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EFFICIENCY OF CURING DEVICES FOR DENTAL COMPOSITES

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INTRODUCTION: The setting reaction of dental composites is a light-activated radical addition. A high monomer-polymer conversion (DC) is sought, as it is associated with high mechanical properties. The DC depends on the efficiency of the initiator system and on the efficacy of the curing devices. For most dental composites, camphorquinone (CQ) is used as photo initiator. Currently, three different technologies are used in the commercial curing units. The light sources are either halogen lamps, ARC plasma lamps or light emitting diodes (LED).

The aim of the present study is to compare the efficiency of five different curing devices. For that purpose, the curing devices were characterized by their spectra and their irradiance. To test their efficiency, the depth of cure of a dental composite was measured after illumination with different exposure times.

The hypothesis tested is that the efficiency of the curing devices depend on the quantity of energy effectively absorbed by the photo initiator, instead of the total energy supplied by the curing device.

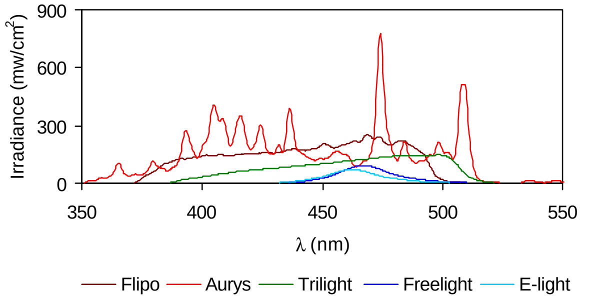
METHODS: The hybrid dental composite Herculite VXR, A2 was used. Two LEDs (Freelight /ESPE; E-light/GC), a halogen (Trilight/ESPE) and two ARC sources (Aurys/DegréK; Flipo/Lokki) were evaluated in the standard mode.

The irradiance was measured using an Avantes fiber optic spectrometer AVS-USB2000 working in the 190 to 850 wavelength range. The irradiance was measured at different distances from the source, as the spectrometer was saturated beyond 4 mW/cm^2.

The depth of cure was determined by measuring the height of cured samples with a micrometer. A PVC opaque mould with a cylindrical cavity of 4mm in diameter and 4 mm in depth was used. The top of the specimens was illuminated using different exposure times (Table 2). The samples were taken out the mold and the uncured material was eventually gently removed. Three samples were made for each illumination condition.Statistical differences in the data were evaluated with a one way analysis of variance, followed by a LSD multiple range test ($p<0.05$).

RESULTS: The obtained spectra are shown in Figure 1.

Fig. 1: Luminous spectra of the five curing units. Their irradiance (mW/cm^2) is given for each



emitted wavelength. The total irradiance is a value integrated over the whole spectrum.

The irradience is given in the Figure 2 for different distances between the source tip and the detector.

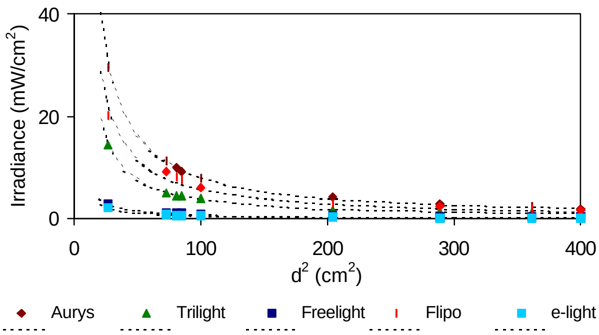


Fig. 2: Irradiance measured at different distances of the source for the five curing devices.

The irradiance in contact with the source was extrapolated from these values, (Table 1). The depths of cure are reported in Table 2.

Table 1. Irradiance Irr (mW/cm2) integrated over two wavelength ranges. Irr are the values given by the manufacturers of the curing devices.*

Curing unit	$Irr_{350-600}$	Irr *	$Irr_{450-490}$
Aurys	1856	1650	523
Flipo	1330	1600	544
Trilight	818	800	297
Freelight	177	400	151
E-light	234	750	203

The energies calculated for the whole spectra range ($E_{350-600}$) and the 450-490 wavelength range (E_{450-}

$_{490}$) are reported in the same table. Values marked with the same letter are not significantly different.

Table 2. Depth of cure for the different conditions and their corresponding energy E (J) emitted over two wavelength ranges .

Curing unit	t (s)	$E_{350\text{-}600}$	$E_{450\text{-}490}$	Depth (mm)
Flipo	1	0.54	0.23	2.19 ± 0.01 b,c
	2	1.07	0.47	2.34 ± 0.02 c
	3	1.61	0.7	2.79 ± 0.11 d,e
	5	2.68	1.17	3.04 ± 0.16 f
	10	5.37	2.34	4.17 ± 0.01 i
Aurys	1	0.74	0.22	1.42 ± 0.03 a
	2	1.48	0.45	2.09 ± 0.04 b
	3	2.21	0.67	2.84 ± 0.03 e
	5	3.69	1.12	3.05 ± 0.08 f
	10	7.38	2.25	4.06 ± 0.06 i
Freelight	10	0.75	0.65	3.36 ± 0.08 g
	20	1.49	1.3	4.05 ± 0.02 i
	40	2.99	2.6	4.17 ± 0.01 i
E-light	10	0.58	0.49	2.65 ± 0.16 d
	20	1.17	0.98	2.81 ± 0.03 e
	40	2.34	1.95	4.19 ± 0.02 i
Elipar	10	3.1	1.39	3.58 ± 0.14 h
	20	6.2	2.79	4.15 ± 0.02 i
	40	12.4	5.58	4.17 ± 0.01 i

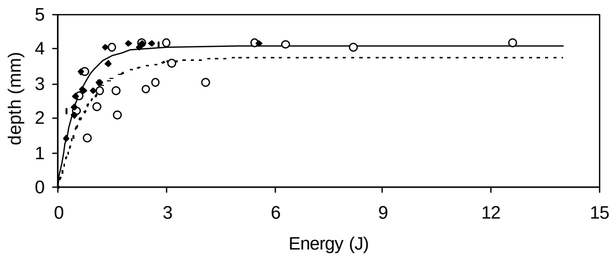
DISCUSSION & CONCLUSIONS: In this work, a single composite was used to exclude the effects of chemical composition on the depth of cure. The maximum depth was obtained by illuminating 10s with the ARC devices, 20s with Elipar and Freelight and 40s with E-light.

The irradiance values given by the manufacturers Irr* are given for the whole emitted. These values correspond to the radiation flux per unit of surface in direct contact with the source. In the present study, the irradiance couldn't be measured in these conditions, because the detector used was saturated at close distances to the sources. However, these values were extrapolated and can be compared to the Irr* (Tab 1). An advantage of measuring the light intensity at different distances is that the source can be considered as being punctual.

To test our hypothesis, the energy emitted by the different sources was calculated by the equation 1,

$$E = IrrSt \qquad (1)$$

where S is the surface of the source tip. A relationship between the depth of cure and the emitted energy was established (Figure 3). The data were best fitted by the equation 2,



$$Depth = a(1\text{-}e^{-bE}) \qquad (2)$$

where a and b are constants.

Fig. 3: Relationship between the depth of cure and the energy emitted by the sources at the different exposure conditions.

A poor correlation was obtained between the depth of cure and the total amount of energy $E_{350\text{-}600}$ (a:3.77; b:1.21; r:0.81; se:0.66). However, it is well known that only the light emitted in the wavelength interval which corresponds to the absorption of the photo initiator is useful to initiate the composite polymerization. The CQ absorption peak in methacryliate resins ranges from 380 to 510 nm with a maximum at 468 nm [1]. Moreover, Nomoto [2] showed that radiation in the 450-490 nm range activated more efficiently the CQ. Consequently, the energy emitted in this range ($E_{450\text{-}490}$) was also calculated. $E_{450\text{-}490}$ corresponded to 43% of $E_{350\text{-}600}$ for the halogen and the Flipo ARC sources, to 30% for the Aurys ARC and to more than 80% for the LEDs. As expected, a better correlation was obtained between the depth of cure and the $E_{450\text{-}490}$ variable (a:4.08; b:1.82; r:0.95; se:0.35), corroborating our working hypothesis.

In conclusion, the five curing devices showed marked differences in the shape and intensity of their emitted light spectra. Despite that the irradiance of the LEDs sources is the lowest, more than 80% of their emitted energy is in the 450-490 wavelength range. 20s were necessary to obtain the maximum depth with the Freelight LED and the halogen source. The exposure time could be reduced by a half by using the two ARC sources. However, for these devices, only 30 % and 43% of the emitted energy is in the wavelength range efficiently absorbed by the CQ.

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