Scientific Article

# Influence of the Light Curing Tip Distance and Material Opacity on Selected Physical Properties of a Pit and Fissure Sealant

Boniek Castillo Dutra Borges, DDS[1] • Paulo Roger de Pinho Silva[2] • Anderson Catelan, MSc[3] • Flávio Henrique Baggio Aguiar, DDS, MSc, PhD[4]

**Abstract:** ***Purpose:*** *The purpose of this study was to evaluate the influence of the light curing tip distance and material opacity on hardness (KHN), degree of conversion (DC), and crosslink density (CLD) of a resin-based fissure sealant (Fluroshield).* ***Methods:*** *One-millimeter-thick white opaque and clear sealant specimens, photoactivated at 1-, 2-, and 3-mm distances, were fabricated (8 groups, N=5). KHN and DC were evaluated 24 hours after polymerization. Specimens were subjected to a new KHN reading after 24-hour immersion in absolute ethanol to indirectly assess the CLD.* ***Results:*** *Samples of clear sealant cured at longer distances presented lower KHN, although there were not differences between opacities at all distances. The mean DC of the opaque white material, however, was lower than that of the clear one at higher distances. There were no differences among CLD for all experimental conditions analyzed.* ***Conclusions:*** *KHN of the clear sealant was affected by increased distances. The clear sealant showed higher DC at increased distances, although CLD was not influenced by the factors under study. Since physical properties of sealing materials are directly related to their clinical efficacy, the clear sealant tested may present a better clinical performance than the opaque one.* *(Pediatr Dent 2011;33:505-9) Received April 20, 2010 / Last Revision July 4, 2010 / Accepted July 7, 2010*

KEYWORDS: PIT-AND-FISSURE SEALANTS, HARDNESS, CROSSLINK DENSITY, DEGREE OF CONVERSION

Pit and fissure sealants have been routinely used in pediatric dentistry.[1] Their efficacy on the primary prevention of pit and fissure caries, mainly in high caries-risk patients, has been well demonstrated.[2,3] Clinical studies have shown the efficacy of pit and fissure sealants as a therapeutic agent,[4,5] even when the carious process has already reached dentin,[6] which reinforces the importance of these materials on the prevention and control of caries disease. Nevertheless, the preventive and therapeutic benefits of a sealing material rely directly on its ability to thoroughly fill pits, fissures, and/or anatomical defects and remain intact and bonded to the enamel surface for a lifetime.[7-9] Therefore, factors which may affect sealant retention must be clarified.

Ensuring sufficient cure is an integral requirement for the clinical success and longevity of a sealant.[10] It has been shown that an insufficient degree of conversion (**DC**) of resin composites may facilitate the proliferation of cariogenic bacterial species[11] and has also been associated with increased solubility of these materials.[12] As both of these factors may contribute to sealant degradation and detachment, a greater amount of monomer units converted into a polymer matrix may increase the retention of pit and fissure sealants and, consequently, their caries preventive action.

Several factors may influence the polymerization of resin-based materials, namely the distance between the tip of the curing unit light guide and the material surface, the material opacity, and the increment thickness.[12-15] It has been demonstrated that an increase in distance of the light source from the resin composite surface and increments thicker than 1-mm promoted a decrease in hardness and DC.[16]

Depending on the cusp size and the morphology of pits and fissures, the light guide of the curing unit may be placed at different distances from the sealant surface during occlusal sealing, which may increase the dispersion and decrease the irradiance of the light that reaches the material. On the other hand, the sealant layer is less than 2-mm thick, which facilitates light transmittance and produces better monomer conversion. Hence, it is important to evaluate if different distances between the curing tip and a 1-mm thick sealant could influence the physical properties of the sealant.

Clear resins may present higher surface hardness than more opaque ones.[13] Pit and fissure sealants with different opacities are available in the market. More opaque materials may be better distinguished from tooth surface,[6] but they might present less favorable properties than clearer materials. Hence, there is a need to evaluate the influence of opacity on the physical properties of pit and fissure sealants.

In this sense, laboratory tests have analyzed the surface hardness, DC, and crosslink density (**CLD**) to determine the quality of resin-based dental materials. The higher the surface hardness and DC of a polymer material, the better its clinical performance.[16] In addition, insufficient crosslinking of the polymer matrix may make resin-based materials more sensitive to the plasticizing effect of exogenous substances which contain a variety of chemicals (eg, acids, bases, salts, alcohols, oxygen, etc) that enter the oral environment during eating and drinking[17] and may have a degradative effect on the polymer network and compromise its

*[1]Dr. Borges is a MSc student, [2]Dr. Silva is an undergraduate, [3]Dr. Catelan is a PhD student, and [4]Dr. Aguiar is a professor, all at Piracicaba Dental School, State University of Campinas, Piracicaba, São Paulo, Brazil.*

*Correspond with Dr. Borges at boniek.castillo@gmail.com*

Table 1. COMPOSITION AND BATCH NUMBER OF THE SEALANTS AND RADIANCE (R) (MW/CM²) OF THE LIGHT CURING UNIT USED IN THE STUDY

| Material | Opacity | Batch | Composition* | | | |
|---|---|---|---|---|---|---|
| FluroShield | Clear | 142812B | Urethane modified Bis-GMA, TEGDMA, barium aluminoborosilicate glass, ester tetracrylic phosphoric acid, sodium fluoride, N-Methyl diethanolamine and camphoroquinone | | | |
| | Opaque white | 182017B | | | | |
| Ultra-Lume LED 5 curing unit | R provided by the manufacturer=800 | | 0 mm distance R=800 | 1 mm distance R=730 | 2 mm distance R=620 | 3 mm distance R=510 |

*Bis-GMA=bisphenol-A glycidil methacrylate; TEGDMA=triethyleneglycol dimethacrylate. The radiances were measured with a curing radiometer (model no. 100; Demetron Research Corp, Danbury, Conn). Distances were established through a digital caliper coupled to a metallic support (Aguiar et al.[18]).

clinical efficacy. Analyzing each of these properties alone, however, may produce erroneous interpretations of polymer characteristics, and the literature is scarce in studies evaluating these 3 properties in pit and fissure sealants. Therefore, the purpose of the present study was to test the hypothesis that the distance from the tip of the curing unit light guide to the sealant surface and the material opacity does not influence the surface hardness, degree of conversion, and crosslink density of a pit and fissure sealant.

## Methods

**Experimental design and specimen preparation.** The Knoop hardness number (**KHN**), DC, and CLD of a filled resin-based pit and fissure sealant (FluoroShield, Dentsply Ind. e Com. Ltda, Petrópolis, Rio de Janeiro, Brazil) were evaluated.

Square-shaped silicone matrices (4 mm² x 1 mm height) were used to fabricate 40 sealant specimens. The sealing material was injected into the matrix's center using the manufacturer's disposable tip under controlled temperature and relative humidity conditions. The sealant surface was covered with a polycarbonate strip and then photoactivated with a third-generation light-emitting diode unit (Ultra-Lume LED 5, Ultradent, South Jordan, Utah) for 20 seconds. The specimens were allocated to 8 groups of 5 specimens each, according to the combinations of sealant opacities (white opaque and clear) and distances between the tip of the curing unit light guide and the sealant surface (1, 2, and 3 mm), as established with a digital caliper coupled to a metallic support.[18] The composition of the sealant, batch numbers, and radiance (**R**) (mW/cm²) of the light curing unit used in the study are shown in Table 1.

After polymerization, the specimens were removed from the matrices and stored dry in light-proof containers at 37°C during 24 hours.[10,13,18] The KHN and DC tests were undertaken after this period.

**KHN analysis**. The initial hardness (**$MH_i$**) reading was undertaken on the top surface of each specimen using a hardness tester (HMV-2T E, Shimadzu Corporation, Tokyo, Japan) with a Knoop diamond indenter under a 50-g load for 15 seconds. Five Knoop measurements were made on the top surface of each specimen: 1 at the center and the other 4 at a distance of approximately 200 µm from the central location. The average of the 5 values was calculated as the KHN value for each specimen.

**DC analysis.** DC readings (%) were also performed on the top surface of each specimen after the $MH_i$ reading using a spectrometer (Spectrum 100 FTIR/UATR; PerkinWlmer, São Paulo, Brazil). Absorption spectra of nonpolymerized and polymerized sealant were obtained from the region between 4,000 and 650 cm$^{-1}$, with 32 scans at 4 cm$^{-1}$. The 1,590 to 1,660 cm$^{-1}$ interval was considered for observation of the absorbances at 1,608 and 1,638 cm$^{-1}$, which indicate, respectively, the absorption peaks of the aromatic vinyl bonds of bisphenol and the aliphatic bonds of the methacrylate functional group. The DC (%) was calculated using the following equation: DC (%)=100 x (1- [R polymerized/R nonpolymerized]), where R represents the ratio between the absorbance peak at 1,638 cm$^{-1}$ and 1,608 cm$^{-1}$.

**CLD analysis.** After analysis of DC, all specimens were immersed in absolute ethanol (100%) at room temperature. The CLD was estimated based on the percentage of hardness decrease (%HD) that occurred on sealant surface as a result of its exposure to ethanol.[19,20] After 24-hour immersion in absolute ethanol, the specimens were subjected to a new hardness reading (**$MH_f$**). Five Knoop measurements were made on the top surface of each specimen as previously described. The analysis of $MH_i$ and $MH_f$ was done by the same operator. The results were tabulated, and the %HD was calculated using the following equation: %HD= 100 -([$MH_f$ x 100]/$MH_i$), where $MH_f$ represents the final KHN value (after absolute ethanol storage) and $MH_i$ represents the initial KHN value (before absolute ethanol storage).

Statistical analysis. The KHN, DC, and LCD data were analyzed statistically by 2-way analysis of variance (ANOVA) and Tukey's test ($\alpha$=0.05). For KHN and DC, the data obtained in the measurements made 24 hours after polymerization were used, while for CLD the percentage of decrease from the initial to the final KHN values was considered for statistical analysis. Pearson's correlation ($\alpha$=0.05) was applied to assess the relationship between the response variables of the study. All analyses were undertaken using Assistat 7.5 beta software (Federal University of Campina Grande, Campina Grande, Brazil).

## Results

**KHN.** ANOVA showed that there were statistically significant differences ($P$=.02) for the light curing distances, while the

Table 2. MEAN KNOOP HARDNESS (KHN) VALUES AND STANDARD DEVIATIONS FOR EACH SEALANT OPACITY AT THE DIFFERENT LIGHT CURING DISTANCES

| Opacity | Light curing distance* | | |
|---|---|---|---|
| | 1 mm | 2 mm | 3 mm |
| Clear | 26.20±2.11Aa | 24.08±2.66ABa | 21.96±3.49Ba |
| Opaque white | 25.97±2.6Aa | 24.26±2.5Aa | 23.94±3.57Aa |

* Different uppercase letters in the rows and lowercase letters in the columns indicate statistically significant differences ($P$<.05).

Table 3. MEAN DEGREE OF CONVERSION (DC) VALUES AND STANDARD DEVIATIONS FOR EACH SEALANT SHADE AT THE DIFFERENT LIGHT CURING DISTANCES

| Opacity | Light curing distance* | | |
|---|---|---|---|
| | 1 mm | 2 mm | 3 mm |
| Clear | 61.92±1.67Aa | 62.63±1.33Aa | 61.74±1.15Aa |
| Opaque white | 60.65±1.53Aa | 60.46±2.09Ab | 59.9±1.96Ab |

* Different uppercase letters in the rows and lowercase letters in the columns indicate statistically significant differences ($P$<.05).

Table 4. MEAN PERCENTAGE OF HARDNESS DECREASE (%HD) VALUES AND STANDARD DEVIATIONS FOR EACH SEALANT SHADE AT THE DIFFERENT LIGHT CURING DISTANCES

| Opacity | Light curing distance* | | |
|---|---|---|---|
| | 1 mm | 2 mm | 3 mm |
| Clear | 55.07 ± 1.62Aa | 52.50 ± 2.41Aa | 53.89 ± 0.15Aa |
| Opaque white | 54.60 ± 0.37Aa | 56.38 ± 1.34Aa | 53.96 ± 1.88Aa |

* Different uppercase letters in the rows and lowercase letters in the columns indicate statistically significant differences ($P$<.05).

opacities and the opacities x distances interaction were not statistically different ($P$>.05). As shown in Table 2, only the clear sealant presented statistically different KHN means at the distances evaluated. The highest KHN was observed at a 1-mm distance and the lowest at a 3-mm distance, although no differences between clear and opaque sealant KHN were found at each distance.

**DC.** ANOVA showed that there were statistically significant differences between the sealant opacities ($P$<.01). On the other hand, the distances and the opacities x distances interaction were not statistically different ($P$>.05). As shown in Table 3, the clear sealant presented higher DC than the opaque white one ($P$<.05) at 2- and 3-mm distances.

**CLD.** There were no statistically significant differences ($P$>.05) for the light curing distances and sealant opacities, since the %HD values were statistically similar for all conditions. The mean %HD values after immersion in ethanol are presented in Table 4.

**Correlations.** The results of the Pearson's correlation test showed no correlation between KHN and %HD (Figure 1) and weak negative correlation between DC and %HD (Figure 2). Also, no correlation was found between KHN and DC (Figure 3).

## Discussion

The clinical success of sealants is well documented in the literature and is directly related to its capacity to remain bonded to occlusal pits and fissures.[6,16] The hardened material forms a strong micromechanical bond to etched tooth enamel, thus physically obturating susceptible areas of the tooth surface and preventing dental caries.[21] Therefore, the physical properties of pit and fissure sealants after polymerization have a direct implication on their long-term clinical success in the oral cavity and should be investigated.

Among the variables that can affect the physical properties of a restorative material, the opacity may be controlled by the professional by choosing clear instead of opaque materials, which have advantages in polymerization over dark or opaque materials. The distance from the curing unit tip to sealant surface is affected by the occlusal anatomy of the tooth to be sealed,[21] which can not be controlled by the operator. Therefore, the goal of the present study is pertinent in view of the need to elucidate the actual influence of these conditions on the physical properties of the polymer generated upon photoactivation.

In the present study, the tested hypothesis was rejected. While sealant opacity and light curing distance influenced DC and KHN of the materials, respectively, CLD was not affected. The hardness of resin materials is influenced by several factors, such as inorganic filler content, polymer matrix composition, and degree of monomer conversion.[22] Hardness tests have been used to indirectly measure the DC of composites[23] and pit and fissure sealants,[21] since a strong correlation between these properties has been documented when materials with the same composition are tested.[16] It should be emphasized that low hardness values are associated with low wear resistance[24] and groove formation,[25] which may, in certain instances, contribute to partial or even complete sealant loss and lead to clinical failure.

The results of the present study elucidate the importance of undertaking multiple laboratory tests to characterize the polymerization of resin materials. While DC values were affected by different opacities, KHN values were not. These findings are contrary to others[21,26] that found higher hardness on the top surface of clear sealants vs. opaque sealants. These distinct results may be justified by the fact that previously mentioned authors used sealants other than FluroShield, different light sources, curing times, and different hardness loads from those of the present investigation. It is likely that the similar composition of both opacities of FluroShield produced surface characteristics that behaved similarly in the hardness test. Conversely, the clear sealant was more sensitive to light irradiance decrease than the white opaque one, considering hardness characteristics. Increased distances between the light curing tip and the material surface decreased their KHN means. Possibly, different polymer networks were found among samples irradiated at distinct distances, providing different KHN means.

The analysis of hardness is less accurate than the DC in the quantification of the monomer conversion rate, since the hardness reading may be influenced by factors such as arrangement of polymer chains and filler particles, and not only the amount of formed polymers. Therefore, small differences in the

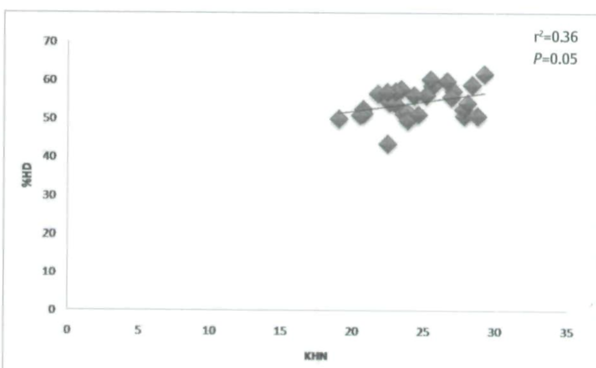


Figure 1. Correlation between Knoop hardness number (KHN) and percentage of hardness decrease (%HD).

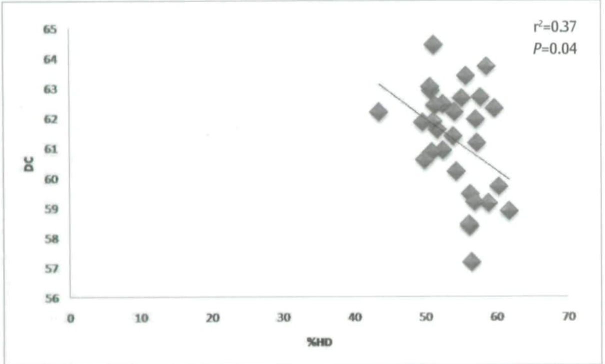


Figure 2. Correlation between percentage of hardness decrease (%HD) and degree of conversion (DC).

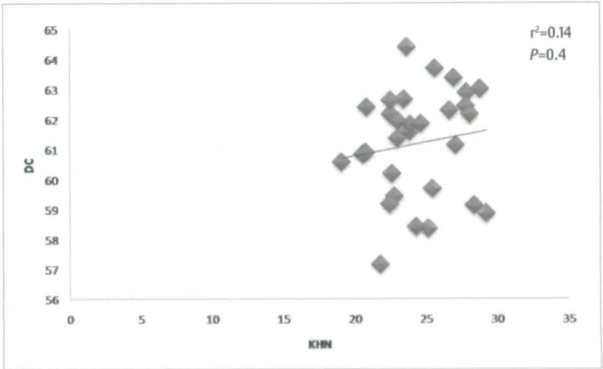


Figure 3. Correlation between Knoop hardness number (KHN) and degree of conversion (DC).

conversion of monomer units may be detected more precisely by Fourier transformed infrared spectroscopy, which captures more detailed information of the transitions between the levels of vibrational energy of the samples[16] for calculating the DC, a fact that can explain the low relationship between KHN and DC found in this study.

In the present study, the direct test for DC measurement showed that sealant opacities and light curing distances had a direct influence on the conversion of monomer units into a polymer matrix. The decrease of energy density by increasing the distance of the light guide tip decreased the DC of the opaque white sealant. The difference in curing characteristics between clear and opaque sealants most likely is related to the opacifying agents present in the opaque white sealant, which probably cause substantial reflection, scattering, and absorption of light energy, thus preventing a more thorough cure through the surface of the sealant.[21] As a result, the polymerization reaction is attenuated in an opaque sealant, and the DC of this material is decreased, which explains the finding that only the highest energy density (1-mm distance) tested in this investigation provided, a similar DC between the opaque sealant and the clear one.

The DC is a critical element in the physical properties of the resultant polymers and their bond to enamel.[21] Nevertheless, polymers with the same DC may present differences in the linearity of the chains generated after light curing,[20] which corroborate the low relationship between DC and CLD in the present work. Polymers with high CLD are morphologically more compacted than those with linear disposition, and are more resistant to solvent degradation, absorption, and wear.[17] Therefore, they are more important after conversion of monomer units into a polymer matrix, since these characteristics would be directly related to the success of pit and fissure sealants. The literature is scarce, however, in studies evaluating the CLD of pit-and-fissure sealing materials. KHN, DC, and CLD and their relationships have not yet been assessed, which underscores the importance of the present study.

Only CLD was not affected by the light curing distance and sealant opacity. In the groups in which DC differed significantly from the other groups, it may be assumed that monomer bonds had similar and linear characteristics. This becomes more evident due to the low correlation between CLD and KHN and between CLD and DC, and may be justified by the composition of the tested materials. Low molecular weight monomers, such as triethyleneglycol dimethacrylate (TEGDMA), reduce the resin matrix viscosity and increase monomer conversion.[27] On the other hand, it was demonstrated that the greater the amount of TEGDMA, the greater the solubility of Bis-GMA/TEGDMA binary compounds.[28] Pit and fissure sealant should present high flow to be considered an adequate sealing material,[29] which means having a high TEGDMA content in its formulation. In the present study, it may be speculated that a greater absorption of ethanol caused rupture of the linear bonds among the polymers, which are less resistant to degradation.[17] This finding is assumed to increase polymer plasticization and result in similar %HD,[30] as observed in the present study. Small decreases in some physical parameters with distance of curing and opacity of the sealant material were observed in this study. One might presume that doubling or sufficiently increasing the curing time could overcome these drawbacks. It has been shown, however, that a 60-second curing time did not improve the physical properties of opaque Fluroshield vs conventional 20-second photoactivation time at a 3-mm distance.[31] Further studies are needed to evaluate the impact of increased light radiant exposure on physical parameters of the clear sealant.

It is important to emphasize that physical properties of restorative materials are related to their clinical performance. Although sealant color did not influence the CLD of the materials tested, KHN and DC were affected. From a clinical standpoint, the clear sealant seems to behave better in the oral environment. In vivo studies are needed, however, to verify if the small, statistically significant differences in the physical parameters of pit and fissure sealants found in this in vitro investigation are likely to affect their clinical performance.

Moreover, further research must be conducted to evaluate if the small decreases in physical parameters with distance of curing and opacity of the sealant material could be overcome by sufficiently increasing the curing time.

## Conclusions

1. Sealant opacity had no influence on the Knoop hardness number.
2. Compared to the opaque sealant, even at increased distances, the clear sealant showed a higher degree of conversion.
3. Crosslink density was not influenced by the factors under study.
4. Since physical properties of sealing materials are directly related to their clinical efficacy, the clear sealant tested may present a better clinical performance than the opaque one.

## Acknowledgment

This study was supported by the Foundation for Research Support of São Paulo (FAPESP), grant #07/02800-3.

## References

1. Matalon S, Peretz B, Sidon R, Weiss EI, Slutzky H. Antibacterial properties of pit and fissure sealants combined with daily fluoride mouth rinse. Pediatr Dent 2010;32:9-13.
2. Azarpazhooh A, Main PA. Pit and fissure sealants in the prevention of dental caries in children and adolescents: A systematic review. J Can Dent Assoc 2008;74:171-7.
3. Ahovuo-Saloranta A, Hiiri A, Nordblad A, Mäkelä M, Worthington HV. Pit and fissure sealants for preventing dental decay in the permanent teeth of children and adolescents. Cochrane Database Syst Rev 2008;8:CD001830.
4. Gomez SS, Basili CP, Emilson CG. A 2-year clinical evaluation of sealed noncavitated approximal posterior carious lesions in adolescents. Clin Oral Investig 2005;9:239-43.
5. Martignon S, Ekstrand KR, Ellwood R. Efficacy of sealing proximal early active lesions: An 18-month clinical study evaluated by conventional and subtraction radiography. Caries Res 2006;40:382-8.
6. Borges BC, Campos GP, Silveira AD, Lima KC, Pinheiro IV. Efficacy of a pit and fissure sealant on arresting dentin noncavitated caries: A 1-year follow-up randomized and controlled clinical trial. Am J Dent 2010;23:311-6.
7. Hevinga MA, Opdam NJ, Bronkhorst EM, Truin GJ, Huysmans MC. Long-term performance of resin based fissure sealants placed in a general dental practice. J Dent 2010;38:23-8.
8. Griffin SO, Oong E, Kohn W, Vidakovic B, Gooch BF. The effectiveness of sealants in managing caries lesions. J Dent Res 2008;87:169-74.
9. Puppin-Rontani RM, Baglioni-Gouveia ME, de Goes MF, Garcia-Godoy F. Compomer as a pit and fissure sealant: Effectiveness and retention after 24 months. J Dent Child 2006;73:31-6.
10. Thomé T, Steagall-Jr W, Tachibana A, Braga SE. Influence of the distance of the curing light source and composite shade on hardness of two composites. J Appl Oral Sci 2007;15:486-91.
11. Takahashi Y, Imazato S, Russell RR, Noiri Y, Ebisu S. Influence of resin monomers on growth of oral streptococci. J Dent Res 2004;83:302-6.
12. Silva EM, Almeida GS, Poskus LT, Guimarães JG. Relationship between the degree of conversion, solubility, and salivary sorption of a hybrid and a nanofilled resin composite. J Appl Oral Sci 2008;16:161-6.
13. 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;19:302-6.
14. Beun S, Glorieux T, Devaux J, Vreven J, Leloup G. Characterization of nanofilled compared to universal and microfilled composites. Dent Mater 2007;23:51-9.
15. Silva EM, Poskus LT, Guimaraes JG. 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;33:287-93.
16. Rode KM, Kawano Y, Turbino ML. Evaluation of curing light distance on resin composite microhardness and polymerization. Oper Dent 2007;32:571-8.
17. Ferracane JL. Hygroscopic and hydrolytic effects in dental polymer networks. Dent Mater 2006;22:211-22.
18. 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;8:1-8.
19. Assmussen E, Peutzfeldt A. Influence of selected components on crosslink density in polymer structures. Eur J Oral Sci 2001;109:282-5.
20. Schneider LF, Moraes RR, Cavalcante LM, Sinhoreti MA, Correr-Sobrinho L, Consani S. Cross-link density evaluation through softening tests: Effect of ethanol concentration. Dent Mater 2008;24:199-203.
21. Christopher Y, Tantbirojn D, Grothe RL, Versluis A, Hodges JS, Feigal RJ. The depth of cure of clear versus opaque sealants as influenced by curing regimens. J Am Dent Assoc 2009;140:331-8.
22. Guiraldo RD, Consani S, Consani RLX, Mendes WB, Lympius T, Sinhoreti MA. Effect of different light curing units on Knoop hardness and temperature of resin composite. Ind J Dent Res 2009;20:208-12.
23. Knobloch LA, Kerby RE, Clelland, Lee J. Hardness and degree of conversion of posterior packable composites. Oper Dent 2004;29:642-9.
24. Say EC, Civelek A, Nobecourt A, Ersoy M, Guleryuz C. Wear and microhardness of different resin composite materials. Oper Dent 2003;28:628-34.
25. Kawai K, Iwami Y, Ebisu S. Effect of resin monomer composition on toothbrush wear resistance. J Oral Rehabil 1998;25:264-8.
26. Platt JA, Clark H, Moore BK. Curing of pit and fissure sealants using light emitting diode curing units. Oper Dent 2005;30:764-71.
27. Sideridou I, Achilias DS, Spyroudi C, Karabela M. Water sorption characteristics of light-cured dental resins and composites based on Bis-EMA/PCDMA. Biomater 2004;25:367-76.
28. Gonçalves L, Filho JD, Guimarães JG, Poskus LT, Silva EM. Solubility, salivary sorption,and degree of conversion of dimethacrylate-based polymeric matrixes. J Biomed Mater Res B Appl Biomater 2008;85:320-5.
29. Kantovitz KR, Pascon FM, Alonso RC, Nobre-dos-Santos M, Puppin-Rontani RM. Marginal adaptation of pit and fissure sealants after thermal and chemical stress. An SEM study. Am J Dent 2008;21:377-82.
30. Asmussen E, Peutzfeldt A. Influence of pulse-delay curing on softening of polymer structures. J Dent Res 2001;80:1570-3.
31. Borges BC, Souza-Junior EJ, Catelan A, et al. Influence of extended light exposure time on degree of conversion and plasticization of materials used as pit and fissure sealants. J Investig Clin Dent 2010;1:151-5.