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The Effect of Light-Curing Devices and Modes on the Physical Properties of Three Universal Single-Shade Resin Composites

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Research Article

History

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ABSTRACT

Objectives: The objective of this *in vitro* study was to assess the microhardness, surface roughness, and hardness ratios of three universal single-shade resin composites using a variety of light-curing units (LCUs) and modes.

Materials and Methods: A total of 150 resin composite specimens were prepared (In each subgroup, n=10), each measuring 5 mm in diameter and with a depth of 2 mm, from three universal single-shade resin composites: Charisma Diamond One/DO, Omnichroma/OC, and Vittra APS. Two modes of a Valo cordless LCU and two modes of a Woodpecker LCU were selected to cure the resins, and an Elipar S10 LCU was used as a control. Vickers hardness measurements were taken from the samples using the HMV-G, while surface roughness was measured using the Surfest SJ301 device. Data were analyzed using Shapiro–Wilk, two-way robust ANOVA, Bonferroni tests, and Spearman's rho correlation.

Results: The highest mean microhardness was achieved on the top surfaces of the Vittra Unique resin composite using the Valo in high-power mode, with significant differences from other combinations. A statistically significant interaction was observed between resin composite types and LCUs on curing depth ($p = 0.001$), with the deepest curing found in the Omnichroma resin composite using the Valo in high-power mode. The highest surface roughness occurred with the VITTRA UNIQUE composite using the Valo in standard mode.

Conclusions: In this study's limitations, three single-shade resin composites showed favorable outcomes, with Charisma Diamond One having the highest microhardness, Omnichroma achieving the greatest curing depths, and VITTRA UNIQUE exhibiting the highest surface roughness. Valo's high-power mode, used for 4 seconds, yielded the highest hardness ratio but did not attain the highest microhardness value; this was achieved by the Elipar device. Nonetheless, Valo's high-power mode is beneficial for reducing chair time.

Keywords: Composite resins, dental curing lights, hardness tests, surface properties, dental materials

Üç Üniversal Tek Renkli Rezin Kompozitin Fiziksel Özellikleri Üzerine Işıkla Polimerizasyon Cihazları ve Modlarının Etkisi

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ÖZ

Amaç: Bu *in vitro* çalışmanın amacı, üç üniversal tek renkli rezin kompozitin mikro sertlik, yüzey pürüzlülüğü ve sertlik oranlarını farklı ışıkla polimerizasyon cihazları (LCU) ve modları kullanarak değerlendirmektir.

Gereç ve Yöntemler: Toplam 150 rezin kompozit örneği (her alt grupta n=10) hazırlandı (çap: 5 mm, derinlik: 2 mm). Kullanılan üç rezin kompozit şunlardı: Charisma Diamond One (DO), Omnichroma (OC) ve Vittra APS. Rezinlerin polimerizasyonu için Valo kablosuz LCU'nin iki modu ve Woodpecker LCU'nin iki modu seçildi; kontrol grubunda ise Elipar S10 LCU kullanıldı. Örneklerin Vickers sertlik ölçümleri HMV-G ile, yüzey pürüzlülüğü ise Surfest SJ301 cihazı ile ölçüldü. Veriler Shapiro–Wilk, iki yönlü robust ANOVA, Bonferroni testleri ve Spearman's rho korelasyonu ile analiz edildi.

Bulgular: En yüksek ortalama mikro sertlik, Vittra Unique rezin kompozitinin üst yüzeyinde Valo yüksek güç modu kullanılarak elde edildi ve diğer kombinasyonlardan anlamlı farklılık gösterdi. Rezin kompozit türleri ile LCU'lar arasında polimerizasyon derinliği açısından istatistiksel olarak anlamlı bir etkileşim gözlendi ($p = 0,001$); en derin polimerizasyon, Omnichroma rezin kompozitinde Valo yüksek güç modu ile sağlandı. En yüksek yüzey pürüzlülüğü ise Valo standart modu kullanılarak Vittra Unique kompozitinde görüldü.

Sonuçlar: Bu çalışmanın sınırları dahilinde, üç tek renkli rezin kompozit olumlu sonuçlar gösterdi: Charisma Diamond One en yüksek mikro sertliğe, Omnichroma en derin polimerizasyona, Vittra Unique ise en yüksek yüzey pürüzlülüğüne sahipti. Valo'nun yüksek güç modu (4 saniye) en yüksek sertlik oranını sağlasa da en yüksek mikro sertlik değeri Elipar cihazı ile elde edildi. Bununla birlikte, Valo'nun yüksek güç modu, tedavi süresini kısaltması açısından avantajlıdır.

Anahtar Kelimeler: Kompozit rezinler, dental polimerize edici ışıklar, sağlamlık testleri, yüzey özellikleri, dental materyaller

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Introduction

Resin composites are the preferred choice from a range of direct restorative dental materials because they improve esthetics, bond well to the tooth structure, and permit conservative dental preparation.[1] The chemical compositions and mechanical characteristics of resin composites suggest that a number of variables affect their clinical performance,[2] and single-shade universal resin composites can display a variety of mechanical and clinical characteristics due to the color-matching mechanisms in their filler structures.[3] Appropriate curing of resin composite restorations also has a significant impact on the material's physical and mechanical features and biocompatibility.[4] Quartz–tungsten halogen, plasma-arc, laser, and light-emitting diode (LED) light-curing units (LCUs) are among the technologies available,[5] with LEDs currently the most advanced for several reasons, including their long lifespan, the lack of need for filters, and their ability to be used cordlessly.[6] LED devices also produce very little heat and do not need cooling fans, which means they can be more compact and weigh less than competing technologies.[7]

Microhardness tests are useful for determining the depth of cure and the efficiency of light curing of resin composites.[8] Testing the cure depth ensures that the light-curing method used results in full curing and thus in the desired mechanical qualities and optimum conversion of unreacted monomers, which reduces both secondary caries and toxicity from unreacted compounds. Resin composite cure depths can be affected by factors such as the photoinitiator, filler type, matrix, shade and translucency, curing unit intensity, spectral output, and placement method,[9] while the resin's composite surface roughness is influenced by factors such as the material's composition, porosity, and polishing methods but primarily its physicochemical properties. Differences in hardness between the resin matrix and filler particles can also lead to variations in post-polishing removal efficiency, thereby affecting surface roughness.[10]

Appropriate polymerization by light is essential for achieving the optimum physical and clinical performance of resin composite materials, and the quantity of light energy transmitted to the top and bottom surfaces of a resin composite repair is affected by a number of factors[11,12] such as the shape and dimensions of the light guide, distance from the light guide pointer made of the resin composite, power and intensity of exposure duration, color and opaqueness of the resin composite, and variations in thickness while maintaining material composition.[11-13]

The objective of this study was therefore to assess the microhardness, surface roughness, and hardness ratios (depth of cure) of three universal single-shade resin composites polymerized with three LCUs operating in different modes under *in vitro* conditions.

The study has three null hypotheses. The first null hypothesis is that there are no differences between the microhardness values of the different universal resin composite types, light-curing modes, and surfaces. The second null hypothesis is that there are no differences between the hardness ratios (depths of cure) of the different universal resin composite types, light-curing devices, and device modes. The third null hypothesis is that there are no differences in the surface roughness of the different universal resin composite types and light-curing modes.

Materials and Methods

Calculation of Sample Size

In the study, hardness ratio is accepted as main trait. From the previous study,[14] the standard deviation for hardness ratio varies between 0.051 and 0.118. Thus, standard deviation was taken as 0.07925. For the 95% of confidence coefficient and approximately 80% power value, Type I error is 0.05 (Z value is 1.96 for the 5% types I error), the effect size was taken as 0.5. Based on this information, the minimum sample size in each group was found as 10 [$n = (1.962^2 \times 0.7925^2 / 0.5^2 \sim= 10$].

Preparation of Specimens

As the study did not involve the use of human or animal materials, obtaining ethical approval was deemed unnecessary. A total of 150 disk-shaped specimens with 5.0 mm diameter and 2.0 mm depth were prepared, with ten specimens for each of 15 combinations of resin and LCU mode. A manual caliper (Elite™ ED-200-126 Ivanson Gauge, Orchard Tower, Singapore) with a precision of ±0.1 mm was used to standardize the thickness of the samples. The composites used in the study are shown in Table 1.

Kulzer Charisma Diamond One/DO, Tokuyama Omnichroma/OC, and FGM Vittra APS were placed in plastic molds for specimen preparation. To achieve smooth polymerized surfaces, polyester matrix strips and rigid glass microscope slides of 1 mm thickness were placed on both sides of each specimen. Finger pressure was then exerted on the slides to remove any excess material followed by photopolymerization using the LCUs. The LCU devices used in the study were consistently maintained in a fully charged state. The output intensity of each LCU was monitored using a radiometer (LED Radiometer, SDI Dental Limited, Melbourne, Australia) after every ten sample preparations. In cases where a reduction in light intensity was detected, the devices were promptly recharged to ensure consistent polymerization conditions. Three devices were used:

- VALO cordless LED (Ultradent Products Inc, South Jordan, UT, USA) with two modes:
  - Standard mode: 1000 mW/cm^2 for 20 seconds
  - High-power mode: 1400 mW/cm^2 for 4 seconds
- Woodpecker DC 5.0V (Guilin Woodpecker Medical Instrument, Guilin, Guangxi, China) with two modes:
  - Turbo mode: 2300 mW/cm²–2500 mW/cm^2 for 20 seconds (screen shows PI)
  - Normal mode: 1000 mW/cm²–1200 mW/cm² for 20 seconds (screen shows P2)
- Elipar S10 (3M ESPE, St Paul, MN, USA) device with one mode:
  - 1200 mW/cm² for 20 seconds (control group)

Table 1. The manufacturer information and properties of the composite resin materials used in the study

Material	Type of composite	Type of resin matrix	Filler	Manufacturer
Omnichroma	Nanofill resin composite	TEGDMA UDMA	79% by weight (68% by volume) of spherical silicazirconia filler (mean particle size: 0.3 µm, particle size range: 0.2 to 0.6 µm) and composite filler.	Tokuyama Dental, Tokyo, Japan
Charisma Diamond One	Nanohybrid resin composite	TCD-urethaneacrylate, UDMA	filler load: 64% by weight: Ba-A-F borosilicate glass, SiO2 nanofiller, 5 nm to 20 µm (mean 0.6 µm) filler. Barium aluminum fluoride glass nanoparticles	Kulzer, Gmb Hanou, Germany
Vittra Unique	Nanohybrid resin composite	UDMA, TEGDMA	photoinitiator composition (APS), Zr, Si, and BPA-free (72–82 wt%/52–60 vol%)	FGM, Joinville, Brazil

TEGDMA: Triethylene glycol dimethacrylate
UDMA: urethane dimethacrylate
BPA: Bisphenol A

Following photo-activation, the upper surfaces of each specimen were marked, and the specimens were then placed in an incubator (Memmert UN 110, Schwabach, Germany) at 37°C in distilled water for 24 hours, providing ample time for the specimens to reach their maximum hardness. After 24 hours, the samples underwent polishing using 600, 800, 1000, and 1200 grit silicon carbide abrasive paper to simulate the finishing procedure performed in intraoral restorations.[15] Subsequently, the specimens received treatment with Sof-lex disks (3M ESPE, St. Paul, MN, USA) in medium (2382M), fine (2382F), and superfine (2382SF) grades for 30 seconds each. Polishing discs were routinely replaced after every ten samples. However, if visible signs of wear were observed prior to this interval, the discs were replaced immediately to maintain consistent polishing performance. This process involved applying moderate pressure in a single direction using a micromotor handpiece (Kavo, Biberach, Germany) at a speed of 10,000 rpm.[16]

Microhardness Test

The microhardness of the top and bottom surfaces of each specimen was measured using a Vickers hardness tester (HMV-G Micro Vickers Hardness Tester, Shimadzu Corporation, Kyoto, Japan) with a 200 g load and a 15 s dwell time. Three measurement indentations were made in different locations on each side of each specimen.

Hardness Ratio (Depth of Cure)

The hardness ratio—the depth of cure of the resin composite—was calculated by dividing the mean hardness of the bottom surface of each sample by the mean hardness of the top surface.

Roughness Measurements

The roughness of the top surface of each specimen was measured at three different locations using a Surfest SJ 301 profilometer (Mitutoyo Corporation, Japan). A 5µm tip with a 90° angle was employed for the measurement, with a standardized measurement force of 4mN. The profilometer sampling length was set at 8mm and cut-off length was at 8mm/8µm. The measuring speed was set at 0.75mm/s. The mean surface roughness (Ra) and the difference between the tallest peak and deepest valley on the surface (Rz) were recorded.

Statistical Analysis

The data were analyzed using IBM SPSS Statistics for Windows, Version 23.0. and R software. Conformity to normal distributions was evaluated using the Shapiro–Wilk test and kurtosis–skewness (±2) values. The curing depth and roughness values were not normally distributed for the resin composites and LCUs, so a two-way robust ANOVA was used from the WRS2 package in R, with the truncated mean as the method. Multiple comparisons were accounted for with a Bonferroni correction. Generalized linear models were used to compare the ratios of the normally distributed microhardness with respect to the resin composites, LCUs, and surfaces (top or bottom), with multiple comparisons accounted for with a Bonferroni correction. The relationship between the roughness and microhardness was analyzed using Spearman's rho correlation coefficient. The results are presented as the trimmed mean ± standard error or mean ± standard deviation. The significance level was $p < 0.05$.

Results

Table 2 show that the highest mean microhardness values were obtained on the top surfaces of the Vittra Unique resin composite using the Valo LCU in high-power mode, which was significantly different from all other combinations ($p < 0.001$).

Robust ANOVA test shows that there was a statistically significant interaction effect of the resin composite types and LCUs on the mean curing depth ($p < 0.001$). The largest mean curing depth was obtained with the Omnichroma resin composite using the Valo LCU in high-power mode. According to Table 3, the highest mean surface roughness value was for the Vittra Unique resin composite using the Valo LCU in standard mode, for which there was a significant interaction effect of resin composite type and LCU ($p = 0.004$).

Table 2. Descriptive statistics and multiple comparison results of microhardness values according to composite and light device

Light Device	Surface	Composite			Total
		Omnichroma	Vittra Unique	Charisma Diamond One	
Valo Standard mode	Top	61.00 ± 10.11^{ABCDE}	74.10 ± 4.36^{BFGHİ}	86.28 ± 6.34^{İJ}	73.79 ± 12.66^{AB}
	Bottom	63.30 ± 4.64^{ABCDE}	55.20 ± 4.57^{ADE}	69.90 ± 7.05^{BCDEFH}	62.80 ± 8.12^{C}
	Total	62.15 ± 7.75^{ABC}	64.65 ± 10.62^{BCD}	78.09 ± 10.64^{FG}	68.30 ± 11.91^{ab}
Valo High-power mode	Top	53.42 ± 5.31^{A}	94.75 ± 23.95^{J}	80.80 ± 4.34^{FGHİJ}	76.32 ± 22.31^{AB}
	Bottom	54.82 ± 7.53^{AD}	52.60 ± 7.59^{A}	57.10 ± 5.09^{ACDE}	54.84 ± 6.85^{D}
	Total	54.12 ± 6.38A	73.68 ± 27.69^{DEF}	68.95 ± 13.00^{CDEF}	65.58 ± 19.62^{b}
Woodpecker Turbo mode	Top	61.77 ± 8.83^{ABCDE}	70.13 ± 5.41^{BCEFGH}	85.00 ± 14.26^{GHİJ}	72.30 ± 13.85^{AE}
	Bottom	53.70 ± 1.32^{A}	60.96 ± 6.96^{ABCDE}	82.38 ± 11.19^{GHİJ}	65.68 ± 14.41^{CE}
	Total	57.74 ± 7.41^{AB}	65.55 ± 7.68^{BCD}	83.69 ± 12.55^{G}	68.99 ± 14.41^{ab}
Woodpecker Normal mode	Top	67.04 ± 8.16^{ABCDEF}	66.68 ± 5.44^{ABCDEF}	79.27 ± 14.48^{FGHİ}	71.00 ± 11.42^{AE}
	Bottom	59.74 ± 3.18^{ABCDE}	56.04 ± 3.91^{ADE}	72.12 ± 5.31^{BCFGHİ}	62.63 ± 8.10^{C}
	Total	63.39 ± 7.10^{ABC}	61.36 ± 7.15^{ABC}	75.70 ± 11.23^{EFG}	66.82 ± 10.68^{b}
Elipar	Top	72.28 ± 16.46^{BCFGHİ}	85.31 ± 17.01$^{Gİ J}$	83.54 ± 9.32^{GHİJ}	80.38 ± 15.34^{B}
	Bottom	63.56 ± 7.34^{ABCDE}	61.27 ± 5.60^{ABCDE}	70.17 ± 3.25^{BCEFGH}	65.00 ± 6.67^{CE}
	Total	67.92 ± 13.19^{CDE}	73.29 ± 17.43^{DEF}	76.86 ± 9.65^{EFG}	72.69 ± 14.06^{a}
Total	Top	63.10 ± 11.88^{A}	78.19 ± 16.82^{C}	82.98 ± 10.47^{C}	74.76 ± 15.74
	Bottom	59.02 ± 6.62^{AB}	57.21 ± 6.60^{B}	70.33 ± 10.49^{D}	62.19 ± 9.94
	Total	61.06 ± 9.78^{a}	67.70 ± 16.51^{b}	76.66 ± 12.21^{c}	68.47 ± 14.57

a-c: No difference between composites with the same letter, A-J: No difference between interactions with the same letter, mean ± s. deviation

Table 3. Descriptive statistics and multiple comparison results of Ra and Rz values according to composite and light device

		Omnichroma	Vittra Unique	Charisma Diamond One	Total
Valo Standard mode	Ra	0.575 ± 0.256^{AB}	2.485 ± 0.353^{D}	0.907 ± 0.159^{ABC}	1.261 ± 0.294^{abc}
	Rz	5.30 ± 1.55^{AB}	13.33 ± 2.57^{AB}	7.83 ± 1.10^{AB}	8.36 ± 0.98^{a}
Valo High-power mode	Ra	0.793 ± 0.075^{A}	1.333 ± 0.199^{C}	1.092 ± 0.302^{ABC}	1.059 ± 0.136^{a}
	Rz	6.89 ± 0.70^{AB}	10.87 ± 0.78^{A}	8.38 ± 1.65^{AB}	8.78 ± 0.73^{a}
Woodpecker Turbo mode	Ra	0.705 ± 0.207^{ABC}	0.487 ± 0.076^{B}	0.840 ± 0.162^{ABC}	0.649 ± 0.081^{b}
	Rz	6.15 ± 1.35^{AB}	3.21 ± 0.27^{B}	6.07 ± 0.89^{AB}	4.85 ± 0.53^{b}
Woodpecker Normal mode	Ra	0.885 ± 0.116^{AC}	1.073 ± 0.299^{ABC}	0.848 ± 0.198^{ABC}	0.924 ± 0.103^{ac}
	Rz	6.49 ± 0.73^{AB}	8.83 ± 1.66^{AB}	6.38 ± 1.17^{AB}	7.14 ± 0.77^{ab}
Elipar	Ra	0.738 ± 0.115^{AB}	0.537 ± 0.099^{AB}	0.948 ± 0.236^{ABC}	0.714 ± 0.084^{bc}
	Rz	7.26 ± 0.80^{AB}	4.83 ± 0.96^{AB}	6.70 ± 1.54^{AB}	6.19 ± 0.66^{ab}
Total	Ra	0.751 ± 0.074	0.989 ± 0.145	0.911 ± 0.089	0.867 ± 0.054
	Rz	6.55 ± 0.53	7.70 ± 0.88	7.07 ± 0.53	7.05 ± 0.36

a-b: No difference between composites with the same letter, A-B: No difference between interactions with the same letter, trimmed mean±s. error

In the Omnichroma composite, a statistically significant negative relationship was obtained between the bottom surface microhardness and Rz values in the light of woodpecker1, and the correlation coefficient was obtained as -0.64 (p = 0.046). In the Vittra Unique composite, a statistically significant negative relationship was obtained between the top surface microhardness and Ra values in the light of woodpecker1, and the correlation coefficient was obtained as -0.709 (p = 0.022). In the Vittra Unique composite, a statistically significant positive relationship was obtained between the bottom surface microhardness and Ra values in the light of woodpecker2, and the correlation coefficient was obtained as 0.673 (p = 0.033). In the Vittra Unique composite, a statistically significant positive relationship was obtained between the bottom surface microhardness and Rz values in the light of woodpecker2, and the correlation coefficient was obtained as 0.636 (p = 0.048). In Charisma Diamond One composite, a statistically significant negative relationship was obtained between the surface microhardness and Ra values in Valo 1 light, and the correlation coefficient was obtained as -0.759 (p = 0.011). No significant relationship was obtained between the variables in the other groups (p > 0.050) (Table 4).

Table 4. Investigation of the relationship between surface roughness and microhardness

Composite	Light		Top		Bottom	
			r	p	r	p
Omnichroma	Valo Standard mode	Ra	- 0.243	0.498	0.295	0.407
		Rz	- 0.237	0.510	0.234	0.515
	Valo High-power mode	Ra	0.207	0.565	0.006	0.987
		Rz	0.402	0.249	0.127	0.726
	Woodpecker Turbo mode	Ra	- 0.176	0.627	- 0.620	0.056
		Rz	- 0.207	0.567	- 0.640	**0.046**
	Woodpecker Normal mode	Ra	- 0.297	0.405	0.127	0.726
		Rz	0.309	0.385	- 0.115	0.751
	Elipar	Ra	0.146	0.688	- 0.146	0.688
		Rz	0.455	0.187	0.091	0.803
Vittra Unique	Valo Standard mode	Ra	0.571	0.085	- 0.228	0.527
		Rz	0.620	0.056	- 0.111	0.761
	Valo High-power mode	Ra	- 0.196	0.587	- 0.209	0.562
		Rz	- 0.061	0.866	0.052	0.886
	Woodpecker Turbo mode	Ra	- 0.709	**0.022**	0.367	0.297
		Rz	- 0.395	0.258	- 0.116	0.751
	Woodpecker Normal mode	Ra	0.042	0.907	0.673	**0.033**
		Rz	0.236	0.511	0.636	**0.048**
	Elipar	Ra	0.301	0.399	- 0.509	0.133
		Rz	0.394	0.260	- 0.406	0.244
Charisma Diamond One	Valo Standard mode	Ra	- 0.759	**0.011**	0.080	0.827
		Rz	- 0.361	0.306	-0.319	0.369
	Valo High-power mode	Ra	0.256	0.475	- 0.560	0.092
		Rz	0.064	0.860	- 0.333	0.347
	Woodpecker Turbo mode	Ra	0.315	0.375	- 0.018	0.960
		Rz	0.523	0.121	0.370	0.293
	Woodpecker Normal mode	Ra	- 0.178	0.623	- 0.018	0.960
		Rz	0.030	0.934	- 0.055	0.881
	Elipar	Ra	- 0.517	0.126	- 0.201	0.578
		Rz	- 0.480	0.160	- 0.036	0.920

r: Spearman's rho correlation coefficient

Discussion

The type, shape, and size of the filler have an impact on microhardness; as the filler content increases, the hardness rises.[14] And based on the results of the current study statistically significant differences were found between the mean microhardness values for the resin composite types, light cure modes, and surfaces ($p < 0.001$). Therefore the first null hypothesis of no difference in microhardness between the universal resin composites, light-curing modes, and surfaces is rejected. Also, The Valo LCU in high-power mode produced higher hardness ratios for the resins at both surfaces than its own standard mode and the Woodpecker and Elipar S10 LCUs. This suggests that the Valo LCU's high-power mode achieves greater polymerization in a shorter period. Therefore, the second null hypothesis is partially rejected. Based on the Robust ANOVA test results, it was determined that both Ra and Rz values for surface roughness demonstrated statistically significant changes in relation to the lighting device and the interaction between the lighting device and the type of universal resin composite. However, it was observed that the type of universal composite did not yield the same effect. Based on that, the third null hypothesis was also partially rejected.

During the fabrication of intraoral composite restorations, polymerization is typically performed directly from the top surface of the restoration; however, achieving uniform polymerization throughout all regions is desirable.[17] And microhardness is a useful tool for understanding the setting properties and hardness ratios of restorative materials that are based on resin.[18] Moreover, microhardness is an indirect indicator that can be used to assess the degree of conversion, and therefore, it is necessary to perform microhardness measurements on both the top and bottom surfaces of the samples.[19] In the literature, it is observed that many studies focusing on the effects of LCUs and polymerization modes on the microhardness of composite restorations have conducted separate measurements on both the top and bottom surfaces of the samples.[20-22] Researchers have reached a consensus that evaluating two distinct measurement surfaces provides a more effective method for determining the efficacy of LCUs.[17] In the present study, in line with these current findings in the literature, microhardness measurements were performed on both the top and bottom surfaces of the samples. In line with previous studies,[17] the findings of the present study also revealed that higher microhardness values were

consistently obtained on the top surfaces across all materials and all LCU modes. The higher microhardness values observed on the top surfaces can be attributed to the initial interaction of the LCU light with the top surface of the restoration, where absorption, reflection, and dispersion—collectively referred to as light attenuation—occur to a greater extent compared to the bottom surface. As noted by Rueggeberg et al.,[23] even in samples with a thickness of 2 mm, irradiance reaching the bottom surface may be reduced by approximately 75% due to light attenuation. The present study assessed the hardening that occurs in the 24 hours following the curing process. Numerous investigations have also examined microhardness after 24 hours because this duration provides adequate time for specimens to achieve maximum hardness.[24,25] Yılmaz Atalı et al.[26] used FTIR, Vickers hardness number (VHN) measurements of top and bottom surfaces, and SEM examination to evaluate the microhardness, degree of conversion, and flexural strength of seven types of single-shade universal resin composites (Kulzer Charisma Diamond One/DO, Admira Fusion xtra/AFX, Tokuyama Omnichroma/OC, OptiShade/OS, Essentia Universal/EU, Zenchroma/ZC, and FGM Vittra APS Unique/VU) and concluded that the Charisma Diamond One resin composite had the highest microhardness value. Although, in the present study, Vittra Unique exhibited high top surface microhardness values when polymerized with the Valo High Power mode (94.75) and the Elipar device (85.31), it is noteworthy that, when the single-shade composites are compared among themselves, Charisma exhibited consistently high microhardness values across multiple curing modes for the top, bottom, and total measurements. This finding is consistent with the results reported by Yılmaz Atalı et al.[26]

Gonulol et al.[27] assessed the effects of three different modes of a Valo device, using an Elipar S10 as a control. They measured the microhardness of a microhybrid resin composite (FiltekTM Z550), a giomer (Beautifil II), a compomer (Dyract eXtra), and an RMGIC (PhotacTM Fil) using a Vickers hardness tester and found that the Elipar S10 produced the highest mean VHN values on both the top and bottom surfaces.[27] Similarly, a statistically significant difference between the mean microhardness values for the LCUs due to differences between the Elipar device, the Valo device in high-power mode, and the Woodpecker device in normal mode, with the Elipar device having the highest microhardness value. There was a statistically significant difference between the mean microhardness values of the surfaces, with the mean value on the top surface being 74.76 and that on the bottom surface being 62.19. Gonulol et al.[27] similarly found higher VHNs for upper surfaces than lower surfaces.

In a study examining the impact of additional polishing and finishing sequences on the microhardness of two different composites, Omnichroma, a universal composite, was compared with Estelite Sigma Quick, a traditional composite. The study reported a significant disparity in microhardness values between the two composites.[28] In the current study, it was observed that there was a notable variance in the microhardness values measured in both the top and bottom sections. Another noteworthy finding of the present study is that, unlike the other single-shade composites, the microhardness values of the Omnichroma samples polymerized with the Valo High-Power mode were lower than those obtained with the Valo Standard mode. A similar trend was also observed in the microhardness values measured with the Woodpecker Turbo mode compared to the Woodpecker Normal mode. The prevailing consensus in the literature is that higher irradiance of light results in significantly greater hardness values compared to lower irradiance levels.[17] However, a limited number of studies have reported higher microhardness values with lower irradiance, suggesting that this outcome may be associated with the composition of the composite material.[20,21] As is well known, Omnichroma contains mequinol, a hydroquinone derivative that sets it apart from other single-shade composites. The primary role of mequinol in the composition is to stabilize the curing process of the resin and to prevent premature polymerization by acting as a polymerization inhibitor. This may have contributed to the lower microhardness values observed in the Omnichroma group despite the use of high irradiance.

Fourth, there was a statistically significant interaction effect of resin composite type, LCU, and surface on mean microhardness ($p<0.001$), with the highest value obtained on the top surface of the FGM resin composite using the Valo device in high-power mode and the lowest obtained on the bottom of the same composite, using the same device and mode. Based on these results, the null hypothesis of no difference in microhardness between the universal resin composites, light-curing modes, and surfaces is rejected.

In a recent study, the researchers assessed the impact of different finishing and polishing systems on the surface properties of universal resin composites, including Omnichroma, Charisma Diamond ONE, Vittra APS Unique, and a conventional nanocomposite. The study revealed that Omnichroma exhibited the smoothest surface, while Charisma Diamond ONE had the roughest structure.[29] Interestingly, our study did not find any statistically significant difference in Ra and Rz measurements between the universal composites, regardless of the lighting device used. This discrepancy in the results may stem from our study's assessment of the lighting device's effectiveness and its impact on surface roughness due to polymerization.

In a recent study by Takamizava et al.[30] that explored the surface characteristics and handling properties of universal resin composites, it was found that five different composites showed statistically similar surface roughness values when polymerized with the same light-curing device. However, the researchers also highlighted that when other factors, such as thermal cycling, were introduced, significant differences in surface roughness

emerged among the universal composite types. In the current study, it was observed that the type of universal composite had no effect on surface roughness, which aligns with previous findings. The changes noted after the thermal cycle represent a noteworthy discovery, shedding light on how the interplay between the lighting device and the composite can influence surface roughness at a statistical level.

Additionally, when the Rz values of the current study were examined in specific, there was no statistically significant difference between the mean Rz values of the different resin composite types (p=0.132).This is in contrast to Gurgan et al.,[31] who compared the surface roughness, microhardness, color change, and translucency of a newly marketed universal nanohybrid resin composite resin (CR) called G-aenial A'CHORD with two nanofilled CRs (Filtek and Estelite Asteria) and two nanohybrid CRs (Kulzer Charisma Diamond and Neo Spectra ST HV), concluding that the surface roughness of the Charisma Diamond One resin, which is also used in the current study, had the highest value.

In vitro studies have certain inherent limitations. The current study also has some significant limitations. For instance, the samples were not exposed to more humid environments, such as artificial saliva, to better replicate the oral environment. Additionally, no aging procedure was applied. Moreover, while measurements were taken to reflect surface characteristics, qualitative analysis-contributing scanning electron microscope evaluations were not conducted.

Conclusions

Within the limitations of this study, the three single-shade resin composites gave good results in different ways, with the Charisma Diamond One having the highest microhardness, the Omnichroma the greatest curing depths, and the Vittra Unique the highest surface roughness values. The Valo device in high-power mode for 4 seconds achieved the highest hardness ratio, but the polymerization of the restorative materials did not achieve the highest microhardness value; this was accomplished by the Elipar device. Nevertheless, this is a positive result for the Valo's high-power mode because its short curing time decreases the patient's time in the chair. The Valo device in standard mode gives the highest roughness.

Conflicts of Interest Statement

No conflicts of interest

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