Effect of different irradiation time on the mechanical properties of conventional dental composite restoration by LED laser

Saad Omar Alsharif, Zainal Arifin Mohd Ishak, Azlan bin Ariffin
School of Materials and Mineral Resources Engineering , Universiti Sains Malaysia,14300 Nibong Tebal, Seberang Perai Selatan, P. Pinang, Malaysia
E-mail: saadelsharif@yahoo.com

ABSTRACT- The aim of this study was to investigate the influence of light emitting diode (LED) laser with different irradiation time on the mechanical properties of conventional dental composite restoration. Experimental composites were prepared from rigid aromatic bisphenol A diglycidyl dimethacrylate (Bis-GMA) as base monomer, triethyleneglycoldim- ethacrylate (TEGDMA) as diluent monomer at the ratio (wt/wt) 60/40, 3-methacryloxyprop- yltrimethoxy silane (MPS) and hydroxyapatite (HA) as filler. The initiation system was based on the pair camphorquinone (CQ)/N, N dimet- hyl amino ethyl methacrylate (DMAEMA). The rectangular specimens (25 mm × 5 mm × 2.5 mm) were moulded in a stainless steel mold according to ISO standard 13586:2000. And the polymerization times were varied from 20 - 80 sec. The experimental results showed the best polymerization times (fracture toughness test) was used 60 seconds. Dental composite formulated with Bis-GMA: TEGMA and HA as filler presented the best compromise between different irradiation time.

Keywords: dental composite, light curing unit, Bis-GMA, TEGDMA, mechanical properties.

I. INTRODUCTION

VISIBLE light curing resin composite was introduced as a direct restorative material over 30 years ago. Dental resin composites are used to replace missing tooth structure and change the color and shape of the teeth in order to improve esthetics [1]. Generally, a dental resin composite is a mixture of silicate glass particles within an acrylic monomer that is polymerized during application [2]. Detail dental resin composites consist of four main components [1], [3], which are an organic polymer matrix, inorganic filler particles, coupling agent, and the initiator-accelerator system [1], [4]. The highly viscous monomer (Bis-GMA), has been widely used as an important dental base monomer [5]. And low-viscosity monomers (TEGDMA), used as diluents [6], [7]. Calcium hydroxylapatite (HA) is a major inorganic component of the hard tissue in the human body [8]. The most common silane used in dental composites is 3-methacrloxypropy- ltrimethoxysilane (γ-MPS) which is expected to bond chemically to the filler surface and to copolymerize with the methacrylic polymer matrix [9]-[11]. The most composites containing photoinitiator is activated by light in the 450–470 nm wave length, with 470 nm being the wavelength of peak absorption for the most commonly used photo initiator (CQ) [12]. Currently, three main types of polymerization sources are available; quarts-tungsten halogen (QTH) bulbs, plasma-arc lamps (PAC) and light-emitting diodes (LED). The (LEDs) can have wavelength peaks of around 470 nm [13]–[14], so negating the need for filters. Furthermore, the thermal emission of the (LED) light curing units is significantly lower than that of (QTH) light curing units [15]. (LCUS) with narrow emission spectra, such as (PAC) or (LED) LCUs, are optimized for oral biomaterials which contains the photoinitiator (CQ) [16]. Some dental resin composite, however, contain co-initiators [17], which absorb light at shorter wavelengths than (CQ). (LEDs) have an expected lifetime of several thousand hours (up to 10,000 h) with little degradation of output [18], [19]. Their markedly lower heat production is expected to enhance their operational longevity [20]. Other than reduce the temperature rise at the tooth surface during irradiation [21]. It has been shown that the depth of cure [18], hardness [22], and degree of polymerization [23], achieved with (LED) LCUs can be at least as good as with (QTH) LCUs. Generally, after improvements in blue (LED) in 1995 semiconductor technology, (LEDs) were proposed as a light source for the polymerization of light cured resins [24], [25]. (LEDs)

are solid-state light sources that change electrical energy directly into a light [26]. Light curing composite resins are now the most widely used dental restorative. The major advantage of this activation mode over the chemical one is the control the operator has over the working time. In addition, a definite amount of energy, which is defined as power multiplied by polymerization time, is necessary to obtain the optimal conversion rate of the dental composite resin. This amount largely depends on the dental resin composite shade, opacity, thickness, photo-initiator, composition, increment size and restoration's configuration [27]–[30]. Although dental resin composite extremely popular because its aesthetic appeal, but an inherent disadvantage of light-activated resin composites is the shrinkage accompanying polymerization [31], [32]. Exposure times for polymerization vary, depending on the type of lamp, depth, shade, and type of the composite. For typical (QTH) or (LED) lights, times may vary from 10 to 60 seconds for a restoration 2-mm thick. Curing times with (PAC) lights are shorter, although laboratory data suggest that some mechanical properties decrease with shorter curing times. Microfilled composites require longer exposure than microhybrid dental resin composites because the small filler particles scatter the light more. Darker shades or more opaque composites require longer exposure times (up to 60 seconds longer) than lighter shades or more translucent composites [33].

Thus, the aim of the present study was to evaluate the effect of different irradiation time on the mechanical properties of conventional dental composite restoration by LED laser.

II. Materials and Methods

The microscopic filler Hydroxyapatite (HA) was purchased from (Fluka Company Frankfurt, Germany), and added incrementally and used as reinforcement filler. Silane coupling agent (γ-MPS) 98% was purchased from (Sigma-Aldrich Germany), and used for the filler surface treatment. The main monomer (Bis-GMA) was purchased from (Esschem, Essington, PA, USA). The co-monomer (TEGDMA) was purchased from (Sigma-Aldrich, Germany). They were used as received without further purification. (CQ) was used as a photosensitizer and was purchased from (Sigma-Aldrich, Germany). (DMAEMA) was purchased from (Sigma-Aldrich Germany).

III. Filler Modification and Characterization

The coupling agent used to treat surface of filler was (γ-MPS) using a 70/30 % acetone-water mixed with 10 wt% (γ-MPS) with respect to filler powder. The filler powder was added to the liquid mixture (acetone – water – silane), and mixed with a stirrer for 4h at 400 rpm, using a magnetic stirrer (model ST0707V2 Germany). Subsequently the mixture filtered and dried in an oven at 110 C° for 24 h. This method was previously described by E. Harper et al., [34]. The treated filler and untreated filler were identified by FTIR analyses. The filler was mixed with potassium bromide (KBr) prior to compacting into thin pellets with hydraulic press for three minutes. The pellets were then inserted and analyzed in the Fourier transformer infrared spectrometer (Perkin Elmer spectrum one, USA).

IV. Preparation of Composite

The resin matrix consisted of (Bis-GMA/TEGDMA) at 60/40 wt. % as matrix phase, was mixed in a glass vessel. The vessel was immersed in an ice bath to prevent heat induced polymerization created by shear in the viscous system. Aluminum foil was used as coverage to reduce light initiated polymerization and the mixing was perfected in the dark [35]. The initiator, (CQ) was added to the resin matrix followed by the addition of (DMAEMA) as a photo-reducing agent [36]. Monomers and photoinitiators were mixed until they dissolved. The filler powder was then dispersed in the resin matrix and hand-mixed.

V. Fracture Toughness Test

Rectangular bar-shaped made from resin matrix composite (2.5 mm × 5 mm × 25 mm), the specimens were prepared in a stainless steel mould. Unpolymerized material was applied to mould, which was covered on both sides with a Mylar matrix strip and rigid glass microscope slide. Light pressure on the outer two slides was utilized to force excess material out of the rectangular slots in the mould. The samples were then cured by a light curing unit LED (3M ESPE Elipar FreeLight2, St. Paul, MN) at 20, 40, 60 and 80 sec. increments on each side. The specimens were removed from the mould and polished with 1000 grit

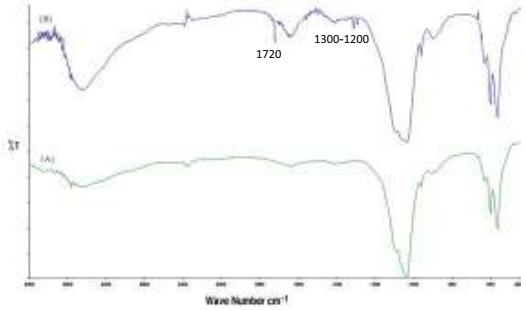
silicon carbide paper. Fracture toughness K_{ic} was calculated as the following equation [37], [38].

$$K_{IC} = \frac{3PSa^{1/2}\, y}{2tw^2} \qquad (1)$$

Where: Geometry correction factor (y)
$y = 1.93 – 3.07\ (a/w) + 14.53\ (a/w)\ 2 – 25.11\ (a/w)\ 3 + 25.8\ (a/w)\ 4$
P = load at peak (N), S = span length (mm),
a = notch length (mm), t = specimen thickness (mm),
w = specimen width (mm).

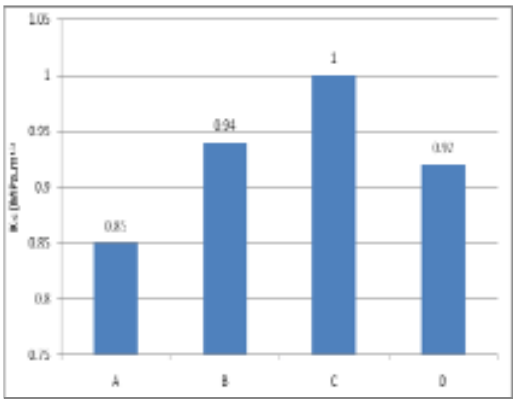
VI. RESULTS

'Figure 1', shows the FTIR spectra of (HA) particles before and after treated with the (γ-MPS). The presence of bands for the carboxyl group (~1720 cm^{-1}) indicates to a treated surface of filler [39]-[41]. And SiO group (~1300-1200 cm-1) indicates the presence of the coupling agent on the surface of (HA) as described by Wang and Bonfield [39].This finding in this study is an agreement with previous reported works [37], [38].



'Figure 1', FTIR spectra of (A) untreated HA and (B) treated HA

The results of fracture toughness test of composite resin are presented in 'Figure 2', There were significant differences between radiation time at 20s and radiation time 40, 80s and there were no significant differences between radiation time at 40s and radiation time at 80 s, on the other hand, there were significant differences between radiation time at 40 and 80s and radiation time at 60s. The radiation time at 60s exhibited significantly higher fracture toughness than that of the other radiation time.



'Figure 2', *Radiation time (A) 20_s, (B) 40_s, (C) 60_s and (D) 80_s*

VII. CONCLUSION

Filler treatment by silane coupling agent (γ-MPS) has moderately improved the mechanical properties of dental resin composite material. This has been attributed to a significant improvement in the filler-matrix interaction. Improved bonding between the filler and the matrix resin which was achieved by both chemical adhesion and tight mechanical coupling leads to better mechanical properties of the dental resin composite. Dental resin composite-conventional filler at radiation time 60s by (LED) produced significantly higher fracture toughness than that of the other radiation time.

REFERENCES

[1] R. Craig, and J. Powers, "Restorative dental materials" 11th ed. St Louis; Mosby, 2002
[2] T. Roberson, H. Heyman, and E. Swift, "Sturdevant's art and science of operative dentistry" 4th ed. St Louis; Mosby, 2002.
[3] J. M. Powers, R. L. and Sakaguchi "Restorative dental materials". 12th ed. St Louis; Mosby, 2006.
[4] R. Van noort "Introduction to dental materials". 2nd ed. St Louis; Mosby, 2002.
[5] RL. Bowen "Dental filling material comprising vinyl-silane treated fused silica and a binder consisting of the reaction product of bisphenol and glycidyl methacrylate" 1962 U.S. Patent. 3, 66-12.
[6] G. P. Sónia, O. Raquel, T. Manuel and G. N. Teresa "Evaluation of two Bis-GMA analogues as potential monomer diluents to improve the mechanical properties of light-cured composite resins" 2005 *J. Dental Materials* 21, 823-830.
[7] M. Izabela "Structure-property relationships in dimethacrylate networks based on Bis-GMA, UDMA and TEGDMA" 2009 *J. dental materials* 25, 1082-1089.
[8] J. Jovanovica, B. Adnadjevicb, M. Kicanovicc and D. Uskokovica "The influence of hydroxyapatite modification on the cross-linking of polydimethyl- siloxane/HAp composites" 2004 Colloids and Surfaces B: Biointerfaces. 39, 181-186.

[9] D. S. Irini, M. K. Maria "Effect of the amount of 3-methacyloxy- propyltrimethoxysilane coupling agent on physical properties of dental resin nanocomposites" 2009 *J. dental materials* 25, 1315-1324.

[10] R. Van Noort "Introduction to dental materials". 2nd ed. London; Mosby, 2002 p. 97.

[11] JP. Matinlinna "An introduction to silanes and their clinical applications in dentistry" 2004 *Int. J. Prosthondont* 17, 155-164.

[12] R. Nomoto "Effect of light wavelength on polymerization of light-cured resins" 1997 *J. Dent. Mater*. 16, 60-73.

[13] RW. Mills "Blue light emitting diodes-another method of light curing" 1995 *Br. Dent. J*. 11,169.

[14] C. Kurachi, AM. Tuboy, DV. Magalhaes and VS. Bagnato. "Hardness evaluation of a dental composite polymerized with experimental LED-based device" 2001 *J. Dent. Mater*. 17, 309-315

[15] AUJ. Yap and MS. Soh "Thermal emission by different light-curing units" 2003 *J. Oper. Dent.* 28, 260-266.

[16] F. Stahl, SH. Ashworth, KD. Jandt and RW. Mills "Light-emitting diode (LED) polymerisation of dental composites: flexural properties and polymerisation potential" 2000 *J. Biomat*. 21, 1379-1385.

[17] YA. Park, KH. Chae and HR. Rawls "Development of a new photoinitiation system for dental light-cure composite resins" 1999 *J. Dent. Mater*. 15, 120-127.

[18] RW. Mills "Dental composite depth of cure with halogen and blue emitting diode technology" 1999 *Br. Dent. J*. 186, 388-391.

[19] MS. Rea, "Lighting handbook". 8th ed. 1993 New York: Illuminating Engineering Society of North America p. 237-240

[20] AW. Bennett and DC. Watts "Performance of two blue light emitting-diode dental light curing units with distance and irradiation-time" 2004 *J. Dent. Mater*. 20, 72-79.

[21] A. Uhl, A. Volpel and BW. Sigusch. "Influence of heat from light curing units and dental composite polymerization on cells in vitro" 2006 *J. Dent* 34, 298-306.

[22] RW. Mills, A. Uhl, GB. Blackwell and KD. Jandt "High power light emitting diode (LED) arrays versus halogen light polymerization of oral biomaterials: Barcol hardness, compressive strength and radiometric properties" 2002 *J. Biomaterials* 23, 2955-2963.

[23] TH. Yoon, YK. Lee, BS. Lim and CW. Kim "Degree of polymerization of resin composites by different light sources" 2002 *J. Oral Rehabil*. 29, 1165-1173.

[24] RW. Mills "Blue light emitting diodes-another method of light curing" 1995 *Br. Dent. J*. 178:169.

[25] S. Nakamura, T. Mukai and M. Senoh. "Candela-class high brightness InGaN/AlGaN double heterostructure blue-light-emitting diodes" 1994 Appl. Phys. Lett. 64, 1687-9.

[26] ES. Duke. "Light-emitting diodes in composite resin photo polymerization" 2001 Compendium 22, 722-725.

[27] R. Nomoto, K. Uchida and AT. Hirasaw. "Effect of light intensity on polymerization of light-cured composite resins" 1994 *J. Dent. Mater*. 13, 198-205.

[28] FA. Rueggberg, WF. Caughman, JW. Curtis and HC. Davis "A predictive model for the polymerization of photo-activated resin composites" 1994 *Int. J. Prosthod.* 7, 159-166.

[29] FA. Rueggeberg, WF. Cauchman and JW. Curtis "Effect of light intensity and exposure duration on cure of resin composites" 1994 *Oper. Dent. J*. 19, 26-32.

[30] MR. Boushlicher, MA. Vargas and DB. Boyer. "Effect of composite type, light intensity, configuration factor and laser polymerization on polymerization contraction forces" 1997 *Am. J. Dent.* 10, 88-96.

[31] AD. Loguercio, A. Reis and RY. Ballester. "Polymerization shrinkage: effects of constraint and filling technique in composite restorations" 2004 *J. Dent. Mater*. 20, 236-243.

[32] CJ. Kleverlaan and AJ. Feilzer. "Polymerization shrinkage and contraction stress of dental resin composites" 2005 *J. Dent. Mater*. 21, 1150-1157

[33] M. P. John and C. W. John "Dental Materials Properties and manipulation" 2008 9th edition St Louis: Mosby.

[34] E. Harper, M. Braden and W. Bonfield "Mechanical properties of hydroxyapatite reinforced poly (ethylmethacrylate) bone cement after immersion in a physiological solution: influence of a silane coupling agent" 2000 *J. Mater. Sci*. 11, 491-497.

[35] J. Leylanaz, and S. Paul "Effect of filler content on the profile of released biodegradation products in micro-filled bis-GMA/TEGDMA dental composite resins" 1999 *J. Biomaterials* 20, 1897-1908.

[36] Y. Finer and J. Santerre "Biodegradation of model composites: dependence on resin chemistry" 1999 Proceedings of the 77th IADR meeting, Vancouver, Canada, March 10-13. Abstract #190.

[37] H. Saied "Mechanical, physical and biological properties of denture base poly (methyl methacrylate) filled with ceramic filler" 2005 D. Phil. Thesis, USM, Penang.

[38] M. Asam, "Preparation and characterization of opaque dental porcelain powder as a filler in denture base poly (methyl methacrylate)" 2008 M.Sc. Thesis, USM, Penang.

[39] M. Wang, and W. Bonfield "Chemically coupled hydroxyapatite-polyethylene composites: structure and properties" 2001 *J. Biomaterials* 22, 1311-1320.

[40] M. Abboud, S.Vol, E. Duguet, and M. Fontanille "PMMA-based composite materials with reactive ceramic fillers, Part I.- Chemical modification and characterization of ceramic particles" 1997 *J. Mater. Chem*. 7, 527.

[41] Liu Q Ding J, DE. Chambers, S. Debnath, SL. Wunder and GR. Baran. "filler-copling agent- matrix interactions in silica/polymet- hacrylate composites" 2001 *J. Biomed. Mater*. 57, 384-393.