EFFECT OF THE LIGHT-EMITTING DIODE UNITS ON THE DEPTH OF POLYMERIZATION OF A COMPOSITE

ABSTRACT

The physical characteristics of composite resins strongly influence their clinical durability. The purpose of this study was to evaluate the influence of different light-emitting diode units on the Knoop hardness (KHN) and plasticization (P) of a composite resin. Disc-shaped specimens (5 x 2 mm) of the Filtek Supreme (3M ESPE) methacrylate-based nanofilled composite were light-cured using second-generation light-emitting diode (LED2) Bluephase 16i (Vivadent) or third-generation (LED3) Ultralume LED 5 (Ultradent) curing units at 1390 and 800 mW/cm2 of irradiance, respectively. After 24 h, KHN was measured with 50-g load for 15 s, and was evaluated by percentage reduction of the hardness after 24 h immersed in absolute alcohol at top and bottom surfaces. Data were subjected ANOVA and Tukey's test at a pre-set alpha of 0.05. LED2 device showed higher KHN than LED3 ($p < 0.05$), top surface of composite cured with LED 2 showed higher softening resistance after alcohol storage than bottom surface ($p < 0.05$), but there was difference on the plasticization values between curing devices and between the top and bottom surface of composite cured with LED3 ($p > 0.05$). The highest irradiance promoted higher KHN, but overall not affected the plasticization.

CATELAN, Anderson*
BARRETO, Bruno de Castro Ferreira**
SUZUKI, Thaís Yumi Umeda***
OKIDA, Ricardo Coelho****
MARCHI, Giselle Maria*****
LIMA, Débora Alves Nunes Leite******
SANTOS, Paulo Henrique*******
AGUIAR, Flávio Henrique dos Santos******

KEYWORDS

Composites resins. Physical properties. Hardness.

DDS, MSc, PhD, Pos-Doc in progress, Department of Restorative Dentistry, Piracicaba Dental School, University of Campinas, Piracicaba, SP, Brazil*
DDS, MSc, PhD, Pos-Doc in progress, Department of Operative Dentistry and Dental Materials, Dental School, Federal University of Uberlandia, Uberlandia, MG, Brazil**
DDS, MSc, PhD Student, Department of Dental Materials and Prosthodontics, Araçatuba School of Dentistry, State University of São Paulo, Araçatuba, SP, Brazil***
DDS, MSc, PhD, Assistant Professor, Department of Restorative Dentistry, Araçatuba School of Dentistry, State University of São Paulo, Araçatuba, SP, Brazil****
DDS, MS, PhD, Associate Professor, Department of Restorative Dentistry, Piracicaba Dental School, University of Campinas, Piracicaba, SP, Brazil*****
fDDS, MS, PhD, Assistant Professor, Department of Restorative Dentistry, Piracicaba Dental School, University of Campinas, Piracicaba, SP, Brazil******
DDS, MSC, PhD, Associate Professor, Department of Dental Materials and Prosthodontics, Araçatuba School of Dentistry, State University of São Paulo, Araçatuba, SP, Brazil*******
Correspondence: catelan@estadao.com.br (CATELAN A) |

Received 25 Aug 2013 **Received in revised form** 01 Sep 2013 **Accepted** 04 Sep 2013

INTRODUCTION

Light-cured composites have been widely used in the dental practice by the simplification of bonding procedures and improvements on adhesives and composition formulations.[1] Currently dental composites are classified in nanofilled, microfilled, or micro/ nano hybrid composite resins.[2] These materials are composed by the resin-based organic matrix, inorganic fillers particles, silane, and photo-initiator system.[3]

Polymerization quality is crucial for clinical performance of resin-based materials.[4-7] Several factors are involved on polymerization process, such as the irradiance of the curing device, the light wavelength emitted by the device, the distance from the light source tip, the irradiation time, and the amount, form, and size of filler particles of the material.[6,8-10]

Hardness and degree of conversion (DC) of a material are factors most commonly analyzed in order to measure the polymerization rate.[4-7] In the same DC value different linear polymer content and C=C concentrations are found, which is more susceptible to softening than a more cross-linked polymer.[11-12]

Quartz-tungsten-halogen curing unit has been extensively used for a long time, but its optical power decreases over time by the lamp and filter degradation, resultant of the bulb overheating.[13] Light-emitting diode (LED) technology presents less degradation over time, blue light emission without require filter, and narrow wavelength (close to maximum absorption peak of the camphorquinone at 468 nm), photo-initiator used in most of light-cured resin-based materials; becoming popular in the dental clinical practice.[13-14]

However, the LEDs of first-generation exhibited low optical power, problem solved when the second-generation LED was developed. These previous light-curing devices have narrow spectrum, close to camphorquinone, thus cure of resinous materials with others photo-initiators is impaired.[13] Third-generation of LED has a light accessory to photo-cure others photo-initiators due to greater spectrum.

The purpose of this study was to assess the Knoop hardness number (KHN) and plasticization (P) of a composite resin light cured with second- or third-generation LED. The null hypotheses tested were that the (2) different light-curing units would not affect the hardness and plasticization of a composite resin and (2) there would no difference on the top and bottom surfaces.

MATERIAL AND METHODS

In this study, one light-cured methacrylate-based nanofilled composite resin (Filtek Supreme, shade A2, St. Paul, MN, USA) was used. Disc-shaped specimens (5 mm in diameter and 2 mm in thickness) were made (n = 10) for KHN and P (n =

10). The circular polytetrafluoroethylene mold was filled with the composite resin held between two glass slabs separated by Mylar strips and the pressed with a 500-g load, to compress the material, prevent bubble formation, and remove material excess. Cavities were filled with only one increment of composite, which was randomly light-cured using a second-generation light-emitting diode (LED2) Bluephase 16i (Vivadent, Bürs, Austria) and a third-generation (LED3), Ultralume LED 5 (Ultradent, South Jordan, UT, USA) device at 1390 and 800 mW/cm^2, respectively. After polymerization, the specimens were removed from the molds, dry stored in light proof containers at 37 oC for 24 h, and polished with 1200-grit silicon carbide (SiC) grinding paper (CarbiMet 2 Abrasive Discs, Buehler, Lake Bluff, IL, USA).

Initial microhardness (MHi) reading was measured in the top and bottom surfaces of each specimen using a microhardness tester (HMV-2T, Shimadzu, Tokyo, Japan) with a Knoop diamond indenter under 50-g load for 15 s. Five indentations were made in each surface of the specimen, one at the center and others 4 at a distance of 100 μm from the central location. The average of the five KHN values was calculated for each specimen.

Plasticization analysis was evaluated by percentage reduction of the microhardness (%MHred) after absolute alcohol storage.[15] After MHi assessments, all specimens were immersed in the 100% ethanol for 24 h. Following this period, a second microhardness measurement (MHf) was made as previously described. The same operator did the KHN test, before and after alcohol storage. The results were tabulated, and the P was calculated using the following equation: %MHred = 100 – [(MHf X 100) / MHi].

The experimental design of this study was constituted of 1 factor (curing unit in 2 levels: LED2 and LED3) and one sub-factor in 2 levels: top and bottom surfaces. KHN and P data were subjected to subdivided parcels one-way ANOVA and Tukey´s test at a pre-set of 0.05. The factor light-curing unit was considered in the parcel and the sub-factor surface (top and bottom) was considered in the sub-parcel.

RESULTS

LED2 showed higher hardness than LED2 ($p < 0.05$). The highest hardness values were observed for top surface compared to bottom, for both light-curing units ($p < 0.05$) (Table 1).

Table 2 illustrates the plasticization data. There was no difference between the light-curing devices ($p > 0.05$). However, bottom surface for LED2 showed higher plasticization than top surface ($p < 0.05$).

Table 1: Knoop microhardness (Kg/mm2) of the composite resin according to light-curing unit and surface analyzed.

Curing unit	Surface	
	Top	Bottom
Bluephase 16i	58.10 (1.86) Aa	49.72 (2.31) Ba
Ultralume LED 5	53.05 (2.10) Ab	42.57 (1.54) Bb

Means (Standard Deviation). Distinct letters (capital in the row and lower in the column) are statistically different ($p < 0.05$).

Table 2. Plasticization (%) of the composite resin according to light-curing unit and surface analyzed.

Curing unit	Surface	
	Top	Bottom
Bluephase 16i	39.26 (5.26) Aa	34.11 (3.47) Ba
Ultralume LED 5	34.77 (5.73) Aa	35.00 (5.42) Aa

Means (Standard Deviation). Distinct letters (capital in the row and lower in the column) are statistically different ($p < 0.05$).

DISCUSSION

The composite resins are widely used as restorative material in the dental practice and several clinical studies have reported an adequate durability of resin-based restorations even after an extended period of time.[2] The first null hypothesis was rejected, because there was difference on the Knoop microhardness of the composite resin light-cured with LED2 and LED3.

The higher irradiance of the LED2 device probably promotes multitude of growth centers and tendency to form a branched polymer,[16] which are less susceptible to the softening action of food substance and to enzymatic attack,[11] and higher monomer conversion rate.[17-18] Hardness of resinous materials is dependent to the monomer conversion rate into polymer and related to wear resistance.[19] Improvements of the mechanical properties have been associated to increase of the conversion of the monomer into polymer.[8,18,20] Thus, the highest monomer conversion probably resulted in higher superficial hardness of the composite resin. However, the different irradiances not affect the plasticization.

The second null hypothesis was also rejected. Light scattering by the filler particles, and the thickness of the composite decline the light intensity that reaches in the bottom surface of the restorative material,[21-22] resulting in lower DC and most hardness values of the bottom compared to top surface of the material. The high optical power of LED2 probably resulted in more polymer growth on the top surface, resulting in a cross-linked polymer structure, affecting the bottom polymerization, this fact could to result in lower resistance of alcohol softening.

A previous study[2] evaluated posterior composite restorations after 22 years and suggested that the physical properties of the material might have some impact on the restoration longevity. Thereby, little differences on the mechanical properties can exhibit similar clinical performance in short-term, but not over extended period of time.[2]

CONCLUSION

The highest irradiance improved the hardness, but overall not affected the plasticization of a camphorquinone-based nanofilled composite.

REFERENCES

1. Catelan A, Briso AL, Sundfeld RH, dos Santos PH. Effect of artificial aging on the roughness and microhardness of sealed composites. J Esthet Restor Dent. 2010 Oct;22(5):324-30.

2. Da Rosa Rodolpho PA, Donassollo TA, Cenci MS, Loguércio AD, Moraes RR, Bronkhorst EM, et al. 22-year clinical evaluation of the performance of two posterior composites with different filler characteristics. Dent Mater. 2011 Oct;27(10):955-63.

3. Filho JD, Poskus LT, Guimarães JG, Barcellos AA, Silva EM. Degree of conversion and plasticization of dimethacrylate-based polymeric matrices: influence of light-curing mode. J Oral Sci. 2008 Sep;50(3):315-21.

4. Knezevic A, Tarle Z, Meniga A, Sutalo J, Pichler G. Degree of conversion and temperature rise during polymerization of resin composite samples with blue diodes. J Oral Rehabil. 2001 Jun;28(6):586-91.

5. Yoon TH, Lee YK, Lim BS, Kim CW. Degree of polymerization of resin composite by different light sources. J Oral Rehabil. 2002 Dec;29(12):1165-73.

6. Thomé T, Steagall W Jr, Tachibana A, Braga SR, Turbino ML. Influence of the distance of the curing light source and composite shade on hardness of two composites. J Appl Oral Sci. 2007 Dec;15(6):486-91.

7. Calheiros FC, Daronch M, Rueggeberg FA, Braga RR. Influence of irradiant energy on degree of conversion, polymerization rate and shrinkage stress in an experimental resin composite system. Dent Mater. 2008 Sep;24(9):1164-8.

8. Aguiar FH, Braceiro A, Lima DA, Ambrosano GM, Lovadino JR. Effect of light curing modes and light curing time on the microhardness of a hybrid composite resin. J Contemp Dent Pract. 2007 Sep;1(6):1-8

9. Rode EM, Kawano Y, Turbino ML. Evaluation of curing light distance on resin composite microhardness and polymerization. Oper Dent. 2007 Nov-Dec;32(6):571-8.

10. da Silva EM, Poskus LT, Guimarães JGA. Influence of light polymerization modes on the degree of conversion and mechanical properties of resin composites: a comparative analysis between a hybrid and a nanofilled composite. Oper Dent. 2008 May-Jun;33(3):287-93.

11. Asmussen E, Peutzfeldt A. Influence of selected components on crosslink density in polymer structures. Eur J Oral Sci. 2001; 109(4): 282-5.

12. Kusgoz A, Ülker M, Yesilyurt C, Yoldas OH, Ozil M, Tanriver M. Silorane-based composite: depth of cure, surface hardness, degree of conversion, and cervical microleakage in Class II cavities. J Esthet Restor Dent. 2011 Oct;23(5):324-35.

13. Faria-e-Silva AL, Lima AF, Moraes RR, Piva E, Martins LR. Degree of conversion of etch-and-rinse and self-etch adhesives light-cured using QTH or LED. Oper Dent. 2010 Nov-Dec;35(6):649-54.

14. Schneider LF, Moraes RR, Cavalcante LM, Sinhoretti MA, Correr-Sobrinho L, Consani S. Cross-link density evaluation through softening tests: effect of ethanol concentration. Dent Mater. 2008 Feb;24(2):199-203.

15. Asmussen E, Peutzfeldt A. Polymer structure of a light-cured resin composite in relation to distance from the surface. Eur J Oral Sci. 2003 Jun;111(3):277-9.

16. Asmussen E, Peutzfeldt A. Influence of pulse-delay curing on softening of polymer structures. J Dent Res 2001 Jun;80(6):1570-3.

17. da Silva EM, Almeida GS, Poskus LT, Guimarães JG. Relationship between the degree of conversion, solubility and salivary sorption of a hybrid and a

nanofill resin composite. J Appl Oral Sci. 2008 Mar-Apr; 16(2):161-6.

18. Catelan A, Caetano T, Borges BC, Soares GP, Barreto BC, Hernandes NM, et al. Impact of the light-curing source and curing time on the degree of conversion and hardness of a composite. J Res Dent. 2013 May/Jun;1(2): 91-7.

19. Lien W, Vandewalle KS. Physical properties of a new silorane-based restorative system. Dent Mater. 2010 Apr;26(4):337-44.

20. Borges BC, Souza-Junior EJ, Catelan A, Ambrosano GM, Paulillo LA, Aguiar FH. Impact of extended radiant exposure time on polymerization depth of fluoride-containing fissure sealer materials. Acta Odontol Latinoam. 2011;24(1):47-51.

21. Aguiar FH, Lazzari CR, Lima DA, Ambrosano GM, Lovadino JR. Effect of light curing tip distance and resin shade on microhardness of a hybrid resin composite. Braz Oral Res. 2005 Oct-Dec;19(4):302-6.

22. Gonçalves F, Kawano Y, Braga RR. Contraction stress related to composite inorganic content. Dent Mater. 2010 Jul;26(7):704-9.