JHB

Journal of Health and Biology

https://journalhb.org/

SPBH

Original Article

Effect of Light-Curing Tip Distance on the Top and Bottom Surface Microhardness of Two Single-Shade Resin Composites: An *In Vitro* Study

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DOI: https://doi.org/10.71428/JHB.2026.0210

Abstract

Aim: The purpose of this *in vitro* experiment was to measure the difference in surface microhardness and bottom-to-top hardness ratio between two single-shade resin composites as a function of increasing light-curing tip distance. **Materials and Methods:** We used Palfique OMNICHROMA and ONEshade Universal to create sixty disk-shaped specimens (n = 30 for each). Using the light-curing tip distance as a criterion, we separated each material into three subgroups (n = 10). After being polymerized for 30 seconds at 1000 mW/cm² in an LED curing machine, the specimens were immersed in distilled water and left to cure at 37°C for 24 hours. We determined the bottom-to-top hardness ratio by measuring the Vickers microhardness on both the top and bottom surfaces. We used three-way mixed ANOVA and two-way ANOVA to analyze the data, with a significance level of $\alpha = 0.05$. **Results**: Both composites showed a significant decrease in microhardness as the curing distance increased ($p < 0.001$). At all curing distances, ONEshade showed considerably stronger top and bottom microhardness compared to OMNICHROMA ($p < 0.001$). Hardness ratios measured from bottom to top fell somewhere between 83.96% and 90.07%, with no group falling below the 80% mark. **Conclusion:** Both single-shade composite microhardness decreased as the light-curing tip distance increased, but the relative polymerization remained sufficient at a specimen thickness of 2 mm. To get the most out of single-shade resin composites mechanically, you should keep the curing-tip distance to a minimum.

Keywords: Single-shade composite; light-curing distance; Vickers microhardness; polymerization; OMNICHROMA; ONEshade.

Introduction

The desirable optical qualities, conservative application, adequate mechanical performance, and bonding ability of resin-based composites have made them the predominant materials utilized for direct esthetic restorations. Fillers have found more and more uses in both front and back teeth thanks to advancements in polymerization processes, photoinitiator systems, resin matrices, and filler technology (1, 2). However, getting enough polymerization across the whole restorative material thickness is still crucial for the clinical success of resin composite restorations in the long run.

To mimic the intricate polychromatic appearance of actual teeth, conventional resin composite systems come in a variety of enamel, dentin, body, and transparent hues. Even though these systems can produce esthetically pleasing results, choosing and blending different shades

Received: June 3, 2026. Accepted: August 1, 2026. Published: September 10, 2026

is time-consuming, technique-sensitive, and dependent on the clinician's skill.(3, 4) Recently, single-shade or universal-shade resin composites have been produced to streamline the restorative process. Through improved translucency, structural color technology, or a combination of pigments and filler-related optical mechanisms, these materials are made to blend with a variety of tooth hues (5, 6). As a result, they might lessen the number of composite syringes needed in clinical practice and the requirement for careful shade selection.

Although they have optical benefits, single-shade resin composites vary greatly in terms of the photoinitiator composition, filler loading, translucency, filler size and distribution, and resin matrices. These differences could affect how light gets through, how polymerization works, how much conversion occurs, and the mechanical qualities.(7, 8). The third, research has shown that commercially available single-shade composites vary significantly in microhardness, hardness ratio, flexural strength, degree of conversion, and elastic modulus (5, 9). The third Hence, it is not always possible to generalize the mechanical behavior and polymerization efficiency of one single-shade material to other materials in the same category.

For resin composites to have the best possible physical, mechanical, and biological qualities, it is crucial to photopolymerize them adequately. Hardness, strength, wear resistance, color stability, water sorption, solubility, marginal degradation, and release of unreacted monomers are all negatively impacted by insufficient polymerization (10, 11). Composition of the composite, shade, translucency, increment thickness, exposure time, irradiance, emission spectrum of the light-curing unit, location of the curing tip, distance from the light source to the restorative material, and operator-related factors are among those that impact the efficacy of polymerization (2, 12).

The ideal light-curing tip position in a laboratory setting is perpendicular to the composite surface and right against it. But in clinical settings, face-to-face interaction isn't always an option (13). The number of factors that can prolong the time it takes for the curing tip to reach the restoration includes the tooth's position, the matrix bands, the depth and shape of the cavity, the cusp height, and the difficulty in accessing the back of the mouth. Because of light dispersion and divergence, increasing this distance can lessen the irradiance and radiation exposure that reaches the composite surface (14). The resultant decrease in energy can jeopardize polymerization, especially on the restoration's underside.

Surface microhardness and polymerization efficacy tend to decrease with increasing distance from the curing tip to the composite surface, according to previous research using conventional and bulk-fill composites. The numbers show that curing distance considerably lowered microhardness, notably at the bottom surfaces, according to a recent experiment analyzing flowable bulk-fill composites at 0, 2, and 4 mm (15). The effect of curing distance appears to be material-dependent, as the size of this reduction differed among the studied materials (16). Similarly, a systematic evaluation found that there is a correlation between the curing unit's light energy output and composite microhardness, with varying results shown across different materials and testing methodologies.

One popular way to indirectly assess the mechanical behavior and efficacy of resin composites during polymerization is to conduct surface microhardness tests. The process is straightforward, repeatable, and less susceptible to variations in curing conditions and composite formulation. It is also possible to determine the bottom-to-top hardness ratio by measuring microhardness on the top and bottom surfaces. It is important to consider the tested material's composition when interpreting a ratio of 0.80 or higher as an indication of appropriate polymerization at the bottom surface, although this threshold has traditionally been utilized (17).

There has been a lot of focus on the optical behavior and color-matching possibilities of single-shade resin composites (18), but there is a lack of information about how these materials behave during polymerization when exposed to differences in curing-tip distance that are clinically important. The three, four Their various optical and compositional methods for universal shade matching mean that these materials may have different transmittances of curing light and different capacities to retain sufficient hardness at increasing distances. It is clinically relevant to evaluate this interaction, especially when positioning the curing tip directly against the repair is not possible.

Hence, this in vitro experiment set out to measure the impact of 0, 2, and 4 mm light-curing tip distances on the surface microhardness of the top and bottom surfaces of two commercially available single-shade resin composites. To measure how well the polymerization held across the whole thickness of the specimen, we also computed the bottom-to-top microhardness ratio.

The null hypotheses were as follows: (1) the top and bottom surface microhardness of the single-shade resin composites tested would not be significantly affected by the light-curing tip distance; (2) the microhardness of the two materials tested would not differ significantly from one another; and (3) the bottom-to-top microhardness ratio would not be significantly affected by either the light-curing tip distance or the material type.

Materials and Methods

Study Design

For this in vitro experiment, researchers used two universal resin composites with a single shade to measure the surface microhardness at both the top and bottom and how light-curing tip distance affected both. Three levels of light-curing tip distance (0, 2, and 4 mm), two levels of specimen surface (top and bottom), and two levels of resin composite material were the experimental parameters. The bottom-to-top microhardness ratio was the secondary objective, while the Vickers microhardness number (VHN) was the primary outcome.

Materials

The Palfique OMNICHROMA and the ONEshade Universal were two universal resin composites that are available for purchase and feature a single shade. Table 1 displays their compositions and categorizations.

Table 1. Resin composites used in the study(6)

Material	Manufacturer	Classification	Resin matrix	Filler system
Palfique OMNICHROMA	Tokuyama Dental Corporation, Tokyo, Japan	Single-shade supra-nano-filled universal resin composite	UDMA, TEGDMA, mequinol, dibutyl hydroxytoluene, and ultraviolet absorber	Uniform spherical silica-zirconia fillers with a mean particle size of approximately 0.3 µm; 79 wt% and 68 vol%
ONEshade Universal	Olident, Krakow, Poland	Nanoparticle-containing microhybrid single-shade resin composite	Diurethane dimethacrylate, Bis-GMA, and tetramethylene dimethacrylate	Silicon dioxide, glass powder, and inorganic fillers with a particle-size range of 0.005–3.0 µm; 75 wt% and 53 vol%

Specimen Grouping

We made 60 specimens in the shape of disks. Separated into two categories based on the resin composite composition, the specimens were:

- Group O: Palfique OMNICHROMA, n = 30.
- Group S: ONEshade Universal, n = 30.

Each material group was subdivided into three subgroups according to the distance between the light-curing tip and the top surface of the specimen:

- Group O0: OMNICHROMA polymerized at a distance of 0 mm, n = 10.
- Group O2: OMNICHROMA polymerized at a distance of 2 mm, n = 10.
- Group O4: OMNICHROMA polymerized at a distance of 4 mm, n = 10.
- Group S0: ONEshade polymerized at a distance of 0 mm, n = 10.
- Group S2: ONEshade polymerized at a distance of 2 mm, n = 10.
- Group S4: ONEshade polymerized at a distance of 4 mm, n = 10.

We used a computer-generated random sequence to determine the order of specimen preparation and microhardness testing.

Specimen Preparation

The specimens were created using a specialized black Teflon mold and had a diameter of 5 mm and a thickness of 2 mm. Using a digital caliper that could measure to within 0.01 mm, we confirmed the mold's internal measurements.

An observational glass slide held the Teflon mold in place on a see-through polyester Mylar strip. A composite instrument covered with Teflon was used to introduce the chosen resin composite into the mold in a single increment. We were careful not to include air bubbles and slightly overfilled the mold.

They laid a second Mylar sheet and a glass slide on top of the composite. Vertically applying a 300 g standard force to the top glass slide for 30 seconds removed superfluous material, improved material packing, and produced level and parallel surfaces.(6)

We proceeded to remove the upper glass slide and standardized load without damaging the upper Mylar strip. Under controlled laboratory circumstances, a single operator prepared all specimens.

Light-Curing Procedure

Specimens were polymerized starting from the top surface using an Eighteenth CuringPen LED light-curing equipment from Changzhou Sifary Medical Technology Co., Ltd. in Changzhou, China. Using a wavelength range of 385-515 nm and an irradiance setting of 1000 mW/cm², the device was operated in continuous normal mode. The 5-mm-diameter specimen surface was entirely covered by the 11-mm-diameter lens that was attached to the curing machine.

Prior to the polymerization process, the light-curing tip was placed centered over the specimen surface, perpendicular to it, and cleaned. The curing unit, operating mode, irradiance level, exposure time, and tip orientation were all consistently applied to all specimens during the 30-second polymerization treatment.

The curing light only reached the upper surface. Not polymerizing the bottom surface separately prevented further bottom irradiation from interfering with the measurement of light transmission through the composite specimen.

Just before specimen preparation and after every five polymerization procedures, we examined the output setting on the digital display of the curing equipment. To keep the light-curing unit's performance constant, we let it cool between each exposure.

Standardization of Light-Curing Tip Distance

The distance between the light-curing tip and the top surface of each specimen was standardized using opaque ring spacers that were custom-made.(16)

The groups with a diameter of 0 mm had their curing tips pressed lightly on the top Mylar strip.

The 2-mm groups had an opaque ring spacer, which was 2 mm thick, placed between the surface of the specimen and the curing point.

The 4-mm groups had an opaque ring spacer, also 4-mm thick, placed between the surface of the specimen and the curing point.

Using a digital caliper, we checked that every ring spacer was the correct thickness. Throughout the polymerization process, the spacers ensured that the curing tip remained balanced and perpendicular to the surface of the specimen.

Specimen Inspection

The specimens were delicately taken out of the Teflon mold and examined under a microscope after polymerization. We discarded and replaced any specimens that showed signs of air bubbles, holes, splits, broken edges, inadequate mold filling, noticeable surface imperfections, or surfaces that were not parallel to one another.

By making a tiny, permanent mark on the side of each specimen, we were able to determine its upper surface. Neither of the test surfaces had the identification mark.

Surface Grinding and Standardization

Utilizing a MoPao 160E metallographic specimen grinding and polishing equipment (LaiZhou Weiyi Experimental Machinery Manufacture Co., Ltd., Shandong, China), the specimens' top and bottom surfaces were wet-ground in a specific order using 400-, 600-, and 1200-grit silicon carbide abrasive sheets (19).

The water-cooling system kept the grinding and polishing machine running at a steady 150 rpm. In this procedure, we used each abrasive paper in turn for 30 seconds on each surface:

40 seconds on silicon carbide paper with a 400-grit surface.

Silicon carbide paper with a granularity of 600 for thirty seconds.

30 seconds on silicon carbide paper with a 1200-grit finish.

There was consistent, light pressure used throughout the grinding process. For consistent surface preparation, we rotated each specimen by 90 degrees between abrasive papers to remove grinding lines from each grit.

We replaced the abrasive papers every five specimens or sooner if we noticed visible deterioration. In each grinding procedure, the same operator used the same rotating speed, pressure, abrasive paper sequence, grinding time, and water cooling.

To eliminate any remaining abrasive particles or surface debris, the specimens were washed with distilled water for 60 seconds after grinding. The next step was to use oil-free compressed air to gently dry them.

Dimensional Verification

Using a digital caliper, we assessed the final diameter and thickness of each specimen at three separate sites after surface grinding. We took note of the average of the three readings.

For inclusion, specimens had to meet certain criteria, such as a diameter of 5.0 ± 0.1 mm, a thickness of 2.0 ± 0.1 mm, and obviously flat and parallel surfaces on both the top and bottom. Excluded and substituted were specimens that did not conform to these dimensions.

Specimen Storage

After measuring each item, we put them in a specifically marked, airtight container with distilled water. To allow for post-irradiation polymerization and to standardize the period between light curing and microhardness measurement, the specimens were kept at 37 ± 1°C for 24 hours.1, 4, 5

Prior to microhardness testing, the specimens were rinsed and carefully dried with absorbent paper after being taken from the distilled water for storage.

Vickers Microhardness Testing

Using a TH714 Digital Micro Vickers Hardness Tester (Beijing TIME High Technology Ltd., Beijing, China), we measured the top and bottom surface microhardness of every specimen.

After positioning each specimen on the testing platform, we ensured that the inspected surface was perpendicular to the Vickers diamond indenter. We dwelled for 15 seconds with a 50 g test load (20). In the middle section of each surface, three depressions were cut into it. Distancing the indentations from the specimen edges by at least half a millimeter allowed them to remain independent of one another and shielded the specimen from edge effects.

Using the built-in microscope of the microhardness tester, we measured the two diagonals of every indentation. Utilizing the following formula, the Vickers hardness number was mechanically determined:

As a representative Vickers microhardness value for each surface, we averaged the three indentations and recorded the result. As a result, each specimen had six indentations—three on the top and three on the bottom.

There was a blinding of the examiner who measured microhardness to the resin composite and curing distance. Numbers were assigned at random to each specimen in order to identify them.

Bottom-to-Top Microhardness Ratio

Using the following equation, we determined the bottom-to-top microhardness ratio for each specimen to evaluate the polymerization efficacy throughout the thickness of the specimen:

$$\text{Bottom-to-top hardness ratio}(\%) = \frac{\text{Mean bottom-surface VHN}}{\text{Mean top-surface VHN}} \times 100$$

A bottom-to-top hardness ratio of 80% or greater was considered indicative of adequate polymerization at the bottom surface.(14, 19)

Outcome Measures

The following outcomes were recorded for each specimen:

1. Mean top-surface Vickers microhardness.
2. Mean bottom-surface Vickers microhardness.
3. Bottom-to-top microhardness ratio.
4. Achievement or nonachievement of the 80% bottom-to-top hardness threshold.
5. Final specimen thickness after surface grinding.

Statistical Analysis

To conduct the statistical analysis, we utilized IBM SPSS Statistics for Windows, version 22.0 (IBM Corp., Armonk, NY, USA).

This study presents descriptive statistics in the form of means, standard deviations, minimum and maximum values, and 95% confidence intervals.

Using the Shapiro-Wilk test and examining Q-Q plots, we checked if the residuals were normal. Using Levene's test, we checked for variance homogeneity.

We utilized a three-way mixed analysis of variance to examine the impact on Vickers microhardness of resin composite material, light-curing tip distance, specimen surface, and their interactions. The curing distance and resin composite material were considered to be characteristics that varied among specimens, while the surface of the specimen was considered to be a factor that occurred repeatedly within specimens.

We used the Bonferroni adjustment to conduct pairwise comparisons when we found main effects or interactions that were statistically significant.

We used two-way analysis of variance to examine the bottom-to-top microhardness ratios independently, taking curing distance and resin composite material into consideration. To do post hoc multiple comparisons, Tukey's honestly significant difference test was leveraged.

We used either Fisher's exact test or a chi-square test to compare the percentages of specimens that reached a bottom-to-top hardness ratio of 80% or above, as applicable.

We set the level of statistical significance at $k0.05$. When appropriate, effect sizes were presented with 95% confidence intervals and as partial eta squared.

Ethical Considerations

The research did not include any animals, biological tissues, or human subjects; instead, it made use of restorative materials that are already on the market. As a result, getting people's permission was unnecessary. The appropriate institutional scientific committee examined the study protocol and gave its approval for it to proceed as an in vitro materials study.

Results

Each experimental group received ten specimens, for a grand total of sixty specimens included in the statistical analysis. Both the preparation and microhardness testing processes did not exclude any specimens. Figure 2 displays the descriptive statistics for top-to-bottom hardness ratios, bottom-to-surface microhardness, and top-to-surface microhardness.

Vickers Microhardness

With a curing distance of 0 mm (62.57 ± 0.99 VHN), ONEshade recorded the highest mean top-surface microhardness, while OMNICHROMA recorded the lowest at 4 mm (40.23 ± 1.72 VHN). Likewise, at 0 mm (55.03 ± 1.61 VHN), ONEshade had the highest mean bottom-surface microhardness, while at 4 mm (33.76 ± 1.27 VHN), OMNICHROMA had the lowest.

As the distance from the light-curing tip to the specimen surface rose from 0 to 4 mm, the top- and bottom-surface microhardness values for both materials dropped. Across the board, ONEshade outperformed OMNICHROMA in terms of top-and bottom-surface microhardness values when evaluated at various curing distances.

Table 2. Vickers microhardness and bottom-to-top hardness ratios according to material and curing distance

Material	Curing distance	Top VHN, mean ± SD	Bottom VHN, mean ± SD	Bottom-to-top ratio, mean ± SD
OMNICHROMA	0 mm	48.61 ± 1.63[a]	42.54 ± 1.31[a]	87.54 ± 1.89[a]
OMNICHROMA	2 mm	44.63 ± 1.59[b]	38.05 ± 1.84[b]	85.30 ± 3.78[ab]
OMNICHROMA	4 mm	40.23 ± 1.72[c]	33.76 ± 1.27[c]	83.96 ± 1.73[b]
ONEshade	0 mm	62.57 ± 0.99[a]	55.03 ± 1.61[a]	87.94 ± 1.72[a]
ONEshade	2 mm	58.70 ± 0.87[b]	51.23 ± 0.99[b]	87.29 ± 1.44[a]
ONEshade	4 mm	55.50 ± 1.17[c]	49.99 ± 1.24[b]	90.07 ± 1.86[b]

SD stands for standard deviation, and VHN is the Vickers hardness number. When there are different lowercase superscript letters within the same material and column, it means that there are statistically significant differences among the curing distances (Tukey-adjusted, p 0.05). The top- and bottom-surface microhardness of ONEshade was noticeably greater than that of OMNICHROMA at all relevant curing distances (p < 0.001).

Three-Way Mixed Analysis of Variance

Resin composite material had a significant main effect on microhardness, with an $F\ (1{,}54) = 1903.75$, $p < 0.001$, according to the three-way mixed analysis of variance. In terms of microhardness values, ONEshade outperformed OMNICHROMA.

$F\ (2{,}54) = 169.02$, $p < 0.001$, also indicated that the distance between light-curing tips had a statistically significant main effect. From 0 to 2 and 4 mm, microhardness decreased with increasing cure distance.

The statistical significance of the material-by-distance interaction $F\ (2{,}54) = 5.76$, $p = 0.005$, suggests that OMNICHROMA and ONEshade were affected differently by curing distance.

Specimen surface had a statistically significant effect on microhardness, $F(1,54) = 1952.68, p < 0.001$. The top-surface microhardness was significantly higher than the corresponding bottom-surface microhardness across all materials and curing distances.

The material-by-surface interaction was not statistically significant, $F(1,54) = 2.45, p = 0.123$. In contrast, the distance-by-surface interaction was statistically significant, $F(2,54) = 4.38, p = 0.017$, indicating that the difference between the top and bottom surfaces varied according to the curing distance.

A statistically significant three-way interaction among material, curing distance, and specimen surface was detected, $F(2,54) = 5.95, p = 0.005$. This finding indicates that the effect of increasing the curing distance on the difference between the top- and bottom-surface microhardness was material-dependent (Table 3).

Table 3. Three-way mixed ANOVA for Vickers microhardness

Source of variation	df	F-value	p-value
Material	1, 54	1903.75	<0.001
Curing distance	2, 54	169.02	<0.001
Material × curing distance	2, 54	5.76	0.005
Surface	1, 54	1952.68	<0.001
Material × surface	1, 54	2.45	0.123
Curing distance × surface	2, 54	4.38	0.017
Material × curing distance × surface	2, 54	5.95	0.005

Statistical significance was set at $p < 0.05$.

Pairwise Comparisons Among Curing Distances

The top-surface microhardness of OMNICHROMA varied considerably across all curing distances. There was a significant difference between the values at 0 mm, 2 mm, and 4 mm ($p < 0.001$), as well as between the values at 2 mm and 4 mm ($p < 0.001$). The bottom surface followed the same pattern, with notable variations over all three curing distances ($p < 0.001$).

The top-surface microhardness varied significantly ($p < 0.001$) for ONEshade across all curing distances. There was a statistically significant difference between the values measured at 2 and 4 mm and 0 mm for the bottom surface ($p < 0.001$). Despite this, there was no statistically significant difference ($p = 0.103$) between the bottom-surface values at 2 and 4 mm.

Compared to OMNICHROMA, ONEshade showed considerably higher top- and bottom-surface microhardness at each relevant curing distance ($p < 0.001$).

Comparison Between Top and Bottom Surfaces

The average microhardness of the upper surface was noticeably greater than the bottom surface in every single experimental group ($p < 0.001$).

For OMNICHROMA at 0, 2, and 4 mm, the mean top-to-bottom disparities were 6.07, 6.58, and 6.47 VHN, respectively. The respective differences for ONEshade were 7.54, 7.46, and 5.52 VHN.

In all materials, the results showed that microhardness decreased with increasing thickness of 2 mm, independent of curing distance.

Bottom-to-Top Microhardness Ratio

The hardness ratios measured from the base to the top varied between 83.96 ± 1.73% and 90.07 ± 1.86%. The predefined criterion for appropriate polymerization was 80%, and all experimental groups demonstrated mean hardness ratios higher than that.

At 0 mm, the mean hardness ratio for OMNICHROMA was 87.54%; at 2 mm, it dropped to 85.30%; and at 4 mm, it dropped to 83.96%. There was a statistically significant difference ($p = 0.014$) between 0 and 4 mm, but no statistically significant difference ($p = 0.160$) or ($p = 0.498$) between 2 and 4 mm.

For ONEshade, the mean hardness ratio was 87.94% at 0 mm, 87.29% at 2 mm, and 90.07% at 4 mm. The ratio at 4 mm was significantly higher than those recorded at 0 mm ($p = 0.023$) and 2 mm ($p =$

0.003). No significant difference was observed between 0 and 2 mm ($p = 0.662$).

Two-way ANOVA of the bottom-to-top hardness ratios demonstrated a significant effect of material, $F(1, 54) = 24.67, p < 0.001$. The overall main effect of curing distance was not statistically significant, $F(2, 54) = 2.13, p = 0.128$. However, the material-by-distance interaction was statistically significant, $F(2, 54) = 8.87, p < 0.001$, demonstrating that the pattern of change in the hardness ratio across curing distances differed between the two materials.

The hardness ratios of the two materials were not significantly different at 0 mm ($p = 0.619$) or 2 mm ($p = 0.148$). At 4 mm, ONEshade exhibited a significantly higher hardness ratio than OMNICHROMA ($p < 0.001$) (Table 5).

Table 4. Differences between top- and bottom-surface microhardness

Material	Curing distance	Mean top–bottom difference, VHN	p-value
OMNICHROMA	0 mm	6.07	<0.001
OMNICHROMA	2 mm	6.58	<0.001
OMNICHROMA	4 mm	6.47	<0.001
ONEshade	0 mm	7.54	<0.001
ONEshade	2 mm	7.46	<0.001
ONEshade	4 mm	5.52	<0.001

Table 5. Two-way ANOVA for the bottom-to-top hardness ratio

Source of variation	df	F-value	p-value
Material	1, 54	24.67	<0.001
Curing distance	2, 54	2.13	0.128
Material × curing distance	2, 54	8.87	<0.001

Statistical significance was set at p < 0.05.

Summary of Findings

The absolute microhardness of the top and bottom surfaces of both single-shade resin composites was considerably lowered when the light-curing tip distance was increased. Compared to OMNICHROMA, ONEshade always showed a greater microhardness. All experimental groups kept a bottom-to-top hardness ratio above 80%, even though bottom-surface microhardness was substantially lower than top-surface microhardness. Hence, improving the curing distance lowered the absolute hardness readings without bringing the mean bottom-to-top ratio down to a level where polymerization was sufficient.

Discussion

This research compared the effects of three different light-curing tip distances on the surface microhardness of two different universal resin composites with a single shade. The main results showed that both materials' absolute microhardness decreased as the curing distance increased, that bottom surfaces had much lower microhardness than top surfaces, and that ONEshade had higher microhardness than OMNICHROMA in every experiment. Still, the average bottom-to-top hardness ratio was above 80% across all categories.

We reject the first null hypothesis that top and bottom surface microhardness of the investigated materials would be unaffected by light-curing tip distance. Microhardness values for both composites peaked at 0 mm, 2 mm, and 4 mm, in that order. Both the top and bottom surfaces showed this reduction; however, the amount of it varied depending on the material and surface.

Reducing irradiance and radiant exposure that reaches the composite surface may account for the detrimental effect of extending the curing distance. The photoinitiator system receives less energy due to light divergence and dispersion as the distance between the light-curing tip and the restorative material grows larger.1, 2 The irradiance and energy density supplied by light-curing devices can be significantly reduced as the distance from the curing tip increases, as shown by Beolchi et al. (12). Less exposure to light slows the polymerization cycle, makes free radicals less abundant, and may reduce the amount of monomer conversion and cross-linking between polymer networks. Surface microhardness can decrease because of these alterations.

Consistent with previous research, the present results support the use of 0-, 2-, and 4-mm curing intervals for polymerizing flowable bulk-fill composites (16). Microhardness on the top and bottom surfaces decreased gradually with increasing curing distance, according to their report. Similarly, Diab et al.(14) discovered that, especially at longer distances, the impact of curing distance on the efficacy of polymerization varied depending on the material. As the distance between the light source and composite surface increased, Tachibana et al. (21) also found that microhardness and bottom-to-top hardness ratios decreased. Francis et al. (17) found that, on average, resin composite microhardness increased with increasing light irradiation; however, the strength of this relationship varied with material composition and experimental circumstances.

The present investigation found that curing distance influenced microhardness on both the bottom and top surfaces. Keeping the curing tip at a clinically relevant distance from the restoration can result in insufficient radiant exposure to the surface closest to the light-curing unit, making this observation clinically essential. Although composite light attenuation is usually thought to be the main culprit for insufficient bottom polymerization, lowering the initial irradiance to the top surface can reduce polymerization everywhere in the specimen.

Additionally, we did not find any evidence to support the second null hypothesis, which stated that the two materials under test were identical. Regardless of the curing distance, ONEshade showed substantially greater top-and bottom-surface microhardness compared to OMNICHROMA (22, 23). Using the same specimen size, surface preparation, storage conditions, light-curing unit, exposure time, and testing settings did not eliminate the noticeable difference between the materials.

Total filler loading is not the only factor that determines the microhardness of resin composites. The degree of conversion, photoinitiator system, polymer-network structure, filler morphology, size and distribution of the fillers, and resin-matrix composition are other factors that could affect these. OMNICHROMA mostly consists of UDMA and TEGDMA resins, with 79 weight percent and 68 volume percent of evenly sized spherical silica-zirconia fillers, respectively. Diurethane dimethacrylate, Bis-GMA, and tetramethylene dimethacrylate make up the resin system in ONEshade, whereas inorganic fillers containing 75 wt% and 53 vol% of the material have a wider particle-size range.

The claimed filler volume of OMNICHROMA is higher, while the microhardness of ONEshade is higher. This discovery suggests that the surface hardness of a resin composite is not only determined by the quantity of filler. It is possible that ONEshade's higher indentation resistance is attributable to its Bis-GMA-containing matrix, microhybrid filler distribution, filler-matrix coupling quality, and the consequent polymer-network structure. Bis-GMA, a monomer that is both very viscous and reasonably stiff, has the potential to make the polymerized resin network even more rigid. The ultimate mechanical behavior, however, is not dependent on any one component but rather on the cumulative impact of the resin and filler.

Prior research has also shown that the properties of single-shade resin composites are dependent on the materials used. Various commercially available single-shade composites showed notable variations in microhardness, degree of conversion, flexural strength, and elastic modulus (12). The mechanical characteristics and reaction to preheating differed significantly among materials with only one shade, as noted more lately by İren and Yiğit (19). Their research showed that OMNICHROMA had lower mechanical values than a number of other composites they examined, lending credence to the idea that different materials with the same single shade shouldn't behave mechanically similarly.

This study's results corroborate those of Atilan Yavuz et al. (7) who found that ONEshade had a higher baseline surface microhardness than OMNICHROMA, and that ONEshade had a higher microhardness overall. On the other hand, prior to thermocycling, Hijazi et al. (6) discovered that the two materials had comparable baseline microhardness values. Variations in specimen preparation, polishing methods, applied indentation load, curing unit, exposure circumstances, storage techniques, and tested surface may explain why different research yields different results. This lack of uniformity in methodology calls attention to the importance of microhardness value standardization when relating to research.

In every single experimental group, the bottom surfaces had a substantially lower microhardness than the top surfaces of the same type. As a result, we also rejected the part of the first null hypothesis that dealt with surface position. The average variation in height between the upper and lower surfaces was 6.61 VHN.

The decrease in bottom-surface microhardness is a result of the composite's ability to attenuate curing light. A variety of substances, including resin, fillers, pigments, photoinitiators, and the interfaces between fillers and matrix, absorb and scatter light. The result is that the bottom surface receives less energy than the top surface. There was still enough attenuation to generate statistically significant top-to-bottom differences in the two materials even when the specimen thickness was 2 mm (6, 19).

There was a notable interaction between distance and surface, suggesting that the disparity between the top and bottom surfaces changed as curing distance increased or decreased. The top-to-bottom reaction to increasing curing distance was not identical for OMNICHROMA and ONEshade, as evidenced by the strong three-way interaction among material, distance, and surface. This discovery lends credence to the idea that the formulation of a material has a significant impact on its light transmission and polymerization behavior.

Since the material effect and the material-by-distance interaction were statistically significant, we may reject the third null hypothesis, which posited that the bottom-to-top hardness ratio would be unaffected by curing distance and material type.

Curing distance did not significantly affect the hardness ratio as a whole.

The average bottom-to-top hardness ratios for all experimental groups were more than 80%, with numbers ranging from 83.96% to 90.07%. One indirect measure of satisfactory bottom-surface polymerization is a bottom-to-top hardness ratio of 80% or above. The 2-mm specimens nevertheless had a respectable relative depth of polymerization under the circumstances we used, even though absolute microhardness decreased dramatically as curing distance increased.

Be careful when interpreting the results of the hardness-ratio test. No matter how close you get to the ideal absolute hardness number for either surface, a ratio just shows how hard the bottom is in comparison to the top. Both very high and very low values, or a proportional reduction in both, can lead to a high ratio. So, the ratio and the absolute VHN values should be considered jointly while making sense of it.

It is worth noting that the ONEshade group cured at 4 mm exhibited the highest bottom-to-top ratio compared to the ONEshade specimens cured at 0 mm, even though they had lower absolute top- and bottom-surface microhardness. Even with a high ratio at 4 mm, it didn't mean the best polymerization. Since the top-surface value likewise declined with increasing curing distance, it was actually the consequence of a reduced proportional difference between the two surfaces.

As one moved from 0 mm to 4 mm, the hardness ratio for OMNICHROMA dropped from 87.54% to 83.96%. On the other hand, ONEshade's ratios were more consistent between 0 and 2 mm, and then they increased at 4 mm. There was clear evidence of material-by-distance interaction, which proved that the hardness-ratio pattern varied between materials. Possible causes for this material-specific reaction include variations in filler size, light-scattering behavior, transparency, and refractive-index matching (12, 16).

To mix with the dental tissues around them, single-shade composites sometimes rely on structural-color mechanisms or improved translucency. Additionally, these optical characteristics might affect how much light gets through the substance. OMNICHROMA creates structural color with spherical fillers of uniform size, whereas ONEshade uses a microhybrid filler system and the chameleon effect. Light attenuation and polymerization reaction may vary due to variations in optical properties. Spectroscopic studies in the future will need to corroborate this theory since the current study did not directly assess optical transmission or conversion degree.

The results highlight the significance of placing the curing tip as near and perpendicular to the restoration as feasible from a clinical standpoint. Factors that can affect the distance between the curing tip and composite surface include cusp height, matrix bands, deep proximal boxes, limited mouth opening, and difficulty accessing posterior teeth. At 2 and 4 mm, the absolute microhardness values dropped dramatically, despite the fact that the hardness ratios remained above 80% throughout the testing. So, to get the most out of single-shade resin composites mechanically, it's still crucial to keep the curing distance to a minimum. Following the guidelines provided by the material and curing-unit manufacturers, doctors should think about increasing radiant exposure when close positioning is not an option.

Limitations

There are a number of caveats that must be considered while analyzing the findings of this study. To start, not all clinical parameters influencing polymerization were present in the controlled laboratory conditions. These factors include: cavity shape, surrounding tooth structure, matrix bands, limited access, and variation in curing-tip angulation.

Second, the study only looked at two resin composites with a single shade, as well as a single specimen thickness, curing unit, irradiance setting, and exposure period. Results may not be applicable to other light-curing devices or composites due to differences in emission spectra, beam profiles, or power outputs.

Third, to standardize the experimental conditions, the specimens were polymerized in a black Teflon mold. However, this mold might not have accurately replicated the light reflection and transmission properties of enamel and dentin cavity walls.

Fourth, microhardness cannot tell you anything about the degree of conversion or monomer elution since it is an indirect metric of polymerization. In order to better evaluate polymerization, future research should integrate microhardness testing with other techniques, such as Fourier-transform infrared spectroscopy or direct irradiance measurement at the specimen surface.

Last but not least, we only stored water for the short term. Aging processes such as thermocycling, long-term water storage, mechanical loading, and others may affect the tested materials' long-term microhardness and polymerization behavior.

Regardless of these caveats, blinded microhardness measurements, regulated curing distances, uniform surface preparation, and defined specimen size enabled a direct and repeatable comparison of the two materials.

Interpretation of the Null Hypotheses

The light-curing tip distance had a substantial impact on the microhardness of both the top and bottom surfaces of the specimens, and there were notable differences between the two surfaces; therefore, the first null hypothesis.

At all curing distances evaluated, ONEshade showed considerably stronger microhardness than OMNICHROMA, thereby rejecting the second null hypothesis.

Material type and the material-by-distance interaction had a substantial impact on the bottom-to-top hardness ratio, leading to the rejection of the third null hypothesis. However, the overall main effect of curing distance on the ratio was not statistically significant.

Conflict of interest: **NIL**

Funding: **NIL**

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