Fibre Distribution of Light Conductors in Dental Visible-light Curing Units

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ABSTRACT

Six commercial visible light (VL) curing units and six experimentally-designed light guides or light conductors (LCs) were examined to evaluate the distributions of fibres occupied at LC section using color image analyzer, LCs of which were used to photopolymerize visible light-cured (VLC) resins. The commercial LCs were composed of glass fibre types (conducting medium) and experimentally-designed LCs plastic fibres. Their intensity values of spectral irradiance were also examined using optical digital powermeter in the wavelength range of 400 to 650 nm. The area occupied by fibres at LCs ranged 50.3 (A4) to 90.4% (B1), and spectral irradiance values (E_i) 144.6 (A1) to 270.9 mW/cm^2 (B2). To clarify the relation of fibre-occupied area and E_i, experimentally-designed LCs with 75.0 to 79.75% were produced. The value of E_i ranged from 297.3 to 313.0 mW/cm^2 with increasing the fibre-occupied area. The results suggest that the photopolymerization affect the depth of cure of VLC composite resins in relation to the integrated spectral irradiance in the wavelength range (400 to 650 nm).

INTRODUCTION

VL curing unit is used to polymerize VLC resins containing camphorquinone (CQ; photosensitizer) and reducing agent, because the wavelength 400 to 500 nm when irradiated by VL units was important with the curing of VLC resins[1-5]. The depth of cure increased with increasing the intensity of the visible light radiation in VLC composite resins[6]. The LCs of VL curing units were composed of glass fibre-tip at the light conductors, and thus the occupied area of fibres might affect curing performance of VLC resins. Comparative study of VL and ultraviolet (UV) curing exhibited that VL curing provided low shrinkage and good depth[7], because visible light was longer wavelength and less scattered than UV.

This study was to examine cross-sectional area of fibres occupied at LC'section of six VL curing units and six experimental designed LCs tested and to measure integrated values (E_i) in the wavelength ranges (400 to 650 nm) to clarify the relation of the occupied area and E_i with the use of experimentally-designed LCs of VL curing unit.

MATERIALS AND METHODS

Six commercial VL curing units and six experimentally-designed LCs investigated were listed in Table 1: Code A1 (Suncure Light; Sanei Electric MFG Co, Osaka), A2 (Daylight Lamp II; Shofu Inc, Kyoto), A3 (Quick Light; J. Morita Co, Kyoto), A4 (Cure Master A; 3M Co, St. Paul, MN, USA), B1 (Grip Light; Sansha Electric Co, Osaka) and B2 (Optilux; Demetron Co, Osaka) as commercial VL units with cross-sectional area 50.3 to 90.4% and code E1 to E6 (experimentally-designed LCs with 75.0 to 79.75%; Mitsubishi Rayon Co, Nagoya). Code A1 to A4 were flexible fibres as optical delivery system, whereas code B1 and B2 hard gun with rod. Figure 1 shows fibre distribution at the tip of fibres with a section of 5 mm diameter in experimentally-designed LCs which were composed of plastic fibres: E1 (area=76.0%; diameter 1.0 mm×19 pieces), E2 (75.0%; 0.5 mm×75 pieces), E3 (78.0%; 1.0

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Table 1 Cross-sectional area and spectral irradiance (E_i) in six commercial light conductors (LCs) of visible light (VL) curing units (A1, A2, A3, A4, B1, B2) and experimentally designed LCs of VL curing units (E1 to E6) investigated.

Code		Cross-sectional area (%)	E_i (mW/cm^2)
A1	Suncure Light	85.9	146.6
A2	Daylight Lamp II	90.1	260.8
A3	Quick Light	87.9	270.4
A4	Cure Master A	50.3	220.6
B1	Grip Light	90.4	230.9
B2	Optilux	76.9	270.9
E1	ESKA 1	76.0	299.8
E2	ESKA 2	75.0	297.3
E3	ESKA 3	78.0	307.7
E4	ESKA 4	78.0	307.7
E5	ESKA 5	79.5	311.1
E6	ESKA 6	79.75	313.0

mm×19 pieces, 0.5 mm×2 pieces), E4 (78.0%; 0.5 mm ×75 pieces, 0.25 mm×12 pieces), E5 (79.5%; 1.0 mm× 19 pieces, 0.5 mm×2 pieces, 0.25 mm×6 pieces) and E6 (79.75%; 1.0 mm×19 pieces, 0.25 mm×15 pieces). The values of fibres area at LCs were measured by color image analyzer, and spectral irradiance E_i was calculated in the wavelength range (400 to 650 nm). A standard light source for the VL units was a tungsten halogen lamp fitted with an integral reflector. The spectrum was produced by VL units which was passing the light through monochrometer (Nikon G-250, Tokyo). The fibre-optic tip attached to light guide was set perpendicular to the detector window (monochrometer).

Fibre area was calculated as indicated in Figure 2, which shows A_w in the equation (2) using A_b in the equation (1). The percentage was analyzed by color image analyzer (CIA-102, Olympus Co, Tokyo). The histogram of n (%) at each area of residual fibre at 512×512 image units was

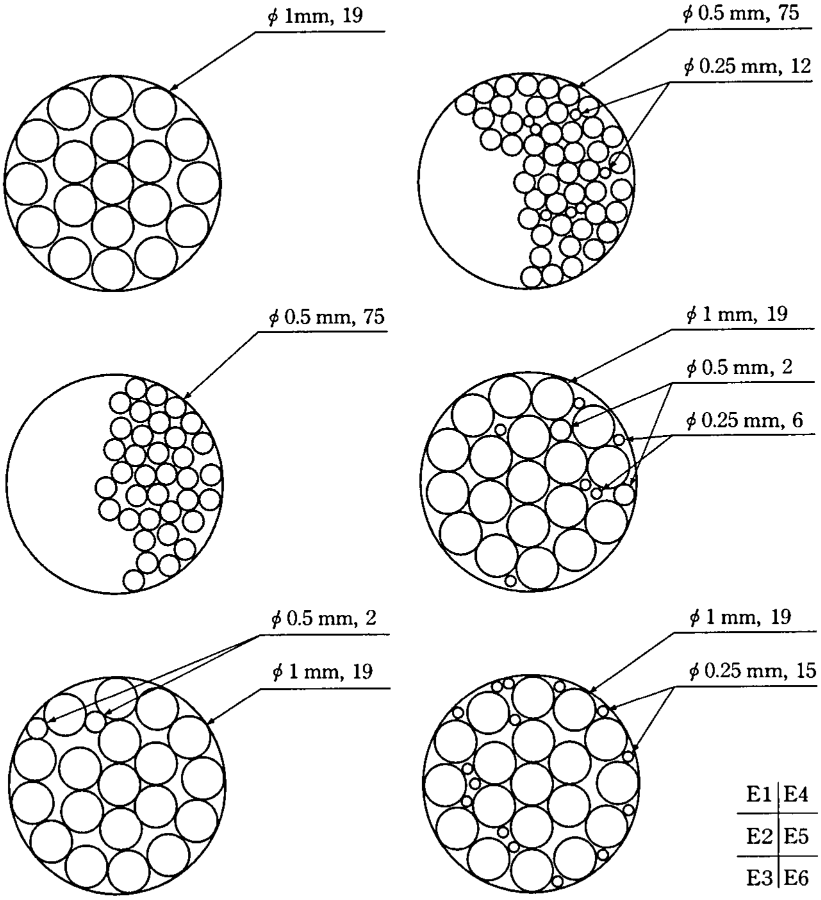
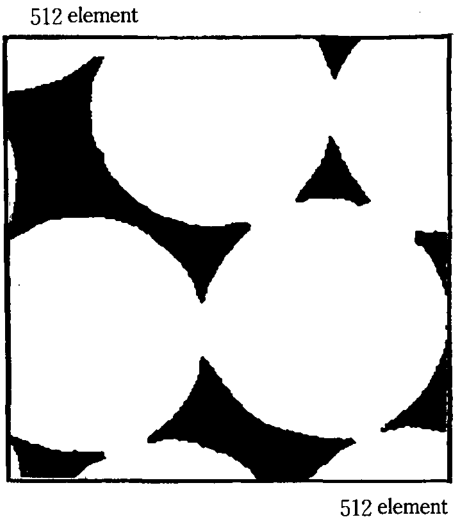


Figure 1 Experimental design of plastic fibres at LC section (E1 to E6).



At measurement condition
(a) unit length = 1.0000 pixel
(b) unit area = 1.0000 square pixel

$$\frac{(\text{Number}) \times (\text{Area})}{512 \times 512} \times 100 = A_b \qquad (1)$$

(Black area)

$$A_w = 100 - A_b \qquad (2)$$

(White area)

Figure 2 Schematic figure to measure cross-sectional area, according to the equations (1) and (2).

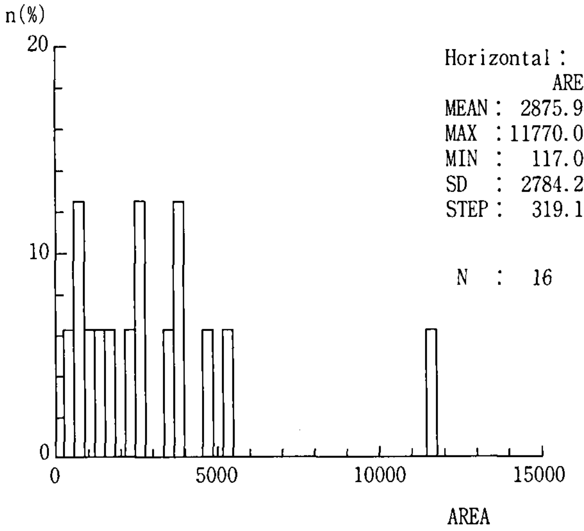
indicated. The residual occupied area of six commercial LCs of VL units and six experimentally-designed LCs irradiated by A2 VL unit were measured.

Spectral irradiance (mW/cm^2) per wavelength (nm) was measured by the spectral VL through the monochrometer with optical digital powermeter (Anritsu Co, Tokyo, Japan; ML93A). Their values were measured three times during VL irradiation.

RESULTS

Figure 3 shows the area which was not occupied by fibres at the tip of LCs, and the percentage of the area section was indicated by the percent (n%) at respective area (measured area = 16). Figures 4 and 5 show the distribution of histogram measured at each area (constant).

The spectral irradiance in the wavelength of three types of VL curing units was indicated in Table 1. The wavelength component below 400 nm was not measured and the measuring range was used for the wavelength between 400 and 650 nm. The integrated values ranged from 146.6 to 270.9 mW/cm^2 for six commercial VL units,



Horizontal : AREA
MEAN : 2875.94
MAX : 11770.00
MIN : 117.00
SD : 2784.24
STEP : 319.15

N : 16

Number	AREA
1	1722.00
2	1348.00
3	2090.00
4	543.00
5	4660.00
6	11770.00
7	555.00
8	117.00
9	3964.00
10	2682.00
11	5432.00
12	457.00
13	2672.00
14	3365.00
15	3821.00
16	817.00

Figure 3 Example: a relation of area (A_b) and number (n) of LCs of VL curing units.

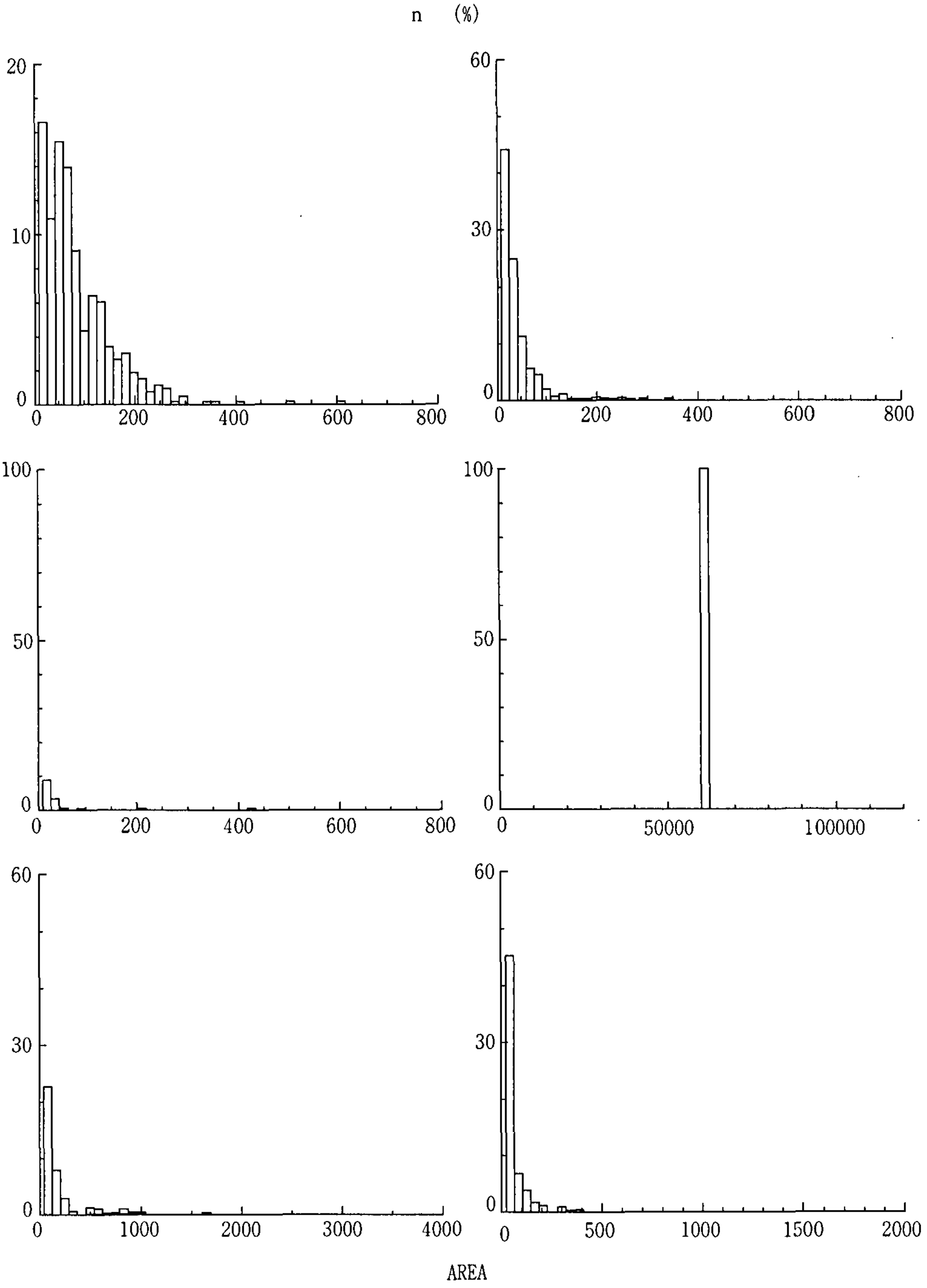


Figure 4 Distribution of number of LCs of VL units (A1 (left), A2 (right); upper, A3, A4; middle, B1, B2; lower).

and from 297.3 to 313.0 mW/cm^2 for six experimentally-designed LCs.

DISCUSSION

The spectral distribution at a 1-cm^2 area of LCs at the tip was measured. VL unit varied significantly in the cross-sectional area of fibres at the fiber-optic tip of the light-guide[7] and also the area occupied by fibre was different between them. The peak wavelength range was 460 to 500 nm in the spectroscopical analysis[8],

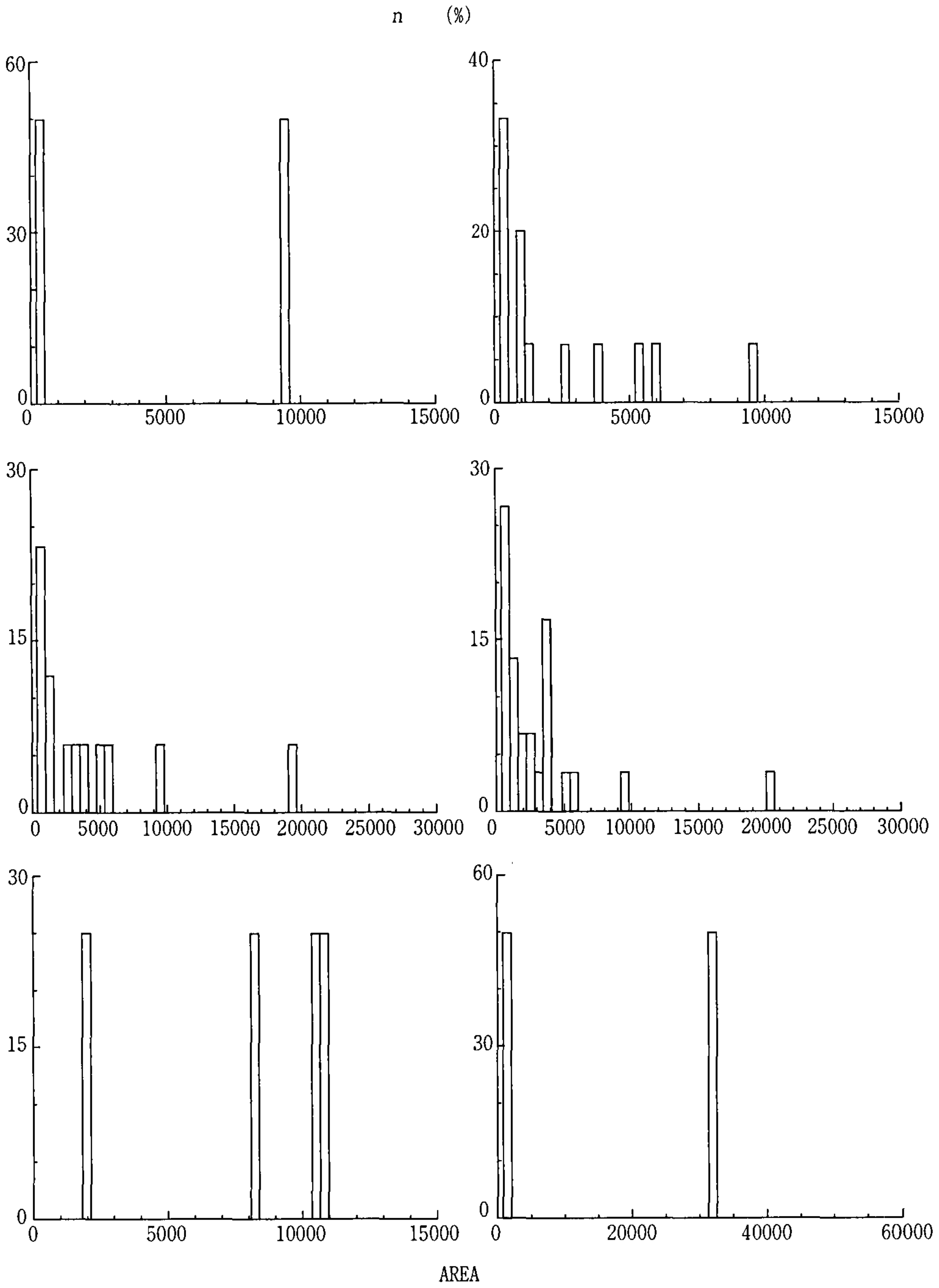


Figure 5 Distribution of number of LCs of VL units (E1 (left), E2 (right); upper, E3, E4; middle, E5, E6; lower).

representing that the peak of the spectral irradiance was within the wavelength region in measuring the spectral irradiance/wavelength profile by different VL units. Cook reported that the irradiance in the wavelength region of 450 to 500 nm was a better indication of the effectiveness in photopolymerization[5]. The photosensitizer's absorption peak at 470 nm was constituted by both a steep slope to 500 nm and a gradual trailing to 410 nm, using a 0.5 wt% solution of camphorquinone in methyl methacrylate[2]. Hirose et al reported that the relation between depth of cure and the characteristics of two VL units was plotted in the wavelength region (460 to 480 nm) to indicate the influence of the narrow wavelength9). With better LCs to choose larger depth of cure which showed the 460–480 nm wavelength, a dental VLC composite resin was irradiated10,11).

The ineffective spectral distribution of the radiation emitted by VL was less than 410 nm and greater than 500 nm3), because the photosensitizer (camphorquinone) peak was effective in the wavelength range 410 to 500 nm to polymerize VLC resins. Moseley et al reported that the optimum distance from LC was 2 mm to cure VLC resins showing the decreased irradiance values with greater distance to 2,5, 10 and 20 mm12). In our LC of VL curing units, the measured distance used was thus 3 mm during the irradiation, as reported by Hirose et al9).

LCs of VL curing units were composed of glass fibres and plastic fibres at the tip of light conductor, and the occupied area of fibres (distribution) affected the magnitude of spectral irradiance. The electric power used was 50, 75, 150 and 300 Watt (W)10,13), showing that smaller values of electric power exhibited lower integrated vlues of spectral irradiance (Table 1). With the use of experimental LCs, an increased area of occupied fibres at the tip (5 mm diameter) showed greater integrated values of spectral irradiance in the visible-light wavelength range.

CONCLUSION

Six dental VL curing units and six experimentally-designed LCs of VL unit to polymerize VLC resins were examined by measuring the integrated values of spectral irradiance to clarify the related area occupied by glass or plastic fibres at LCs of VL units. The LCs with greater cross-sectional area of fibres showed greater integrated values of spectral irradiance using experimentally-designed fibres at LCs. The results suggest that LCs used in our experiment polymerize VLC resins with better curing performance when irradiated by greater plastic fibre-occupied area.

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