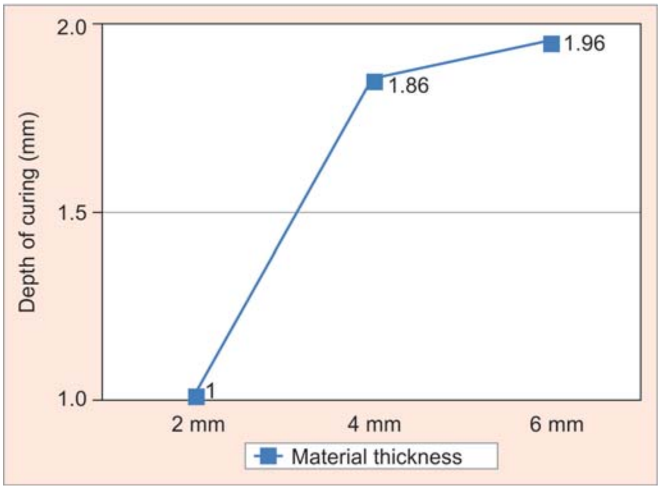
p-value 0.002

Fig. 1: The effect of raised voltage (180 to 220 V) on the depth-of-cure of resin composite

Table 3: Combined effect of voltage, thickness and shade on the depth-of-cure

Model	*Adjusted R^2*	*Std. error*	*p-value*
Model 1: Voltage	0.44	0.41	0.002
Model 2: Voltage + thickness	0.62	0.25	<0.001
Model 3: Voltage + thickness + shade	0.82	0.17	<0.001

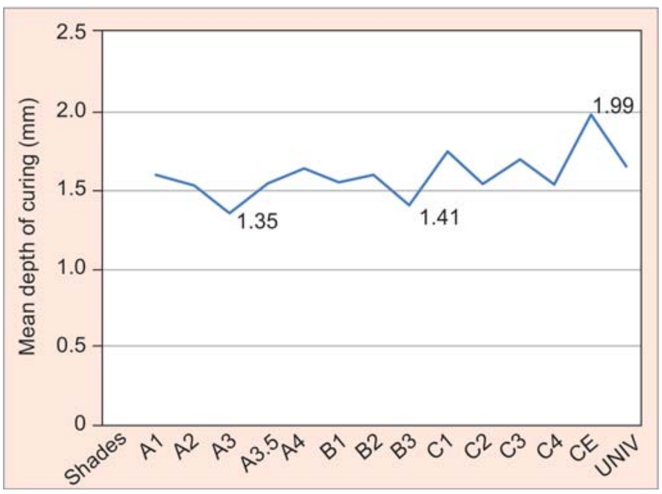
Model building using regression analysis; Combined effect of independent variables on depth-of-cure



The mean depth of curing at:
- 2 mm thickness was 1 mm (±0.52)
- 4 mm was 1.86 mm (±0.06)
- 6 mm was 1.96 mm (±0.06)

p-value 0.001

Fig. 2: The effect of increment thickness on the depth-of-cure



- Shade A2, A4, B2, C1, C3, CE and UNIV exhibited deeper depth-of-cure than the reference (A1).
- Whereas shades A3, B1, C2 and C4 showed shallower depth of cure, p-value <0.001

Fig. 3: The effect of composites shade on the depth-of-cure

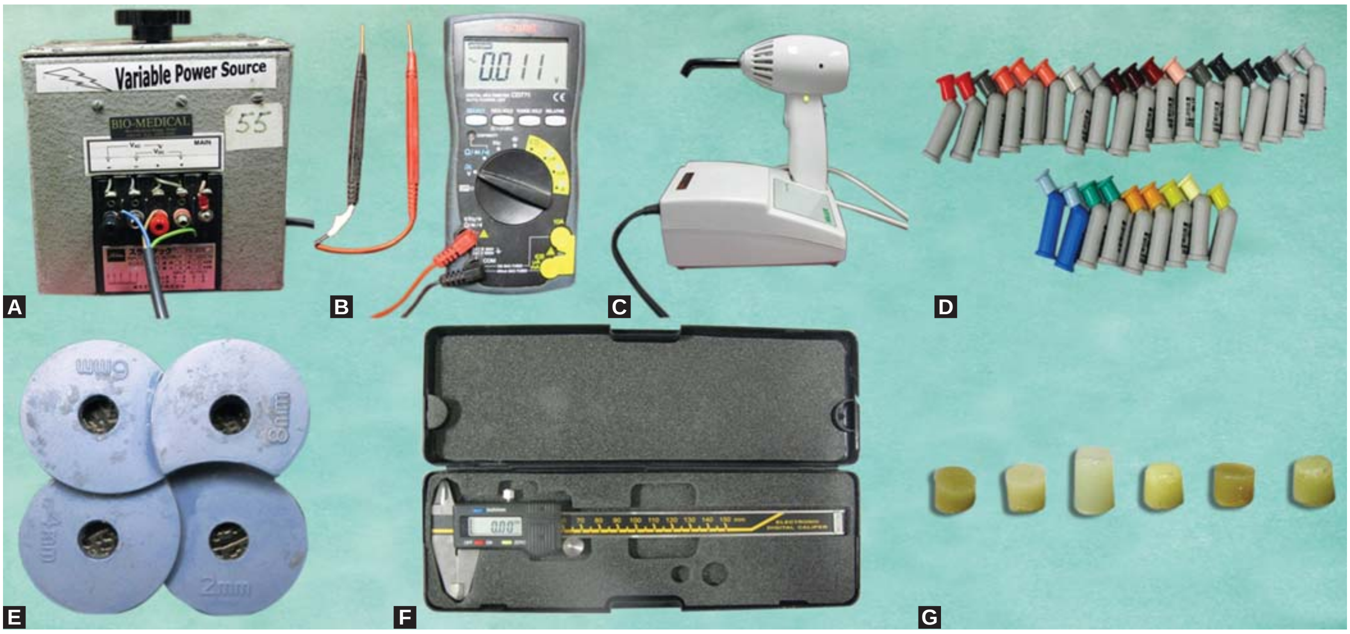
There are studies which have reported that the resin composite depth of cure decrease significantly from surface to its depth as the material cures.[11,12] This could be misleading if the total cured increment is taken as the polymerized value. Preferably, the degree of curing should be the same throughout the depth of the restoration. It is a known phenomenon that when the blue light enters the resin composite, there is a dispersion of light within its substance. Due to this reason, the light is unable to effectively cure the material from the surface to its bottom equally. This leads to a lower curing effectiveness.[13]

Therefore, in the scraping test, the investigator has the advantage to scrap away any soft under polymerized portion of the material after its curing which provide a more reliable reading of the cured portion of material. However, overestimation of the cured increment with this method cannot be ruled out.[7]

In our study, dropping down of the voltage produced 44% variation on the final depth-of-cure value (p-value 0.002). This shows how voltage could significantly affect resin composite curing. At a lowered voltage of 180 V, shades A3, A3.5, B1, B3, C2 and C4 could not meet the ISO standard of 1.5 mm curing whereas at the optimum voltage of 220 V, all the shades successfully met the ISO standard except A3 as shown in Table 1. Similarly, Fan had also reported that at reduced voltage of 90 V, the composite curing is significantly compromised.[1] The available data on different voltages is scarce and whatever data is available is obtained on the older composite types. Thus, our study is high relevance to the practitioners who use modern composites but practice in areas of frequent voltage fluctuations.

We found that up to 58% influence on the depth-of-cure of composite was due to the material thickness alone. In our study, the depth-of-cure never exceeded 2 mm depth. Laura Ceballos[14] et al have also reported that composites should not be cured in increments higher than 2.5 mm regardless of the curing light used or the irradiation time applied. This is due to the fact that the hardness of the resin composite tends to decrease with increasing thickness. Furthermore, at optimum voltage of 220 volts the curing light adequately cured around 2 mm of resin composite (see Fig. 2) which is considered as a standard value for clinical use.[15]

Based on our results, around 15% of the observed variations on the depth-of-cure were due to the effect of different shades (p-value <0.001). Shades A2, A4, B2, C1, C3, CE and UNIV exhibited deeper depth-of-cure than the reference (A1). While, shades A3, B1, B3, C2 and C4 showed shallower depth-of-cure. This finding is in agreement with Tarle[16] who found that darker shades have a shallower depth-of-cure as compared to lighter shades. This may be due to the possible effect of the colorants that are incorporated in the resin composite shades.[17,18]



Figs 4A to G: Armamentarium used in the study: (A) Voltage convertor used in this study to drop down the voltages from optimum 220 to 180 V (*Courtesy:* Aga Khan University, Biomedical Department), (B) Digital multimeter was used to monitor the acquired and reduced voltages during the experiments, (C) Hilux 250 QTH curing lights used in this study, (D) Esthet-X HD resin composite (various shades) included in the experiment, (e) depth-of-cure measuring gauge (Dentsply) used for the resin composite scraping test, (F) Digital Vernier Caliper used for measurements of resin composite cured increment cylinders, (G) cured samples of various shades and lengths. Each sample was measured three times and a mean reading was calculated as the depth-of-cure value for the cured increment

Our study answers an important research question that is relevant to developing countries with energy crises, such as Pakistan. The observations generated were large in number. Experiments were conducted in a standard format (low variation in the results). Multiple range of shades were tested and ISO standardized technique was used. Regression analysis was performed to form a prediction model.

A particular limitation of this study is that it is confined to just one brand of composite. Only one type of curing light was used (Quartz Tungsten-Halogen in this case). Other variables, such as distance of light guide tip to the sample, curing time, intensity of light, wavelength/ bandwidth, etc. were not studied as these were kept constant to standardize the experiment. Thus, their affect could not be studied. Finally, low sensitivity of the scraping test is a known limitation.

CONCLUSION

The voltage, material thickness and different shades contribute significantly to the microhybrid composite depth-of-cure.

At an optimal voltage of 220 V, 13 out of 14 (92.85%) shades met the ISO standard but when it was reduced to 180 V, only 8 out of 10 (57.14%) passed the ISO standard.

CLINICAL SIGNIFICANCE

Electric fluctuations are prevalent in the developing world and thus poor voltage flow could be a factor behind dental composite's inadequate curing. Thus, we recommend installation of voltage stabilizer at dental clinics for optimum curing of composite restorations.

REFERENCES

1. Fan PL, Wozniak WT, Reyes WD, Stanford JW. Irradiance of visible light-curing units and voltage variation effects. J Am Dent Assoc 1987;115(3):442-45.
2. Bouschlicher MR, Rueggeberg FA. Effect of ramped light intensity on polymerization force and conversion in a photoactivated composite. J Esthet Dent 2000;12(6):328-39.
3. Bouschlicher MR, Rueggeberg FA. Effect of stepped light intensity on polymerization force and conversion in a photoactivated composite. J Esthet Dent 2000;12(1):23-32.
4. Feilzer AJ, De Gee AJ, Davidson CL. Setting stress in composite resin for two different curing modes. Dent Mater 1993;9(1): 2-5.
5. Lim BS, Ferracane JL, Sakaguchi RL, Condon JR. Reduction of polymerization contraction stress for dental composites by two-step light activation. Dent Mater 2002;18(6):436-44.
6. Sakaguchi RL, Berge HX. Reduced light energy density decreases post-gel contraction while maintaining degree of conversion in composites. J Dent 1998;26(8):695-700.
7. Fan PL, Schumacher RM, Azzolin K, Geary R, Eichmiller FC. Curing-light intensity and depth of cure of resin-based composites tested according to international standards. J Am Dent Assoc 2002;133(4):429-34.
8. Hansen EK, Asmussen E. Visible-light curing units: Correlation between depth of cure and distance between exit window and resin surface. Acta Odontol Scand 1997;55:162-66.
9. ISO-Standards 2000 ISO 4049 dentistry-polymer-based filling, restorative and luting materials. Geneva: International Organization for Standardization 2000:1-27.

10. Yap AU, Soh MS. Curing efficacy of a new generation high-power LED lamp. Oper Dent 2005;30(6):758-63.
11. Hansen EK, Asmussen E. Reliability of three dental radiometers. Scand J Dent Res 1993;101:115-19.
12. Rueggeberg FA, Caughman WF, Curtis JW, Davis HC. Factors affecting cure at depths within light-activated resin composites. Am J Dent 1993;6(2):91-95.
13. DeWald JP, Ferracane JL. A comparison of four modes of evaluating depth of cure of light-activated composites. J Dent Res 1987;66(3):727-30.
14. Ceballos L, Fuentes MV, Tafalla H, Martínez A, Flores J, Rodríguez J. Curing effectiveness of resin composites at different exposure times using LED and halogen units. Med Oral Patol Oral Cir Bucal 2009;14(1):E51-56.
15. Hervás-García A, Martínez-Lozano MA, Cabanes-Vila J, Barjau-Escribano A, Fos-Galve P. Composite resins. A review of the materials and clinical indications. Med Oral Patol Oral Cir Bucal 2006;11(2):E215-20.
16. Tarle Z, Meniga A, Ristic M, Sutalo J, Pichler G. Polymerization of composites using pulsed laser. Eur J Oral Sci 1995;103:394-98.
17. Bayne SC, Heymann HO, Swift EJ Jr. Update on dental composite restorations. J Am Dent Assoc 1994;125(6):687-701.
18. Fleming GJ, Awan M, Cooper PR, Sloan AJ. The potential of a resin-composite to be cured to a 4 mm depth. Dent Mater 2008;24(4):522-29.

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