Original Article

Surface microhardness of nanohybrid and microhybrid composite resins light cured at different distances

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Abstract

Objective: This study aimed to compare the surface microhardness of a nanohybrid and a microhybrid resin composite light-cured at two different distances.

Methods: A total of 40 disc specimens were prepared for this in vitro experiment; 20 from a nanohybrid composite resin (Filtek P60; 3M ESPE) and 20 from a microhybrid composite resin (Filtek Z250; 3M ESPE). Each group was divided into two equal subgroups (n=10), based on the distance between the light-curing device and the composite surface (either 2 or 4 mm). After 24 hours of curing, the teeth underwent the microhardness test to determine the Vickers hardness number (VHN) at the surface. The data were subjected to statistical analysis using a two-way analysis of variance (ANOVA) at the significance level of $P<0.05$.

Results: The nanohybrid resin composite showed higher microhardness values than the microhybrid resin at both 2 mm and 4 mm distances, although the difference between the two groups was only significant at the distance of 4 mm ($P = 0.017$). No significant difference was observed in the nanohybrid composite resin between the two curing distances ($P = 0.151$). However, the hardness of the microhybrid composite decreased significantly with increasing the curing distance from 2 to 4 mm ($P = 0.015$).

Conclusions: This study reveals that light-curing distance significantly affects the microhardness of microhybrid composite resin. The nanohybrid composite showed comparable hardness up to the distance of 4 mm, indicating its suitability to be used in situations where a close curing distance cannot be achieved.

Keywords: Composite resins, Curing lights, Hardness test, Microhybrid composite, Nanohybrid composite, Restorative treatment

Introduction

Due to the high patient demand for cosmetic dental procedures, clinicians need to be familiar with esthetic restorative materials and their components (1). Composite resins have gained increasing popularity in dentistry due to their aesthetics and excellent physical properties. There is currently a wide variety of commercially available resin composites used for both anterior and posterior teeth (2).

The fillers used in composite resins directly affect their physical characteristic. Hybrid resin composites contain a heterogeneous aggregate of filler particles. The combination of different particle sizes gives a hybrid composites favorable physical properties such as greater wear resistance, enhanced esthetic properties, better polishability, and also a superior color presentation by incorporating micro fillers in uniform layers between larger particles (3, 6). Hybrid composites can be subdivided into microhybrid and nanohybrid types (3). The microhybrid composites have a particle size of 0.7-2.0 µm, whereas nanohybrid composites consist of microsized (diameter of 0.3 - 1 µm) and nano-sized (diameter of 0.02 - 0.05 µm) filler particles.

Polymerization is the process by which a resin composite hardens and obtains its physical properties (7). Inadequate polymerization can lead to excessive water absorption, reduced microhardness, and the presence of free monomers with possible toxic effects (8). Furthermore, incomplete polymerization enhances gap development between the dental substrate and the restorative material, which may consequently lead to microleakage, postoperative sensitivity, recurrent caries, poor mechanical properties, and even tooth fracture (9, 10).

The polymerization of resin composites depends on several factors, including the filler content, the photoinitiators used, and the color and thickness of the

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composite material. The most common photoinitiator of resin composites is camphorquinone, which is optimally sensitive to blue light at 470 nm (11). However, other photoinitiators exist with peak sensitivities ranging from 370 nm to 420 nm. To properly harden all types of dental resins, a curing light needs to generate wavelengths across this range (12,13). Other factors that influence resin polymerization are the intensity and duration of light exposure, as well as the distance between the light source and the material surface (14).

Previous studies have shown that if the curing distance exceeds 2 mm, the light scatters and may not completely polymerize the composite resin. Therefore, the distance between the curing light and resin should be kept at 2 mm or less (15). In clinical conditions, it is not always possible to keep the 2 mm distance between the composite resin and the light curing device. Hence, it is interesting to investigate the difference between the mechanical properties of microhybrid and nanohybris resin composites after curing at different distances. This study aimed to compare the surface microhardness of a nanohybrid and a microhybrid composite resin photocured at two different distances.

Materials and Methods

This in vitro study included 40 disc specimens made from two types of resin composites. Twenty specimens were prepared from Filtek P60 (3M ESPE, St. Paul, MN, USA,), and the remaining 20 were prepared from Filtek Z250 (3M ESPE). Each group was divided into two subgroups of 10 each, based on the distance between the light-curing device and the composite surface (2 mm or 4 mm).

For specimen preparation, the composite resin was placed in a mold measuring 5 mm in diameter and 2 mm in height. The composite surface was covered with a layer of celluloid tape to prevent oxygen inhibition of polymerization and then placed under a glass slab. One subgroup from each material was cured at a distance of 2 mm and the other at a distance of 4 mm. The desired distance was maintained by a metal tube with a height of 2 mm or 4 mm placed over the glass slab. The light curing was performed for 20 seconds, according to the manufacturer's recommendations, using a light-emitting diode (LED) device (Woodpecker Medical Instrument Co., China) at 1000 mW/cm². The specimens were polished, and any disc exhibiting bubbles, fractures, or cracks were excluded from the study.

After 24 hours of curing, microhardness was assessed using an LG hardness tester (HV-1000, Mitutoyo, Japan), by measuring the indentation depth created by the diamond shape indenter. The measurements were conducted at three different points on the disc surface (P1, P2, and P3), and the average value was calculated to present the Vickers hardness number (VHN) for that specimen.

Statistical analysis

The normal distribution of the data was confirmed by the Shapiro-Wilk test ($P>0.05$). A two-way analysis of variance (ANOVA) was applied to assess the effect of resin composite type and the curing distance on VHN. The statistical analysis was performed with Stata 17.0 statistical software (Stata Corporation, Texas, USA) at the significance level of $P<0.05$.

Results

Figure 1 and Table 1 present the mean and standard deviation (SD) of microhardness values belonging to microhybrid and nanohybrid composite resins at 2 and 4 mm curing distances. There was a significant interaction between the two factors of resin composite type and the curing distance ($P=0.03$); therefore independent samples-t-test was applied for further analysis.

The average microhardness value of the nanohybrid composite resin was greater than that of the microhybrid composite at both 2 mm (61.6 ± 3.8 versus 59.6 ± 2.5 VHN) and 4 mm (59.7 ± 2.8 versus 56.8 ± 2.1 VHN) distances. There was no significant difference in the microhardness of nanohybrid and microhybrid resin composites at the distance of 2 mm ($P=0.226$; Table 1). However, a significant difference was observed in the mean VHN of the two groups at a distance of 4 mm ($P=0.017$; Table 1).

The nanohybrid composite showed no significant difference in microhardness between the two curing distances ($P=0.151$; Table 1). However, the microhardness of the microhybrid composite resin decreased significantly with increasing the curing distance from 2 to 4 mm ($P=0.015$; Table 1).

Discussion

The present study compared the surface microhardness of nanohybrid and microhybrid light-cured composite resins at two different distances of 2 mm and 4 mm. The outcomes revealed that the nanohybrid resin (Filtek P60; 3M ESPE) possesses a higher surface microhardness compared to the microhybrid resin composite (Filtek Z250; 3M ESPE), a finding that remains consistent across the two distances tested. However, the difference between the two groups was not statistically significant at the distance of 2 mm, whereas the microhardness

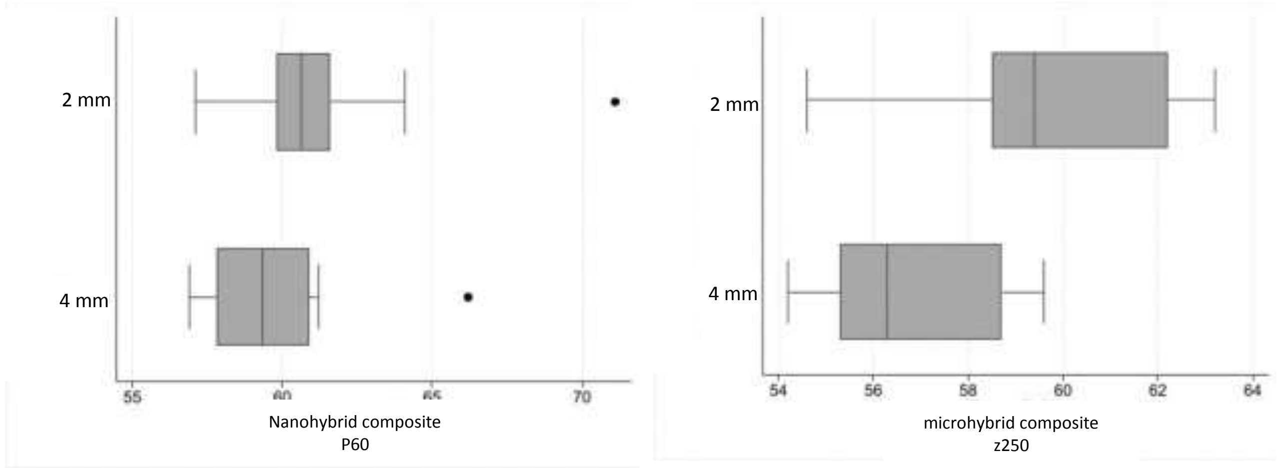

Figure 1. Box plots representing average Vickers microhardness of nanohybrid (Fiktek P60) and microhybrid (Filtek Z250) composite resins at 2 mm and 4 mm curing distances

Table 1. Mean and standard deviation (SD) of average Vickers microhardness number in the two composite resin groups cured at different distances

Resin Composite	2 mm distance	4 mm distance	
	Mean ± SD	Mean ± SD	P-value
Nanohybrid (Filtek P60)	61.6 ± 3.8	59.7 ± 2.8	0.151
Microhybrid (Filtek Z250)	59.6 ± 2.5	56.8 ± 2.1	0.015
P-value	0.226	0.017	

of the nanohybrid composite was significantly greater than the microhybrid composite at a 4 mm distance.

The findings of this study are in agreement with the results of Abd El Halim (16) who compared the microhardness and surface roughness of nanohybrid and microhybrid resin composites and found that the nanohybrid composite statistically showed a higher microhardness value.

In the present study, the microhardness values of the nanohybrid resin did not show a significant difference between the distance of 2 mm and 4 mm. However, the microhybrid resin exhibited a significant difference in microhardness between the two distances, showing statistically higher microhardness at a shorter curing distance. This highlights the sensitivity of the microhybrid resin to changes in the light curing distance.

Previous studies emphasized the effect of curing distance on the mechanical properties of resin composites. Saati et al. (17) evaluated the microhardness of two different bulk-fill composite resins and one conventional composite resin at specific depths (0.1, 1, 2, 3, 4 and 5 mm). They found that in all composite resin samples, hardness decreased with increasing the measurement depth (17). Aguiar et al. (18) evaluated the influence of different curing tip distances (2 mm, 4 mm, and 8 mm) and resin shades (A1, A3.5, and C2) on the microhardness of a hybrid resin composite sample (Z250) at the top and bottom surfaces. The results showed that bottom surface samples light-cured at 2 mm and 4 mm presented significantly higher hardness values than that of the 8 mm distance. However, for the top surface, there were no statistical differences among the curing tip distances (18). Cekic-Nagas et al (19) compared the microhardness of five different hybrid resin composites at different irradiation distances (2 mm and 9 mm) using three light curing units (a tungsten quartz halogen, a light-emitting diode, and a plasma arc). They found that the type of resin composite, the type of light curing unit, and the irradiation distance all had a significant effect on microhardness values (19). Although the nanohybrid composite in this study showed no significant difference in microhardness between the two distances, it should be noted that the curing distance range in this study was narrower than that of Cekic-Nagas et al (19). It is possible that increasing the curing distance would affect the microhardness of nanohybrid composite resin as well.

The differences in microhardness of nanohybrid and microhybrid resins could be attributable to their distinct compositional structures and how these structures interact with varying distances of the light curing unit (20). The nanohybrid resin, with its finer filler particles, likely allows for more uniform and effective light penetration during the curing process. This could lead to a more consistent cross-linking of the polymer chains, regardless of the employed light curing distance (21). On the other hand, the microhybrid resin, with larger filler particles, may present a less uniform surface for light interaction, leading to more significant variations in microhardness values at different distances (22). The superior microhardness of the Z250 microhybrid resin at the 2 mm distance, as opposed to the 4 mm distance, suggests a more efficient activation of the photoinitiators at a lower distance. The insights obtained from this study are valuable in material selection and optimizing the curing process in restorative procedures.

This study was limited to evaluating only two types of light-cured composite resins, and two curing distances. Investigating other resins with different curing distances could provide a better understanding of the effect of curing distance on resin polymerization, and should be performed in future research.

Conclusion

Under the conditions used in this study:

1. The nanohybrid resin composite showed higher microhardness values than the microhybrid resin at both 2 mm and 4 mm distances, although the difference between the two groups was only significant at the distance of 4 mm.
2. The hardness of the microhybrid composite decreased significantly with increasing the curing distance from 2 to 4 mm. The nanohybrid composite showed comparable hardness up to the distance of 4 mm, indicating its suitability to be used in situations where a close curing distance cannot be achieved.

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