The Effect of Standard and Extended Curing Time in Different Distances on Composite's Degree of Conversion

Original Article

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Abstract

Introduction: The aim of this study was to investigate the effect of irradiation duration and distance of light tip to prepared samples in two different light curing unites on the degree of conversion of resin composite.

Materials and Methods: Conventional halogen and blue Light emitting diode (LED) units were used for polymerization of an Opalis resin composite. The conversion measurements were carried out at 0 and 8 mm distance from the directly irradiated surface in manufactured recommended curing time as well as in doubled curing time. The curing efficiency was observed with FTIR (Fourier transform infrared spectroscopy). Data was analyzed using ANOVA and Tukey post hoc test.

Results: The LED curing unit exhibited the most homogenous in-depth curing efficiency at the same time (20 sec). The most amount of conversion degree in LED group was related to distance 0 and irradiation time of 20 sec.

However, in halogen groups the highest grade was observed in distance 0 and exposure time of 40sec. With increasing the distance between light guide tip and resin composite to 8 mm, being inevitable especially in class 2 box filling

Conclusion: The result of our study confirmed that the best result for each group obtained in maximum contact with light source meanwhile reduplicating the manufacture recommended exposure time. Besides, in our research, LED showed a better outcome in proposed time of 20 sec in both distances.

Key words: •Dental composite resin •Fourier transform infrared spectroscopy •Light curing unite

Introduction

Visible light-cured composite resins are widely used in restorative dentistry. Although, polymerization of methacrylate monomers in these resin composites leads to a highly cross linked structure, residual in saturation occurs mainly in the form of pendant methacrylate groups, due to steric hindrance.[1,2] The degree of conversion defined as the percentage of reacted C=C bonds, affects many properties including mechanical properties, solubility, dimensional stability, color change and biocompatibility of the resin composite.[3–5] Thus, it has been postulated that the degree of conversion plays an important role in determining the ultimate success of the restoration.[2,6] Therefore, determination of conversion is a critical component in the interpretation of test results of both commercial and experimental dental materials.

Currently, four main types of polymerization sources are available: halogen bulbs, plasma-arc lamps, argon-ion lasers and light-emitting diodes (LED). Since the most popular photo-polymerization strategy is based on halogen light; emitting a wide range of the visible spectrum, band-pass filters are required to limit the wavelength between 370 and 550 nm, which fits to the peak absorption of camphoroquinone (CQ). Maximum CQ absorption happens at 468 nm solid-state.[7,8]

Regarding the difference between the two light curing unites, LEDs are less energy-consuming[9] , need no external cooling and require no filter. Because the very narrow spectral output of gallium nitride blue LED conveniently falls within the absorption spectrum of camphoroquinone. In addition, LEDs have an expected lifetime of several thousand hours without significant degradation of light intensity over time.[2,10]

It is well known that the degree of conversion of a given photopolymerizable composite is mainly influenced by the light intensity of the curing unit.[11-13] the total exposure duration, and the distance between resin surface and light tip.[14] It has been shown that the same degree of conversion is produced by a fixed energy amount (energy density: J/cm2), independent of variations in light irradiance[15]. Thus, a recommendation of 21 and 24 J/cm2 energy density has been made for the adequate polymerization of 2 mm thick composite specimen.[5,15] Furthermore, Hansen and Asmussen[16] described ,that a class II cavity in upper molars can exhibit cavity depths of up to 7 mm. Therefore, this distance has to be considered in an investigation on curing efficiency.

To the aim of this study, two clinical relevant distances of 7mm between the light guide tip, the cavity floor (bottom side of test sample) and direct contact which is widely recommended was taken into consideration, in order to determine the minimum exposure time required for employing the blue LED-curing device and QTH(Quartz tungsten Halogen).

The hypothesis was set that the minimum exposure time can be reduced to 10 sec for the LED and 20 sec for the QTH with respect to resin.

Materials and Methods

The restorative resin composite opalis(Lot: 100212, A3 DENTSCARELTD,B brazil) was used in this study. The material was based on a bisphenol glycidyl methacrylat (BisGMA)/ urethane dimethacrylate (UDMA)/triethylene glycol dimethacrylate (TEGDMA) resin matrix, with camphoroquinone as photoinitiator and 57 vol% inorganic filler content.

Opalis is clinically indicated as a universal fine particle hybrid resin composite for anterior and posterior restorations.

Light curing units:

In the current study, one halogen curing unit(Litex 680 A, Dentamerica, USA) and another LED system(LED.G,Woodpecker, China) were used. Both of them were used in standard mode (continuous, constant light intensity).

Radiometer:

Before light curing, the power density was checked with the radiometer(Digi Rate, LM-100, Taiwan).

The Curing-light attenuation was determined as follows. The tip of the irradiating light guide was clamped directly above and perpendicular to the sensitive window (8 mm diameter) of the radiometer.

The obtained result was 548 $^{mW}/_{cm^2}$ for halogen device and 867 $^{mW}/_{cm^2}$for LED

Therefore, both of them meet the required amount of power density.

Measurement of degree of conversion:

To evaluate the degree of conversion, we prepared 24 samples (n=3) of thin compressed composites which were made between two fine sheet of polyethylene to meet the required thickness of 100- 150 micrometer.

The degree of photo polymerization conversion of samples was measured using FTIR spectroscopy (EQUINOX 55, Bruker, Germany) at a resolution of 4 cm-1 and 32 scans in the range of 4000–400 cm-1. First of all, the absorbance spectrum of the uncured samples was obtained.

These samples were randomly divided to 8 groups and light cured as follow:

- Group A:
  (LED) distance: 0
  curing time:10 s
- Group B :
  (LED) distance: 0
  curing time: 20 s
- Group C:
  (LED) distance :8mm
  curing time:10 s
- Group D:
  (LED) distance :8mm
  curing time: 20 s
- Group E:
  (Q.T.H) distance: 0
  curing time : 20s
- Group F:
  (QT.H) distance: 0
  curing time:40 s
- Group G:
  (QTH) distance: 8mm
  curing time: 20 s
- Group H:
  (QTH) distance 8mm
  curing time: 40 s

The curing tip distance of 8 mm was controlled via the use of metal hollow tube in 8mm height and diameter.

Eventually, F.T.I.R spectrum was taken after polymerizing in above given requirements.

The percent of DC(Degree of Conversion) was calculated from the aliphatic C=C peak at 1638 cm, and normalized against the aromatic C-C peak at 1608 cm according to formula(1)

$$DC\% = \left[1 - \frac{C_{aliphatic}/C_{aromatic}}{U_{aliphatic}/U_{aromatic}} \right] \%$$

$C_{aliphatic} \rightarrow$ absorption peak at 1638cm^{-1} of the cured specimen

$C_{aromatic} \rightarrow$ absorption peak at 1608cm^{-1} of the cured specimen

$U_{aliphatic} \rightarrow$ absorption peak at 1638cm^{-1} of the uncured specimen

$U_{aromatic} \rightarrow$ absorption peak at 1608cm^{-1} of the uncured specimen

Finally ANOVA and Tukey post hoc test was used for statistical analysis.

Results

Results are shown in figures 1 and 2. According to one way ANOVA there is significant different among LED groups [$p<0.0001$; DF(3,7), F= 176.322)] and QTH groups [$p<0.0001$; DF(3,7), F= 82.65] Tukey post hoc analysis revered no significant difference between LED (A) and (D) but for other comparisons analysis showed significant different ($P<0.005$).

For QTH group Tukey reveald no significant different between group E and H but other groups showed significant difference ($P<0.02$).The FT-IR measurements showed that the best Dc result was related to the usage of optimum distance i.e. No space and doubling the recommended exposure time, it In other words, means 20 sec in LED group and 40 sec in Q.T.H groups.

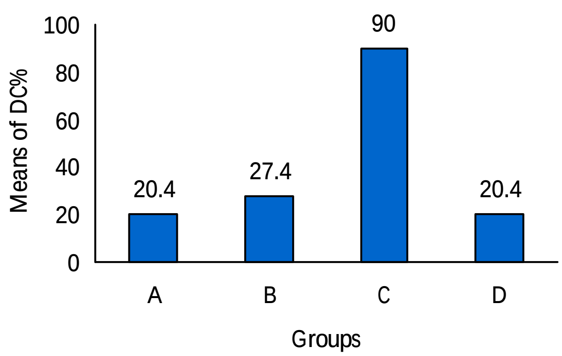
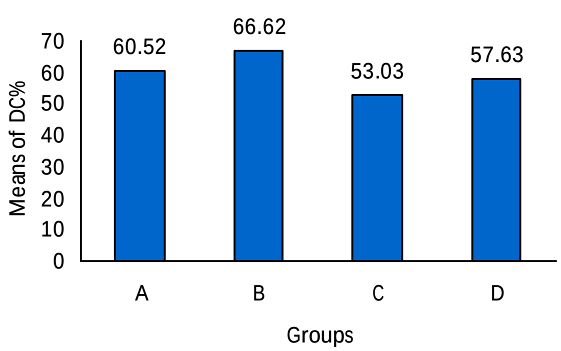


Figure 1. DC average comparison among LED groups

Figure 2. Dc average comparison among QTH



groups

Discussion

Among several methods to determine the degree of conversion (DC) of composites, Fourier transform infrared spectroscopy (FTIR) has been proven to be a powerful technique and has been widely used as a reliable method[17-20] which it detects the C-C stretching vibrations directly before and after curing of materials. The aim of current study was to determine the amount of exposure required to achieve the optimal curing in two commonly encountered distances. As Nomoto showed, the DC of light-cured composites depends not only on light intensity emitted from light-curing units but also on irradiation time.[21] Therefore, the total amount of exposure, the product of the light intensity and the irradiation time, should be considered for light-curing systems.

The results of our study confirmed that the best result for each groups was obtained in a maximum contact with light source and increasing the exposure duration as long as it did not lead to any adverse effects likes such as increasing in tooth temperature etc. This finding is in agreement with the study that of Ferranda et al.[22] those which showed revealed the a development of both polymerization stress and conversion over time for all experimental conditions.

In our study, the samples of halogen group in 8 mm distance did not meet the minimum requirement of DC which is 55%, so in an area with a minimum access or the bottom of class II cavity LED device work the best. Apart from effects inherent to curing protocol or resin composite material, there are further practical considerations on the applied light source and hence on the quality of the final restoration.

Fluctuations in the line voltage, the condition of bulb and filter, contamination of the light guide, damage to the fiber optic bundle, and heat build-up within the unit might reduce the light output, which eventually results in incomplete polymerization.[23] In addition, a considerable amount of heat is generated, requiring the use of cooling fans. Cooling problems limit the development of higher energy output which might allow for the reduction of irradiation times—in a certain range—so as to save clinicians' time.[24] Light-curing units with narrow emission spectra around 470 nm, such as plasma arc lamps or LED curing units are optimized for dental resins containing the photo-initiator camphoroquinone. Some resin composites, however, contain co-initiators, which absorb light at shorter wavelengths than camphorquinone, thus might not be activated by those curing units.[25] For clinically successful restorative dentistry, a minimum DC has not yet been precisely established.

Nevertheless, a negative correlation of in vivo abrasive wear depth with DC has been established for DC values in the range between 55% and 65%.[26]

This suggests that, for occlusally loaded restorative layers, a quantity of less than 55% DC at the material surface might be contraindicated.

In our study, these requirements are not fulfilled by using LED and QTH curing unites at manufactured recommended exposure time in 8 mm depth. So, for obtaining optimum DC result in this distance we had to reduplicate the recommended curing time.

Furthermore, it has been reported that L.E.D technology polymerizes resin composite as well good or better than some QTH lights. (27.28.29) Besides, in our study, also, LED showed a better outcome in proposed time of 20 second in both distances.

Conclusion

Based on the data from this in vitro study, it can be concluded that an optimum polymerization resulting in composite's curing can be obtained via enclosing the light tip to the composite in accessible cases. Also, in our study extending exposure time improved our acquired result .However; any increase in exposure time must be done with obsession because of its proposed side effects like pulp damages, etc.

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References

1. Asmussen E, Peutzfeld A. Influence of pulse-delay curing on softening of polymer structures. J Dent Res 2001; 80: 1570–3.
2. Yoon TH, Lee YK, Lim BS, Kim CW. Degree of polymerization of resin composites by different light sources. J Oral Rehabil 2002; 29:1165–73.
3. Vaidyanathan J, Vaidyanathan TK. Interactive effects of resin composition and ambient temperature of light curing on the percentage conversion, molar heat of cure and hardness of dental composite resins. J Mater Sci: Mater Med 1992; 3: 19–27.
4. Silikas N, Eliades G, Watts DC. Light intensity effects on resin-composite degree of conversion and shrinkage strain. Dent Mater 2000; 16: 292–6.
5. Correr Sobrinho L, de Goes MF, Consani S, et al. Correlation between light intensity and exposure time on the hardness of composite resin. J Mater Sci: Mater Med 2000; 11: 361–4.
6. Peutzfeld A, Sahafi A, Asmussen E. Characterization of resin composites polymerized with plasma arc curing units. Dent Mater 2000; 16: 330 –6.
7. Teshima W, Nomura Y, Tanaka N, et al. ESR study of campherquinone/amine photoinitiator systems using blue light-emitting diodes. Biomaterials 2003; 24: 2097–103.

8. Hofmann N, Hugo B, Schubert K, Klaiber B. Comparison between a plasma arc light source and conventional halogen curing units regarding flexural strength, modulus, and hardness of photoactivated resin composites. Clin Oral Invest 2000; 4: 140–7.
9. Uhl A, Mills RW, Jandt KD. Polymerization and light-induced heat of dental composites cured with LED and halogen technology.b iomaterials 2003; 24: 1809–20.
10. Stahl F, Ashworth SH, Jandt KD, Mills RW. Light-emittingdiode (LED) polymerization of dental composites: flexural properties and polymerization potential. Biomaterials2000; 21: 1379–85.
11. Rueggeberg FA, Caughman GB, Curtis JW. Effect of light intensity and exposure duration on cure of resin composite. Oper Dent 1994;19:26–32.
12. Lovell LG, Newman MS, Donaldson MM, Bowman CH. The effect of light intensity on double bond conversion and flexural strength of a odel, unfilled dental resin. Dent Mater 2003; 19: 458–65.
13. Rueggeberg FA, Caughman WF, Curtis JW, Davis HC. Factors affecting cure at depths within light-activated resin composites. Am J Dent 1993; 6: 91–5.
14. Rueggeberg F, Jordan DM. Effect of light-tip distance on polymerization of resin composite. Int J Prosthodont 1993; 6:364–8.
15. Emami N, So¨derholm KJM. How light irradiance and curing time affect monomer conversion in light-cured resin composites. Eur J Oral Sci 2003; 111: 536–42.
16. 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: 162-6.
17. Park S-H, Lee CS. The difference in degree of conversion between light-cured and additional heat-cured composites. Oper Dent 1996; 21: 213-7.
18. Rueggeberg FA, Hashinger DT, Fairhurst CW. Calibration of FTIR conversion analysis of contemporary dental resin composites. Dent Mater 1990; 6: 241-9.
19. Chung KH, Greener EH. Correlation between degree of conversion, ®ller concentration and mechanical properties of posterior composite resins. J Oral Rehabil 1990; 17: 487-94.
20. Imazato S, Tarumi H, Kobayashi K, et al. Relationship between the degree of conversion and internal discoloration of light- activated composite. Dent Mater J 1995; 14: 23-30.
21. Nomoto R, Uchida K, Hirasawa T. Effect of light intensity on polymerization of light-cured composite resins. Dent Mater J 1994; 13(2):198–205.
22. Fernanda C. Calheirosa, Ma´ rcia Daroncha, Influence of irradiant energy on degree of conversion, polymerization rate and shrinkage stress in an experimental resin composite system. Dent mater J 2008; 24:1164-1168.
23. Nomura Y, Teshima W, Tanaka N, et al. Thermal analysis of dental resins cured with bluelight-emitting diodes (LEDs). J Biomed Mater Res (Appl Biomater) 2002; 63: 209–13.
24. Hofmann N, Hugo B, Klaiber B. Effect of irradiation type (LED or QTH) on photo-activated composite shrinkage strain kinetics, temperature rise, and hardness. Eur J Oral Sci 2002, 110: 471–9.
25. Uhl J, Mills RW, Vowles RW, Jandt KD. Knoop hardness depth profiles and compressive strength of selected dental composites polymerized with halogen and LED light curing technologies. J Biomed Mater Res B 2002; 6:729–38.
26. Silikas N, Eliades G, Watts DC. Light intensity effects on resin-composite degree of conversion and shrinkage strain. Dent Mater 2000; 16: 292–6.
27. Da Silva GR, Simamoto-Júnior PC, Da Mota AS, Soares CJ. Mechanical properties of light-curing composites polymerized with different laboratory photo-curing units. Dent Mater J. 2007 Mar; 26(2):217-23.
28. Uhl A, Sigusch BW, Jandt KD. Second generation LEDs for the polymerization of oral biomaterials. Dent Mater 2004; 20(1):80-7.
29. Peris AR, Mitsui FH, Amaral CM, et al. The effect of composite type on microhardness when using quartz-tungstenhalogen (QTH) or LED lights. Oper Dent 2005; 30(5):649-54.