A New Laboratory Polymerizing Apparatus Equipped with Halogen and Metal Halide Light Sources

Naomi TANOUE1, Mitsuru ATSUTA2, Shin-ichi KITAZAWA3, Hiroyasu KOIZUMI4 and Hideo MATSUMURA4
1Department of Specialized Dentistry, Nagasaki University Hospital of Medicine and Dentistry, 1-7-1, Sakamoto, Nagasaki 852-8588, Japan
2Division of Fixed Prosthodontics and Oral Rehabilitation, Nagasaki University Graduate School of Biomedical Sciences, 1-7-1, Sakamoto, Nagasaki 852-8588, Japan
3Toho Dental Products Co. Ltd., 2-10-2 Uchiya, Minami-ku, Saitama 336-0034, Japan
4Department of Crown and Bridge Prosthodontics, Nihon University School of Dentistry, 1-8-13 Kanda-Surugadai, Chiyoda-ku, Tokyo 101-8310, Japan
Corresponding author. E-mail: t-naomi@net.nagasaki-u.ac.jp

Received October 28, 2004/Accepted December 24, 2004

We developed a new laboratory polymerizing unit (Twinkle MIII; M3) equipped with different light sources (a metal halide and two halogen lamps) that could illuminate independently. This study introduced the structure of the curing unit and examined the curing depth of a representative indirect composite (Artglass). The composite material was cured with the following modes: 1) M3 - halogen only; 2) M3 - metal halide only; 3) M3 - both halogen and metal halide (HM); 4) conventional xenon; and 5) preliminary halogen. The results obtained from analysis of variances and post-hoc tests revealed that curing depth was affected significantly (p<0.05) by both exposure mode and time, and that HM mode exhibited the most favorable curing performance (p<0.05) among the curing units and polymerization modes. In conclusion, the M3 unit was found to be well suited to polymerizing the composite material tested.

Key words: Indirect composite, Laboratory polymerizing apparatus, Light source

INTRODUCTION

Recently, laboratory polymerizing apparatus have been developed with high-intensity light sources — since a high-intensity light-polymerizing unit is able to satisfactorily achieve post-curing properties (such as low solubility and high hardness) in light-activated, indirect composites1,2. The use of a high-intensity unit also has clinical advantages as it reduces the total handling time required in polymerizing light-activated materials.

However, it is also quite likely that higher-intensity, light-activated polymerization causes greater polymerization shrinkage3,4. With restorative composites, polymerization shrinkage caused by high-intensity intraoral curing negatively affects the marginal integrity of restoration-cavity interfaces. This is because contraction gap formation of light-activated composites is related to the light intensity of the polymerizing unit5. Correspondingly, high-intensity laboratory polymerization reduces the bond strength between indirect composites and dental casting alloys6.

A new polymerization technique using, in advance, a curing unit with reduced light energy density has thus been introduced for restorative systems to improve the bond strength between dentin and composite materials7. The ‘pre-polymerization’ or ‘soft-start polymerization’ method, which initially polymerizes the restorative composite material at low intensity followed by high intensity, is reported to be effective in enhancing bond strength8-10. Further, the use of preliminary polymerization at low intensity — as part of laboratory light-polymerizing procedure — enhances the interfacial bonding between an indirect composite and a dental alloy9.

Laboratory light-polymerizing units are generally designed as a boxed up container with a sliding door or shutter, in which composite materials are light-exposed. The structure of a laboratory unit must ensure that the light emitted is harmless to the human body. Therefore, laboratory apparatus can be equipped with various light sources providing a wide range of wavelengths.

On this note, it is possible for laboratory polymerizing units to control light intensity, wavelength distribution, and processing time period by selecting proper combination of light sources. It is also necessary for polymerization units to emit both low- and high-intensity lights for soft-start and quick polymerization. In this manner, wide ranges of wavelength and emission energy enable the unit to polymerize various types of resin-based material with the most appropriate condition.

In the current study, a new laboratory polymerizing apparatus was designed. It was equipped with...
different light sources to provide diverse polymerization methods. The curing depth of light-activated composite materials is positively related to the light intensity of the curing unit\textsuperscript{11,12}. As such, assumptions made about the light intensity in this study were based on the curing depth of the composite material tested. In addition, information about the curing performance of dual-mode unit is important, especially when light sources were used either singly or in dual mode. This study reported the structure of the new apparatus and compared the curing depths of an indirect composite polymerized by this unit and other existing units.

MATERIALS AND METHODS

Laboratory polymerizing apparatus

A laboratory light-polymerizing apparatus (Fig. 1), now commercially available as Twinkle MIII (M3, Toho Dental Products, Saitama, Japan), was fabricated for laboratory polymerization of light-activated, dental resin materials. The unit was characterized by its two different light sources, namely the halogen and metal halide lamps. The halogen lamp is a conventional light source utilized in both laboratory and hand-held curing devices, while the high-intensity metal halide lamp is limited to uses in laboratory procedures due to its emission of high-intensity ultra-violet (UV) light (250-400 nm)\textsuperscript{1}. For the purpose of diversifying the polymerization modes, the unit was designed such that different light sources could illuminate either independently or concurrently.

The unit was equipped with a 150 W metal halide lamp, two 150 W halogen lamps, a turntable, a main switch, a changeover switch, two sliding radiation timers, start and set switches, and a cooling fan. In addition, a removable UV light cutting filter, which

Fig. 1 A. Completed laboratory photo-polymerizing apparatus; B. Metal halide lamp (left) and halogen lamp (right); C. Schematic representation of the apparatus.
was used only when visible light exposure was needed for polymerization, was positioned in front of the metal halide lamp. The unit could basically be used in three modes: 1) halogen only (HA); 2) metal halide only (ME); and 3) both halogen and metal halide (HM). These three modes were accomplished when different light sources were selected to radiate from the beginning of the polymerization procedure. The HA mode was mainly for preliminary polymerization, while the HM mode was for final polymerization. When UV light was required, HM and/or ME modes could serve the purpose. In addition, if occasion so required, soft-start polymerization could be achieved by combining polymerization modes 1) and 3) (as given above).

Two conventional laboratory units (Dentacolor XS and UniXS, Heraeus Kulzer GmbH, Wehrheim, Germany) were selected as control models. These units were comparable to the M3 unit with an HM mode. Similar to the metal halide lamp of M3, the xenon lamp used in the two control units was a high-intensity laboratory light source that irradiated both visible and UV lights. In addition, a preliminary halogen unit (Targis Quick, Ivoclar Vivadent, Schaan, Liechtenstein), to which composite material was exposed in open air, was selected as reference control for HA mode. Information on all light-polymerizing units used in this study is summarized in Table 1.

Composite material
An indirect composite material (Artglass, Heraeus Kulzer Inc., NY, USA) was used in this study. The Artglass material consisted of visible light-activated resin in a single paste and was designed for inlays, onlays, crowns, and fixed partial denture veneers. According to Mandikos et al.13, the Artglass material was a bis-glycidyl acrylate- and triethylene glycol dimethacrylate-based microfilled composite that included silicon dioxide and barium alumina as filler particles. According to Sumi et al.14, the filler composition of Artglass dentin was 66.8wt% for SiO₂, 25.3wt% for BaO, and 7.9wt% for Al₂O₃. The selected shade was equivalent to that of A2 shaded dentin porcelain (VMK 68.541, Vita Zahnfabrik GmbH, Bad Säckingen, Germany).

Depth of cure
Depth of cure of material was determined by means of a scraping technique as described in International Organization for Standardization (ISO) 4049 (2000)15. 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, and the specimen was placed at the center of the turntable in each unit. With the TAQ unit, the specimen was placed under the light source and exposed perpendicularly to ensure that distance from light source to specimen was maintained at 30 mm in accordance with manufacturer's specifications. With the M3 unit, specimens were exposed without a UV cutting filter to facilitate emission of higher-intensity light from the light source. The mold was exposed from the top for 20, 30, 60, and 90 seconds in each unit. Immediately after polymerization, the composite was removed from the mold and the non-polymerized material 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., Kanagawa, Japan). Five specimens were subjected to each exposure time period in each polymerizing unit. The curing depth results for TAQ and UXS units were as previously reported6,16.

Statistical analysis
Average and standard deviations of five curing depth specimens for each condition were calculated. Values for the three modes of M3 were analyzed by two-way analysis of variance (ANOVA), one-way ANOVA, and post-hoc Duncan new multiple range test with the value of statistical significance at 0.05 level. In addition, using the same statistical methodology, the curing depth results for HM mode were compared with those for DXS and UXS units; and the values for HA mode were also compared with those for the TAQ unit.

RESULTS
Fig. 2 shows the curing depth results for the M3 unit for three polymerization modes. Two-factor ANOVA indicated that the interaction between polymerization
mode and exposure period was significant \( (F=8.361; \ p=0.0001) \), and that curing depth was affected by both the polymerization mode with higher \( F \) value \( (F=1587.179; \ p=0.0001) \) and exposure period \( (F=838.398; \ p=0.0001) \). The HM mode exhibited the most excellent curing depth \( (p=0.0001) \) regardless of exposure time.

Fig. 3 shows the curing depth results for M3 unit for HA and HM modes, as compared with the conventional control units. For curing depths in HM mode, when compared to DXS and UXS units, two-factor ANOVA revealed that the interaction between polymerizing unit and exposure period was significant \( (F=20.017; \ p=0.0001) \), and that curing depth was affected by both the polymerization unit \( (F=1497.116; \ p=0.0001) \) and exposure time \( (F=2165.583; \ p=0.0001) \). Besides, the curing depth in HM mode was statistically \( (p=0.0001) \) greater than the other two units. As for HA mode and TAQ unit, two-factor ANOVA revealed that the interaction between polymerizing unit and exposure period was significant \( (F=12.842; \ p=0.0001) \), and that curing depth was affected by both the polymerization unit \( (F=1086.815; \ p=0.0001) \) and exposure time \( (F=630.099; \ p=0.0001) \). Further, the curing depth in HA mode was statistically \( (p=0.0001) \) lower than the conventional TAQ unit.

**DISCUSSION**

The curing depth results for M3 unit were significantly affected by the three different polymerization modes. The HM mode, which exhibited the most excellent curing depth, was considered to have the highest light intensity among the three modes and in comparison with the other conventional xenon units (DXS and UXS). Thus, to acquire satisfactory levels of post-curing properties in indirect, light-activated composites, HM mode would be recommended.

However, higher-intensity polymerization produces greater polymerization shrinkage\(^3\)\(^4\). To counter this, it is recommended to apply slow-start polymerization, multi-step polymerization, or layered placement of composite material when fabricating bulky prostheses and long-spanned fixed partial dentures.

The HA mode exhibited the lowest curing depth among the three modes and against the TAQ unit – indicating that HA mode had the lowest light intensity. In the current study, the curing depth of the preliminary TAQ unit compared with the xenon light sources. As light intensity is influenced by distance.
from the light source\textsuperscript{17}, the higher curing depth for TAQ unit might be caused by the distance of 30 mm — the shortest among the units tested because its structure allowed for exposure in open air. Therefore, low-intensity HA mode can be used for preliminary polymerization since low-intensity polymerization is effective in reducing polymerization shrinkage\textsuperscript{18}.

Recently, various light-initiators with wide ranges of absorption spectra have been developed\textsuperscript{19}, and polymerizing apparatus such as M3 equipped with different light sources may be useful on account of its wide range of wavelengths. Visible light-activated resin materials contain an amine reducing agent to induce discoloration of the composite material\textsuperscript{20}. When using a metal halide light source that radiates a wide range of wavelengths including UV light, the amount of amine reducing agent in the material can be decreased while still ensuring sufficient color stability due to presence of a UV light activator. Therefore, for the HM mode, the laboratory unit should be used without the UV cutting filter since the filter reduces light intensity\textsuperscript{21}.

However, the UV light activator in the composite material reduced the unpolymerized layer on the surface\textsuperscript{22}. As such, a layering technique would be needed for composite material formation. When using a dual-curable composite containing both visible and UV light initiators, HM mode should be used with a UV cutting filter except for the final exposure.

The most notable characteristic of the M3 unit was its time-staggered exposure — by utilizing its different light sources. Slow-start polymerization could be set up by exposure time lag. Further, other polymerization methods could be set up extemporaneously by adjusting the wavelength, light intensity, and exposure time. Consequently, the new M3 unit, because of its excellent diversity of polymerization modes, was thought to be a competent laboratory polymerizing apparatus — not only for the composite material assessed in this study, but also for other light-activated resin materials.

ACKNOWLEDGEMENTS

This study was supported in part by a Grant-in-aid for Scientific Research (B(2) 16390566 and B(2) 16791210) from the Japan Society for the Promotion of Science (JSPS).

REFERENCES

