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COMPOSITE RESINS IN THE LAST 10 YEARS - LITERATURE REVIEW. PART 3: PHOTOACTIVATION AND DEGREE OF CONVERSION

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ABSTRACT

Introduction: This is the third article of a series of six manuscripts about composite resins in the last 10 years. Since composite resin is widely used, the aim of this review was to analyze the relationship between different types of light-curing units (LCU) and the composition of several composite resins. **Methods:** A search in PubMed database was performed using the MeSHs photoactivation and composite resins. The articles were chosen according to relevance and publishing date from 2008 to 2018. After completely reading the articles, 28 were select for this literature review. **Results:** The results were distributed in two tables. The first table presents the data of light-curing associated with degree of conversion of commercial composites. The best result was for the monowave and poliwave LED light-curing units, since most composites present camphorquinone (CQ) as a photoinitiator. The second table relates the spectrum of light emitted by LCU with the photoinitiators of experimental composites and their degree of conversion. CQ was the photoinitiator that showed the best results, as well as halogen LCU and poliwave LED. **Conclusions:** The best results of degree of conversion are related to the use of photoinitiators compatible with the wavelength emitted by LCU used.

KEYWORDS: Light curing units. Degree of conversion. Photoactivation. Photoinitiators. Composite resins.

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INTRODUCTION

Composite resins are widely used in dentistry because good compatibility and aesthetics properties, in addition to excellent adhesive capacity to dental hard tissues.[1-3] To perform restorative procedures, composite resins are activated by light to initiate the polymerization process.[4-7] Thus, in order to get a better clinical performance, it is indispensable to know about curing process for the success of restoration.[2,3,8]

Ensure good polymerization avoids unwanted clinical consequences, as the incidence of secondary caries and restoration stain.[2,9-11] The degree of conversion is directly related to the mechanical properties of composites. In turn, this depends on the amount of light that reaches all areas of the restoration. Low degree of conversion results in decrease of mechanical properties such as wear resistance. In addition, it causes low color stability and increase of water sorption and chance of secondary caries.[2,9] The way composite resins are photoactivated influence directly on their properties, may compromise longevity and clinical performance.[1,9]

Despite the drastic reduction in use of equipment with halogen light and there are no longer any reasons to use them, they are still quite cited in literature because they have all visible wavelengths of light. Highlights in market and in the most current studies are devices with LEDs that can be monowave or polywave. Monowave-type devices emit only the wavelength of blue light, which requires the sensitization of camphorquinone molecule.[17,18] Polywave devices emits light at wavelengths ranging from 400 nm to 470 nm, from violet to blue light spectrum.[17,19,20] Each photoinitiator is sensitized by a certain wavelength which according to the manufacturer would justify the development of polywave devices.[6]

Considering that quality of restoration is influenced by correct use of light curing.[21-23] This literature review is part 3 of 6 articles series that will approach different clinical, scientific and biomechanical aspects that affect composite resins in the last 10 years. Mechanical properties, color stability and longevity of composite resins are discussed in parts 2, 5 and 6, respectively.

In this way, considering the importance of photoactivation process to work with composite resins, the objective of this literature review is analyze degree of conversion of commercial and experimental composites taking into account the manufacture or the photoinitiator presents in composition, besides the different light spectrum or light curing unit used in photoactivation. In order to demonstrate the importance of the correct use of light curing units and selecting a compatible device with the material to be used, thus premised demonstrate that the choice of curing equipment should be part of the dentist planning.[8]

MATERIALS AND METHODS

The articles used in this literature review were searched in Pubmed/Medline database with combination of Mesh terms "Curing Lights, Dental" and "Composite Resins". This results in a search of 1500 articles dating between 2008 and 2018. After title and abstract lecture and the exclusion of opinion articles, clinical cases and case studies, were included 28 articles in this review. The select articles were separated by themes: types of light curing units and different spectra of light emitted in relation to degree of conversion and characteristics of composite resin after photoactivation. The most relevant articles were selected according to the theme chosen. Considering the publication in the periodic, the date of publication, the relevance of presented data, the methodology used and the agreement with the subject to be studied. In addition, the data obtained through the articles were also annotated and related in tables to obtain a better result.

RESULTS

Table 1 describes degree of conversion data of composite resins photoactivated by 17 different light curing units, obtained in 12 articles. Twenty-six different resins were tested, and the "Tetric Evo-Ceram" was the most frequent resin. The types of photoactivating devices most used were the polywave and monowave LEDs. Table 2 presents the results of conversion degree of experimental composites. It relates the photoinitiators present in composition with the light curing unit used in photoactivation. Data from 16 articles were tabulated and the LEDs were again the most tested devices, among which the most used are Bluephase G2 (Ivoclar Vivadent, Liechtenstein, Germany) and Valo (Ultradent, Salt Lake City, Utah, USA). The photoinitiators compared were mainly camphorquinone (CQ), TPO, BAPO, MAPO and PPD. For the different photoinitiators of CQ, the devices that presented the best results were polywave and halogen light.

Table 1. Degree of conversion (%) of commercial composite resins related to type of light curing units.

Table 2. Degree of conversion (%) of experimental composites with different photoinitiators.

Table 1:

Degree of conversion (%) of commercial composite resins related to type of light curing units.

YEAR	AUTHOR	LIGHT CURING UNITS	COMPOSITE RESINS AND DEGREE OF CONVERSION (%)
2012	Santini et al.[24]	**LED**	**TetricEvoCeram**
		Bluephase G2	59,50%
		Valo	63,90%
		Bluephase	48,60%
2013	Kopperud et al.[25]	**LED**	**TetricEvoCeram**
		Bluephase 16i	57%
		L.E.Demetron II	59%
		Mini L.E.D	54,50%
		HALÓGENO	**TetricEvoCeram**
		VCL 400	62%
2014	Catelan et al.[26]	**LED**	**FiltekSupreme**
		Bluephase 16i	50,90%
		Ultralume5	46,15%
		HALÓGENO	**FiltekSupreme**
		XL 3000	44,69%
		Opitlux 501C	51,45%
2014	Lucey et al.[27]	**LED**	**Vit–l–escence**
		Bluephase G2	63,31%
		Valo	64,24%
		Bluephase	60,52%
2015	Catelan et al.[28]	**LED**	
		Bluephase 16i	
2016	Pereira et al.[29]	**LED**	
		Coltolux	

		CONCLUSION
Vit-l-escence	**Herculite XRV Ultra**	Using the Bluephase G2 and Valo equipment the composite with the best conversion grade was Vit-l-escence, and using the Bluephase equipment the composite with the best conversion degree was Herculite XRV Ultra. The device that promoted the best conversion degree in two of the three composites was Valo.
70,10%	61,20%	
72,50%	61,03%	
64,80%	65,00%	
Z250		TetricEvoCeram showed the best result regardless of equipment used.
45%		
38%		
37,50%		
Z250		TetricEvoCeram showed the best result.
39%		
4Seasons		All composites presented similar results of conversion degree, regardless of light curing unit.
50,28%		
49,18%		
4Seasons		The composite resin with better results is the 4Seasons, regardless of the equipment.
50,63%		
54,55%		
Herculite XRV Ultra		Both composites showed similar results to all light curing units. However, when Bluephase G2 is used Herculite XRV Ultra showed the best result.
62,81%		
62,34%		
67,26%		
Filtek Z250		For this type of LED this composite has a satisfactory degree of conversion.
67,48%		
FiltekSupreme XT		For this type of LED this composite does not have a satisfactory degree of conversion.
31,30%		

Table 1 (continuation):

Degree of conversion (%) of commercial composite resins related to type of light curing units.

YEAR	AUTHOR	LIGHT CURING UNITS	COMPOSITE RESINS AND DEGREE OF CONVERSION (%)	
2017	Ilie et al.[30]	**LED**	**Filtek Bulk Fill Flowable**	**Admira Fusionx-tra**
		Bluephase Style	51,85%	52,40%
2017	Shimokawa et al.[4]	**LED**	**Filtek Supreme Ultra**	**TetricEvoCeram A2**
		Protótipo luz azul	79,30%	31,90%
		Protótipo luz de amplo espectro	83,00%	55,60%
2018	Kaya et al.[31]	**LED**		
		Optima 10		
		Valo		
		Demi Ultra		
2018	Salgado et al.[1]	**LED**	**IPS EmpressDirect**	**Filtek Z350 XT**
		Bluephase G2	A3D 56,50%	A3D 51,00%
			A3E 50,20%	A3E 50,80%
			Trans 20 43,60%	CT 58,30%
2018	Derchi et al.[32]	**LED**	**Filtek Bulk Fill**	**Surefil SDR**
		Bluephase M8	37,00%	70,00%
		Bluephase style	39,00%	73,00%
		Valo	41,00%	62,00%
2018	Yancey et al.[33]	**LED**	**NovaProFill**	**Filtek Z250**
		Bluephase G2	58,00%	50,60%

				CONCLUSION
	TetricEvoFlow Bulk Fill	**SDR**	**Venus Bulk Fill**	The best result for the BluephaseStyle equipment was Venus Bulk Fill.
	55,38%	55,98%	62,97%	
	TPH Spectra High Viscosity		**TetricEvoCeram T**	The best result of conversion degree was FiltekSupreme Ultra, regardless of type of light.
	63,30%		29,80%	
	63,00%		50,20%	
Giomer				The best result for this composite was for Demi Ultra.
47,60%				
39,70%				
58,20%				
	Estelite Quick		**Opallis**	Using Bluephase G2, Opallis presented the best conversion degree result, regardless of color.
	OA3 51,10%		DA3 59,90%	
	A3 54,70%		EA3 58,80%	
	CE 50,80%		T-Neutral 58,80%	
	TetricEvoceram Bulk Fill			Surefil SDR showed best results when used with Bluephase M8 and Stylethe. TetricEvoceram Bulk Fill presented the best conversion degree when used Valo.
	58,00%			
	58,00%			
	67,00%			
	Esthet-X HD			All composites have similar degree of conversion.
	54,70%			

Table 2:
Degree of conversion (%) of experimental composites with different photoinitiators

YEAR	AUTHOR	LIGHT CURING UNITS (LIGHT SPECTRUM)	PHOTOINITIATOR AND DEGREE OF CONVERSION (%)			
2009	Shin et al.[34]	Demetron 400 (halógeno)	**CQ**	**1CQ:2OPPI**		
			4,33%	48,10%		
2010	Brandt et al.[12]	XL 2500 (halógeno)	**CQ**			
			65,10%			
		UltraBlue IS (monowave)	62,80%			
		UltraLume 5 (poliwave)	63,00%			
2011	Kameyama et al.[18]	Bluephase G2 (poliwave)	**CQ+EDMAB**			
			83,96%			
		Bluephase (poliwave)	81,92%			
2012	Ely et al.[35]	XL 3000 (halógeno)	**CQ+EDMAB**	**CQ+ QTX+ EDAB**	**QTX+ EDAB+ DPHIFP**	**QTX+EDAB+BARB**
			43,00%	43,50%	39,50%	32,00%
2012	Miletic et al.[36]	Bluephase G2 (poliwave)	**CQ+EDMAB**			
			83,43%			
		Bluephase (poliwave)	82,07%			
2012	Schneider et al.[16]	Quartz—Tungsten—Halogen (halógeno)	**CQ+EDMAB**			
			59,00%			
2013	Albuquerque et al.[15]	Optilux 501 (halógeno)	**CQ+EDMAB**	**TPO**		**TPO+EDMAB**
			58,50%	55,10%		53,50%
2014	Palin et al.[37]	Swiss Master Light (poliwave)	**CQ**			
			63,00%			
2014	Randolph et al.[38]	Aura Light device (poliwave)	**CQ**			
			57,00%			
2015	Oliveira et al.[39]	BluePhase G2 (poliwave)	**CQ**			
			DMAEMA: 57,5%, EDMAB: 65,0%, DMPOH: 62,5%			
		SmartLite (monowave)	DMAEMA: 61,0%, EDMAB: 66,0%, DMPOH: 65,0%			

*LED: diodo emissor de luz; CQ: canforoquinona; OPPI: hexafluoroantimonato de p-octiloxi-fenil-fenil-iodônio; DMAEMA: metacrilato de dimetilaminoetilo; PPD:1-fenil-1,2-propanediona; EDMAB: etil-4-dimetila-minobenzoato; TPO: óxido de trimetilbenzoil-difenilfosfina; QTX: cloreto de 2-hidroxi-3- (3,4dimetil-9-oxo-9H- tioxanteno-2-iloxi) -N, N, N-trimetil-1-propanamio; EDAB: 4-dimetilaminobenzoato de etilo; DPHIFP: hexafluorofosfato de difeniliodônio; BARB: ácido 1,3-dietil-2-tio-barbitúrico; SULF: hidrato de sal sódico do ácido p-toluenossulfínico; BAPO: óxido de fenilbis(2,4,6-trimetilbenzoil)fosfina; MAPO: monoacilfosfinooxido; BisGMA: glicidilmetimetacrilato; Fit: monômero FIT-852; BHT: butil-hidroxitolueno.

<table>
<tr><th colspan="4"></th><th>CONCLUSION</th></tr>
<tr><td colspan="2">1CQ:2DMAEMA</td><td colspan="2">1CQ:1OPPI:1DMAEMA</td><td rowspan="2">For halogen light, the degree of conversion is higher in 1: 1 combination of CQ, OPPI and DMAEMA.</td></tr>
<tr><td colspan="2">41,21%</td><td colspan="2">63,99%</td></tr>
<tr><td colspan="2">PPD</td><td colspan="2">CQ/PPD</td><td rowspan="4">Degree of conversion is higher for LED equipment, regardless of whether poly or monowave, except for the Q CQ associated with halogen light.</td></tr>
<tr><td colspan="2">58,80%</td><td colspan="2">61,40%</td></tr>
<tr><td colspan="2">61,60%</td><td colspan="2">60,90%</td></tr>
<tr><td colspan="2">62,90%</td><td colspan="2">62,60%</td></tr>
<tr><td colspan="2">TPO</td><td colspan="2">CQ+EDMAB+TPO</td><td rowspan="3">The best conversion degree was from the Bluephase G2, regardless of photoinitiator used.</td></tr>
<tr><td colspan="2">89,33%</td><td colspan="2">87,45%</td></tr>
<tr><td colspan="2">80,49%</td><td colspan="2">77,85%</td></tr>
<tr><td>QTX+
EDAB+
SULF</td><td>CQ+EDAB</td><td>QTX+
DPHIFP+
BARB</td><td>QTX+
DPHIFP+SULF</td><td rowspan="2">All experimental composites showed similar degree of conversion.</td></tr>
<tr><td>46,00%</td><td>44,50%</td><td>37,50%</td><td>48,00%</td></tr>
<tr><td colspan="2">TPO</td><td colspan="2">CQ+EDMAB+TPO</td><td rowspan="3">The best degree of conversion was from the Bluephase G2, regardless of the photoinitiator.</td></tr>
<tr><td colspan="2">89,46%</td><td colspan="2">87,97%</td></tr>
<tr><td colspan="2">79,60%</td><td colspan="2">76,79%</td></tr>
<tr><td colspan="2">TPO</td><td colspan="2">TPO+EDMAB</td><td rowspan="2">TPO associated with EDMAB presented the best results.</td></tr>
<tr><td colspan="2">62,00%</td><td colspan="2">64,00%</td></tr>
<tr><td colspan="2">BAPO</td><td colspan="2">BAPO+EDMAB</td><td rowspan="2">All experimental composites showed similar degree of conversion.</td></tr>
<tr><td colspan="2">57,70%</td><td colspan="2">57,10%</td></tr>
<tr><td colspan="4">MAPO</td><td rowspan="2">For poliwave device, the highest degree of conversion is from the photoinitiator TPO.</td></tr>
<tr><td colspan="4">70,00%</td></tr>
<tr><td colspan="4">TPO</td><td rowspan="2">For polywave device, the highest degree of conversion is from the photoinitiator TPO.</td></tr>
<tr><td colspan="4">70,00%</td></tr>
<tr><td colspan="2">BAPO</td><td colspan="2">TPO</td><td rowspan="3">Highest values of the degree of conversion was related to poliwave device, expect to CQ that had better performed for monowave device.</td></tr>
<tr><td colspan="2">68,50%</td><td colspan="2">68,00%</td></tr>
<tr><td colspan="2">49,50%</td><td colspan="2">3,50%</td></tr>
</table>

Table 2 (continuation):

Degree of conversion (%) of experimental composites with different photoinitiators

YEAR	AUTHOR	LIGHT CURING UNITS (LIGHT SPECTRUM)	PHOTOINITIATOR AND DEGREE OF CONVERSION (%)	
2016	Manojlovic et al.[40]		**BisGMA_CQ**	**BisGMA_TPO**
		(Monowave) 20s	42,20%	34,20%
		(Monowave) 40s	53,00%	51,80%
		(Poliwave) 15s	40,80%	51,80%
		(Poliwave) 30s	53,80%	58,60%
2016	Nassar et al.[41]	L.E.Demetron (halógeno)	**CQ**	**1CQ:1BHT**
			64,90%	59,90%
2016	Oliveira et al.[14]		**CQ**	
		Radii-Call (monowave)	76,40%	
		Valo (poliwave)	79,30%	
		XL2500 (halógeno)	78,10%	
2017	Cardoso et al.[13]	Optilux (halógeno)		
		Radii (monowave)		
		Bluephase (poliwave)		
2017	Vaidyanathan et al.[5]	Bluephase C8 (poliwave)	**CQ**	
			70%	
2018	Eshmawi al.[42]	Optilux 401 (halógeno)		
		Radii (monowave)		
		Demi Ultra (poliwave)		

CQ (camphorquinone); TPO (diphenyl(2.4.6-trimethylbenzoyl)-phosphine oxide); PPD (1-phenyl-1.2-propanedione); BHT (butylhydroxytoluene); BisGMA (bisphenol A glycidyldimethacrylate); Fit (a modification of UDMA with a central core and side arms); BAPO (phenylbis(2.4.6-trimethylbenzoyl) phosphine oxide); MAPO (monoacylphosphinooxide); EDMAB (ethyl 4-(dimethyamino) benzoate); DMAEMA (2-(dimethylamino) ethyl methacrylate); DMPOH (4-(N.N-dimethylamino) phenethyl alcohol); QXT (2-hydroxy-3-(3.4 dimethyl-9-oxo-9H-thioxanthen-2-yloxy)-N.N.N-trimethyl-1-propanaminium chloride); DPHIFP (diphenyliodonium hexafluorophosphate); SULF (p-toluenesulfinic acid and sodium salt hydrate); BARB (1.3-diethyl-2-thiobarbituric acid); EDAB (ethyl 4-dimethylaminobenzoate); OPPI (p-octyloxy-phenyl-phenyl iodonium hexafluoroantimonate)

		CONCLUSION
Fit_CQ	**Fit_TPO**	The degree of conversion is greater when using CQ with monowave and TPO with polywave.
45,40%	50,00%	
58,60%	55,80%	
47,40%	53,60%	
54,20%	64,30%	
1CQ:1/2BHT	**1BHT:1/2CQ**	The combination of photoinitiators decrease conversion degree of experimental composite. It is higher when only CQ was used.
59,90%	64,80%	
CQ/PPD	**PPD**	The best degree of conversion was related to polywave device and the combination of two photoinitiators.
75,40%	75,70%	
87,50%	82,80%	
79,30%	77,70%	
TPO		Photoactivation with monowave device for TPO photoinitiator was insufficient compared to other equipment.
59,80%		
1,40%		
58,80%		
TPO		The polywave device has little difference in the conversion degree of photoinitiators CQ and TPO.
75%		
CQ+TPO		For this type of combined photoinitiator of CQ and TPO, it does not make difference whether the LED used is poly or monowave, but it makes difference if the light used is halogen.
57,00%		
63,00%		
65,00%		

DISCUSSION

Composite resins need to be activated by light to get the desired result. Therefore activation is indispensable for the clinical work with this material.[2,3,8] Taking into account the commercial composites with different photoinitiators present in their composition and the photoactivation devices with different light spectra, degree of conversion of commercial and experimental composites were analyzed.

The results organized in table 1 showed that composites that were most used have camphorquinone (CQ) as the main composition of photoinitiators. Although it is present data from degree of conversion, table 1 focuses on the potential of light curing units independent of composite used. The most commonly light curing used were Valo and Bluephase G2. The best results were for Valo independent of composite used.[3,8] The best results are related to LEDs, except for monowave devices related to composites containing the photoinitiator TPO, because this photoinitiator does not activate satisfactorily in the presence of only polarized blue light.[6,13,14,39]

Table 2 used articles that tested experimental composites related to LED and halogen light-emitting devices. The results of halogen light related to all photoinitiators were satisfactory, because it has all visible light spectrum.[12-16] Already the results of monowave LED, which only emit blue light wavelength,[17,18] were not satisfactory when used with TPO and BAPO photoinitiators. Since these are best activated in the presence of violet light.[13,14,39,40] On the other hand, it presented good performance when related to composites with photoinitiator CQ. The polywave LED was the one that presented best results, because it can emit peaks of light at wavelengths 450 at 470nm, blue light, and 400 at 410 nm, violet light,[17,19,20] taking better of different photoinitiators, although it does not attend to all in a similar way.[39,43] Already the photoinitiator that responded better to all the light curing units was the CQ, for being better photoactivated in the presence of blue light,[17,18] present in all equipment related in the articles researched. In both tables the best performance of polywave LED and halogen light equipment was observed. Although halogen light is not the most commonly used device in clinical practice, it is still recurrent in research as a comparison with other devices, since it is efficiency as a photoactivator is still significant.[12,15]

Results indicate that light curing unit and light spectrum influence the composites degree of conversion. It can produce different results according to combination of different spectra of light and different photoinitiators present in composites. Whereas the commercial composites hardly tell the composition and the percentage of this photoinitiator, if the dentist does not know the photoinitiator of composite he uses, even more work with different composites, it may be safer to use equipment that emits greater wavelength amplitude.

In carrying out this study, some difficulties were found. Commercial composites manufacturers do not provide for their buyers and researchers the amount of photoinitiators present in the resins, as can be seen in Part 1 of this Literature Review. In consequence, the articles presents in this study that showed data from photoinitiators related with photoactivation devices were performed in experimental composites. This is not only a hindrance to research but also detrimental to dental surgeons using these composites, since to carry out a satisfactory polymerization it is necessary to relate the photoactivating devices, which emits a corresponding wavelength to the photoinitiator present in the composite.[3]

In addition, although there are numerous articles about photoactivation of composite resins, there are few articles that relate the type of composite and the photoactivation devices used in order to directly analyze composite degree of conversion. Therefore, some data were collected from articles with different objectives from those related to this study, but that had data to be added or information on conversion degree. Another difficulty deriving from obtaining these data is limiting the evaluation of values of great importance that are closely related to degree of conversion, such as irradiance. Due to the influence of irradiance on the degree of conversion as well as the light spectrum,[44] the results showed the existence of a great difference in degree of conversion of composite resins to each photoactivator device studied. Some devices have the same spectrum of light, but different values of irradiance, or have different spectra but also have different irradiances, a fact that directly influence the degree of conversion.[4,45]

In addition to that analyzed in this article, the way in which the photoactivation equipment is used can influence the quality of restoration with composite resins.[28,46-49] The time,[11,38,47-49] the distance between tip and surface[28,46,49] and the position of device in relation to tooth[46,49] are important factors to be observed during the photoactivation. It should also be analyzed the polymerization depth related with techniques used for each material, according to its composition, to know the best way to use that fiver gives the best properties of material after curing.[3,11,26]

Characteristics related to the apparatus used can affect the properties of composites after curing.[2,8,50,51] With the increasing use of composites, the use of light curing devices has also increased, with it the number of different devices also.[2,52] This change brings several new features related to light curing devices on the market that must be understood. The type of edge used,[8] the battery level in the case of equipment which is not connected to sockets,[29,53] the gear power (W) and the irradiance (mW / cm^2).[4] Therefore it is fundamental that the dentist knows by which light curing unit the resin that he is using is better activated. Since the mechanical properties of the composite are directly related to degree of conversion. Consequently, good polymerization of the composites makes the work more satisfactory and long-lived[2,9-11]. In addition, it is important that manufacturers make it clear in the package inserts or technical profiles, which photoinitiators are used and with which percentage, facilitating the clinician's choice based on this information.

CONCLUSION

The use of light curing compatible with this photoinitiator in the composite is essential. Each photoinitiator has a maximum activation at a particular wavelength of light. The most studied photoinitiators are CQ and TPO, which are better photoactivated by blue light and violet light, respectively. Therefore, the best performance is related to composites with different photoinitiators, when photoactivated by devices that emit a greater amplitude of visible light wavelength, the polywave LED. Considering that most of the composites have camphorquinone (CQ), both polywave and monowave LEDs have performed well.

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REFERENCES

1. Salgado VE, Rego GF, Schneider LF, Moraes RR, Cavalcante LM. Does translucency influence cure efficiency and color stability of resin-based composites? Dent Mater. 2018;34(7):957-66.
2. Tongtaksin A, Leevailoj C. Battery charge affects the stability of light intensity from light-emitting diode light-curing units. Oper Dent. 2017;42(5):497-504.
3. Rueggeberg FA, Giannini M, Arrais CAG, Price RBT. Light curing in dentistry and clinical implications: a literature review. Braz Oral Res. 2017;31(suppl 1):e61.
4. Shimokawa C, Sullivan B, Turbino ML, Soares CJ, Price RB. Influence of emission spectrum and irradiance on light curing of resin-based composites. Oper Dent. 2017;42(5):537-47.
5. Vaidyanathan TK, Vaidyanathan J, Lizymol PP, Ariya S, Krishnan KV. Study of visible light activated polymerization in BisGMA-TEGDMA monomers with Type 1 and Type 2 photoinitiators using Raman spectroscopy. Dent Mater. 2017;33(1):1-11.
6. Santini A, Gallegos IT, Felix CM. Photoinitiators in dentistry: a review. Primary Dent J. 2013;2(4):30-3.
7. Shin DH, Yun DI, Park MG, Ko CC, Garcia-Godoy F, Kim HI, et al. Influence of DPSS laser on polymerization shrinkage and mass change of resin composites. Photomed Laser Surg. 2011 Aug;29(8):545-50.
8. Soares CJ, Rodrigues MP, Oliveira LRS, Braga SSL, Barcelos LM, Silva GRD, et al. An evaluation of the light output from 22 contemporary light curing units. Braz Dent J. 2017;28(3):362-71.
9. Faria ESAL, Pfeifer CS. Impact of thio-urethane additive and filler type on light-transmission and depth of polymerization of dental composites. Dent Mater. 2017;33(11):1274-85.
10. Soares CJ, Faria ESAL, Rodrigues MP, Vilela ABF, Pfeifer CS, Tantbirojn D, et al. Polymerization shrinkage stress of composite resins and resin cements - What do we need to know? Braz Oral Res. 2017;31(suppl 1):e62.
11. Rodriguez A, Yaman P, Dennison J, Garcia D. Effect of light-curing exposure time, shade, and thickness on the depth of cure of bulk fill composites. Oper Dent. 2017;42(5):505-13.
12. Brandt WC, Schneider LF, Frollini E, Correr-Sobrinho L, Sinhoreti MA. Effect of different photo-initiators and light curing units on degree of conversion of composites. Braz Oral Res. 2010;24(3):263-70.
13. Cardoso KA, Zarpellon DC, Madruga CF, Rodrigues JA, Arrais CA. Effects of radiant exposure values using second and third generation light curing units on the degree of conversion of a lucirin-based resin composite. J Appl Oral Sci. 2017;25(2):140-6.
14. Oliveira D, Rocha MG, Correa IC, Correr AB, Ferracane JL, Sinhoreti MAC. The effect of combining photoinitiator systems on the color and curing profile of resin-based composites. Dent Mater. 2016;32(10):1209-17.
15. Albuquerque PP, Moreira AD, Moraes RR, Cavalcante LM, Schneider LF. Color stability, conversion, water sorption and solubility of dental composites formulated with different photoinitiator systems. J Dent. 2013;41 Suppl 3:e67-72.
16. Schneider LF, Cavalcante LM, Prahl SA, Pfeifer CS, Ferracane JL. Curing efficiency of dental resin composites formulated with camphorquinone or trimethylbenzoyl-diphenyl-phosphine oxide. Dent Mater. 2012;28(4):392-7.
17. Price RB, Labrie D, Rueggeberg FA, Sullivan B, Kostylev I, Fahey J. Correlation between the beam profile from a curing light and the microhardness of four resins. Dent Mater. 2014;30(12):1345-57.
18. Kameyama A, Hatayama H, Kato J, Haruyama A, Teraoka H, Takase Y, et al. Light-curing of dental resins with GaN violet laser diode: the effect of photoinitiator on mechanical strength. Lasers Med Sci. 2011;26(3):279-83.
19. Michaud PL, Price RB, Labrie D, Rueggeberg FA, Sullivan B. Localised irradiance distribution found in dental light curing units. J Dent. 2014;42(2):129-39.
20. Price RB, Labrie D, Rueggeberg FA, Felix CM. Irradiance differences in the violet (405 nm) and blue (460 nm) spectral ranges among dental light-curing units. J Esthet Restor Dent. 2010 Dec;22(6):363-77.
21. Carvalho AA, Moreira FC, Fonseca RB, Soares CJ, Franco EB, Souza JB, et al. Effect of light sources and curing mode techniques on sorption, solubility and biaxial flexural strength of a composite resin. J Appl Oral Sci. 2012;20(2):246-52.
22. Milly H, Banerjee A. Evaluating the clinical use of light-emitting diode vs halogen photocuring units. Oral Health Prev Dent. 2018;16(1):21-5.
23. Gonulol N, Ozer S, Tunc ES. Effect of a third-generation LED LCU on microhardness of tooth-colored restorative materials. Int J Paediatr Dent. 2016 Sept;26(5):376-82.
24. Santini A, Miletic V, Swift MD, Bradley M. Degree of conversion and microhardness of TPO-containing resin-based composites cured by polywave and monowave LED units. J Dent. 2012 July;40(7):577-84.
25. Kopperud HM, Johnsen GF, Lamolle S, Kleven IS, Wellendorf H, Haugen HJ. Effect of short LED lamp exposure on wear resistance, residual monomer and degree of conversion for Filtek Z250 and Tetric EvoCeram composites. Dent Mater. 2013;29(8):824-34.
26. Catelan A, Mainardi MC, Soares GP, Lima AF, Ambrosano GM, Lima DA, et al. Effect of light curing protocol on degree of conversion of composites. Acta Odontol Scand. 2014;72(8):898-902.
27. Lucey SM, Santini A, Roebuck EM. Degree of conversion of resin-based materials cured with dual-peak or single-peak LED light-curing units. Int J Paediatr Dent. 2015 Mar;25(2):93-102.
28. Catelan A, Araujo LS, Silveira BC, Kawano Y, Ambrosano GM, Marchi GM, et al. Impact of the distance of light curing on the degree of conversion and microhardness of a composite resin. Acta Odontol Scand. 2015;73(4):298-301.
29. Pereira AG, Raposo L, Teixeira D, Gonzaga R, Cardoso IO, Soares CJ, et al. Influence of battery level of a cordless led unit on the properties of a nanofilled composite resin. Oper Dent. 2016;41(4):409-16.
30. Ilie N. Impact of light transmittance mode on polymerisation kinetics in bulk-fill resin-based composites. J Dent. 2017 Aug;63:51-9.
31. Kaya MS, Bakkal M, Durmus A, Durmus Z. Structural and mechanical properties of a giomer-based bulk fill restorative in different curing conditions. J Appl Oral Sci. 2018 Jan 18;26:e20160662.
32. Derchi G, Vano M, Ceseracciu L, Diaspro A, Salerno M. Stiffness effect of using polywave or monowave LED units for photo-curing different bulk fill composites. Dent Mater J. 2018 Sept 30;37(5):709-16.
33. Yancey EM, Lien W, Nuttall CS, Brewster JA, Roberts HW, Vandewalle KS. Properties of a new nanofiber restorative composite. Oper Dent. 2019 Jan-Feb;44(1):34-41.
34. Shin DH, Rawls HR. Degree of conversion and color stability of the light curing resin with new photoinitiator systems. Dent Mater. 2009;25(8):1030-8.
35. Ely C, Schneider LF, Ogliari FA, Schmitt CC, Correa IC, Lima Gda S, et al. Polymerization kinetics and reactivity of alternative initiators systems for use in light-activated dental resins. Dent Mater. 2012;28(12):1199-206.
36. Miletic V, Santini A. Micro-Raman spectroscopic analysis of the degree of conversion of composite resins containing different initiators cured by polywave or monowave LED units. J Dent. 2012;40(2):106-13.

37. Palin WM, Hadis MA, Leprince JG, Leloup G, Boland L, Fleming GJ, et al. Reduced polymerization stress of MAPO-containing resin composites with increased curing speed, degree of conversion and mechanical properties. Dent Mater. 2014;30(5):507-16.

38. Randolph LD, Palin WM, Watts DC, Genet M, Devaux J, Leloup G, et al. The effect of ultra-fast photopolymerisation of experimental composites on shrinkage stress, network formation and pulpal temperature rise. Dent Mater. 2014;30(11):1280-9.

39. Oliveira DC, Rocha MG, Gatti A, Correr AB, Ferracane JL, Sinhoret MA. Effect of different photoinitiators and reducing agents on cure efficiency and color stability of resin-based composites using different LED wavelengths. J Dent. 2015;43(12):1565-72.

40. Manojlovic D, Dramicanin MD, Milosevic M, Zekovic I, Cvijovic-Alagic I, Mitrovic N, et al. Effects of a low-shrinkage methacrylate monomer and monoacylphosphine oxide photoinitiator on curing efficiency and mechanical properties of experimental resin-based composites. Mater Sci Eng C Mater Biol Appl. 2016 Jan 1;58:487-94.

41. Nassar H, Chu TM, Platt J. Optimizing light-cured composite through variations in camphorquinone and butylhydroxytoluene concentrations. Braz Oral Res. 2016 May 20;30(1). pii: S1806-83242016000100256.

42. Eshmawi YT, Al-Zain AO, Eckert GJ, Platt JA. Variation in composite degree of conversion and microflexural strength for different curing lights and surface locations. J Am Dent Assoc. 2018 Oct;149(10):893-902.

43. Sampaio CS, Atria PJ, Rueggeberg FA, Yamaguchi S, Giannini M, Coelho PG, et al. Effect of blue and violet light on polymerization shrinkage vectors of a CQ/TPO-containing composite. Dent Mater. 2017;33(7):796-804.

44. Konerding KL, Heyder M, Kranz S, Guellmar A, Voelpel A, Watts DC, et al. Study of energy transfer by different light curing units into a class III restoration as a function of tilt angle and distance, using a MARC Patient Simulator (PS). Dent Mater. 2016;32(5):676-86.

45. Guimaraes GF, Marcelino E, Cesarino I, Vicente FB, Grandini CR, Simoes RP. Minimization of polymerization shrinkage effects on composite resins by the control of irradiance during the photoactivation process. J Appl Oral Sci. 2018;26:e20170528.

46. Faria ESAL, Fanger C, Nguyen L, Howerton D, Pfeifer CS. Impact of material shade and distance from light curing unit tip on the depth of polymerization of composites. Braz Dent J. 2017;28(5):632-7.

47. Shimokawa CA, Carneiro PM, Lobo TR, Arana-Chavez VE, Youssef MN, Turbino ML. Five second photoactivation? A microhardness and marginal adaptation in vitro study in composite resin restorations. Int Dent J. 2016;66(5):257-63.

48. Borges BC, Souza-Junior EJ, Catelan A, Lovadino JR, Santos PH, Paulillo LA, et al. Influence of extended light exposure time on the degree of conversion and plasticization of materials used as pit and fissure sealants. J Investig Clin Dent. 2010 Nov;1(2):151-5.

49. Holroyd M, Ilie N. Effects of exposure time and exposure distance on the degree of cure in light-activated pit and fissure sealants. J Dent. 2013;41(12):1222-8.

50. Dsouza R, Subhash H, Neuhaus K, Kantamneni R, McNamara PM, Hogan J, et al. Assessment of curing behavior of light-activated dental composites using intensity correlation based multiple reference optical coherence tomography. Lasers Surg Med. 2016 Jan;48(1):77-82.

51. Harlow JE, Sullivan B, Shortall AC, Labrie D, Price RB. Characterizing the output settings of dental curing lights. J Dent. 2016 Jan;44:20-6.

52. Morimoto S, Zanini RA, Meira JB, Agra CM, Calheiros FC, Nagase DY. Influence of physical assessment of different light-curing units on irradiance and composite microhardness top/bottom ratio. Odontology. 2016;104(3):298-304.

53. AlShaafi MM, Harlow JE, Price HL, Rueggeberg FA, Labrie D, AlQahtani MQ, et al. Emission characteristics and effect of battery drain in "budget" curing lights. Oper Dent. 2016;41(4):397-408.

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ERRATA:

Errata of the article published in v.16, n.1 edition of the Journal of Clinical Dentistry and Research, pages 45 to 56, entitled "Composite resin in the last 10 years - Literature Review. Part 1: Chemical composition" by Paulo Vinicius Soares, Thiago Silva Peres, Amanda Ribeiro Wobido and Alexandre Coelho Machado. DOI: https://doi.org/10.14436/2447-911x.16.1.045-056.oar"

On page 48, Table 1, 13th line, in the "Manufacturer" column, where it reads: VOCO GmbH, Cuchaven, Germany; It should read: VOCO GmbH, Cuxhaven, Germany.

On page 48, Table 1, 13th line, in the "Matrix" column, where it reads: Bis-GMA, HEMA, UDMA, TEGDMA; it should read: Free formulation of Bis-GMA, HEMA, UDMA, TEGDMA.

On page 48, Table 1, 14th line, in the "Manufacturer" column, where it reads: "VOCO GmbH, Cuchaven, Germany"; it should read "VOCO GmbH, Cuxhaven, Germany".

Errata of the article published in v.16, n.1 edition of the Journal of Clinical Dentistry and Research, pages 58 and 72, entitled "Composite resin in the last 10 years - Literature Review. Part 1: Chemical composition" by Paulo Vinicius Soares, Gabriela Resende Allig, Amanda Ribeiro Wobido and Alexandre Coelho Machado. DOI: https://doi.org/10.14436/2447-911x.16.1.058-072.oar

On page 63, Table 1, concerning to the product "N'Durance", in the Brand column, where "Coltene" appears, read: "Septodont".