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Depth of cure and hardness of an indirect composite polymerized with three laboratory curing units

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Abstract: This study determined the hardness and curing depth of a light-activated indirect composite polymerized with three laboratory light-polymerizing units for the purpose of comparing the curing performance of the three units. A light-activated composite material for indirect application (Vita Zeta) was polymerized with three light-polymerizing units equipped with the following light sources: 1) one halogen lamp and two fluorescent lamps (α-Light II); 2) three halogen lamps (Twinkle HLG); and 3) one metal halide lamp (Twinkle LI). Knoop hardness and curing depth were determined for groups of five specimens using standardized testing methods. The results were compared using analysis of variance (ANOVA) and Scheffé's S intervals ($\alpha = 0.05$). The Knoop hardness number (KHN) generated with the halogen-fluorescent unit (12.5 KHN) was significantly ($P < 0.05$) lower than those produced by the halogen unit (13.9 KHN) and the metal halide unit (14.2 KHN). Of the three units, the halogen-fluorescent unit exhibited the lowest depth of cure. Both the hardness and curing depth of the composite were influenced by the laboratory polymerizing units employed. (J. Oral Sci. 49, 25-29, 2007)

Keywords: indirect composite; Knoop hardness; polymerizing unit.

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Introduction

A halogen bulb-based light-polymerizing unit is commonly used to polymerize light-activated materials for both direct and indirect uses. Visible light with a wavelength spectrum of 380-760 nm emitted by the halogen light is suitable for usage with the representative photo-initiator camphor quinone which has an absorption curve ranging from 360-520 nm with maximum activation at 470 nm (1). Although the usefulness of halogen units with appropriate wavelengths is well known in clinical practice, there is still a need for developing a more efficient light source because of inherent drawbacks such as a limited effective lifetime and reduced output (2,3).

In a laboratory polymerizing unit, various light sources with a wider range of wavelengths can be used because of the box-type structure. Fluorescent and xenon lamps are representative laboratory light sources. In addition, a metal halide lamp that emits both ultraviolet and visible light is one of the new extra-oral light sources with high light-intensity. The effectiveness of the metal halide unit in polymerization of light-activated material has been demonstrated by many researchers (4-8).

The majority of prosthetic composites for indirect application are currently light-curable and their widespread usage is due to their ease of handling. The properties of light-activated composites vary in accordance with the type of light-curing unit used for polymerization, and the type of laboratory light-polymerizing unit also affects the post-curing properties of indirect composites. Post-curing properties of composite materials can be improved generally by high-intensity polymerization. Tanoue et al. (9) examined certain properties of indirect composites polymerized with different light sources, and reported that hardness and water solubility were strongly influenced by the type of laboratory light-polymerizing units. The role of the laboratory light-polymerizing unit has also been indicated for improvement of curing depth and wear resistance (5,10).

The factors regarding material such as filler content, filler type, shade, and transmission coefficient have another significant impact on resin composite polymerization (11-13). The Vita Zeta Crown and Bridge Veneering system (Vita Zahnfabrik GmbH, Bad Säckingen, Germany) is a composite/acrylic system comprised of separate veneering materials that give practitioners a choice of polymerization methods, and the Vita Zeta LC (VZ) material is an indirect veneering composite that can be polymerized with various light-polymerizing apparatuses. There is little information concerning the properties or clinical performance of this material, although the type of laboratory unit is likely to affect post-curing properties of the material. The present study determined the Knoop hardness and curing depth of this material polymerized using three laboratory light-polymerizing units, with the aim of confirming the projected performance of the material and evaluating the influence of the polymerizing device in the case of indirect application.

Materials and Methods

Indirect composite and polymerizing apparatus

The VZ material evaluated in the experiment is a light-activated single paste composite material. According to the manufacturer, the composite includes multiphase feldspar frits and SiO_2 (44.7 wt%). The monomer matrix is composed of 2,2-bis [4-(2-hydroxy-3-methacryloyloxy-propoxy) phenyl] propane (Bis-GMA), 1,6-bis (2-methacryloyl-oxyethoxycarbonylamino) -2,4,4-trimethylhexane (UDMA), and triethyleneglycol dimethacrylate (TEGDMA). The shade selected for all experiments was equivalent to that of A2-shaded dentin porcelain (VMK 68, 541, Vita Zahnfabrik GmbH).

Three laboratory light-polymerizing units were used: α-Light II (AL; J. Morita Corp., Suita, Japan), Twinkle HLG (TH; Toho Dental Products, Saitama, Japan) and Twinkle LI (LI; Toho Dental Products). The AL unit has one halogen lamp and two fluorescent lamps as light sources. The TH unit is equipped with three halogen lamps, and the LI unit is provided with a metal halide lamp. The specifications of the three units are summarized in Table 1.

Table 1 Laboratory light-polymerizing units assessed

Curing unit	Abbreviation	Light source		Wavelength
α-Light II	AL	Halogen lamp	360 W × 1	400-600 nm
		Fluorescent lamp	27 W × 2	
Twinkle HLG	TH	Halogen lamp	150 W × 3	400-600 nm
Twinkle LI	LI	Metal halide lamp	150 W × 1	250-600 nm

Knoop hardness

The material was packed into a split polytetra-fluoroethylene (PTFE) mold with a cylindrical opening 10 mm in diameter and 2 mm in height. Specimen thickness was established as 2 mm to achieve uniform polymerization, especially internally, when the specimens were exposed to the light-polymerizing units. The material was covered with polyester strips, irradiated for 60 sec on each side in the units, and removed from the mold. Five specimens were irradiated with each type of light-polymerizing unit. All of the specimens were stored in water at 37°C for 24 h in order to complete post-irradiation hardening. The top surfaces of each specimen were ground with a series of silicon-carbide (SiC) papers and polished with felt and 0.3 μm alumina to produce smooth, uniform surfaces. Knoop hardness was determined using a universal indenter (MVK-H1 Hardness Tester, Akashi Corp., Kako, Japan). The Knoop hardness number (KHN) was calculated after application of 50 g loading for 30 sec.

Depth of cure

The depth of cure of the material was determined by a scraping technique described by the ISO4049 third edition (14). The material was filled into a stainless steel mold with a cylindrical opening 4 mm in diameter and 6 mm in height. Each specimen surface was covered with a piece of polyester film. For each light-polymerizing unit, one group of five specimens was exposed from the top of the mold for 30 sec, the second group of five specimens was exposed for 60 sec, and the third group of five specimens was exposed for 90 sec. Immediately after polymerization, the composite material was removed from the mold, and the non-polymerized material was scraped off with alcohol-treated gauze. The thickness of the cured material was measured at the central portion of the resulting cylinder using a micrometer (Digimatic Micrometer, Mitutoyo Corp., Kawasaki, Japan).

Statistical analysis

Specimens used for Knoop hardness testing were divided into three groups according to the three light-polymerizing units. Mean values and standard deviations (SD) of five specimens were calculated for each group, and one-way analysis of variance (ANOVA) was used. Specimens for curing depth were divided into nine groups by different combinations of the three light-polymerizing units and three exposure periods. Mean values and SDs of five specimens were also calculated for each group, and the values were analyzed by two-way ANOVA. When F tests were significant, Scheffé's S intervals were calculated with the value of statistical significance set at $\alpha = 0.05$.

Results

Figure 1 illustrates the results of the Knoop hardness test. One-way ANOVA indicated that the Knoop hardness of the VZ material was significantly ($P = 0.0009$) affected by the type of laboratory light-polymerizing unit. One-way ANOVA and Scheffe's S multiple comparison intervals grouped the three units into two: 1) the AL unit and 2) the TH and LI units. Specifically, the Knoop hardness number (KHN) generated with the AL unit (12.5 ± 0.1 KHN) was significantly lower than those produced by the TH unit (13.9 ± 0.8 KHN) and the LI unit (14.2 ± 0.5 KHN).

Figure 2 shows the curing depths of the material exposed to the three light-polymerizing units for 30, 60 and 90 sec, respectively. Two-way ANOVA performed on the curing depth indicated that the interaction between the type of the light-polymerizing unit and the exposure period was significant (F = 11.3; $P = 0.0001$). The curing depth was also affected by the type of the light-polymerizing unit (F = 1,197.304; $P = 0.0001$), as well as by the exposure period (F = 1,706.0; $P = 0.0001$). The results were, therefore, analyzed by one-way ANOVA followed by Scheffe's S intervals, and seven groupings were generated: 1) AL-30 sec; 2) LI-30 sec; 3) AL-60 sec; 4) TH-30 sec and LI-60 sec; 5) LI-60 sec and AL-90 sec; 6) LI-90 sec and TH-60 sec; and 7) LI-90 sec. Extension of the exposure period increased the depth of cure for all groups. It was noted that the groups exposed with the TH unit exhibited greater depth of cure than those exposed with the other two units for the same exposure periods.

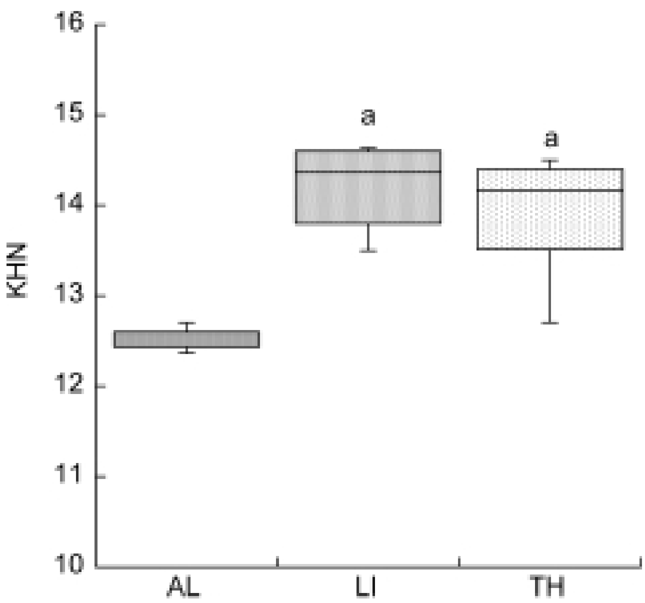

Fig. 1 Knoop hardness test results. Identical letters indicate that the values are not significantly different ($P > 0.05$).

Discussion

Post-curing properties of a composite material are influenced by the polymerizing method. Although factors such as the distance of the light source from the composite and the exposure time are controllable, the light intensity and wavelength are generally characteristic of the polymerizing unit. The performance of the laboratory unit in polymerizing light-activated prostheses is diverse because of the box-type structure that enables the use of various light sources. Therefore, the properties of an indirect composite would be affected by the type of the unit. The VZ material does not have a proprietary polymerizing unit, and the post-curing properties of the material are

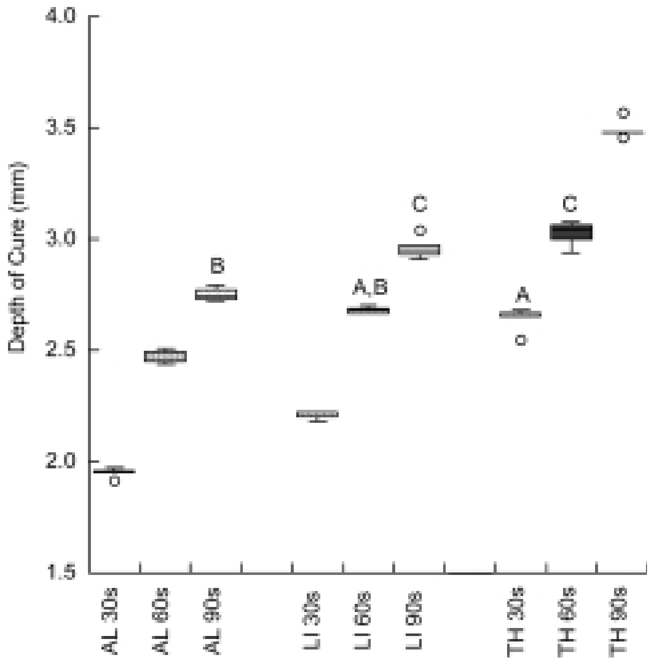

Fig. 2 Relation between curing depth and exposure period with the three photo-curing units. Identical letters indicate that the values are not significantly different ($P > 0.05$).

thought to be affected by the type of the polymerizing apparatus selected by the dentists/dental technicians. This study, therefore, evaluated two post-curing properties, i.e., the hardness and depth of cure, of an indirect composite in order to confirm the clinical performance of the material when polymerized with different laboratory light-polymerizing units.

The influence of high-intensity light-polymerizing units on the hardness of light-activated composites has been reported by many researchers (6,9,15). The KHN test results with the greatest values were generated with the TH and LI units, possibly signifying that these two units have higher light intensities than AL. Nevertheless, the TH unit with three halogen lamps showed greater curing depth than the LI with one metal halide lamp. Considering that the curing depth of composite material is strongly related to the light intensity of the polymerizing unit when it is below a certain critical level (16-18), the curing depth results might reflect the light intensity of the units more accurately than the KHN. The curing depth data is extremely useful in assessing the light intensity of the laboratory apparatus, since it is designed to irradiate only while the door is closed for safety.

All the KHN testing results were considerably low when compared with those for the other indirect composites (9). It might be because of the lower filler content of the material (44.7 wt%). The light intensity of the polymerization unit is associated with the degree of conversion of light-activated composite (19), and an appropriate light-polymerizing method enables the light-activated composite to achieve high conversion (20). The KHN test results of the VZ material might strongly reflect the hardness of the resin matrix, and the hardness might be related to the conversion.

Three light sources, i.e., the fluorescent, halogen, and metal halide lamps, were used in the current experiment, and the light intensity of the LI unit equipped with a metal halide lamp was thought to be higher than that of the AL unit with one halogen and two fluorescent lamps. The metal halide lamp that produces a bright white light is a so-called high-intensity-discharge (HID) lamp, and its efficiency has been reported not only in industrial chemistry but also in dentistry (4). The results also indicated that the curing performance of the metal halide light source was sufficient.

Using a high-intensity light-polymerizing unit is more convenient than extending the exposure time. Especially for an indirect composite with low filler content, the polymerizing unit should be carefully selected considering its light intensity and performance. The wavelength spectrum for the absorption curve of the photo-initiator in the composite material should also be considered. In conclusion, polymerization with a high-intensity unit is both useful and convenient for improving properties of composite material, since it reduces handling time.

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