Original Article

Effects of Different Light-curing Modes on the Compressive Strengths of Nanohybrid Resin-based Composites: A Comparative *In Vitro* Study

Franco Mauricio[1], Julia Medina[1], Luzmila Vilchez[1], Oscar Sotomayor[1], César Muricio-Vilchez[1], Frank Mayta-Tovalino[2]

[1]Academic Department, Faculty of Dentistry, Universidad Nacional Federico Villarreal, Lima, Peru, [2]Postgraduate Department, CHANGE Research Working Group, Faculty of Health of Sciences, Universidad Científica del Sur, Lima, Peru

Abstract

Objective: To evaluate the effects of polymerization conducted by using LED lamps of different wavelengths (polywave and monowave) on the compressive strengths of nanohybrid composite resins Filtek™ Bulk Fill - 3M and 3M™ Filtek™ Z350 XT. **Materials and Methods:** The study was prospective, experimental *in vitro*, and comparative. The sample consisted of nanohybrid composite resins. The sample size (n) was 100 specimens, divided into 10 groups. CRIS (Checklist for Reporting In-vitro Studies) Guidelines were used for writing this article. **Results:** There were statistically significant differences between all groups with $P < 0.001$. Group 2 (nanohybrid composite resin blocks 3M™ Filtek™ Z350 XT with Monowave LED lamps) showed the highest compressive strength of 238.36±34.69 N; CI (213.55–263.18) N. This was followed by Group 4 (nanohybrid composite resin blocks 3M™ Filtek™ Z350 XT with Poliwave LED lamps, High Power) and Group 6 (nanohybrid composite resin blocks 3M™ Filtek™ Z350 XT with Poliwave LED lamps, Soft Star), with compressive strengths of 222.33 ± 53.09 N, and 209.21 ± 22.52 N, respectively. **Conclusions:** Significant differences were found between the compressive strengths of 3M™ Filtek™ Z350 XT and Filtek™ Bulk Fill - 3M resins, and that of resins photopolymerized with monowave and polywave LED lamps and halogen light. Thus, the types of light and lamp directly influence the compressive strengths of the composite resins.

Keywords: *Compressive strength, dentistry, in vitro study, light-curing, nanohybrid composite*

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Introduction

There is a great demand for aesthetic dental treatments in the current times. This has motivated research on composite resins as biomaterials that can mimic the color of teeth. Composite resins have displaced amalgam restorations owing to their better cost–benefit ratio and because of the mismanagement of mercury during the disposal of amalgam residues, which results in environmental pollution and dangerous health issues.[1-4]

Several factors are necessary to achieve successful clinical performance and longevity of composite resins: adequate polymerization, particle loading in relation to quantity (percentage, volume, or by weight), volume, and shape. The aim is to ensure that the patient does not need further dental appointments due to changes in their restorations. To achieve optimal polymerization, it is necessary to activate photo-initiators in a physical or chemical way. Typically, a light source capable of activation is required.[3-5]

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Address for correspondence: Dr. Frank Mayta-Tovalino, Postgraduate Department, Faculty of Dentistry, Universidad Nacional Federico Villarreal and Universidad Científica del Sur, Av. Paseo de la República 5544, Miraflores 15074, Peru.
E-mail: fmayta@unfv.edu.pe

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Photo-initiators convert light energy into chemical energy, via formation of free radicals that break the carbon–carbon double bonds of the monomers, allowing the reaction to form single covalently bound polymers. Fillers must be prepared with resin aggregates not larger than 2mm to ensure adequate homogeneity and to reduce shrinkage.[5-7]

Fast light sources with different wavelengths are currently being developed in conjunction with the development of polymer technologies. Therefore, it is important to know the characteristics of the equipment (light source) and the properties that can be achieved by using the equipment with different resins, using a criterion based on scientific evidence.[7-14] In particular, resistance to compression is very important because this is the main type of loading that occurs during chewing.

The objective of this research was to evaluate the effects of polymerization by using LED lamps of different wavelengths (polywave and monowave) and halogen lamps on the compressive strengths of nanohybrid composite resins Filtek™ Bulk Fill - 3M and 3M™ Filtek™ Z350 XT.

Materials and Methods

Study design and participants

The study was prospective, experimental *in vitro*, and comparative. The universe comprised nanohybrid composite resins of the type Filtek™ Bulk Fill - 3M and 3M™ Filtek™ Z350 XT. The sample size was calculated by the mean comparison formula using the statistical program Stata® 15. The sample size (*n*) was 100 specimens, divided into 10 groups. The experimental work was conducted at the Laboratory for the mechanical testing of materials, High Technology Laboratory Certificate (HTL), Lima-Peru. Finally, CRIS Guidelines (Checklist for Reporting In-vitro Studies) were used for writing this article.[11]

Inclusion and exclusion criteria

Inclusion criteria

- Final restorative nanohybrid composite resins that are within the expiration date
- Composite resins Filtek™ Bulk Fill - 3M and 3M™ Filtek™ Z350 XT
- Specimens with a diameter of 5.00 mm and a height of 15.63 mm
- Specimens without structural defects such as bubbles or cracks

Exclusion criteria

- Fluid composite resins
- Self-curing composite resins
- Presence of bubbles or cracks

Allocation

The following groups were formed:

Group 1: Nanohybrid composite resin blocks Filtek™ Bulk Fill - 3M + LED Monowave lamps
Group 2: Nanohybrid composite resin blocks 3M™ Filtek™ Z350 XT + LED Monowave lamps
Group 3: Nanohybrid resin composite blocks Filtek™ Bulk Fill - 3M + Poliwave LED lamps (High Power)
Group 4: Nanohybrid composite resin blocks 3M™ Filtek™ Z350 XT + Poliwave LED lamps (High Power)
Group 5: Nanohybrid composite resin blocks Filtek™ Bulk Fill - 3M + Poliwave LED lamps (Soft Star)
Group 6: Nanohybrid composite resin blocks 3M™ Filtek™ Z350 XT + Poliwave LED lamps (Soft Star)
Group 7: 10 Nanohybrid composite resin probes Filtek™ Bulk Fill - 3M + Poliwave LED lamps (Low Power)
Group 8: Nanohybrid composite resin blocks 3M™ Filtek™ Z350 XT + Poliwave LED lamps (Low Power)
Group 9: Nanohybrid composite resin blocks Filtek™ Bulk Fill - 3M + halogen light lamps
Group 10: Nanohybrid composite resin blocks 3M™ Filtek™ Z350 XT + halogen light lamps

Preparation of specimens

For the preparation of the composite resin blocks, the resins Filtek™ Bulk Fill - 3M and 3M™ Filtek™ Z350 XT [Figure 1], with expiration dates in 2021, were used. A specifically designed acrylic matrix with a cylindrical hole diameter 5.0 mm and length 15.63 mm was used to cast the resin blocks,. Measurements were verified with a 200 mm digital Vernier caliper from Mitutoyo. The resin was loaded into the hole in the matrix with a metallic spatula. Pressure was applied through the matrix to a glass plate with dimensions of 10 cm × 10 cm [Figure 2]. This ensured the presence of flat and parallel surfaces on the resin blocks. In this manner, 100 resin blocks were made. The blocks were then separated into

Figure 1: Composite resins

the different groups for polymerization with different lamps and with different intensities [Figure 3].

Polymerization

Nanohybrid composite resin blocks, Filtek ™ Bulk Fill - 3M and 3M ™ Filtek ™ Z350 XT, were photopolymerized in an environment with natural lighting. The specimens (5.00 × 15.63 mm) were photopolymerized for 20 s at 1 cm. Groups 1 and 2 were photopolymerized at 430–490 nm, with a power of 800 mw/mm^2, from the light source. Groups 3 and 4 were photopolymerized at 385–515 nm, with a power of 1200 mw/mm^2; groups 5 and 6 were photopolymerized at 385–515 nm, with a power of 1200 mw/mm^2; and groups 7 and 8 were photopolymerized at 385–515 nm, with a power of 650 mw/mm^2. Finally, control groups 9 and 10 were light-cured with the Halogen Newsletter 2000(C) lamp with a power of 800 mw/mm^2.

Figure 2: Matrix used for making the samples

Figure 3: Specimen blocks

Compression tests

Compression tests of the composite resin specimens were carried out at the HIG Technology Laboratory Certificate SAC. The specimen matrix had a diameter of 5 mm and a height of 15.63 mm. It was calibrated with a caliper (200 mm digital Vernier, Mitutoyo) with an accuracy of 0.01 mm. The length and diameter of the specimens were 15.63 mm and 5.00 mm, respectively [Figure 4]. The test specimens were stored in distilled water at 37°C in an oven for 48 h. The compressive strength tests were performed by using a CMT-5L Universal Digital Testing Machine from LG.

Statistical analysis

The data obtained from the measurements (mean, standard deviation, median, minimum, and maximum) were tabulated, and the compressive strength of each resin was evaluated. To compare the compressive strengths between the groups, ANOVA was used because the data had normal distributions, with a significance level of 0.05. All analyses were performed by using Stata 15 software (Texas, USA).

Results

The comparative analysis of the compressive strengths of the composite resins polymerized with different polymerization lamps showed that there were statistically significant differences between all the groups evaluated ($P < 0.001$). Group 2 showed the highest compressive

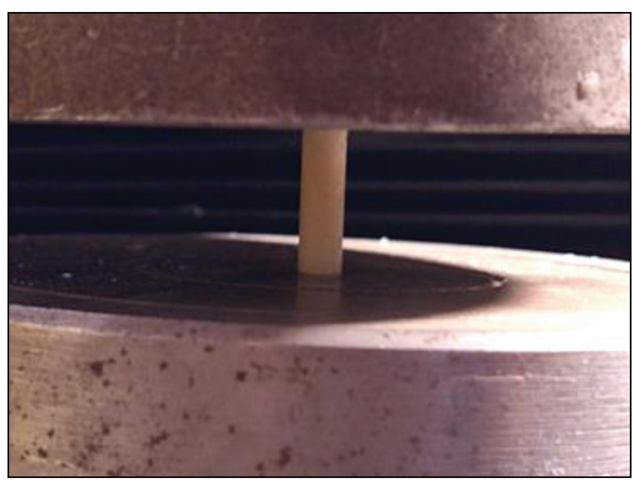


Figure 4: Compressive strength test

strength of 238.36 ± 34.69N, CI (213.55–263-18)N. Group 3 showed the lowest compression strength of 97.71 ± 22.95N [Table 1, Graph 1], followed by Groups 4 and 6, which had compressive strengths of 222.33 ± 53.09 and 209.21 ± 22.52N, respectively [Table 2].

Discussion

The resin composite 3M™ Filtek™ Z350 XT polymerized with an LED monowave lamp had a higher average compressive strength (238.36 ± 34.69) than the nanohybrid composite resin Filtek™ Bulk Fill - 3M, which was polymerized with the same lamp. The 3M™ Filtek™ Z350 XT resin polymerized with a Poliwave LED lamp (high power) presented a higher average compressive strength (222.33 ± 53.09 N). The lowest average compressive strength was obtained by using the Filtek™ Bulk Fill - 3M resin and a Poliwave LED lamp (high power) (97.71 ± 22.95). The highest average compressive strengths were obtained with the 3M™ Filtek™ Z350 XT resins polymerized with Poliwave High Power, Soft Star, and Low-Power LED lamps.

The study by Nassar *et al.*[12] examined the irradiation values of commonly available light sources. They investigated the in vitro irradiation output of 10 brands of LCDs available in Saudi Arabia, with a digital radiometer, and concluded that all the LCD polymerization devices tested had sufficient irradiation values for proper polymerization of composite resins. Further, Besegato *et al.*[13] investigated the effect of two light-curing protocols on the mechanical behavior of three composite resins, based on their optical properties. They used 4-mm-thick specimens of Opus Bulk Fill, Tetric N-Ceram, and Filtek Bulk Fill Flow resins, and they subjected them to two photopolymerization protocols. They concluded that the light-curing protocol with lower irradiation and longer exposure time resulted in lower polymerization shrinkage and higher hardness. This is consistent with our results, wherein the effect of light (intensity) on the specimen disks (1 mm in thickness, 6 mm in diameter) was investigated at distances of 0, 2, 4, 6, 8, and 10 mm from the light tip with two Elipar S10 (3M-ESPE) and Silverlight (GC) light-curing units. Increasing the distance between the light-curing tip and the surface of the material reduced the extent of absolute irradiation underneath the material.

The study conducted by AlShaafi *et al.*[15] identified the effects of composite resin polymerization and the different process factors that lead to a proper cure. They reviewed 10 factors and defined recommendations to improve the polymerization process. These factors included the duration of light-curing, incremental thickness, light unit system used, diameter of the cavity, location of the cavity, distance from the light curing tip, and temperature of the oral cavity. They concluded that these factors should be considered, in addition to the type of halogen light. Zorzin *et al.*[16] evaluated the polymerization properties of composite resins by using

Table 1: Compressive strength of polymerized composite resins with different lamps and wavelengths

Groups	Mean	SD	Median	Min	Max
1	126.34	34.82	115.20	81.39	180.39
2	238.36	34.69	240.82	186.63	282.94
3	97.71	22.95	91.92	69.70	137.20
4	222.33	53.09	237.11	141.54	283.74
5	101.43	23.12	98.53	62.70	132.99
6	209.21	22.52	213.59	156.88	230.03
7	105.60	29.49	104.63	66.28	159.36
8	215.76	49.11	207.45	151.48	281.35
9	150.52	22.33	146.78	117.55	198.44
10	206.96	47.27	194.11	131.47	277.01

All values are expressed in Newtons (N)

Group 1: Nanohybrid composite resin blocks Filtek™ Bulk Fill - 3M + LED Monowave lamps.

Group 2: Nanohybrid composite resin blocks 3M™ Filtek™ Z350 XT + LED Monowave lamps.

Group 3: Nanohybrid composite resin blocks Filtek™ Bulk Fill - 3M + Poliwave (High Power) LED lamps

Group 4: Nanohybrid composite resin blocks 3M™ Filtek™ Z350 XT + Poliwave LED lamps (High Power)

Group 5: Nanohybrid composite resin blocks Filtek™ Bulk Fill - 3M + Poliwave LED lamps (Soft Star)

Group 6: Nanohybrid composite resin blocks 3M™ Filtek™ Z350 XT + Poliwave LED lamps (Sof Star)

Group 7: 10 Nanohybrid composite resin probes Filtek™ Bulk Fill - 3M + Poliwave LED lamps (Low Power)

Group 8: Nanohybrid composite resin blocks 3M™ Filtek™ Z350 XT + Poliwave LED lamps (Low Power)

Group 9: Nanohybrid composite resin blocks Filtek™ Bulk Fill - 3M + halogen light lamps

Group 10: Nanohybrid composite resin blocks 3M™ Filtek™ Z350 XT + halogen light lamps

Table 2: Comparison of the compressive strength of polymerized resins with different polymerization lamps

Groups	Mean	SD	CI 95%	*P**	*P***
1	126.34	34.82	101.43, 151.25	>0.05	
2	238.36	34.69	213.55, 263.18	>0.05	
3	97.71	22.95	81.29, 114.12	>0.05	0.000
4	222.33	53.09	184.35, 260.31	>0.05	
5	101.43	23.12	84.90, 117.97	>0.05	
6	209.21	22.52	193.10, 225.32	>0.05	
7	105.60	29.49	84.50, 126.70	>0.05	
8	215.76	49.11	180.62, 250.89	>0.05	

All values are expressed in Newtons (N)

Group 1: Nanohybrid composite resin blocks Filtek™ Bulk Fill - 3M + LED Monowave lamps.

Group 2: Nanohybrid composite resin blocks 3M™ Filtek™ Z350 XT + LED Monowave lamps.

Group 3: Nanohybrid composite resin blocks Filtek™ Bulk Fill - 3M + Poliwave (High Power) LED lamps

Group 4: Nanohybrid composite resin blocks 3M™ Filtek™ Z350 XT + Poliwave LED lamps (High Power)

Group 5: Nanohybrid composite resin blocks Filtek™ Bulk Fill - 3M + Poliwave LED lamps (Soft Star)

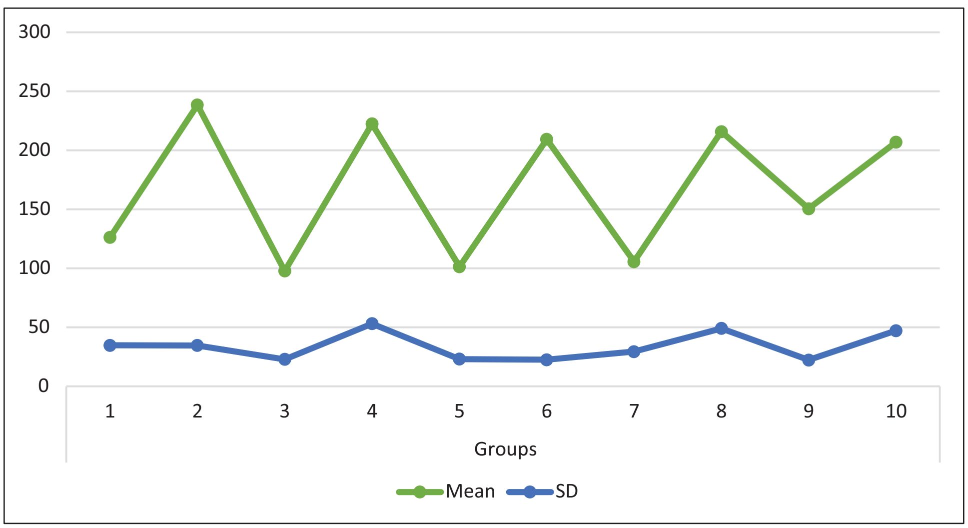
Group 6: Nanohybrid composite resin blocks 3M™ Filtek™ Z350 XT + Poliwave LED lamps (Sof Star)

Group 7: 10 Nanohybrid composite resin probes Filtek™ Bulk Fill - 3M + Poliwave LED lamps (Low Power)

Group 8: Nanohybrid composite resin blocks 3M™ Filtek™ Z350 XT + Poliwave LED lamps (Low Power)

*Shapiro-Wilk test

**ANOVA test



Graph 1: Evaluation of the compressive strengths of polymerized composite resins prepared with different light sources

two different light-curing protocols to measure the degree of conversion, Vickers hardness, polymerization volume shrinkage, and polymerization shrinkage stress. All the composite resins obtained sufficient curing properties at a depth of 4 mm. It was concluded that longer curing times resulted in improved curing properties of the composite resins.

Practitioners should be aware that longer curing times may be necessary to achieve optimal curing characteristics for composite resins. Increased exposure time should be considered with regard to combinations of different times and light types; however, there is a theoretical limit to radiation exposure. Therefore, the law of reciprocal exposure should be used with care, as irradiation and exposure time can independently affect composite resins.[17-19]

This study has significance at social, scientific, and practical clinical levels. At a social level, it is expected that the use of LED lamps with different wavelengths has a significant impact on the polymerization processes. Optimized polymerization will cause less contamination of the material, which will, in turn, lead to reduced infiltration. In this way, the need to achieve an adequate restoration, both functional and aesthetic, will be met for the benefit of the patients. At a scientific level, our study increases knowledge about the compatibility of different light sources with resins using different photo-initiators. This will allow dental surgeons to achieve adequate polymerization and thus create restorations with greater longevity.

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None to declare.

Conflicts of interest

There are no conflicts of interest.

Author contributions

Study conception (FM, JM, LV), data collection (FM, CMV, JM), data acquisition and analysis (FM, OS, FMT), data interpretation (FMT, FM, JM, LV), and article writing (FM, CMV, FMT, JM, OS, LV).

Ethical policy and institutional review board statement

This study used inert dental materials for which it was exempted from review by the ethics committee, since it was clearly an experimental *in vitro* study.

Patient declaration of consent

Not applicable.

Data availability statement

The data that support the study results are available from the author (Dr. Franco Mauricio, e-mail: fmauricio@unfv.edu.pe) on request.

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