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EFFECT OF LIGHT INTENSITY ON THE CURE CHARACTERISTICS OF PHOTO-POLYMERISED DENTAL COMPOSITES

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ABSTRACT

Objective: To determine the light intensity emitted by light curing units (LCUs) and its effect on the cure characteristics of composites polymerised with it.
Design: A laboratory based cross sectional study.
Setting: Public and private dental clinics in Nairobi, Kenya.
Results: Thirty five (42.17%) LCUs produced light of intensity $\leq 300 mWcm^{-2}$ while 43 (51.8%) LCUs had their intensities between 300 and $1200 mWcm^{-2}$. Mean DOC and surface hardness for the $0\text{-}300 mWcm^{-2}$ LCUs was 1.34mm and 46.60VHN respectively. The mean DOC increased steadily from the lowest intensity group (1.34mm) to the $1200\text{-}1500 mWcm^{-2}$ group (2.32 mm) and then declined to 1.98mm for the $1500\text{-}1800 mWcm^{-2}$ group. Statistical analysis showed significant differences in the mean DOC (p=0.000) and surface micro-hardness (p=0.002) for the different intensity groups.
Conclusion: Light intensity output of LCUs has a significant influence on the cure characteristics of dental composites with both DOC and surface micro-hardness increasing with increase in light intensity up to $1500 mWcm^{-2}$.

INTRODUCTION

The demand for aesthetic restorative materials has led to a widespread use of photo-activated direct resin composites in many parts of the world (1). Modern dental composite restorations are wholly dependent on the use of Visible Light Curing devices for their polymerisation. The output of these devices is among many interrelated factors that influence the polymerisation and quality of light activated resin composites. The factors include material characteristics, the tooth structure in which the restoration is placed, the light source and how it is used (2-4). The main factors that are of essence in the light source are its intensity output, the band width of the light, curing mode and time, filter quality (where applicable) and light tip characteristics - including diameter, distance from the restoration and direction of the light beam relative to the restoration surface (2, 5-7).

Various tests have been employed to assess the cure characteristics of dental composites. These include direct measurement of the degree of double bonds conversion using Fourier Transform Infra Red (FTIR) spectroscopy (8) and linear polymerisation shrinkage and indirectly through micro-hardness and depth of cure measurements (9,10). The micro-

hardness and depth of cure tests are good indicators of carbon-carbon double bonds conversion (11-13). Additionally, the light intensity output of a curing light could be measured using a visible light meter. Naturally, the desire among restorative dentists is to produce an optimally polymerised (cured) composite restoration within a short time for patient comfort and to save chair-time so as to hold the string on costs. This desire is what has fuelled the search for light curing machines with ideal output characteristics for the last three decades. The focus in this search has been to increase the light intensity output and to narrow the band width in order to cut out unnecessary heat and glare. The outcome has been the arrival of light curing devices with very high intensities, some as high as $3000 mWcm^{-2}$ (9, 14). Despite the gains made, the down side of this has been the occurrence of the now familiar problem of heat generation and temperature increases within the unit and in the restoration. This heat not only contributes to the deterioration of the unit but is also injurious to the pulp (15). Concerns have equally been raised about the effect of the high intensity on the cure properties of the material (16-21). In order to shine more light on these factors which influence the polymerisation and quality of light activated resin composite restorations, this study

set out to determine the light intensity emitted by light curing units (LCUs) in dental clinics in Nairobi and study its effect on the cure characteristics (depth of cure and surface micro-hardness) of composites polymerised with it.

MATERIAL AND METHODS

The study was laboratory based, cross-sectional and analytical. Eighty three light curing units, which were in use in private and public dental health facilities in Nairobi, Kenya, were studied. The intensity of the light emitted by the LCUs and depth of cure and surface micro-hardness of composites specimens polymerised with the lights were measured as described below.

Light intensity: The LCU was switched on and allowed to run for about five seconds (Figure 1). The tip of the fibreoptic light guide was then made to contact a sensor on the light meter which then displayed the light intensity reading on a screen in mWcm^{-2}. The measurement was repeated three times to ensure reliability.

Fabrication of specimens: A single batch of a commonly used resin based composite (Amelogen Plus, Ultradent, South Jordan, Utah, USA) was used to fabricate the specimens for DOC and surface micro-hardness test. The shade and composition of the material were controlled so as to exclude the influence of material factors on the variables being measured. Light curing units in the sampled clinics were used to cure the composite specimens, which were all cylindrical. The one for micro-hardness evaluation measured eight millimetres in diameter and three millimetres in height while the other for depth of cure evaluation measured four millimetres in diameter and six millimetres deep. Split brass moulds made to these specifications were used to fabricate the specimens (Figures 2 and 3). The mould was positioned on a mylar strip supported underneath by a glass slab. The resin composite was then filled into the mould using a plastic instrument and a condenser. The filled mould was then covered with another mylar strip and finger-pressed with a microscope slide to give an even top surface. Any excess material that extruded during the pressing was removed before curing so as to give a constant depth for all the specimens.

The specimens were cured only from the top with the light guide angulated at 90^0 to the resin surface. Irradiation times of 40 seconds for Light Emitting Diodes (LEDs) and Quartz-Tungsten Halogen (QTH) and 10 seconds for Plasma Arc Curing (PAC)LCUs were applied. Throughout the curing period, the tip of the light guide was in contact with the mylar strip covering the top surface of the specimen. Thus the light source-restoration distance was constant and equivalent to the thickness of the Mylar strip (100μm). After curing, the specimen was retrieved from the mould, inspected and the procedure repeated if it was found to have been defective. Each specimen was then placed in a serialised envelope and immediately stored in a light-proof cooler box at room temperature to await conduction of the tests.

Evaluation of surface micro-hardness and depth of cure: Surface micro-hardness evaluation was done after 24 hours in a laboratory using a Vickers's micro-hardness tester (V-tester 2, Amsler Otto Wolpert-Werkke, GMBH). (Figure 4) using a load of 200 g and a dwell time of 15 seconds. Three indentations were made on the top surface of each specimen by a diamond indenter and the hardness determined by measuring the diagonals of each indentation with a measuring light microscope ($\times$200 magnification). The measurements were then converted into Vickers Hardness Numbers (VHNs) using conversion tables. The average of the three measurements was taken as the Vickers Hardness Number of the specimen and recorded.

The depth of cure was measured, within six to seven hours of specimen fabrication. The uncured material at the bottom of the specimen was removed by shaking it in 99% acetone for 15 seconds using a capsule and a mixing device (Ultramat 2, SDI, Australia). The acetone removed all the uncured material and left a macroscopically even surface. The remaining length of the composite cylinder was measured using a digital Vanier Calliper (Shengya Machine & Tools Co., Ltd. China). In line with the ISO 4049 recommendations, the DOC was taken as a half of the remaining length of the cylinder.

RESULTS

Distribution of light curing units according to light intensity output: Table 1 shows the LCUs grouped according to the light intensity they emit in spans of 300 mWcm^{-2}. Thirty five (42.17%) LCUs produced light intensities of 0-300 mWcm^{-2}. Fourty three (51.8%) of the LCUs had their intensities between 300 and 1200 mWcm^{-2}. The mean DOC and surface hardness for the 0-300mWcm^{-2} was 1.34 millimetres and 46.60 VHN respectively. This group had the lowest mean DOC and surface hardness. The mean DOC increased steadily from the lowest intensity group (1.34 mm) to the 1200-1500 mWcm^{-2} group (2.32 mm) and then declined to 1.98 millimetres for the 1500-1800 mWcm^{-2} group.

One way ANOVA showed a statistically significant difference in the mean DOC for the different intensity groups (P=0.000). Post Hoc tests showed that the mean DOC for the 0-300 m Wcm^{-2} group differs significantly from all other groups (p=0.000) while the mean DOC for the 301-600 mWcm^{-2}

group significantly differed from that of all other groups except the 1501-1800 mWcm^{-2} group (0.322). One way ANOVA also showed that the mean VHN for the different light intensity groups significantly differ (P=0.002).

Relationship of light intensity with DOC and surface micro-hardness: The relationship between light intensity, DOC and surface micro-hardness was also investigated in their continuous form. The relationship was curvilinear. It was noted that there was an initial exponential rise in DOC with increase in the light intensity up to an intensity of about 800mWcm^{-2} (Figure 6). Above this intensity, the rise became gradual and nearly plateaued between 1000 and 1500mWcm^{-2}. Although the number of units which had intensity of above 1500 mW/cm^2 was small, the plot showed that there was a slight decline in the DOC above this level of intensity. For the surface hardness, it may be estimated from the scatter plot that above an intensity of about 500 m Wcm^{-2}, there is only minimal increase in surface micro-hardness with increase in intensity (Figure 7).

Table 1

Light intensity frequencies and associated mean DOC and surface micro-hardness

Light intensity (mWcm^{-2})	Depth of cure (mm)			Surface micro-hardness		
	n	mean	SD	n	mean	SD
0- 300	35	1.34	0.27	24	46.60	19.17
301-600	17	1.71	0.12	11	60.47	5.89
601 - 900	14	1.97	0.17	9	64.34	6.82
901 - 1200	12	2.17	0.13	11	64.11	4.57
1201 - 1500	2	2.32	0.04	1	71.60	-
1501 - 1800	3	1.98	0.30	2	63.85	6.43

Figure 1
Visible light curing meter used for light intensity measurement

Figure 2
A sketch of the split mould used for fabrication of the micro-hardness test specimen
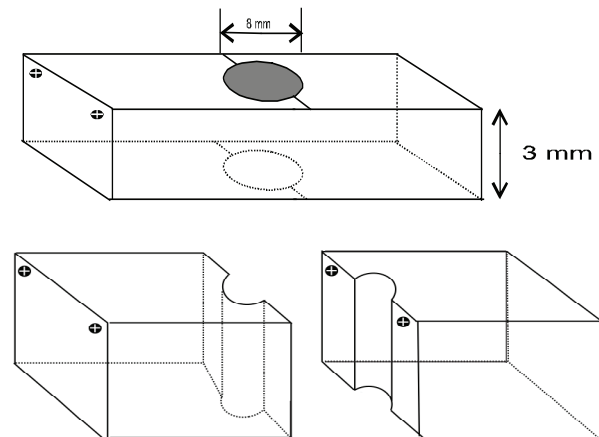
Figure 3
A sketch of the split mould for fabricating the depth of cure specimen
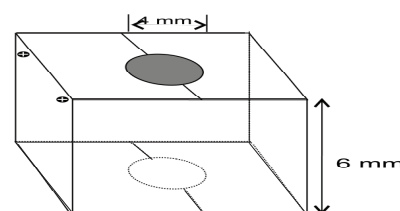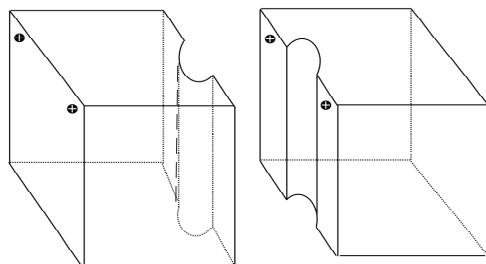
Figure 4
*The Vickers hardness tester used for the surface
hardness evaluation*

Figure 5
*The Electronic Digital Vanier Caliper used to measure
the DOC with a specimen in situ*
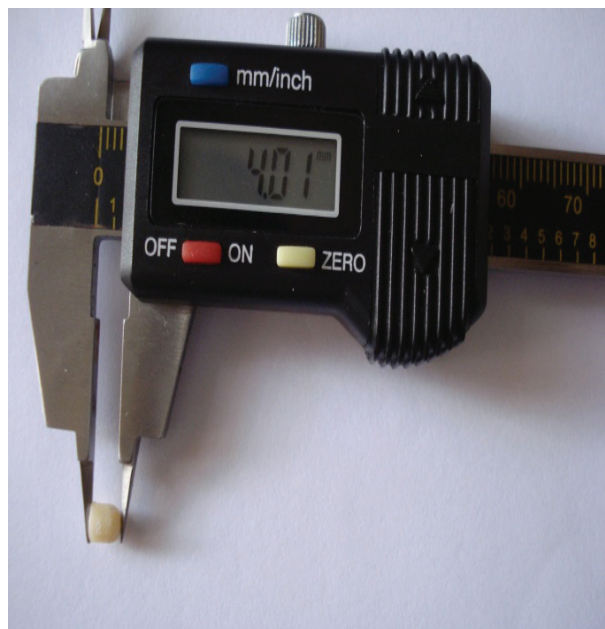
Figure 6
The relationship of light intensity output and DOC
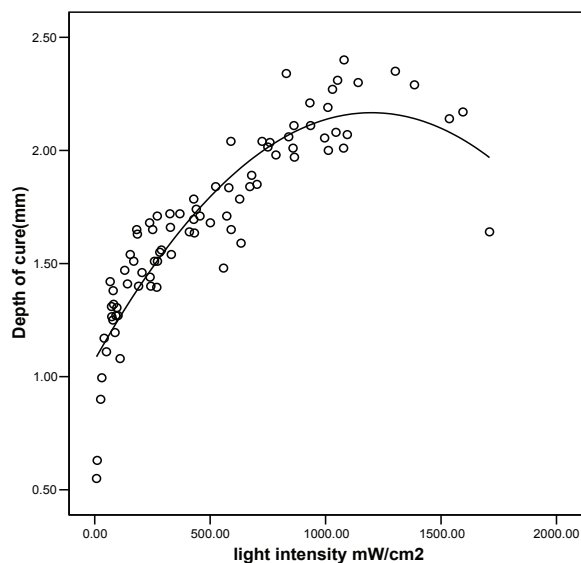
Figure 7
*Relationship of light intensity output and surface
micro-hardness*
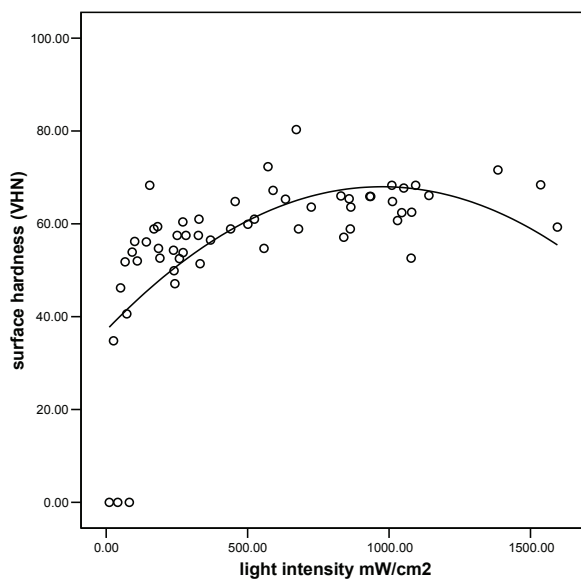
DISCUSSION

Despite half a century of research, there is still no
end in sight in the search for the ideal light curing
system that would, once and for all, help overcome
the drawbacks of light cured composites and raise
this incredible material to new levels with respect
to mechanical and aesthetic properties. Although
gains have been made, light activation of this
material still remains influenced by a plethora
of interrelated factors which account for its less
than ideal cure properties (16-21). This study was
driven by a desire to shine some more light on

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