Original Article

LIGHT TRANSMISSION THROUGH RESIN COMPOSITES

Nicoleta Ilie[1a*], **Eva-Maria Plenk**[2b]

[1] Department of Operative Dentistry and Periodontology, University Hospital, Ludwig-Maximilians-Universität München, Goethestr. 70, D-80336 Munich, Germany
[2] Privat clinic, Bahnhofsweg 6, D-82008 Unterhaching, Germany

[a] Prof. Dr. Dipl. Eng.
[b] DDS, Dr.

ABSTRACT

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Introduction: The study aimed to quantify the amount of light that passes through different resin-based composite (RBC) types and to assess if a clinically used polymerization procedure in curing incrementally filled deep cavities is justified.
Methodology: Light transmission through 2-mm thick specimens made of three regular RBCs - a nano, a flowable nano and a microhybrid – of the same shade A3, was analyzed under 24 different curing conditions, that resulted by varying the curing mode, exposure distance and exposure time when using a violet-blue LED light curing unit. Incident and transmitted irradiances were assessed in real-time on a spectrophotometer and radiant exposure, transmittance (T) and absorbance (A) were calculated. A multivariate analysis assessed the effects of various parameters on T and A.
Results: Incident irradiance varied among 656.4 (8.1) mW/cm^2 (Standard mode, exposure distance = 7 mm) and 3361.5 (33.6) mW/cm^2 (Plasma Emulation mode, 0 mm). The *filler amount (weight and volume %)* exerted a significant effect on transmitted irradiance ($p < 0.001$; partial eta squared $\eta P^2 = 0.400$ and 0.362, respectively) while the effect of *exposure distance* was low ($p < 0.001$, $\eta P^2 = 0.141$). Light transmittance was material-dependent and very low. The significant lowest absorbance was identified in Filtek Supreme XTE flow (1.11 ± 0.09), followed by Filtek Silorane (1.21 ± 0.03) and Filtek Supreme XTE (1.62 ± 0.13). Incident and transmitted radiant exposure correlated exceptionally well in each RBC (Pearson correlations coefficient > 0.99).
Conclusion: When restoring a deep cavity with regular RBCs, each increment needs to be cured adequately, since final curing to compensate for deficits in polymerisation is insufficient.
Keywords: resin-based composites, light curing unit, irradiance, radiant exposure, transmittance, absorbance.

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***Corresponding author:** Prof. Dr. Dipl. Eng. Nicoleta Ilie, Department of Operative Dentistry and Periodontology, University Hospital, Ludwig-Maximilians-Universität München, Goethestr. 70, D-80336 Munich, Germany,
Phone: +49-89-44005-9412, Fax: +49-89-44005-9302
e-mail: nilie@dent.med.uni-muenchen.de

1. Introduction

The optical properties of light cured resin-based composites (RBC) are essential material characteristics that are relevant for both the esthetical appearance of a restoration [1,2] and the quality of curing in depth [3]. The latter is fundamentally related to the translucency of the material and thus to the amount of light (photons) that is allowed to pass through the RBC during polymerization. While the surface of an RBC filling is prevalently sufficiently cured, the polymerization of deeper increments is decisively influenced by the light transmitted through the material [4]. Yet, an insufficient polymerization may not be immediately noticeable. It is evidenced later in the reduced mechanical properties [5], low degree of conversion [6], elution of unreacted monomers [6], increased toxicity [7] and potential hypersensitivities.
The transmitted light through a material sums the remaining light, after the incident light, striking the surface of the RBC, was reflected, absorbed and scattered. Light absorption occurs when atoms or molecules of the RBC's constituents, such as monomers [8], filler particles [9,10], photo-initiator molecules [11], dyes and pigments [8,12,13] take up the energy of a photon of light. In contrast, scattering take place on reinforcing particles or porosity voids [9]. The extent of scattering at the interfaces between reinforcing particles and polymer matrix is minimized when the mismatch in refractive index between each material is reduced [14]. It is thus a function of the chemical composition of both constituents and differs accordingly within individual RBCs. In addition to the refractive index, also the filler dimension exerts a significant effect on light scattering, that was shown to be highest when the filler diameter approaches approximately one-half the wavelength of incident light, i.e. ~0.2–0.3 µm [3]. It must also be noted that large variation in light transmission was observed also within resin composite of similar shade [15]. Moreover, light transmittance varied during polymerization, while increasing or decreasing during curing as a function of the RBC type and composition [16].
In clinical dentistry, many of the aspects described above are not sufficiently considered when making recommendations on restoration techniques. It is, for instance, occasionally acclaimed to only "pre-cure" the first, lowest increment for 2-3 seconds, when restoring incrementally a deep cavity with an RBC. This proceeding is justified by the additional amount of light that would pass through the filling when the upper RBC increments are exposed to light or, as usual clinically, when the entire filling is exposed again to light at the end of the restoration.
Therefore it was the aim of the present study to

Table 1. Resin composite brand, type, chemical composition of matrix and filler as well as filler content by weight (wt.) and volume (vol.) %. All materials are manufactured by 3M ESPE.

RBCs	RBC-Type	Batch	Shade	Resin Matrix	Filler	Filler wt%/ vol%
Filtek™ Supreme XTE	Nano	N229448	A3 Dentin	Bis-GMA, Bis-EMA, UDMA, TEGDMA, PEGDMA	ZrO_2, SiO_2 ZrO_2/SiO_2	78.5/63.3
Filtek™ Supreme XTE flow	flowable Nano	N236527	A3	Bis-GMA, Bis-EMA, TEGDMA, PEGDMA	ZrO_2, SiO_2 ZrO_2/SiO_2	65/55
Filtek™ Silorane	Microhybrid	N225426	A3	3,4-Epoxycyclo-hexylethylcyclopolym ethylsiloxane Bis-3,4-epoxycyclo-hexylethylphenyl-methylsilane	SiO_2, YF_3	76/55

simulate and quantify the amount of light that would pass through 2 mm thick increments of different RBC types - a nano, a flowable nano and a microhybrid – as it would be received from a lower layer in a resin composite filling. To simulate clinically relevant curing conditions, 24 different radiant exposures were considered for each material, that were obtained by varying the curing mode of a modern, high-performance LED light-curing unit (LCU), the exposure distance and the exposure time.

The null hypotheses assume: a) similar light transmittance (= ratio of transmitted to incident radiant power) through all material types; b) within one material, similar transmittance for all curing modes of the LCU; c) similar absorbance in all materials.

2. Materials and Methods

Light transmission through three regular RBCs (Table 1) was analyzed under different curing conditions at a specimen thickness of 2 mm. Therefore the violet-blue LED LCU VALO (Ultradent, South Jordan, USA, serial number VO 7710) was applied in three different exposure modes (Standard, High Power and Plasma Emulation), at various exposure times (5 s, 10 s, 15 s, 20 s and 40 s in the Standard mode; 1 s, 2 s, 3 s, 4 s and 12 s in the High Power mode and 3s and 6s in the Plasma Emulation mode) and exposure distances (0 mm and 7 mm). This resulted in 24 different curing conditions.

2.1. Spectrophotometry: measurement of the Incident irradiance and Light Transmittance

Incident irradiance and light transmittance through the analyzed RBCs were assessed on a laboratory-grade National Institute of Standards and Technology (NIST)-referenced USB4000 Spectrometer (MARC (Managing Accurate Resin Curing) System, Blue light Analytics Inc., Halifax, NS, Canada). The incident irradiance (the irradiance reaching the specimen's surface) was determined on five occasions, by applying the curing unit directly to the sensor.

With each program (standard, high power, plasma emulation) and material (Table 1) the maximum irradiance reaching the sensor was measured in a random order. The exposure distance was set at 0 mm and 7 mm.

Specimens were prepared in cylindrical Teflon molds (6 mm diameter, increment thickness 2 mm, n = 5), and cured by applying the aforementioned curing unit directly, perpendicularly and centered on the surface of the sample using a mechanic arm. While the specimens were cured, the spectrophotometer measured in real-time the irradiance at the bottom of the specimens. The cylindrical Teflon molds containing the material were aligned centered on the round detector of the spectrometer, which had a diameter of 3.9 mm. Consequently, the irradiance and radiant exposure reaching this area were considered. The miniature fiber optic USB4000 Spectrometer employs a 3648-element Toshiba linear Charge-coupled Device (CCD) array detector and high-speed electronics (Ocean optic, Largo, FL, USA). The spectrometer was calibrated using an Ocean Optics' NIST-traceable light source (300–1050 nm). The system uses a CC3-UV Cosine Corrector (Ocean optic, Largo, FL, USA) to collect radiation over a 180° field of view, thus mitigating the effects of optical interference associated with light collection sampling geometry. Irradiance and radiant exposure at a wavelength range of 360–540 nm were individually collected at a rate of 16 records/s. The sensor was triggered at 20 mW. The radiant exposure was calculated by integrating the irradiance versus the wavelength at the used exposure time.

2.2. Transmittance and absorbance

Transmittance (T) is defined as the ratio of transmitted irradiance (radiant power) to incident irradiance: $T = I_t/I_0$, where I_t is the irradiance after the beam of light passes through the specimen and I_0 is the irradiance of the incident light.

Transmittance is related to absorbance by the expression: Absorbance (A) = – log(T) = $-\log(I_t/I_o)$, where absorbance stands for the amount of photons that are absorbed.

Being defined as ratios of irradiance values, transmittance and absorbance are dimensionless.

2.3. Statistical Analysis

A Shapiro–Wilk test verified the normal distribution of the data. A multivariate analysis (general linear model) assessed the effects of various parameters as well as their interaction terms on the transmitted irradiance and absorbance. The partial eta-squared statistic reports the practical significance of each term, based on the ratio of the variation accounted

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for by the effect. Larger values of partial eta-squared indicate a greater amount of variation accounted for by the model effect, to a maximum of 1. Correlation among incident and the transmitted radiant exposure was assessed by a Pearson correlation analysis. In all statistical tests, p-values < 0.05 were considered statistically significant when using SPSS Inc. (Version 24.0, Chicago, IL, USA).

3. Results

The irradiance of the analyzed LED LCU at an exposure distance of 0 mm amounted to 1174.1 (12.4) mW/cm^2 in the Standard mode, 1760.3 (9.8) mW/cm^2 in the High Power mode and 3361.5 (33.6) mW/cm^2 in the Plasma Emulation mode. The incident irradiance decreased at an exposure distance of 7 mm to 656.4 (8.1) mW/cm^2, 986.3 (10.6) mW/cm^2 and 1917.8 (31.6) mW/cm^2, respectively (Fig. 1).

The effect of the parameter filler amount (weight and volume %) was proved to be significant on the transmitted irradiance ($p < 0.001$; partial eta squared $\eta P^2 = 0.400$ for weight % and 0.362 for volume %), while the effect of exposure distance was low ($p < 0.001$, $\eta P^2 = 0.141$).

The Plasma Emulation mode induced the highest transmitted irradiances in each analyzed RBC, while the lowest values were identified when the LCU was run in the Standard mode. Increasing the exposure distance from 0 mm to 7 mm lowered the transmitted irradiance by 43 % to 49 % (Table 2), while the incident irradiance was lowered by 42.9% to 44.1%.

Within each curing mode and exposure distance, the significant highest transmitted irradiances were identified in the Filtek Supreme XTE flow, followed by the Filtek Silorane, while the significant lowest values were identified in the Filtek Supreme XTE ($p < 0.001$). Within the analyzed incident irradiances, which varied in the range 656.4 (8.1) mW/cm^2 (Standard mode, 7 mm exposure distance) to 3361.5 (33.6) mW/cm^2 (Plasma mode, 0 mm exposure distance), the transmitted irradiance was reduced within the range 16.5 (1.3) mW/cm^2 to 71.7 (4.9) mW/cm^2 in Filtek Supreme XTE, 49.5 (2.3) mW/cm^2 to 217.9 (13.0) mW/cm^2 in Filtek Silorane and 49.7 (2.4) mW/cm^2 to 249.1 (16.3) mW/cm^2 Filtek Supreme XTE flow (Fig 2). This means that within the above-mentioned intervals the percentage of transmitted irradiance relative to the incident irradiance amounted 1.4% to 2.1% in the Filtek Supreme XTE, 4.2% to 6.5% in the Filtek Silorane and 4.2% to 7.4% in the Filtek Supreme XTE flow. Within these limits, by trend, the lower the incident irradiance, the higher the % transmitted light related to the initial irradiance.

The significant lowest absorbance was identified in the Filtek Supreme XTE flow (1.11±0.09), followed by the Filtek Silorane (1.21±0.03) while the highest absorbance was measured in the Filtek Supreme XTE (1.62±0.13). A strong influence on absorbance was identified in the parameter RBC ($p < 0.001$; partial eta squared $\eta P^2 = 0.744$), followed by the parameter curing mode ($p < 0.001$; $\eta P^2 = 0.364$) while the exposure distance exerted only a low influence ($p < 0.001$; $\eta P^2 = 0.117$) (Table 2).

Within the 12 analyzed curing conditions at an exposure distance of 0 mm, the highest incident radiant exposure was identified when the LCU was run in the Standard mode and an exposure time of 40s (46.96 J/cm^2), followed by the 20s exposure in the same curing mode (23.48 J/cm^2), the 12 s exposure in the High Power mode (21.12 J/cm^2), and the 6s exposure time in the Plasma Emulation mode (20.17 J/cm^2). The lowest radiant exposure resulted at an exposure time of 1s in the High Power mode (1.76 J/cm^2) (Fig. 3). For an exposure distance of 7 mm, the

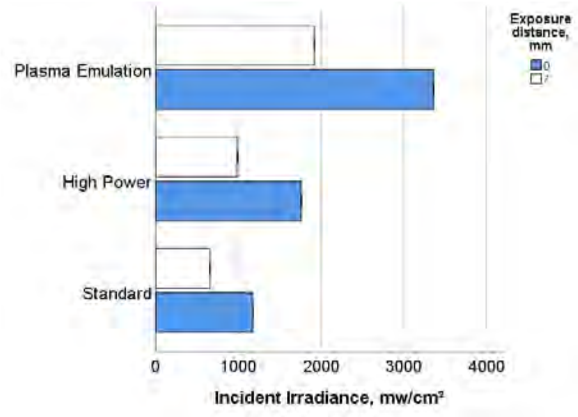


Figure 1. Incident irradiance as a function of the curing mode and exposure distance.

Table 2. Absorbance as a function of RBC, curing mode and exposure distance as well as loss in transmitted irradiance (Δ I, %) at an exposure distance of 7 mm related to 0 mm within each RBC and curing mode.

Curing mode	RBC	Exposure distance	Absorbance	Δ I
Standard	Filtek™ Supreme XTE	0mm	1.58 (0.2)	43.3 %
		7mm	1.57 (0.21)	
	Filtek™ Supreme XTE flow	0mm	1.08 (0.14)	47.1 %
		7mm	1.10 (0.14)	
	Filtek™ Silorane	0mm	1.1 (0.15)	43.1 %
		7mm	1.10 (0.143)	
	air	0mm	-	44.1 %
		7mm	-	
High Power	Filtek™ Supreme XTE	0mm	1.63 (0.03)	46.6 %
		7mm	1.65 (0.006)	
	Filtek™ Supreme XTE flow	0mm	1.1 (0.0001)	49.3 %
		7mm	1.14 (0.003)	
	Filtek™ Silorane	0mm	1.13 (0.0001)	42.9 %
		7mm	1.13 (0.013)	
	air	0mm	-	44.0 %
		7mm	-	
Plasma E.	Filtek™ Supreme XTE	0mm	1.66 (0.01)	45.1 %
		7mm	1.69 (0.008)	
	Filtek™ Supreme XTE flow	0mm	1.13 (0.006)	48.5 %
		7mm	1.17 (0.006)	
	Filtek™ Silorane	0mm	1.14 (0.2)	47.0 %
		7mm	1.22 (0.02)	
	air	0mm	-	42.9 %
		7mm	-	

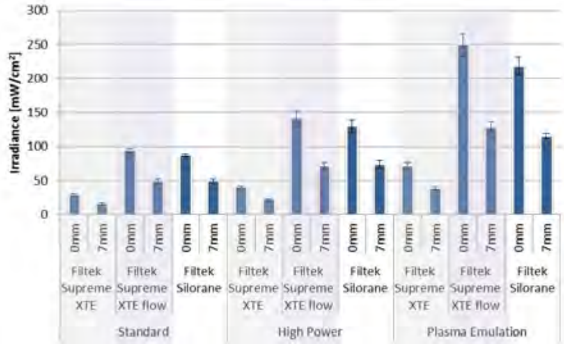


Figure 2. Transmitted irradiance through 2 mm thick specimens of the analysed RBCs as a function of curing mode and exposure distance.

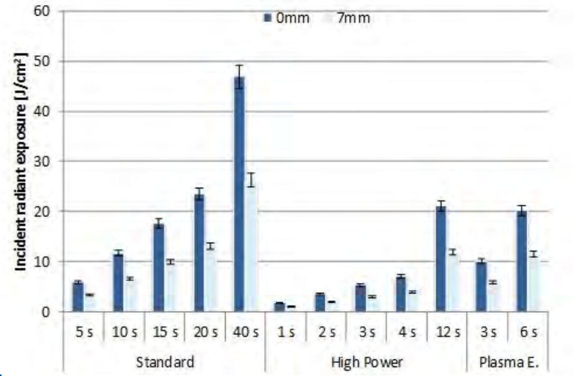
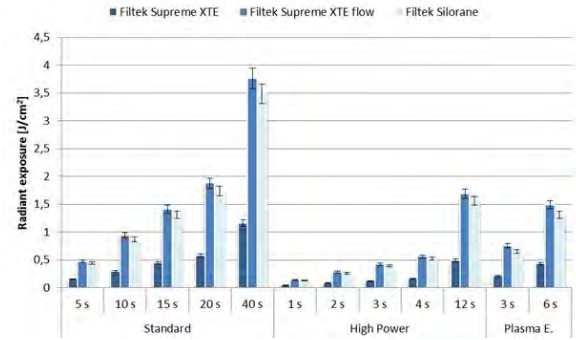
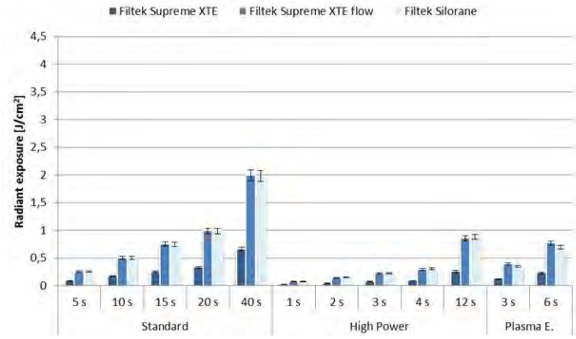


Figure 3. Radiant exposure received by the top-surface of the analysed specimens as a function of exposure time, distance and curing mode.



(a)



(b)

Figure 4. Radiant exposure as recorded at the bottom of 2-mm thick specimens of the analysed RBCs, as a function of exposure time and curing mode at an exposure distance of a) 0 mm and b) 7 mm.

radiant exposure varies in the same sequence at lower values, which varied from 26.26 J/cm^2 (40s, standard mode) to 0.99 J/cm^2 (1s, High Power mode).

An excellent correlation was found in each RBC between the incident and the transmitted radiant exposure (Fig. 4 a, b) (Pearson correlations coefficient = 0.997 for Filtek Supreme XTE, 0.999 for Filtek Supreme XTE flow and 0.925 for Filtek Silorane).

4. Discussion

The present study quantifies the attenuation of light when traveling through different types of resin composite specimens of a predetermined thickness of 2 mm. This thickness was chosen owing to the fact that all three analyzed materials are regular RBCs that need to be placed incrementally, while the thickness of an increment should not exceed 2 mm. The selected materials belong to different RBC types - nano, flowable nano and microhybrid. Two of the analyzed RBCs - Filtek Supreme XTE flow and Filtek Supreme XTE – have a quite similar chemical composition of all their constituents and primarily differ with respect to the filler amount (Table 1). Both are methacrylate-based RBCs. The difference in filler amount resulted in significantly lower light transmittance and a ca. 50% higher absorbance in the higher filled material. Although light transmittance was higher in the Filtek Supreme XTE flow, it amounted to less than 250 mW/cm^2 also at the highest analyzed incident irradiance (3361.5 ± 33.6 mW/cm^2, Plasma Emulation). Considering that the polymerization at such high irradiances should not exceed a few seconds, due to the increased risk to over-heat the pulp, the amount of light available to potentially complete the curing of an underneath pre-cured increment might be by far insufficient. There are more reasons against exposure to high irradiance, as curing fast at high irradiances leave no room to relieve internal stresses accumulated during shrinkage [17].

To address light transmittance also from the perspective of a different chemical composition of the organic matrix, the silorane based material Filtek Silorane was additionally selected. It must be noted that this material is no longer on the market. The reasons therefore were not motivated in the physical properties or curing behavior of Filtek Silorane, since there were comparable to regular methacrylate-based RBCs [18,19]. The siloran monomer was obtained from the reaction of oxirane and siloxane molecules, thus combining the two key advantages of the individual components: low polymerization shrinkage due to the ring-opening oxirane monomer and increased hydrophobicity due to the presence of the siloxane species [20]. It is a four-branched monomer (methacylate monomers are only two-branched) which suggest a high crosslinking density of the final polymer and, as a result, good chemical stability. A further particularity of this system is the cationic initiated polymerization which is less sensitive to oxygen compared to the radical polymerization of the methacylate-based RBCs. The cationic polymerization initiation system consists of camphorquinone, an iodonium salt, and an electron donor. In the redox process, the electron donor decomposes the iodonium salt to an acidic cation which then starts the ring-opening polymerization process [20].

The transmittance and absorbance characteristics measured in the present study for Filtek Silorane were rather comparable to the flowable then to the nano RBC Filtek Supreme XTE. Apart from differences in the refractive index and filler size that influence light scattering and thus light transmittance [3,14] as mentioned above, the results may be explained by the similar volumetric filler amount of both materials (Table 1).

The 24 different curing conditions analyzed in the present study were simulated by using a violet-blue LED LCU that offers three different curing programs of medium and high irradiances: 1174.1 (12.4) mW/cm^2 in the Standard mode, 1760.3 (9.8) mW/cm^2 in the High Power mode and 3361.5 (33.6) mW/cm^2 in the Plasma Emulation mode. The LCU is equipped with four high-power LED chips emitting three different wavelength ranges (two chips with a peak at 465 nm, one chip with a peak at 445 nm and 405 nm, respectively) and placed directly into the head of the LCU.

In addition to the exposure distance, the angle at which an LCU is placed on the restoration plays a major role for the quality of polymerization. Particularly in posterior cavities that are difficult to access, the LCU may not be placed perpendicularly on the restoration. In this case, the RBC may cure inhomogeneously in depth, according to the placement of the LCU, even if the surface appears to be well cured. This situation is a good indication for using a "pin-shaped" LCU, like the one analyzed in the present study. Furthermore, in a clinical situation, if the composite surface is larger than the light exit window of the LCU, it must be polymerized in an overlapping manner to cover the entire composite surface. It must also be taken into account that the amount of light emitted by an LCU is not equal to the amount of light a restoration receives. Apart from angulation, the access to lower increments in deep restorations in a clinical situation may be impeded by the presence of cusps. Therefore, the exposure distance was set in the present study either at 0-mm, to simulate the closest contact between restoration and LCU, or at 7 mm. As shown in the present study the enlarged exposure distance lead to a loss of almost 50% of the incident irradiance related to the closest contact, also when using a modern, high-performance LCU.

For economic reasons, clinicians often demand short curing times when polymerizing RBCs. This led to the development of the concept of "exposure reciprocity". This concept considers the product of the incident irradiance (mW/cm^2) and exposure time (s), which is denominated as radiant exposure (J/cm^2). It assumes that, at a given radiant exposure, the effect induced in the RBC would be similar, irrespective if the radiant exposure is reached by lowering the exposure time and increasing the irradiance or vice versa. Even if this simple construct sounds plausible and useful in a clinical situation, it is not universally valid. It does not apply especially if very high or very low irradiances are used. [21]. Numerous studies in recent years have clearly shown that efficient polymerization, especially in depth, is achieved with LCU of moderate irradiance (maximum 1200 mW/cm^2) and exposure times of at least 20 s [5].

The recommendation to pre-cure the lowest increment for only few seconds as justified by the additional amount of light supplied during the cavity restorations must be declined. As summarized in Fig. 2, the light that passes through 2 mm thick layers of various RBCs after light exposure by means of a high-performance LCU is too low. It must be pointed out that, within the analyzed curing conditions, the transmitted light related to the incident light amounted only 1.4% to 2.1% in the Filtek Supreme XTE, 4.2 to 6.5 in the Filtek Silorane and 4.2% to 7.4% in the Filtek Supreme XTE flow. In terms of radiant exposure measured at the bottom of 2-mm thick increments, this amounted to less than 4 J/cm^2 in the most translucent RBCs at highest incident radiant exposure (40s, standard mode, exposure distance 0 mm) and less than 2 J/cm^2 at an exposure distance of 7 mm at similar curing conditions. A general value for the radiant exposure that is needed to adequately cure a 2 mm increment of an RBC is indicated as 16 J/cm^2, thus the transmitted values measured in the present study are far away from fulfilling this requirement (Fig 4).

To transfer these data to a clinical relevant situation, we may consider the Standard mode of the LCU used in the present study (ca. 1200 mW/cm^2), which would correspond to a modern and well-working LCU, as used by many clinicians. For this curing settings and under ideal laboratory conditions (exposure distance 0 mm, LCU placed perpendicularly on the RBC's surface) significantly less than 100 mW/cm^2 pass through a 2 mm increment of a flowable RBCs (FiltekTM Supreme XTE flow), which was the most translucent material analyzed in the present study. These values are even reduced to 87.2 (1.9) in the FiltekTM Silorane and to 29.1 (1.3) in the FiltekTM Supreme XTE. Thicker composite layers, as they may result in a clinical situation during restoring a cavity, are even completely impermeable to light [22]. Under clinical relevant conditions, light transmittance may be even lower, accounting for numerous factors related to the LCU or clinician. This comprises the use of LCUs with low irradiance, defect or contaminated waveguides, improper polymerization due to angulation and high exposure distances. Thus, the present study provides clear arguments against the above-claimed curing techniques and reinforces the recommendation to sufficiently polymerize each RBC layer. The data also suggest that a subsequent polymerization of an RBC filling to potentially alleviate tooth sensitivity due to insufficient polymerization in depth is useless. Besides, it should also be mentioned that an important requirement for a successful polymerization is an intact and clean waveguide. This needs to be checked clinically before each exposure, as residues of composite or adhesive, which often sticks to the waveguide, leading to a strong reduction in the irradiance of the LCU, as the results of the present study suggest. It should also be borne in mind, that the variation of irradiance with exposure distance is LCU-specific. What is especially fast is the reduction of the irradiance with the distance for LCUs when using a so-called "turbo" waveguide.

5. Conclusions

All null hypotheses must be rejected. Light transmittance was shown to be material dependent and very low in regular RBCs, irrespective of RBC composition and type. It is therefore indicated to adequately cure each increment when restoring a deep cavity, and not to relay on a final curing of a restoration to compensate for deficits in polymerisation in deeper increments.

Author contributions

NI: designed the study, designed and established the methods and infrastructure, analysis and interpreted the data, made statistics and wrote the manuscript. EP: collected and analyzed the data.

References

1. Miyagawa Y, Powers JM, O'Brien WJ. Optical properties of direct restorative materials. J Dent Res. 1981;60(5):890-894. doi: 10.1177/00220345810600050601.
[Full text links] [PubMed] Google Scholar(142) Scopus(80)
2. Tsubone M, Nakajima M, Hosaka K, et al. Color shifting at the border of resin composite restorations in human tooth cavity. Dent Mater. 2012;28(8):811-817. doi: 10.1016/j.dental.2012.04.032.
[Full text links] [PubMed] Google Scholar(6) Scopus(3)
3. Palin WM, Leprince JG, Hadis MA. Shining a light on high volume photocurable materials. Dent Mater. 2018;34(5):695-710. doi: 10.1016/j.dental.2018.02.009.
[Full text links] [PubMed] Google Scholar(1) Scopus(1)
4. Frauscher KE, Ilie N. Depth of cure and mechanical properties of nano-hybrid resin-based composites with novel and conventional matrix formulation. Clin Oral Investig. 2012;16(5):1425-1434. doi: 10.1007/s00784-011-0647-3.
[Full text links] [PubMed] Google Scholar(35) Scopus(20)
5. Ilie N, Bauer H, Draenert M, et al. Resin-based composite light-cured properties assessed by laboratory standards and simulated clinical conditions. Oper Dent. 2013;38(2):159-167. doi: 10.2341/12-084-L.
[Full text links] [PubMed] Google Scholar(19) Scopus(11)
6. Durner J, Obermaier J, Draenert M, et al. Correlation of the degree of conversion with the amount of elutable substances in nano-hybrid dental composites. Dent Mater. 2012;28(11):1146-1153. doi: 10.1016/j.dental.2012.08.006.
[Full text links] [PubMed] Google Scholar(89) Scopus(52)
7. Sigusch BW, Pflaum T, Völpel A, et al. Resin-composite cytotoxicity varies with shade and irradiance. Dent Mater. 2012;28(3):312-319. doi: 10.1016/j.dental.2011.12.007.
[Full text links] [PubMed] Google Scholar(40) Scopus(21)
8. Yeh CL, Miyagawa Y, Powers JM. Optical properties of composites of selected shades. J Dent Res. 1982;61(6):797-801. doi: 10.1177/00220345820610062901.
[Full text links] [PubMed] Google Scholar(34) Scopus(17)
9. Grajower R, Wozniak WT, Lindsay JM. Optical properties of composite resins. J Oral Rehabil. 1982;9(5):389-399.
[Full text links] [PubMed] Google Scholar(37) Scopus(23)
10. Friebel M, Povel K, Cappius HJ, et al. Optical properties of dental restorative materials in the wavelength range 400 to 700 nm for the simulation of color perception. J Biomed Opt. 2009;14(5):054029. doi: 10.1117/1.3250292.
[PubMed] Google Scholar(14) Scopus(10)
11. Hadis MA, Shortall AC, Palin WM. Competitive light absorbers in photoactive dental resin-based materials. Dent Mater. 2012;28(8):831-841. doi: 10.1016/j.dental.2012.04.029.
[Full text links] [PubMed] Google Scholar(25) Scopus(17)
12. Haas K, Azhar G, Wood DJ, et al. The effects of different opacifiers on the translucency of experimental dental composite resins. Dent Mater. 2017;33(8):e310-e316. doi: 10.1016/j.dental.2017.04.026.
[Full text links] [Free full text] [PubMed] Google Scholar(5) Scopus(3)
13. Powers JM, Yeh CL, Miyagawa Y. Optical properties of composites of selected shades in white light. J Oral Rehabil. 1983;10(4):319-324.
[Full text links] [PubMed] Google Scholar(30) Scopus(27)
14. Shortall AC, Palin WM, Burtscher P. Refractive index mismatch and monomer reactivity influence composite curing depth. J Dent Res. 2008;87(1):84-88. doi: 10.1177/154405910808700115.
[Full text links] [PubMed] Google Scholar(173) Scopus(119)
15. Masotti AS, Onófrio AB, Conceição EN. UV-vis spectrophotometric direct transmittance analysis of composite resins. Dent Mater. 2007;23(6):724-730. doi: 10.1016/j.dental.2006.06.020.
[Full text links] [PubMed] Google Scholar(38) Scopus(18)
16. Johnston WM, Reisbick MH. Color and translucency changes during and after curing of esthetic restorative materials. Dent Mater. 1997;13(2):89-97.
[Full text links] [PubMed] Google Scholar(175) Scopus(99)
17. Ilie N, Jelen E, Hickel R. Is the soft-start polymerisation concept still relevant for modern curing units? Clin Oral Investig. 2011;15(1):21-29. doi: 10.1007/s00784-009-0354-5.
[Full text links] [Free PMC Article] [PubMed] Scopus(18)
18. Ilie N, Hickel R. Macro-, micro- and nano-mechanical investigations on silorane and methacrylate-based composites. Dent Mater. 2009;25(6):810-819. doi: 10.1016/j.dental.2009.02.005.
[Full text links] [PubMed] Google Scholar(35) Scopus(105)
19. Ilie N, Hickel R. Silorane-based dental composite: behavior and abilities. Dent Mater J. 2006;25(3):445-454.
[Full text links] [PubMed] Google Scholar(201) Scopus(91)
20. Weinmann W, Thalacker C, Guggenberger R. Siloranes in dental composites. Dent Mater. 2005;21(1):68-74. doi: 10.1016/j.dental.2004.10.007.
[Full text links] [PubMed] Google Scholar(740) Scopus(389)
21. Musanje L, Darvell BW. Polymerization of resin composite restorative materials: exposure reciprocity. Dent Mater. 2003;19(6):531-541.
[Full text links] [PubMed] Google Scholar(130) Scopus(85)
22. Bucuta S, Ilie N. Light transmittance and micro-mechanical properties of bulk fill vs. conventional resin based composites. Clin Oral Investig. 2014;18(8):1991-2000. doi: 10.1007/s00784-013-1177-y.
[Full text links] [PubMed] Google Scholar(167) Scopus(57).

Nicoleta ILIE

Dipl. Eng, PhD, Professor
Department of Operative/Restorative Dentistry, Periodontology and Pedodontics
Faculty of Medicine, Ludwig-Maximilians University of Münich
Münich, Germany

CV

Dipl. Eng. Nicoleta Ilie attended the "Technology of silicates and high-temperature oxides" at the Traian Vuia University, Timişoara, Romania (1989-1993). She studied material sciences with a focus on glass and ceramics at the Friedrich Alexander University, Erlangen-Nuremberg, Germany (1994-1999). She got her doctoral degree in material sciences from the Ludwig-Maximilians-University, Dental School, Münich, Germany (1999-2004), followed by her postdoctoral lecture qualification (habilitation) at the same university (2004-2009). Since 1999, she has been assistant professor, associated professor (2009) and tenured professor (2014) of biomaterials at the Dental School of the Ludwig-Maximilians-University in Münich.

Original Article

Questions

1. Which parameters do not affect light transmittance through resin composites?

❑a. Reflection, absorption and scattering of the incident light;
❑b. Refractive index of filler and matrix;
❑c. Filler size;
❑d. Type of resin composites.

2. Which type of resin composites has been analyzed in the present study?

❑a. A bulk-fill resin composite;
❑b. A macro-fill resin composite;
❑c. A resin-modified glass-ionomer;
❑d. Nano and microhybrid resin composites.

3. Light transmittance through the analyzed 2-mm thick resin composite increments amounted:

❑a. > 50% of the incident light;
❑b. > 25% of the incident light;
❑c. < 10% of the incident light;
❑d. 0% of the incident light.

4. When restoring a deep cavity with resin composites incrementally:

❑a. The lower increment needs to be cured adequately;
❑b. The lower increment must only be pre-cured for few seconds since it will receive sufficient light at the end of the restoration;
❑c. At very high irradiance, curing each increment for 1-2 s is sufficient, since exposure reciprocity is a valid concept;
❑d. Curing at very high irradiance will reduce shrinkage stress.