The Effect of Shade and Curing Time on Depth of Cure (DOC) in Two Types of Composites, Polymerized with a Halogen Light Cure System

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Abstract:

The aim of study was to determine the depth of cure DOC of different shades in light-activated composite polymerized with a halogen light cure unit with different curing times. 90 samples were prepared that divided into 18 groups of 5 samples for each group using a tube-like stainless steel mold utilizing two composite materials (SwissTEC and Composan LCM), three shades (Al, A2 and A3) cured for 20, 40 and 60 seconds. The cured samples removed from the mold and uncured material scrapped manually and remaining length of each sample measured by micrometer. 3-way ANOVA (at $p \geq 0.05$) followed by Duncan multiple range test showed that DOC of SwissTEC is significantly higher than Composan LCM, lighter shade Al give more DOC than others followed by A2 and A3 successively, and 60s curing time resulted in better DOC than 40s and the latter was better than 20s.The conclusions of this study are that all materials, shades and cuing times passed the ISO 2000/4049 requirements, Darker shades had less DOC than lighter shades, but increasing the curing time can improve DOC of darker shades. The method used in this study may be used as one of the simple methods for checking the efficiency of halogen LCUs in dental clinics.

Key words: depth of cure, DOC, light cure composite, shade, curing time.

Introduction:

The development of dental resin based composite restorative materials, started in the late 1950s and early 1960s by Bowen[1-3].Now a days composites are presently the most popular tooth colored materials[4].Basically, composite restorative materials consist of a continuous polymeric or resin matrix in which inorganic filler is dispersed[5] .

The first composites were cured by chemically activated polymerization process. known as cold curing or chemical curing, and was initiated by mixing two pastes[3].

Overcoming problems of chemical activation types, curing dental composites with blue light were first introduced in 1970s[6,7].The source of blue light is normally a halogen bulb combined with filter, so that light in the range of 410 -500 nm region of the visible light is produced, light in this range of wave lengths is effectively absorbed by the camphorquinone photo initiator[8], that is presented as a component of light activated dental composite as the light causes excitation of camphorquinone, which in combination with an amine produces free radicals which lead to polymerization of the resin monomer at the molecular scale .Macroscopically, the dental composites are hardened typically after light exposure times ranging from 20 to 60 seconds[9].

Conventional Halogen light is tile most common method of polymerizing dental composite restorations, however, there has been a concern that the quality of restorative composite depends on the capability of the light source to adequately polymerize the resin with a specified exposure time.(10)For more than two decades, visible-light curing units have" been based on quartz-tungsten-halogen technology[11].

A decrease in output of light with time and with distance may result in a low degree of conversion and a shallow depth of cure, which in turn reduce the quality of the final restoration[12].

Recently, other curing methods such as laser and xenon arc sources are used in clinical practice with the advantage of a reduced curing time. These devices have a more complex construction and are more costly compared with halogen sources. In addition, lasers require stringent additional safety precautions(6,9).

Several factors can affect the curing of composite material such as composition, shade (opacity), type of photo initiator, wave length, light intensity , the distance between the cured mass and the curing tip of the curing system, and finally the thickness of the cured increment (depth of cure)(13-16) .

A group of methods such as hardness test, translucency changes, interaction with color dies, nuclear magnetic resonance, double bond conversion, micro imaging, tactile tests, penetration and scraping tests that are used to measure the depth of cure of composites, that is included in this study.

According to ISO 2000/4049 standard for polymerization of resin based composite requires material to have a minimum depth of cure 1.5 mm when irradiated for the manufacturer's recommended time, and when the depth of cure is defined in this specification as 50 % of the length of cured composite sample after the soft uncured portion has been scraped away manually.

Aim of study :

This study investigates whether the depth of cure with different shades of two commercially available composite restorative materials met the ISO defined depth of cure required when irradiated by using halogen light cure system with intensity of 425 mw/cm^2 and wave length of 505 nm. The study also suggests a method by which dentists can establish the depth of cure of composite and periodically verify the consistency of light cure systems in regard to depth of cure.

Materials & Methods:

A stainless steel model with 6 mm diameter and 8 mm height(17,18);this model is fabricated by using a nozzle of diesel engine which has a hollow(tube like) gap inside, with 6 mm in diameter and it has a corresponding shaft (rod) that can be perfectly fitted within the gap Fig(l).The body of nozzle is cut by turner machine at length of 8 mm, thereby a solid tube model with highly smooth inner surfaces of 8 mm in height and of 6 mm in diameter have been obtained, the remaining part of the nozzle was discarded Fig(2).

Fig (1)

Fig(2)

A: as received nozzle. B:the discarded part

C : model . D: shaft(rod).

The composite materials used are :

1. SwissTEC Composite :which is available in shades: Al, A2 and A3.

2.Composan LCM Composan LCM is available in shades: Al, A2 and A3.

The information about each material is listed in table (1) according to the leaflet.

Table (1): The composite materials used .

Material	Type	Filler % by volume	Filler % by wt	Particles size range	Manufacturer
SwissTEC	Hybrid	59	78	0.04-2.8 µm	Coltene®/Whaledent AG (Manufacturer) Feldwiesenstrasse 20 9450 Altstatten/Switzerland
Composan LCM	Hybrid	60	76.5	0.05-2 µm	PROMEDICA Domagkstr. 24537 Neumunster Germany

The light cure system is Coltolux®50 (Coltene®/ Whaledent GmbH Fischenzstrasse 39 D-78462 Konstanz Germany) (Fig.3); it is a halogen type with preset times of curing 20, 40, 60 seconds; A new device for first time is used and light intensity is evaluated by radiometer (CROMATEST 7041, Curing Radiometer, Germany).

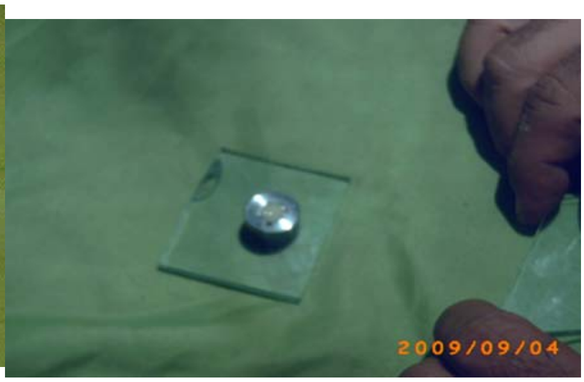
Transparent strips used are; Hawe Transparent strips (Hawe neos Dental CH-6925 Gentilino Switzerland)

Fig(3)

Samples fabrication:

The stainless steel mold is placed on a flat glass slab covered with transparent strip Fig (4), then composite material is packed into a mold with ash 6 hand instrument ,after complete loading of the mold the material was covered with another transparent strip on the top of the filled mold Fig (5).

Fig(4)

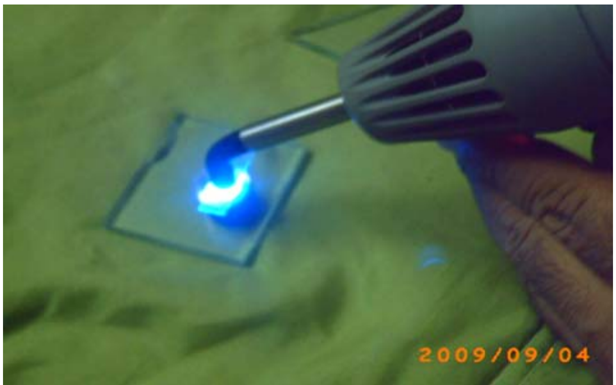


Fig(5)

We press another flat glass slab against the top layer of transparent strip to extrude the excess of resin-based composite, forming a flat surface[11] Fig(6), after that top glass slab is removed Fig(7), the tip of curing system is placed in contact with the transparent strip on top of the material in the mold, Fig(8), A total of 90 samples were prepared, for the two selected materials (SwissTEC and Composan LCM) with three shades (Al, A2, A3), each 5 samples were cured for either 20, 40 or 60 seconds curing times (Table 2).The DOC is determined by using the method described in the ISO 2000 /4049 for resin based filling restorative and luting materials as follows; Immediately after polymerization, the top transparent strip was removed Fig(9), Then the uncured material at the bottom of the mold is removed Fig(10) to make a gap for insertion of the corresponding rod to push the sample from its bottom toward the other direction, to the top side of the tube-like mold Fig (11-13).

As sample is retrieved from the mold, the remaining uncured material at the bottom of the sample removed manually by scraping it away with a plastic spatula. Finally, the remaining uncured material at the scrapped side was scraped off with alcohol-treated gauze (15) to insure complete removal of uncured composite and cleaning of the sample.

Fig(6) Fig(7)



Fig(8) Fig(9)

Fig(10) Fig(11)

Fig(12) Fig(13)

The length of the cured sample is measured to the nearest (0.0l mm) using a micrometer(19,20). The micrometer is (Digimatic Micrometer, Mitutoyo Corp., Kawasaki, Japan), (0-25mm, accuracy ± 0.01 mm) .

Each sample is measured three times and the mean value of these three readings was recorded(12), as the DOC is 50% of the mean measured length.

Table (2): Samples distribution and grouping

Material	Shade	Curing Time	Groups
SwissTEC	A1	20s	SwissTEC - A1 - 20s
		40s	SwissTEC - A1 - 40s
		60s	SwissTEC – A1 – 60s
	A2	20s	SwissTEC – A2 - 20s
		40s	SwissTEC – A2 - 40s
		60s	SwissTEC – A2 – 60s
	A3	20s	SwissTEC – A3 - 20s
		40s	SwissTEC – A3 - 40s
		60s	SwissTEC – A3 – 60s
Composan	A1	20s	Composan - A1 - 20s
		40s	Composan - A1 - 40s
		60s	Composan – A1 – 60s
	A2	20s	Composan – A2 - 20s
		40s	Composan – A2 - 40s
		60s	Composan – A2 – 60s
	A3	20s	Composan – A3 - 20s
		40s	Composan – A3 - 40s
		60s	Composan – A3 – 60s

Results:

Mean and standard deviation of DOC (in millimeters) for each tested group are calculated and listed in Table (3) and represented by a histogram in Figure (14).

Data are analyzed using 3-factor analysis of variance (3-way ANOVA) to indicate if there are any statistical differences among groups ($p \leq 0.05$), as shown in Table (4)

Effect of Composite Material Type:

Analysis of variance Table (4) shows that there is a highly significant difference in DOC between SwissTEC and Composan LCM composite. Duncan multiple range test for the two materials that is represented in Table (5) indicates that DOC of SwissTEC (2.75 mm) is significantly more than that of Composan LCM (2.57 mm).

Effect of Shade:

ANOAVA reveals that there are highly significant differences among different shades. Duncan multiple range test for the tested shades Table (6) indicates that DOC of A1 shade (2.72 mm) is more than other shades, followed by A2 shade (2.66 mm) and the least value is for A3 shade (2.61 mm).

Effect of Curing Times:

ANOAVA reveals that there are highly significant differences among different curing times. Duncan multiple range test for the three curing times Table (7) indicates that DOC of 60 seconds(2.96) mm is greater than the other two curing time, while DOC of 40 seconds (2.72) mm is greater than of 20 seconds (2.32) mm.

Effect of Composite Type and Shade Interaction:

ANOVA indicates that composite type and shade interaction significantly affect the DOC. Duncan multiple range test for interaction between composite type and shade Table(8) and Figure (15) indicates that SwissTEC-Al has greater DOC (2.78 mm), then SwissTEC-A2 (2.75 mm), then SwissTEC-A3 (2.73 mm), Composan-Al (2.67 mm), Composan-A2 (2.58 mm) and

Composan-A3 (2.48 mm) respectively.

Effects of Composite Type and Curing Time Interaction:

ANOVA indicates that composite type and curing time interaction significantly affects the DOC. Duncan multiple range test for interaction between composite type and curing time Table (9) and Figure (16) indicates that SwissTEC-60s has greatest DOC (3.05 mm), then Composan-60s (2.86 mm), SwissTEC-40s (2.78 mm), Composan-40s (2.66 mm), SwissTEC-20s (2.42 mm) and Composan-20s (2.21 mm) respectively.

Effects of Shade and Curing Time Interaction:

ANOVA indicates that composite shade and curing time interaction significantly affect the DOC. Duncan multiple range test for interaction between composite shade and curing time Table (10) and Figure (17) indicates that Al-60s has greatest DOC (3.02 mm), then A2-60s (2.92 mm), A3-60s (2.91 mm), with no significant difference with A2-60s group, Al-40s (2.77 mm), A2-40s (2.74 mm), A3-40s (2.62 mm), Al-20s (2.38 mm), A2-20s (2.33 mm) and A3-20s (2.25 mm) respectively.

Effects of Composite Type, Shade and Curing Time Interaction:

ANOVA indicates that composite type, shade and curing time interaction significantly affect the DOC. Duncan multiple range test for interaction among composite type, shade and curing time Table (11) and Figure (14) indicates that SwissTEC-Al-60s has greatest DOC value (3.09 mm), then SwissTEC-A2-60s (3.03 mm), SwissTEC-A3-60s (3.02 mm), Composan-Al-60s (2.95 mm), Composan-A2-60s (2.82 mm), Composan-A3-60s (2.81 mm), SwissTEC-Al-40s (2.79 mm), SwissTEC-A2-40s (2.79 mm), SwissTEC-A3-40s (2.77 mm), Composan-Al-40s (2.74 mm), Composan-A2-40s (2.69 mm), Composan-A3-40s (2.53 mm), SwissTEC-Al-20s (2.44 mm), SwissTEC-A2-20s (2.42 mm), SwissTEC-A3-20s (2.40 mm), Composan-Al-20s (2.32 mm), Composan-A2-20s (2.23 mm) and the least DOC was for Composan-A3-20s (2.11 mm).

Although the mean value of some groups are higher than others, but statistically no significant differences present among some groups as follows: no significant differences between(SwissTEC-A2-60s and SwissTEC-A3-60s), (Composan-A2-60s and Composan-A3-60s), (Composan-A3-60s, SwissTEC-Al-40s and SwissTEC-A2-40s), (SwissTEC-Al-40s, SwissTEC-A2-40s and SwissTEC-A3-40s), (SwissTEC-Al-20s and SwissTEC-A2-20s), (Composan-A2-20s and Composan-A3-20s) groups.

Table (3): Mean and Standard Deviation for DOC of All Tested Groups.

Groups (Type - Shade – Curing Time)	N	Mean	Std
SwissTEC - A1 - 20s	5	2.44	0.042
SwissTEC - A1 - 40s	5	2.79	0.022
SwissTEC – A1 – 60s	5	3.09	0.023
SwissTEC – A2 - 20s	5	2.43	0.035
SwissTEC – A2 - 40s	5	2.79	0.022
SwissTEC – A2 – 60s	5	3.03	0.019
SwissTEC – A3 - 20s	5	2.40	0.010
SwissTEC – A3 - 40s	5	2.77	0.016
SwissTEC – A3 – 60s	5	3.02	0.021
Composan - A1 - 20s	5	2.32	0.015
Composan - A1 - 40s	5	2.74	0.008
Composan – A1 – 60s	5	2.95	0.023
Composan – A2 - 20s	5	2.23	0.018
Composan – A2 - 40s	5	2.69	0.007
Composan – A2 – 60s	5	2.82	0.018
Composan – A3 - 20s	5	2.11	0.007
Composan – A3 - 40s	5	2.53	0.015
Composan – A3 – 60s	5	2.81	0.012

N = number of samples s = seconds A1, A2, A3 = shades
Std = Standard Deviation

Table (4): 3-way Analysis of Variance (ANOVA).

Source	DF	MS	F-value	*P* - value
Composite Type	1	0.6777	1600.95	0.0001 **
Shade	2	0.0992	234.31	0.0001 **
Curing time	2	3.0906	7300.65	0.0001 **
Type × Shade	2	0.0372	87.88	0.0001 **
Type × Curing time	2	0.0122	28.81	0.0001 **
Shade × Curing time	4	0.0047	11.15	0.0001 **
Type × Shade × Curing time	4	0.0043	8.13	0.0001 **
Error	72	0.0004		
Total	89			

DF = degree of freedom , ** = highly significant ($p<0.001$) ,F=F calculated ,
P = probability value, MS = mean square

Table (5): Duncan Multiple Range Test for the two Composite Materials.

Composite Type	N	Mean (mm)	Std	Duncan grouping
SwissTEC	45	2.75	0.262	A
Composan	45	2.57	0.283	B

N = number of samples , *Std* = Standard Deviation ,
Groups with same Duncan grouping letters are not significantly different

Table (6): Duncan Multiple Range Test for the Three Shades Used.

Shade	N	Mean (mm)	Std	Duncan grouping
A1	30	2.72	0.275	A
A2	30	2.66	0.271	B
A3	30	2.61	0.305	C

N = number of samples *Std* = Standard Deviation
Groups with same Duncan grouping letters are not significantly different

Table (7): Duncan Multiple Range Test for the Three Curing Times.

Curing Time	N	Mean (mm)	Std	Duncan grouping
20s	30	2.32	0.123	C
40s	30	2.72	0.092	B
60s	30	2.96	0.120	A

N = number of samples *Std* = Standard Deviation
Groups with same Duncan grouping letters are not significantly different

Table (8): Duncan Multiple Range Test for Composite Type and Shade Interaction.

Type - Shade	N	Mean (mm)	Std	Duncan grouping
SwissTEC - A1	15	2.77	0.274	A
SwissTEC - A2	15	2.75	0.259	B
SwissTEC - A3	15	2.73	0.266	C
Composan - A1	15	2.76	0.274	D
Composan - A2	15	2.58	0.264	E
Composan - A3	15	2.48	0.298	F

N = number of samples Std = Standard Deviation
Groups with same Duncan grouping letters are not significantly different

Table (9): Duncan Multiple Range Test for Composite Type and curing Time Interaction.

Type – Curing Time	N	Mean (mm)	Std	Duncan grouping
SwissTEC - 20s	15	2.42	0.036	E
SwissTEC - 40s	15	2.78	0.021	C
SwissTEC - 60s	15	3.05	0.036	A
Composan - 20s	15	2.23	0.088	F
Composan - 40s	15	2.66	0.092	D
Composan - 60s	15	2.86	0.069	B

N = number of samples   Std = Standard Deviation
Groups with same Duncan grouping letters are not significantly different

Table (10): Duncan Multiple Range Test for the Shade and Curing Time Interaction.

Shade – Curing Time	N	Mean (mm)	Std	Duncan grouping
A1 – 20s	10	2.38	0.074	F
A1 – 40s	10	2.77	0.031	C
A1 – 60s	10	3.02	0.076	A
A2 – 20s	10	2.33	0.108	G
A2 – 40s	10	2.74	0.054	D
A2 – 60s	10	2.93	0.113	B
A3 – 20s	10	2.25	0.152	H
A3 – 40s	10	2.65	0.125	E
A3 – 60s	10	2.93	0.114	B

N = number of samples   Std = Standard Deviation
Groups with same Duncan grouping letters are not significantly different

Table (11): Duncan Multiple Range Test for Composite Type, Shade and Curing Time Interaction.

Type - Shade – Curing Time	N	Mean (mm)	Std	Duncan grouping
SwissTEC - A1 - 20s	5	2.44	0.042	J
SwissTEC - A1 - 40s	5	2.79	0.022	E F
SwissTEC – A1 – 60s	5	3.09	0.023	A
SwissTEC – A2 - 20s	5	2.43	0.035	J
SwissTEC – A2 - 40s	5	2.79	0.022	E F
SwissTEC – A2 – 60s	5	3.03	0.019	B
SwissTEC – A3 - 20s	5	2.40	0.010	K
SwissTEC – A3 - 40s	5	2.77	0.016	F
SwissTEC – A3 – 60s	5	3.02	0.021	B
Composan - A1 - 20s	5	2.32	0.015	L
Composan - A1 - 40s	5	2.74	0.008	G
Composan – A1 – 60s	5	2.95	0.023	C
Composan – A2 - 20s	5	2.23	0.018	M
Composan – A2 - 40s	5	2.69	0.007	H
Composan – A2 – 60s	5	2.82	0.018	D
Composan – A3 - 20s	5	2.11	0.007	N
Composan – A3 - 40s	5	2.53	0.015	I
Composan – A3 – 60s	5	2.81	0.012	E D

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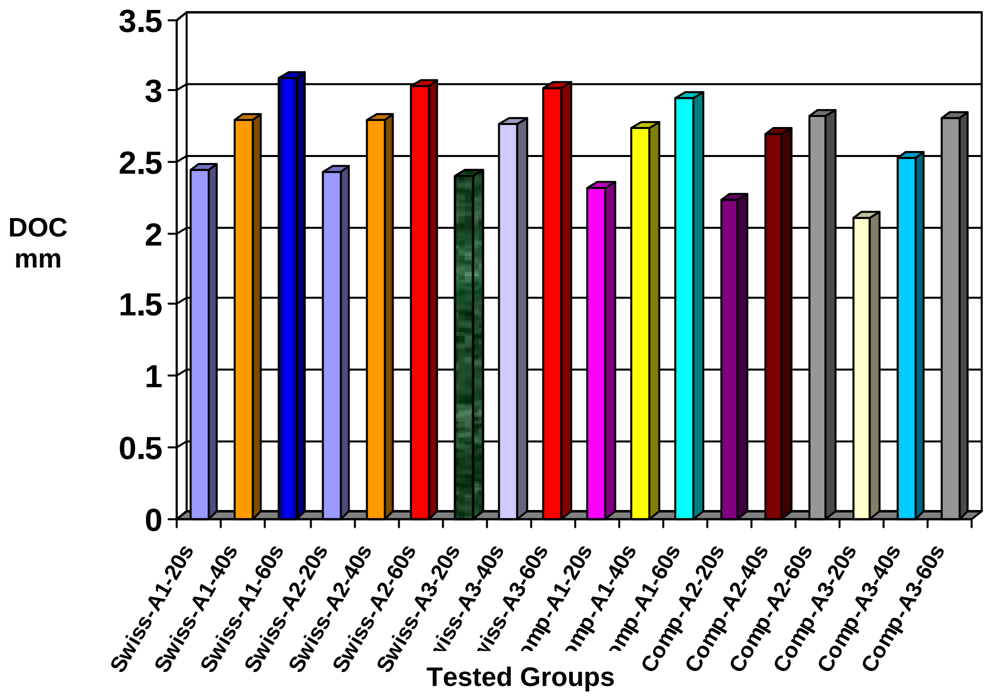
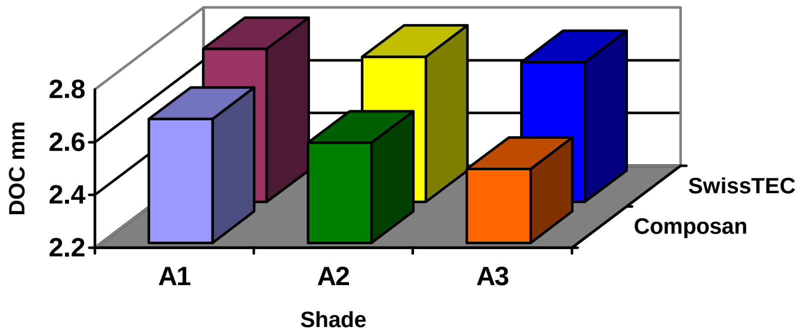
Groups with same Duncan grouping letters are not significantly different

Fig (14): A Histogram Representing the Mean DOC for Each Tested Group.



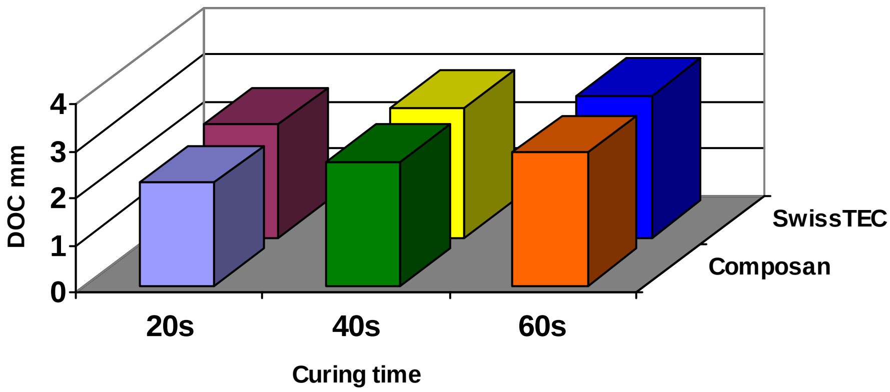
Columns with same color are not significantly different.

Fig (15): A Histogram showing the effects of composite type and Shade Interaction on DOC.



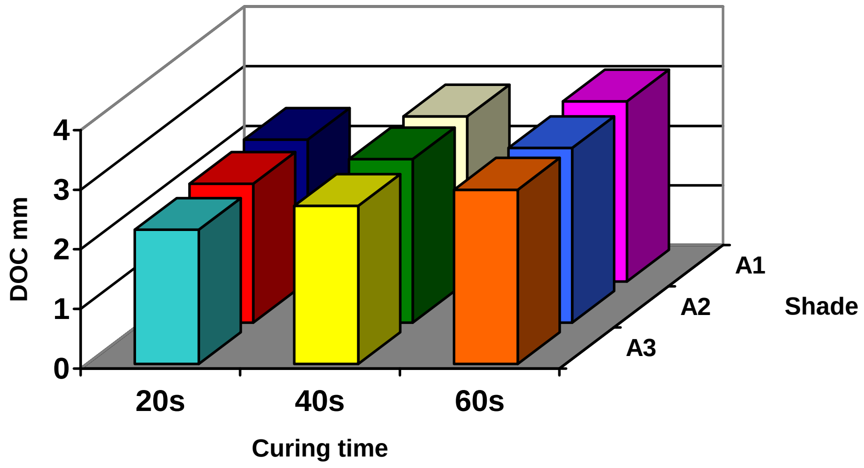
Columns with same color are not significantly different.

Fig (16): A Histogram Showing the Effects of Composite Type and Curing Time Interaction on DOC.



Columns with same color are not significantly different.

Fig (17): A Histogram Showing the Effects of Shade and Curing Time Interaction on DOC.



Columns with same color are not significantly different.

Discussion :

Regarding the results of the present study, all samples for each material with 3 shades at curing time 20,40,60 seconds were passing the requirements of ISO 2000/4049, as all records of DOC are more than 1.5 mm requested ; which is in fact half of the actual length measured by the micrometer this is explained according to Fan 2009(The ISO test method for depth of cure is to scrap off the uncured material at the bottom of the cylinder of the composite, measure the remaining length as divided by 2. This is because the composite hardness of the bottom of the remaining material is almost 0 and would not be adequately cured for clinical purposes. Researches showed that at 50% of length, the hardness is about 80% of the hardness of the top of the sample. A bottom: top hardness ratio of 0.8:1.0 is considered adequate cure by most researchers)[(21)].

A stainless steel tube-like mold have been used for samples preparation, substituting section of 5 to 10 mm that cut from a clear straw advocated by other authors[(22)]to perform the same task. This substitution have been done in an attempt to secure more consistent and more reliable results, rigid and easy handled stainless steel mold rather than sections made of clear straw.*

Absorption of light with an appropriate wavelength initiates a free radical polymerization process of the methacrylate groups in visible light cured composite resins resulting in the formation of a cross-linked polymeric matrix[(23,24)].

The intensity of light (strictly, the irradiance), at a given depth and for a given irradiation period, is a critical factor in determining the extent of reaction of monomer into polymer, typically referred to as "degree of conversion"[(25,26)]. A certain degree of conversion (DC) in resin-based materials must be achieved for the material to develop adequate physical and mechanical properties so as to withstand masticatory forces and also attain adequate biocompatibility[(27,28)] color stability[(29)] ,and as such would be expected to be associated with the clinical success of the restoration.

It is therefore important to achieve sufficient irradiance at the bottom surface of each of the incremental layers used in building up the restoration. The concept of the point of sufficiency in this respect is called “depth of cure” (DOC).

However , the degree of conversion of the monomers in visible light curing dental composite resins is restricted and ranges from 35% to 75%, with the remaining unreacted methacrylate groups being either in the form of pendent methacrylate groups or as residual monomers[(30,31)]

One of the problems associated with the use of direct placement , visible light cured, filled resin dental restorative materials is the decrease in curing-light intensity with depth in the material. As useable curing wavelengths are attenuated in the resin, less camphorquinone will be activated[32].

Many factors influence the degree and adequacy of the polymerization process, such as the type and relative amount of monomers, filler and initiator/catalyst as well as the shade and translucency of the material, its temperature during polymerization, the wavelength and intensity of the incident light, and the irradiation time[33-39].

** To evaluate the effective depth of cure of a specific light-curing unit, cut a small section of 5 to 10 mm from a clear straw and place it on a glass slide. Pack the section with composite. Apply the light directly to the top surface for 20 to 40 seconds according to the recommended technique. Cut off the straw, and scrape uncured composite from the bottom of the specimen with a sharp knife. Measure the length of the apparently cured specimen and divide in half to estimate the effective depth of cure.*

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Halogen lamp found in most LCUs have an effective life time of approximately 50 hours. The degradation of light out-put over time result in reduction of the curing effectiveness[40]. The lower effective limit of irradiance for halogen LCUs in dental practice is 300 mw/cm^2 [41].

According to ISO standard (ISO TS 10650/ 1999), the acceptable range of light intensity for halogen LCUs in the range of 400-515 nm wavelength region is 300-1000 mw/cm^2. Halogen LCU used in the current study perfectly matched these requirements as it was a new unused unit and operated for the first time for the purpose of performing this study, and tested by a radiometer which reveals a light intensity of (425 mw/cm^2) and wave length of (505 nm). Absorption and scatter within the material are the major factors associated with light attenuation [42] , other than reflection from the restoration surface [43] for this is dependent on the formulation of the material, particularly the filler size, type and content[44,45].

The location of the light tip in relation to material to be cured is also a factor that can affect the polymerization or DOC [16]that is to say, the direction and distance between the tip of light cure system and the mass to be cured, so that all samples were cured in such a way that the light cure tip is perpendicular and exactly over the transparent strip on the top of stainless steel model as a standardization measure.

Composition of composite has been shown to affect the depth of cure, since smaller filler particles scatter the light more than large filler particles because those particle sizes are similar to the wavelengths emitted from composite curing lights[24]. Light attempting to penetrate small particle composites, therefore, has a more difficult task to penetrate the deeper regions of the material and greater irradiances or exposure times are required to cure the composite adequately. The ratio of filler relative to resin is also important, the higher the proportion of filler, the more difficult it is for the light to penetrate the composite[7]. All of the microfills and many of the hybrid composites used today have filler particles that fall into that size ranges which may contribute with light scattering. Therefore, we would expect less depth of cure when these types of composites are used. However, the relative contribution of filler size to the other factors, such as duration of exposure and thickness of an overlying material, is very small[24].

Although both materials that used in this study are hybrid type, but however SwissTEC showed a significantly higher DOC value compared with Composan. This may be due to that SwissTEC made by the same of the used halogen LCU manufacturer (Coltene Co.). So that photoinitiators present within SwissTEC may respond more conveniently than Composan to the light irradiated from this curing device.

Maximum filler size for Composan is 2 µm which may scatter the light to a more extent than those relatively larger particles of SwissTEC (maximum filler size is 2.8 um). Although the percentage by weight of total inorganic fillers within Composan (76.5 %) is lower than that of SwissTEC (78 %), but the percentage by volume of total inorganic fillers of Composan (60 %) is more than that of SwissTEC (59%), both materials appear to be comparable regarding filler content and no significant difference (about 1%) found between them. However the volume or filler size rather than weight may play the effective role in attenuating the light intensity passing through composite resin. So that further studies may pay an attention to these points as its out of scope of this study.

Many studies demonstrated that the "light shades" resin-based composites cure to a greater depth than "darker shades"[37,39,46].

A study by Koupisa et al, 2004 investigated several resin-based composites, A2 shade resulted in significantly greater DOC values compared to darker A4 shaded[47]. Darker shades would normally be associated with shallower depth of cure, since the pigments in darker shades absorb more light and thereby reduce its penetration into the resin material[43,48].

The results of this study are in coincidence with these findings as Al shade for both composite types showed significantly greater DOC value, followed by darker A2 shade, while the least value was for A3 shade which is the darkest among the 3 shades used.

Physical properties and degree of conversion are apparently improved by increasing curing time (to a certain limit) [49,50].

Halogen ECU recommended curing time generally vary from 20-60 seconds for 2 mm increment of composite[6,7] at a minimum irradiance of 280 mw/cm[24].

The mean DOC value for all tested groups pass successfully these recommendations as all groups demonstrated mean DOC values more than 2 mm. But however, for all shades and both composite types, groups that were cured for 60 seconds gave significantly higher DOC values than groups that cured for 40 seconds, while 20 seconds curing time gave the least DOC values. On the other hand, (Al shade-60 seconds curing time) revealed significantly higher value among all shade-curing time interaction groups. The other groups arranged in a descending manner with increasing the shade darkness and decreasing curing time. (A3 shade-20 seconds curing time) showed the lowest value, (A3 shade-60 seconds) were significantly higher than lighter color A2 cured for 40 seconds, these indicating that darker shades can perform as well as lighter shades if curing time is prolonged to certain limits, when esthetics is not critical, the lightest shade can be used as lighter shade so can be cured for shorter curing time and have better DOC value[51,52].

Conclusions: The most important findings in the present study are:

1 . All the samples regardless the type of composite , shade and curing intervals were passing the requirement of ISO.
2. Darker shades had less DOC than lighter others, but increasing the curing time can improve

DOC of darker shades.

3. Among the methods that can be used by dentists, the method in this study can be used as one of the simplest methods for checking the efficiency of halogen LCUs in dental clinics.

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