Effect of monowave and polywave light curing on the degree of conversion and microhardness of composites with different photoinitiators: An in vitro study

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Abstract

Aim: The purpose of this study was to evaluate the effect of light-curing units (LCUs) on the degree of conversion (DC) and microhardness of composites with varying photoinitiator systems.

Materials and Methodology: Two groups were formed based on LCU – monowave (Group M) and polywave (Group P). Each group was further divided into two subgroups based on photoinitiator systems – combination of camphorquinone (CQ), Ivocerin, and 2,4,6-trimethylbenzoyl diphenylphosphine oxide (Subgroup CIT) and only CQ (Subgroup C) in the composite. Samples prepared were 4 mm thick. Microhardness was measured at bottom surface by Vickers hardness tester, and DC was evaluated by Fourier transformation infrared spectroscopy.

Statistical Analysis: Kolmogorov–Smirnov test was used.

Results: Both the mean microhardness and DC of composite in subgroup C were similar (P > 0.05) in Group M (52.42 ± 2.67 and 48.30 ± 5.81) and Group P (51.77 ± 1.96 and 48.50 ± 4.87). The mean microhardness of composite containing a combination of photoinitiators was more in Group P (57.09 ± 2.61) as compared to Group M (47.37 ± 3.51). The mean DC was higher in Group P (59.75 ± 5.30) as compared to Group M (39.70 ± 3.57), and these differences were statistically significant (P < 0.05).

Conclusion: The type of LCU affects DC and microhardness only in the case of composites containing a combination of photoinitiators.

Keywords: Bulk fill; camphorquinone; degree of conversion; Ivocerin; microhardness; photoinitiators

INTRODUCTION

Dental composites are being increasingly used these days. However, conventional composites require significant chairside time and have high polymerization shrinkage. To overcome this, bulk-fill composites were introduced which have the advantage of having low polymerization shrinkage and less chairside time.

Polymerization of composites occurs by free-radical polymerization. These free radicals are produced by photoinitiators present in composites. The most commonly used photoinitiator is camphorquinone (CQ). It is a bright yellow Type II photoinitiator that absorbs
light in the spectrum of 430–480 nm. However, CQ has the disadvantages of being toxic and yellow in color. Hence, other photoinitiators were considered such as Ivocerin (390–445 nm), 2,4,6-trimethylbenzoyl diphenylphosphine oxide (TPO) (380–425 nm), bisacylphosphine oxide (BAPO) (380–450 nm), and monoacylphosphine oxide (MAPO) (380–450 nm). They have higher photopolymerization reactivity because of higher molar extinction coefficient.[1]

Monowave light-emitting diode (LED) light-curing units (LCUs) are commonly used for curing composites. The output wavelength of these LCUs is generally in the visible range of 445 nm to 480 nm which is sufficient to activate the commonly used photoactivator – CQ. However, at these wavelengths, photoinitiators such as TPO, BAPO, MAPO, and Ivocerin are not efficiently activated resulting in a lower degree of conversion (DC).[2] To efficiently cure a wide range of composites with alternative photoinitiators, manufacturers have introduced polywave LCU. These polywave LCUs have LED chips that emit light in the broader range of 380–550 nm, allowing different photoinitiators to be more efficiently activated.[3]

For a successful resin-based composite (RBC) restoration, an adequately polymerized resin is considered to be the main criterion and this is achieved mainly by having a proper DC.[4] During polymerization, ideally, all of the monomers should be converted to polymers. However, all the composites exhibit considerable residual monomer in the final product, with a DC ranging from 55% to 75%.[5] This is due to the occurrence of gel effect, which reduces the diffusion rate of the components of the organic mixture and blocks the polymeric network preventing their total conversion.[6]

Another mechanical test which influences the physical properties of composite restoration is microhardness. It is generally correlated with mechanical strength, rigidity, and resistance to intraoral softening.[7]

Hence, the purpose of this study was to assess the effect of different LCUs on DC and microhardness of composites having different photoinitiator systems.

The null hypothesis tested was that there is no difference in DC and microhardness of bulk-fill composites containing different photoinitiators when cured with monowave or polywave LCU.

**MATERIALS AND METHODOLOGY**

The sample size calculated was 20 using the standard deviation (SD) value of 0.99 from a study.[8]

The formula was:

\[ N = (SD \times \frac{Z}{P} \text{ value}) \]

- S.D – Standard deviation taken from the study
- Z – Value from the table of probabilities of the standard normal distribution for the desired confidence level
- P value – Measure of the probability that an observed difference could have occurred just by random chance and was kept as 0.05 to get a statistically significant result.

**GROUP DIVISION [Figure 1]**

**Microhardness testing**

**Sample preparation**

Teflon ring molds of 4-mm internal diameter and height were prepared after sectioning two long hollow black
Teflon tubings. Rings were stabilized on a Mylar strip and placed on a black-coated glass slab.

**Group M**
The curing light used to polymerize the sample was monowave LED.

**Subgroup C**
Samples were prepared by filling the molds with composite having photoinitiator CQ using the composite filling instrument and leveled at the top using Mylar matrix. A glass slide was placed over it, and finger pressure was applied to achieve a flat and smooth surface. Curing was done for 10 s as recommended by the manufacturers. After every 3rd sample, the intensity of the LCU was checked by intensitometer to maintain appropriate intensity. Samples were later stored in dark air-tight containers at 37°C for 24 h.

**Subgroup CIT**
Samples were prepared similarly as mentioned for Subgroup C except the composite used contained a combination of photoinitiators.

**Group P**
The curing light used to polymerize the sample was polywave LED.

**Subgroup C**
Samples were prepared similarly to Group M Subgroup C except the LCU used was polywave.

**Subgroup CIT**
The whole procedure was carried out similar to Group M Subgroup CIT except that polywave LCU was used.

**Analysis**

**Microhardness**
Samples were polished with 600–1200 grit silicon carbide abrasive paper under water coolant. Measurements of the Vickers microhardness were carried out at bottom of the cured samples using a Digital Vickers Diamond Microhardness Tester. Each specimen was subjected to three indentations under 200-g load with a dwell time of 30 s at randomly selected locations, and the average of these three measurements was calculated as Vickers hardness number.

**Degree of conversion**
DC was evaluated using Fourier transform infrared (FTIR) spectrophotometer with attenuated total reflectance (ATR) accessory unit. Samples were analyzed in absorbance mode with a scanning range of 450–4000 cm⁻¹ at a resolution of 4 cm⁻¹ s⁻¹ and 16 scans. After background scanning, for obtaining spectra of uncured composite, the composite material was directly placed on ATR crystal and absorbance intensities were recorded at 1608 cm⁻¹ and 1638 cm⁻¹.

For obtaining spectra of cured samples, samples were prepared and stored similarly to that done for microhardness analysis. Each sample was finely pulverized using mortar and pestle and was subjected to FTIR spectrophotometry and spectra were obtained at 1608 cm⁻¹ and 1638 cm⁻¹.

DC was calculated by a formula given below:

\[ DC\% = 1 - \frac{A_{1638}}{A_{1608}} \]

\[ A_{1638} / A_{1608} \text{ uncured} \]

A – Absorbance intensity at respective wavenumber.

**RESULTS**

The DC and microhardness of the groups were analyzed using Kolmogorov–Smirnov test. The Statistical Package for the Social Sciences software version 23 (2015) was used.

The values of microhardness and DC in CQ-containing composites were approximately similar for both the monowave (microhardness: 52.42 ± 2.67 and DC: 48.30 ± 5.81) and polywave (microhardness: 51.77 ± 1.96 and DC: 48.50 ± 4.87) groups, and the difference was statistically insignificant (P > 0.05) [Table 1].

On the other hand, the mean microhardness values of composites containing a combination of photoinitiators were more in the polywave group (57.09 ± 2.61) as compared to the monowave group (47.37 ± 3.51), and this difference was statistically significant (P < 0.05). Similarly, the mean DC was significantly (P < 0.05) higher in the polywave group (59.75 ± 5.30) as compared to the monowave group (39.70 ± 3.57) [Table 2].

**DISCUSSION**

For a successful restoration, adequate polymerization serves an important criterion and the properties that are well

| Table 1: Comparison of microhardness and degree of conversion between Group M Subgroup C and Group P Subgroup C |
|----------------|----------------|----------------|----------------|----------------|
|                | Microhardness | Degree of conversion |               |                |
| Variable       | Groups        | Mean ± SD          | Difference    | P              |
| Microhardness  | Group M Subgroup C | 52.42 ± 2.67       | 0.64          | 0.390          |
|                | Group P Subgroup C | 51.77 ± 1.96       |               |                |
| Degree of conversion | Group M Subgroup C | 48.30 ± 5.81       | −0.20         | 0.907          |
|                | Group P Subgroup C | 48.50 ± 4.87       |               |                |

P ≤ 0.05 is statistically significant. SD: Standard deviation
Table 2: Comparison of microhardness and degree of conversion between Group M Subgroup camphorquinone, Ivocerin, and 2,4,6-trimethylbenzoyl diphenylphosphine oxide and Group P Subgroup camphorquinone, Ivocerin, and 2,4,6-trimethylbenzoyl diphenylphosphine oxide

| Variable               | Groups                  | Mean± SD   | Difference | P       |
|------------------------|-------------------------|------------|------------|---------|
| Microhardness          | Group M Subgroup CIT    | 47.37±3.51 | -9.73      | 0.001*  |
|                        | Group P Subgroup CIT    | 57.09±2.61 |            |         |
| Degree of conversion   | Group M Subgroup CIT    | 39.70±3.57 | -20.05     | 0.001*  |
|                        | Group P Subgroup CIT    | 59.75±5.30 |            |         |

*Significant difference at P<0.05. Independent t-test. SD: Standard deviation, CIT: CQ, Ivocerin and TPO

correlated to polymerization are DC and microhardness. Factors influencing these major properties include composition of composite material, duration of irradiation, thickness of restorative material, distance between LCU and restoration surface, shade of composite, and type of LCU.[10] The type of LCU used plays an important role in polymerization of RBCs. That’s why the effect of different LCU on DC and MHD of composites having different photoinitiators was evaluated in the present study.

The null hypothesis tested was partially rejected as there was no difference when composite-containing CQ was cured by polywave or monowave LCU. However, the difference was significant in the case of composite containing a combination of photoinitiators (CQ, TPO, and Ivocerin).

Composites containing a combination of photoinitiators cured by polywave LCU had higher DC and MHD than the monowave LCU. This finding is attributed to the narrow spectrum of monowave LED LCU (450–470 nm) which is sufficient to activate CQ only. It leaves the remaining photoinitiators (TPO and Ivocerin) unactivated which might have resulted in lower microhardness and DC in the monowave group. While, polywave LCU irradiates light between 385 and 515 nm which allows activation of additional photoinitiators also (Ivocerin and TPO). Therefore, a higher DC was achieved for composites containing a combination of photoinitiators cured by polywave LED than those cured with monowave. This is in agreement with previous studies.[8,10] Kolpakova in 2015 suggested that in the case of composite-containing CQ, TPO, and Ivocerin, it takes longer to reach the maximum irradiance that continues to increase slowly after about 9 s of irradiance. It was also shown that they had higher percent transmittance with both LCUs.[11] However, higher transmittance and slow increase of the maximum irradiance results in higher total power going through the composite[12] to activate all photoinitiators which might also explain greater DC and microhardness for composites containing a combination of photoinitiators when cured with polywave LED. In contrast to the finding of the present study, a study conducted by Araujo et al.[13] in 2021 showed that monowave LCU has better effectiveness in curing nanohybrid composites compared to polywave LCU. The authors stated that in polywave light due to the incorporation of violet light, blue emission is reduced. This caused less activation of CQ at greater depths, reducing polymerization at 3-mm depth. However, since manufacturers did not specify the ratio of TPO and CQ in composite, this was considered doubtful.

For CQ-containing composites, the results of the present study showed almost similar mean DC and MHD values irrespective of the curing light. This might be explained on the basis that when composite containing only CQ as a photoinitiator is exposed to curing light the irradiance increases to its maximum almost immediately and remains constant for the rest of the curing period for both types of LCUs.[13] In addition, a study by Kolpakova in 2015 showed that for composites containing only CQ, power transmitted by polywave light drastically decreases when the thickness of samples were more than 3 mm.[11] This can also explain why samples of CQ-containing composites showed almost similar results when cured with either of the curing light, as the thickness of samples in the present study was 4 mm.

Another factor which influences DC and microhardness of composite is scattering. It is dependent upon the size of the particles and the scattering coefficient, which varies inversely with the fourth power of the wavelength.[14] Thus, the shorter wavelengths of light are scattered much more than the longer wavelengths which is called Rayleigh scattering. This could also explain why shorter wavelengths might not have reached the bottom of samples resulting in lower microhardness. It is in contrast to a study by Derchi et al.[10] in 2018 where CQ-containing composites (Filtek) showed significantly better performance when cured with polywave light in comparison to monowave LED. According to the study by Price & Felix, the DC of composites containing different monomers varies and in following order, bisphenol A glycidyl dimethacrylate (Bis-GMA) < bisphenol A ethoxylate dimethacrylate < urethane dimethacrylate (UDMA) < triethylene glycol dimethacrylate.[19] UDMA present in Filtek bulk fill shows higher DC than Bis-GMA present in Wonder bulk fill used in the present study. This can justify the different findings in both studies.

In the present study, it was observed that groups having higher DC also have higher microhardness than their counterparts, so it can be inferred that there is a correlation between DC and microhardness of bulk fill composites. This finding is in agreement with Neves et al., who observed a strong correlation between DC and microhardness for three types of composites.[16]

The limitations of the present study are its in vitro nature and unknown concentration of photoinitiators in
composites (could not be withdrawn from manufacturers). Other factors which can affect DC and microhardness such as type of monomer, filler size, and filler loading were not considered.

**CONCLUSION**

Composite containing a combination of photoinitiators (CQ, TPO, and Ivocerin) exhibited significantly higher DC and microhardness when cured with polywave LCU. For composite containing only CQ as photoinitiator, DC and microhardness were similar when cured with either monowave or polywave curing light.

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**Conflicts of interest**
There are no conflicts of interest.

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