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Original article

The Influence of Different Light Curing Modes on the Depth of Cure of the Composite Resin

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SUMMARY

The aim of this study was to investigate the influence of different light curing modes on the depth of cure of the composite resin.

The metal block with formed round holes served as a mold for the placement of the composite resin. The composite resin was cured with Penguin DB-685 lamp with four optional working modes: strong, low, gradually strong, and flashing. Unpolymerized part of the composite specimen was removed by scraping with a plastic spatula, and then each specimen was placed into the capsule with 1 ml of ethanol alcohol and mixed for 20 s in amalgamator. The length of the remaining composite specimen was measured with the digital caliper with a precision of 0.01 mm. The measured values were divided by 2 (according to ISO 4049 standard) and then statistically processed.

Based on the measured lengths of the polymerized part of the composite specimens, the lowest average value of the depth of cure (2.75 ± 0.08 mm) was determined after polymerization with the low mode and the highest value was obtained (2.98 ± 0.08 mm) with strong polymerization mode. Statistically significant difference ($p < 0.05$) was determined between low polymerization mode and all other modes (strong, gradually strong and flashing mode).

The observed statistically significant differences are not clinically important because all curing modes provided the necessary depth of cure, which is in accordance with the clinical recommendation of 2 mm thick composite layer.

Key words: **depth of cure, curing mode, composite resin**

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INTRODUCTION

The use of composite resin in dentistry is ubiquitous, mainly because of good aesthetic qualities and physical properties (1). Many efforts have been made to improve the clinical characteristics of this material since the composite resin has appeared (2).

Adequate polymerization of the composite resin is an important factor in obtaining good clinical performance of fillings (3). The depth of cure of dental resin influences their mechanical properties, dimensional stability, solubility, discoloration, and biocompatibility (4). The insufficient polymerization degree affects the composite resin properties such as water absorption, poor strength, and wear resistance (3). The filler particle size, polymeric matrix, and radiant exposure generated by the light source can influence the degree of depth of cure of the composite resin, thus on mechanical properties (2).

The characteristics of the light source are a significant factor which influences the depth of cure of composite resin material (3). The main factors of the light source that are essential are its intensity output, curing time and mode, the bandwidth of the light, filter quality and light tip characteristics (5). Also, the distance of the light source from the composite resin is important (6).

Light emitting diode (LED) lights are becoming increasingly popular in dentistry over conventional halogen lights (7). Different polymerization modes of LED lamp can influence a composite resin polymerization reaction (8). A standard mode uses high initial intensity of light and provides a higher degree of the depth of polymerization (9). This mode can induce higher shrinkage stress during the curing composite resin (10). High power density modes are characterized by the activation of a large number of photoinitiator molecules at the same time, which will produce more inner stresses (9). Gradual polymerization modes have been introduced to minimize polymerization shrinkage and consequent microleakage (11). In the flashing curing modes, light intensity varies between high and low during the polymerization of composite resin (9).

The aim of this study was to investigate the influence of different light modes on the depth of cure of the composite resin. The hypothesis was that there is a statistically significant difference between the influences of different light modes on the depth of cure of the composite resin.

MATERIAL AND METHODS

The research was conducted at the Clinic of Dentistry in Niš, at the Department of Restorative Dentistry and Endodontics. In this study, as a material, composite resin Valux Plus (3M ESPE, USA) with light shade (A1) was used. The composite resin was cured with Penguin DB-685 lamp (Coxo, China), which produces a light power of 1200 mW/cm^2 and wavelength of 420-480 nm. This lamp had four optional working modes: strong, low, gradually strong, and flashing.

The metal block (8 mm thick) was used for specimen preparation. The round holes were cut into the block, 4 mm in diameter. The metal block with holes was isolated with isolation liquid Picosep (Renfert, Germany) and placed on a glass slab. The composite resin was placed inside the hole in the metal block by plastic spatula, and the second glass slab was placed over the composite resin. After that, the second glass slab from the metal block was removed. Curing of the composite resin was performed according to the recommended curing time by the manufacturer (40 s). Samples were deployed to four groups according to the light mode polymerization. Ten samples were in each group.

The specimens were immediately removed from the molds after polymerization, and the uncured material was scraped away with a plastic spatula. Each specimen was placed in a capsule with 1 ml of 96% ethanol alcohol (ROE, Serbia) and mixed for 20 s in amalgamator (Silamat, Vivadent, Liechtenstein), due to the additional removal of the unpolymerized composite resin. The length of the remaining polymerized composite specimen was measured with a digital caliper (Asimeto 307-06-1, Canada) with an accuracy of 0.01 mm in three places and an average length was calculated. The measured values were divided by 2, according to the ISO 4049 standard.

Statistical analysis was performed using the software package SPSS version 16.0 (SPSS Inc., Chicago, Illinois). Data were presented as the mean and standard deviation, and also as median, minimum and maximum value. Data normality was tested by Shapiro-Wilk test. Statistical analysis of significance between groups was done using one-way ANOVA test with post-hoc Tukey HSD test.

RESULTS

On the basis of the measured lengths of the polymerized part of the composite specimens, the lowest average of depth of cure (2.75 ± 0.08 mm) was determined after polymerization with the low mode.

The highest average value of the depth of cure (2.98 ± 0.08 mm) was determined with strong polymerization mode. The lowest value of the depth of cure was 2.63 mm (low mode), and the maximum was 3.12 mm (strong mode) (Table 1).

Normal distribution was found in all the tested groups by applying the Shapiro-Wilk test.

The one-way ANOVA showed statistically significant difference between groups. A significant difference was determined between group A (low mode) and all other groups (strong, gradually strong, and flashing mode) with post-hoc Tukey HSD test.

Statistical difference between groups B (strong mode), C (gradually strong mode) and D (flashing mode) was not significant (Table 2).

Table 1. Average values of depth of cure of composite resin (mm) with different light polymerization modes

Light polymerization mode	Mean	SD	Min	Max	Median
Low mode	**2.75**	0.08	**2.63**	2.88	2.74
Strong mode	**2.98**	0.08	2.86	**3.12**	2.99
Gradually strong mode	2.93	0.11	2.77	3.11	2.91
Flashing mode	2.90	0.12	2.75	3.11	2.86

Table 2. The comparison between different light curing modes

Groups pair	One-way ANOVA	TukeyHSD
	F-value	**p-value**
A vs B		0.01*
A vs C		0.01*
A vs D		0.08*
B vs C	9.93	0.59
B vs D		0.28
C vs D		0.9

* The result was significant at $p < 0.05$.

A - low mode, B - strong mode, C - gradually strong mode, D - flashing mode

DISCUSSION

Knowing the depth of cure of the composite resin guides dentists in regard to the thickness of composite layer that can be adequately cured (12). The ISO 4049 scraping test is used to determine the depth of polymerization composite resin that requires minimal instrumentation and can be performed simply in a dental practice (13). The modification of ISO depth of cure test (acetone/ethanol shaking test) has been recently done. The acetone shaking test was explained by Kleverlaan and De Gee (14), while ethanol shaking test was described by Miletić et al. (15).

The ethanol shaking test as an indicator of the depth of cure was used in our study. Kleverlaan and De Gee conducted a similar study, but they used the

acetone shaking test which showed higher precision compared to the ISO standard test (14). Also, Miletić et al. proved that ethanol can be used to replace the acetone in testing the depth of cure (15). This prompted us to use ethanol in our examination.

In order to achieve the adequate curing of the composite resins, the recommended intensity of curing light is 900-1500 mW/cm^2 and the exposure time is 40 s (5). Our study is in accordance with the above recommendation and we used lamp which produces a light intensity of 1200 mW/cm^2 and exposure time of 40 s. Alto et al. concluded that energy density (time (s) x light intensity (mW/cm^2)) is also an important factor which influences the depth of cure (16). Our study confirms that regime of higher light density (strong mode) produces a deeper degree of polymerization than the regime of low density (low mode) of the same lamp.

Yap et al. in their study showed that there was no statistical significance between different light modes after the depth of cure testing (17). Our study is not in full compliance with this study because we showed statistical significance. Statistical difference was present between the low and other examined modes (strong, gradually strong and flashing modes). The gradually strong mode was proposed by many studies in order to improve the marginal adaptation of composite and prevent marginal gap formation (18, 19). In addition, we showed that this light mode provides satisfactory depth of cure.

The degree of curing should be the same throughout the depth of the composite restoration. The light passes through composite resin during the polymerization and loses intensity in deeper parts of restoration due to dispersion. This leads to lower effectiveness of curing. There is a recommendation that composite resin layers should be limited to the maximum thickness of 2.0 mm for satisfactory polymerization (20). In our research, all tested modes achieved an appropriate depth of cure, over 2.0 mm.

CONCLUSION

The highest degree of the depth of cure was in the group where strong polymerization mode was used, while the lowest degree of the depth was observed with the use of a low mode. There was no statistically significant difference between the strong, gradually strong, and flashing mode. All curing modes provided a necessary depth of cure in accordance with the clinical recommendation of 2 mm thick composite layer.

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Uticaj različitih režima prosvetljavanja na dubinu polimerizacije kompozitnih smola

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SAŽETAK

Cilj rada bio je da se ispita uticaj različitih režima prosvetljavanja na dubinu polimerizacije kompozitnih smola.

Metalni blok sa formiranim kružnim otvorima je služio kao kalup za postavljanje kompozita. Kompozit je prosvetljavan Pengin DB-685 lampom sa četiri polimerizaciona režima: strong, low, gradually strong and flashing režim. Nepolimerizovani deo kompozita je uklanjan struganjem plastičnom špatulom, a zatim je preostali deo kompozita postavljan u kapsule sa 1 ml etanol alkohola i miksiran 20 s u amalgamatoru. Dužina preostalog kompozitnog uzorka je merena digitalnim nonijusom sa preciznošću od 0,01 mm. Izmerene vrednosti su podeljene sa 2 (prema ISO 4049 standardu), a zatim statistički obrađene.

Na osnovu izmerenih dužina polimerizovanih delova kompozitnih uzoraka, najmanja prosečna vrednost dubine polimerizacije je određena nakon prosvetljavanja low režimom (2,75 ± 0,08 mm), a naveća strong režimom (2,98 ± 0,08 mm). Statistički značajna razlika ($p < 0,05$) je određena između low režima i ostalih režima prosvetljavanja (strong, gradually strong and flashing režima).

Uočene statistički značajne razlike nemaju veći značaj u kliničkoj praksi zato što su svi režimi prosvetljavanja obezbedili potrebnu dubinu polimerizacije, što je u saglasnosti sa kliničkom preporukom od 2 mm debljine kompozitnog sloja.

Ključne reči: **dubina polimerizacije, režim prosvetljavanja, kompozit**