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Effect Of Different Light Curing Strategies On Compressive Strength Of Bulk-Fill Composite Resin- An In-Vitro Experimental Study

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Abstract:

Background

The incremental layering procedure, which involves the deposition of composite resins in increments of thickness not exceeding 2mm, is one such protocol recommended to combat polymerization shrinkage. Another strategy apart from the incremental layering technique is by varying the light intensity which is used to cure the resin such as step cure polymerization, pulse delay curing, and ramp curing by allowing some time for the release of stresses associated with Polymerization when compared to the classic and recommended uniform continuous curing technique. So, it might be logical to assume that by controlling polymerization shrinkage we can also improve the mechanical properties of composites.

Objective:

The objective of the study is to compare the compressive strength of bulk-fill composite in Megapascals using different light cure strategies such as Uniform continuous cure, Step cure, Ramp cure, and Pulse delay cure.

Materials and methodology:

In this Invitro study, 160 bulk-fill composite samples were fabricated and they were randomly divided into 4 groups with each group containing 40 samples Each sample was cured with different light-curing strategies. GROUP 1-Uniform continuous cure, GROUP 2- Step cure, GROUP 3- Pulse delay cure, GROUP 4- Ramp cure. Universal testing machine at a crosshead speed of 0.5 cm/min was used to measure the compressive strength.

Results :

The order of compressive strength reported was as follows (Based on p-value)GROUP 1> GROUP 2 = GROUP 3> GROUP 4

Conclusion:

Bulkfill composite cured by uniform continuous cure showed the highest Compressive strength value. The ramp cure method showed the lowest compressive strength value among all the samples tested. In all of the test results, there were no discernible differences between step cure and pulse delay cure.

Keywords: Polymerization shrinkage, Uniform continuous cure, Step cure, Ramp cure, Pulse delay cure

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1. Introduction

In dentistry, a synthetic resin called dental composite is utilized to create restorations that blend in with natural teeth.[1] Because of their high aesthetic and functional standards, resin-based composites are widely used in dentistry.[2] When first introduced, composite materials were not nearly as versatile as amalgam. The use of amalgam has been widely successful over the years, but some patients refuse to have it because of concerns about their health and appearance. Early composite materials could only be utilized to restore the front teeth due to their weak mechanical characteristics. As a result of polymerization shrinkage, these composites are brittle, easily crack, and leak after being worn down even a little.[3]

Composite resin suffers from polymerization shrinkage, a reduction in volume that occurs during the curing process.[4] This shrinkage is thought to be the primary barrier to achieving the lifespan of composite restorations because it causes stresses at the resin tooth interface, micro gap creation, secondary caries, and post-operative sensitivity.[5]

With developments in material science and the use of various clinical protocols and techniques, the shrinking can be managed to an extent. One such protocol suggested is the incremental layering technique which is widely regarded as a golden standard for the placement of resin-based composite (RBC) restorations, which involves the placement of composite resins in increments of thickness not exceeding 2mm.[6] This method is time-consuming and inconvenient when dealing with large cavities that need to be filled. To speed up the process of placing traditional resin composite restorations, dentists developed bulk-fill composites with altered physical and mechanical properties. It is claimed that this material has better characteristics than regular resin-based composite and may be placed in increments as thick as 4 mm .[7] Studies have shown that compared to traditional composite, bulk fill composite ensured better polymerization shrinkage and reduced cuspal deflection.[8]

Changing the light intensity used to cure the resin using techniques like step cure polymerization, pulse delay curing, and ramp curing is another method used to combat polymerization shrinkage in addition to incremental layering. That differs from the standard and recommended uniform continuous curing method by giving time for the release of stresses involved with Polymerization. In the uniform continuous curing method, the light of consistent intensity is used during the whole curing procedure.[8]

2. Materials And Methods

Ivoclar Vivadent tetric n-Ceram bulk fill composite (Shade A2) was used in this study. Cylindrical molds (4mm thick, 7mm in diameter) were used to create the specimens. To prevent buckling during compressive strength testing, the specimen's diameter was made slightly larger than its thickness. The sizes of the specimens were estimated using data from an experiment by Aleem H et al published in 2018.[9] Plastic straws cut into this size are used as molds. There were a total of 160 samples used in this investigation. Traditional (continuous), stepped (two stages), ramped (exponential), and pulse delay light curing were all tested with 40 samples each. Mold interiors coated with petroleum jelly. The cylindrical mold was set down on a cellulose acetate mylar strip lying on a slab of transparent glass. The entire setup was set down on a dark, non-reflective surface. Instruments designed specifically for composite filling were used to compact bulk-fill composite material into molds. With a Mylar strip, the final composite increment was protected. The composites were then pressed into the mold and the excess material was expelled by placing a glass slab on top of them and applying pressure. The excess flash was removed by pressing the Mylar strip matrix on the top surface of the material and cured using an LED cure unit with different light-curing strategies.

3. Curing the bulk-fill composite specimens

Ivoclar Bluephase N MC (100-240V) and Edge Endo LED Polymerization Curing Lights were employed for the light cure throughout this work. One of the many features of the Edge Endo LED curing light is the ability to use the stepped approach. The Ivoclar Bluephase system also provides ramping and homogeneous continuous curing options. Edge Endo Led polymerization light was used in a step-and-pulse delay curing process. Bluephase N was used to cure the material in a uniform and ramped fashion. After polymerizing each specimen, the LED curing lights were returned to their battery charger and recharged in accordance with the manufacturer's instructions. Using a stainless-steel dental gauge caliper (RENFERT 1119), the curing distance of each specimen was measured after curing to ensure conformity with the standard. The curing tip's angle was parallel to the surface being treated. Samples are randomly grouped into

GROUP 1-Uniform continuous cure
GROUP 2- Step cure

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GROUP 3- Pulse delay cure
GROUP 4- Ramp cure, of 40 samples each

In the **Uniform continuous cure** technique, the intensity was kept continuous at 600mW/cm2 for a constant and continuous period of 40sec
In the **Step curing technique,** light intensity is applied in two stages, being first at a low light intensity and finishing at a high light intensity. The value of this intensity was 200mW/cm2 for 10sec and 600mW/cm2 for 20secs respectively.

In **Ramped technique** light intensity was applied exponentially, reaching 1000mW/cm2 during 10s initially, followed by an additional 10sec at this intensity.

In the **Pulse delay curing technique,** the intensity was applied at 200mW/cm^2 for 5sec, followed by a time interval of 3min and final light curing at 600mW/cm^2 for 30sec.

The intensity was checked after every 10 specimens throughout the study for repeatability and reliability with the help of an LED Light Meter Cure Power Curing Tester (Woodpecker). After curing, the plastic straw molds were longitudinally sectioned throughout the specimens with coarse black Super-snap disks (Shofu). Final finishing and polishing were done with Shofus Supersnap violet (Finishing) and Supersnap green (polishing) disks. Dimensions of the specimen were conformed with a stainless steel dental gauge caliper (Renfert 1119). The samples were immediately transferred to closed boxes to prevent additional contact with light.The specimens' compressive strength was evaluated after being stored for 48 hours. Compressive strength was measured using universal testing equipment (SHIMADZU, JAPAN) with a crosshead speed of 0.5 cm/min.

4. Results

Data were analyzed using the SPSS 26.0 statistical package (SPSS Inc., Chicago, IL) and the significance level was set at $p<0.05$.The normality of the data was assessed using the Shapiro-Wilkinson test. Statistical analysis of mean compressive strength was done using One Way ANOVA and reported a significant difference on an overall basis ($p<0.05$) and the post hoc test reported a significant difference between all the pair groups ($p<0.05$) except STEP CURE vs PULSE DELAY ($p>0.05$). There were statistically significant differences (ANOVA $p<0.05$) between the mean values with the Uniform continuous cure showing higher compressive strength values and the ramp cure strategy showing the lowest values. However, there was no significant difference between the Step cure strategy and the pulse delay cure strategy ($p>0.05$). The order of compressive strength reported was as follows (Based on p-value) GROUP A> GROUP B= GROUP C> GROUP D

Table 1- Descriptive Data

	Uniform continuous cure	Step cure	Pulse delay	Ramp cure
MEAN	**304.21**	**299.7136**	**298.567**	**282.8603**
SD	**4.02**	**3.120483**	**2.929571**	**4.289982**
MIN	**298.56**	**292.316**	**291.116**	**272.457**
MAX	**312.25**	**307.168**	**306.816**	**290.618**
STD ERROR	**0.10**	**0.07**	**0.07**	**0.10725**

Table 2- Analysis Of Compressive Strength

	Material	MEAN	SIDE
COMPRESSSIVE STRENGTH	**Uniform continuous cure (A)**	**304.21**	**4.02**
	Step cure (B)	**299.71**	**3.12**
	Pulse delay (C)	**298.56**	**2.92**

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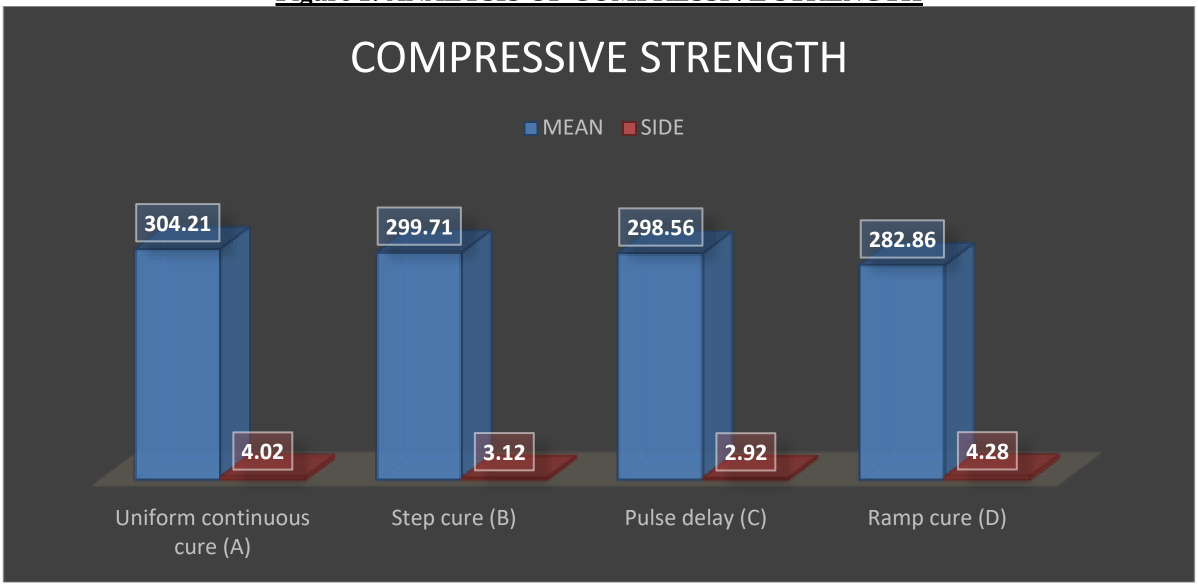
	Ramp cure (D)	**282.86**	**4.28**
P VALUE (ONE WAY ANOVA TEST)		**0.0001* (F=262.86)**	
P VALUE(TUKEY'S HSD TEST)	**A vs B**	**0.0001***	
	A vs C	**0.0001***	
	A vs D	**0.0001***	
	B vs C	**0.15**	
	B vs D	**0.0001***	
	C vs D	**0.0001***	

***P <0.05 IS STATISTICALLY SIGNIFICANT**

Figure 1: ANALYSIS OF COMPRESSIVE STRENGTH



5. Discussion

The traditional technique of composite restoration is time-consuming. The composite was placed in layers of 2mm and each layer has to be cured before placing the next one. This is done because the curing light cannot penetrate beyond that and also, curing in increments reduces the overall polymerization shrinkage.[10] Apart from being time-consuming, if it is not carried out effectively, for example, if we increase the thickness of the layer unknowingly, the resin at the base of the layer may remain uncured or partially cured. This will prevent the restoration from being adequately sealed, leading to post-operative sensitivity and premature restoration failure.[11]

The matrix composition, filler content, and polymerization settings are the main factors that affect how well resin composites polymerize.[12] In these composites, to control the polymerization shrinkage, some modifiers are added which are supposed to regulate the polymerization reaction and, in this way, reduce shrinkage stress. For example, some manufacturers use additional fragmentation monomers, what it does is during polymerization, the central group can fragment to release stress. The fragments can then repolymerise later when there is lower stress.[13] The other component which is added to reduce the polymerization shrinkage is aromatic urethane dimethacrylate. Traditional dimethacrylate monomers are smaller in size, this one is larger than the monomer in traditional dimethacrylate, so it limits the number of shrinkage zones. This aids in minimizing the effects of stress and shrinkage during polymerization.[14] The specific fillers with a low elastic modulus are another option. This makes it possible for them to handle the stress of polymerization. The resin composite absorbs and scatters light when exposed to light. As the depth grows, the light's intensity attenuates and its effectiveness decreases.

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Several bulk-fill composite resins now feature fillers with increased dimensions. Generally speaking, when the filler size is 20 microns or more, the filler-matrix interaction is reduced. Therefore, bulk-fill composite resins with a tiny matrix filler interface increase the depth of penetration of blue light. More light can penetrate the resin and activate the photoinitiator if the filler quantity is decreased and the filler size is increased.[15] This ability to allow light to pass through is known as translucency. So, this material has high translucency. This is the reason we can cure the material in bulk. Some manufacturers use additional photoinitiators. For example, a powerful reactive photoinitiator called Ivocerin is used in some materials. Compared to other photoinitiators, such as camphor quinone, this one enables the material to polymerize in bigger increments.[16]

The curing light is absorbed by photoinitiators, which then use that energy to kick off a chemical reaction. When energy is absorbed and used to excite molecules, free radicals are produced, which in turn initiates the polymerization process (in the presence of one or more activators).Unless the material is exceptionally translucent or contains only a small number of light-reflecting additives, it can be difficult to appropriately polymerize thick increments. [17]

Compressive strength is the appropriate metric to use for assessing materials that are often brittle and weak in tension. The restorative materials must be strong enough to withstand occlusal forces.[18] Both the photoinitiator and the composite resin need to be exposed to sufficient energy at the appropriate wavelength for polymerization to occur.[19] Restorative material polymerization is highly sensitive to the intensity and duration of irradiation from light-curing units (LCUs).[20]

For uniform traditional continuous curing, the composite resin is exposed to a constant light source of a predetermined intensity for a predetermined duration of time. Step curing involves initially curing the composite at a low energy level, and then curing it at a higher energy level for a predetermined amount of time. There is less polymerization stress now that the composite is flowing in a gel condition". Ramp cure technology starts at a lower power density during polymerization and gradually increases it during the curing phase to maximize marginal adaptability.[21] Short, intense bursts of energy (1000-2800 mW/cm2) are used in the high-energy pulse cure method, which is three to six times as powerful as conventional curing methods. In the pulse delay approach, a brief exposure step is followed by a period of no exposure. The last stage of curing is then completed. By extending the pre-gel phase's duration, this approach seeks to lessen the shrinking stress. Because of this, the substance keeps its flexibility for a long time before curing.[22,23]

In the current study, the compressive strength of the traditional continuous cured bulk-fill composite samples was higher compared to other light cure methods like step cure, ramp cure, and pulse delay cure. This can be explained by the duration of light intensity in composite resin, which has a direct impact on final polymerization & then on the mechanical properties.

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