Evaluation of Composite Resin Cure with Softstart and Standard mode of Polymerization - An *In Vitro* Study

Dissertation submitted to

THE TAMIL NADU Dr. M.G.R. MEDICAL UNIVERSITY

In partial fulfillment for the Degree of

MASTER OF DENTAL SURGERY

BRANCH III CONSERVATIVE DENTISTRY

FEBRUARY 2005

CERTIFICATE

This is to certify that this dissertation titled **"EVALUATION OF COMPOSITE RESIN CURE WITH SOFTSTART AND STANDARD MODE OF POLYMERIZATION – AN INVITRO STUDY"** is a bonafide record of work done by **Dr. SAYANTAN MUKHERJEE** under my guidance during his postgraduate study period between 2002 - 2005.

This dissertation is submitted to **THE TAMIL NADU Dr. M.G.R. MEDICAL UNIVERSITY**, in partial fulfillment for the degree of **Master of Dental Surgery in Branch III – Conservative Dentistry and Endodontia.**

It has not been submitted (partially or full) for the award of any other degree or diploma.

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INTRODUCTION

Light activated composite restorative materials have revolutionized clinical adhesive dentistry. They have several advantages including control of contour during restoration, improved colour stability and increased polymerization. Photopolymerization of dimetha acrylate dental resin is a complex process that exhibits diffusion controlled kinetics and heterogenous network growth. A high degree of conversion of light cure dental resin composite should be obtained at the end of the polymerization process. This leads to optimal mechanical, physical and biological properties. An inherent disadvantage of visible light activated resin composite is polymerization shrinkage. This is due to the formation of short-range covalent bond between the monomer units, which results in shortening of the final network of polymer.

Composite shrinkage can be divided into two phases:

1. Pre Gel polymerization shrinkage.
2. Post Gel polymerization shrinkage.

During pre gel polymerization the composite flows and stresses within the structure are relieved (Davidson and Degree 1984). In post gel polymerization flow ceases and cannot compensate for shrinkage. Thus post gel polymerization results in significant stress in the surrounding tooth structure. (Felzer and Davidson 1987).

During polymerization with standard intensity, flow does not tend to occur in light activated composite resin because of characteristically more rapid achievement of cross-linking and elastic limit.

Stresses arising from post gel polymerization shrinkage can cause defect in the composite tooth interface leading to bond failure with associated

postoperative sensitivity, microleakage and recurrent caries (Elich and Welch 1986). If the composite tooth bond is good, it may also cause deformation of the surrounding tooth structure resulting in microcracks in enamel. (Bowen, Nomoto, Rapson 1983)

One way of minimizing polymerization shrinkage of light cure composite resin is to allow flow through controlled polymerization during setting. This can be attained by pre gel polymerization at low intensity followed by final cure at high intensity (Soft Start Polymerization). Studies have shown that this polymerization model results in smaller marginal gap with increased marginal integrity. (Uno and Asmusen 1996).

The result of material evaluation like test for mechanical strength, microhardness and leachable components are linked closely to polymer conversion. Thus determination of composite cure is a critical component which affects the longevity of the restoration.

Among the several methods to determine the degree of composite cure is Fourier transformation infrared spectroscopy (F.T.I.R). F.T.I.R has been proven to be a widely used reliable method. This method detects the C=C stretching vibration directly before and after polymerization of composite resin.

Micro hardness can be used as one of the indicators for the completeness of polymerization since the hardness of a polymer is directly related to its degree of cure. Vicker hardness is a suitable method for measuring the surface hardness of a restorative dental material.

The aim of the present study was to determine the degree of conversion and effectiveness of composite cure associated with standard mode and soft start polymerization by F.T.I.R and microhardness testing.

REVIEW OF LITERATURE
(DEGREE OF CONVERSION)

Richard. J. Blankenau et al (1983)[60] stated that the photosensitizers in the composite resins generally require a wavelength in the range of 468 to 480 nm to activate polymerization.

J.M. Antonucci and E.E. Toth (1983)[3] studying the extent of polymerization of dental resins by differential scanning calorimetry and stated that the presence of unreacted monomer and oligomers can have a plasticizing effect on the polymer, thereby altering the physical and mechanical properties of the resin restoration.

C.L. Davidson and A.J. De Gee (1984)[20] studied the relaxation of polymerization contraction stress by flow in dental composite. The studied showed that the adhesive composite-enamel junction can resist the polymerization contraction forces and that the material is not damaged by this tensile stress.

Ferrance *et al.* (1984)[14] compare the sample preparing method for F.T.I.R. to analysis the degree of polymerization. Diluent concentration, curing mode, and activator types were investigated. DP ranged from 55 to 72%. Degree of polymerization enhanced in the bulk of the resin, as determined by RBr-pellet technique, in comparison with result from a thin film method.

Developments in composite Resins Mc Cabe (1984)[51] in his workshop stated that further developments and improvements in enamel and dentine bonding systems are likely along with clinically viable systems for the pretreatment of dentine as a means of improving bonding. He stated that the exposure time has an effect on depth of cure which varies from one product to another. Increasing the exposure time from 20 seconds to 60 seconds can increase the cure depth by as little as 5% or as mush as 82%.

Joshua Friedman et al (1984)[36] conducted a comparative study of visible curing lights and hardness of light cured restorative materials. Curing lights with higher light output provided greater hardness of light cured restorative materials. The differences in curing ability were more apparent among various units they applied to dark or more opaque shades. An increased area of light transmission provided improved hardness of light cured restorative materials. Curing lights with greater output and greater transmission area provided an increase in bottom hardness of light-cured resins.

J.A. Yearn (1985)[73] evaluated the factors affecting cure of visible light activated composites and concluded that light cured composites are now being more widely used in the restoration of occlusal cavities in posterior teeth, where the technique offers advantages of control, handel ability and a lack of porosity unattainable in a chemically cured system.

Clark.M.Stanford et al (1986)[18] evaluated the Polymerization of composites by sequential and continuous Irradiation with visible light and reported that the composites activated by visible light, when irradiated continuously or sequentially for the same total exposure, polymerize to a similar extent when the time of irradiation is adequate.

An assessment of visible-light polymerizing sources was done by H.Moseley.R.Strang and K.W.Stephen (1986)[54] and reported that the ability of a light to polymerize a visible-light-cured material is dependent on the functional irradiance of the light and the absorption characteristics of the material. The recommendation of a particular light cannot be made solely from the knowledge of the performance of the light; a knowledge of the `functional' wavelengths for the materials is also required.

Depth of cure of visible light-cured resin : Clinical simulation by H.Matsumoto et al (1986)[50] concluded that, in general, manufactures designated illumination times for specific depths are inadequate to ensure complete

polymerization. Layering the composite may still be the best method for filling cavity preparations that extend 3 to 4 mm in depth.

Eliades GC, Vougiouklakis GJ, Caputo (1987)[24] evaluated the degree of double bond conversion in light cured composites. The results of this study indicated that the microfilled materials present smaller depth of cure and higher amount of unconverted (C-C) bonds as a function of distance and curing time. The thermal properties of the filler fraction affect the degree of unsaturation.

J.P.Dewald and J.L.Ferracane (1987)[22] did a comparison of four modes of evaluating depth of cure of light=activate composites. Optical and scraping methods correlate well, but severely overestimate depth of cure as compared with hardness testing or degree of conversion analysis. Degree of conversion appears to be the most sensitive test of depth of cure.

K.Chung and E.H.Greener (1988)[16] studied the degree of conversion of seven visible light-cured posterior composites. The degree of conversion ranged from 43.5 to 73.8%. Interestingly, composites of different molecular structures as revealed by infrared were found to have equivalent degree of conversion. The role of the additional filler concentration and changes in the morphology do not seem to affect the final cross link density in these resins.

F.A.Rueggeberg and R.G.Craig (1988)[61] correlated the parameters used to estimate monomer conversion in a light-cured composite. The sensitivities of Fonrier transform infrared spectroscopy, Knoop hardness, water sorption, and resin leaching were compared for their ability to distinguish differences between composite samples cured through different thickness of overlying resin. Sensitivity to differences was greatest and equal for FTIR spectroscopy and knoop hardness, while resin leaching proved to have woderate sensitivity, and water sorption none.

Massaki Takamizu, et al (1988)[70] evaluated the efficacy of visible-light generators with changes in voltage. Two specific output patterns were observed;

one sensitive to line voltage change, the other relatively stable. Depth of cure was dependent on light intensity and exposure time. The best result was obtained from visible-light curing units with greater intensity and voltage regulation.

F.A. Rueggeberg, D.T. Hashinger and C.W. Fairhurst (1990)[63] studied the Calibration of FTIR conversion analysis of contemporary dental resin composites. An aliphatic to aromatic C=C molar ration of up to 6/1 needs to be used in order to establish a calibration curve that validly determines monomer conversion.

R.L. Sakaguchi, W.H.Douglas and M.R.B.Petrs (1992)[68] studied the curing performance and polymerization of composite restorative materials. A linear relationship was demonstrated between polymerization contraction and light intensity. The polymerization contraction of a microfilled composite and posterior composite, using a constant curing time and light intensity, decreased linearly with increasing sample thickness. Less than optimal light output of the curing light source can be compensated by increasing application time within reasonable limits.

Erik Keith Hansen et al (1993)[31] studied relation between depth of cure and surface hardness of light activated resin. The study concluded that the essential problem is, even a poor light source could cure the surface just as effectively as a good light source. But the hard surface concealed poorly polymerized or even non polymerized resin. Therefore the assessment of the efficacy of a curing unit cannot be based upon the surface hardness of an irradiated resin.

M.Kawaguhi et al (1994)[39] studied Relationship between cure depth and transmission coefficient of visible light activated resin composites. The Relationship between the transmission coefficient and cure depth were evaluated on light activated resin composites. The transmission coefficient

ranging from 0.042 to 0.263, was dependent upon the shade of the resin. There was a good correlation between the transmission coefficient and the cure depth for different shades for each resin composite. The microfilled resin composite showed transmission coefficient and cure depth lesser than twice of the hybrid and small particle filled resin composites.

C.S.Fowler ML Swartz BK Moore (1994)[28] evaluated the efficacy testing of visible light curing units. The data indicated that a light meter is a more efficacious means of monitoring curing light performance than is a tactile test of resin surface hardness.

William P. Kelsey et al (1994)[72] study the effects of wand positioning on the polymerization of composite resin. The study strongly recommended that the curing light be held steady during the polymerization cycle, and if the restoration is larger than the area being irradiated, multiple, stationary light applications should be used in preference to moving the wan slowly over the restoration surface. This will result in a deeper, more through cure of the restorative material, thereby enhancing the clinical performance of the resin restoration.

F.A. Rueggeberg et al (1994)[66] studied the effect of light intensity and exposure duration on cure of resin composite. The result recommended the routine exposure time of 60 seconds and using light-source intensities of at least 400 mW/cm^2. Sources with intensity values less than 233 mW/cm^2 should not be used because of their poor cure characteristics.

Novel approach to measure composite conversion kinetics during exposure with stepped or continuous light-curing by Fredric. A rueggeberg, Janet.W.Ergle, Donal J. Mettenberg (1999).[61] The objective of this research was to evaluate novel approach to monitor the polymerization reaction during a light-curing exposure by using infrared (IR) spectroscopy. Stepped intensity curing for the ESPE highlight unit was shown to produce significantly lower

conversion rates at the surface and at 1-mm depths, but larger exposure times were still required to provide conversion values equivalent to continuous exposure.

Murray. R. Bouschicher (2000)[55] evaluated, the effect of stepped light intensity on polymerization shrinkage force and conversion in a photoactivated composite. The mean maximum shrinkage force and force rate exhibited during the first 300 seconds of polymerization were not influenced by using stepped light exposure. Degree of conversion was equivalent for exposures of similar total duration at 2-mm depth. Mode of cure had no effect on degree of conversion.

Richard B. Price *et al.* (2000)[59] determined the effect of distance on the power density from standard and turbo light guide. The design of the light guide of a light curing unit affect light dispersion, power density. For these reasons manufacturer should report the power density at the tip of the light guide.

Verslus et al (2000)[72] observed that pre-gel composite flow was not directed toward the curing light in this mathematical model. Instead, for both chemically cured composite and light cured composite, pre-gel composite flow was directed toward the preparation walls as long as successful bonding was obtained. When this bonding was absent composite pulled away from the preparation walls, but still did not flow towards the light source.

Auj Yap (2000)[6] evaluated the effectiveness of Polymerization in composite restoratives claiming bulk placement:- Impact of cavity depth and exposure time. The composite restoratives evaluated should not be placed in increments greater than 2 mm in order to obtain uniform and maximum polymerization. The findings did not support the manufacturer's claim of bulk placement.

AUJ-Yab (2000)[8] demonstrated polymerization shrinkage of visible-light cured composite. Under the conditions of this *in vitro* study the polymerization

reaction of both conventional and polyacid-modified composite resin was accompanied by a dimensional change that result in shrinkage.

S.Imazato et al (2001)[32] compared the degree of conversion of composites measured by DTA and FTIR. The aim of this study was to measure the Degree of conversion of experimental 2, 2-lispropane based composites and proprietary composites by DTA and FTIR. Results showed that the higher the proportion of TEGDMA, the greater the degree of conversion of Bis GMA/TEGDMA CO-polymers. The DC determined by DTA for 605 irradiation was significantly greater than that by FTIR. The amount of heat evolved during polymerization could be well related to the conversion of C=C, DTA gives the value of DC excluding the unreacted species in the filler and DTA is considered to be a valuable method to determine the curing behaviour.

DL Leonard et al (2001)[45] in an in vitro study determined the minimum irradiance values required for adequate polymerization of a microfill and a hybrid resin composite when cured for 40 and 60 sec. The generally accepted value of 300 mW/Cm^2 appears to be adequate for proper polymerization of the hybrid resin composite used in this study. However, the microfill resin composite required twice the irradiance as that of the hybrid for adequate polymerization. Higher minimum irradiance values need to be established and recommended for microfill resin composites.

Anne Pentzfeldt (2001)[2] studied the indirect resin and ceramic systems and stated that numerous in vitro studies have reported the effect of additional or secondary cure on the properties of composite resins. All studies found a positive influence on the degree of conversion as a result of an additional cure. The degree of conversion increased by 6-44%.

Auj Yap *et al.* (2002)[14] evaluated effectiveness of composite cure with pulse activation and soft-start polymerization. Effectiveness of cure with

different modes was determined by measuring the surface microhurelness. Degree of conversion determined by F.T.I.R. study, K.H.N. obtained with control was significantly greater than soft start node. The absorbance ration of carbon double bonds to aromatic ring obtained with the control group was significantly greater.

Erik Asumusen *et al.* (2003)[25] studied the influence of two step curing on double bond conversion softening of a dental polymer after 1 day ethanol storage. According to study two-step curing of resin composite may result in polymer with increased susceptibility to the action of softening substances in food and beverage.

Auj Yap *et al.* (2004)[10] demonstrate influence of curing light and modes on cross link density of dental composite. The cross link density of composites was light and curing mode dependent. For halogen curing light-soft-start irradiation significantly reduced cross link density.

Daranec Tantbirajn (2004)[19] evaluate tooth deformation patterns in molar after composite restoration. Residual stresses from polymerization shrinkage in composite restoration deform or tooth. This study quantified and visualized the pattern of cuspal deformation.

MICRO HARDNESS TESTING

Richard J. Blankenau et al. (1983)[60] stated that the photosensitizers in the composite resins generally require a wavelength in the range of 468 to 480 nm to activate polymerization.

J.F. Mc Cabe (1984)[51] stated that the exposure time has an effect on depth of cure, which varies from one composite resin to another. Increasing the exposure time from 20 seconds to 60 seconds can increase the cure depth by as little as 5% or as much as 82%.

Joshua Friedman et al. (1984)[36] conducted a study with five different brands of light cure units and with dark and light shades of composite. Curing lights with higher light output provided greater hardness of light cured restorative materials. The differences in curing ability were more apparent among various units when they applied to dark or more opaque shades. An increased area of light transmission provided improved hardness of light cured restorative materials. Curing lights with greater output and greater transmission area provided an increase in bottom hardness of light cured resins.

Clark M Stanford et al. (1986)[18] stated that the use of adequate total time exposure sequentially is a viable method of photopolymerization. Sequential exposure might reduce the effect heat generated by the visible light curing units, which may cause damage to the pulp.

DeWald J.P. and Ferracane J.L. (1987)[22] compared four commonly used methods for depth of cure in light-activated composite. Optical and scraping methods correlate well, but severely overestimate depth of cure as compared with hardness testing or degree of conversion analysis. Degree of conversion appears to be the most sensitive test of depth of cure.

Fan P.L. et al. (1987)[26] measured the irradiance of nine visible light curing units and the wavelength region from 45 to 500 nm. This may be considered representative of the effectiveness in polymerizing currently available visible light activated composite resins and they also measure the effects of voltage variation on the irradiance of these visible light curing units and the resultant depth of cure of composite resins. In their results irradiance of none visible light curing units in the wavelength region from 450 to 500 nm range from 8.3 to 192.7 mw/cm^2 when the units are operated at 120 V output. Irradiance in this region indicates the effectiveness of photopolymerization. Variations in input

voltage affect the irradiance of light-curing units. Irradiance of these units decreased with lower voltage. This was accompanied by shallower depth of cure of composite resins a determined by the half-scraping value. The operation of these visible light-curing units at low voltage may compromise the physical properties and performance of composite resin restorations.

McCabe J.F. and Carrick T.E. (1989)[51] showed a simple and reproducible method for monitoring the intensity of radiation from composite light-activation units. The method depends upon the use of a cadmium sulfide photoconductive cell, the electrical resistance of which varies with the amount of light falling upon its surface. The depth of cure for various types of composite material were measured with use of a penetrometer that enabled the thickness of unpolymerized material at the base of the test mould to be determined. The depth of cure was inversely proportional to the attenuation of light caused by the composite resin at 470 mm. The relationship between depth of cure and light intensity at 470 mm was not a simple linear one over all intensity values. Above a certain critical value of intensity. The depth of cure appeared to be almost independent of intensity. Below this critical value, depth of cure fell markedly with decreasing intensity.

S.Y. Lee et al. (1993)[43] stated that the intensity delivered by curing units at the desired wavelength should be evaluated to assure a complete and deep cure of the composite resin. The narrow band of 450-500 nm is assumed to be more effective for photopolymerization.

Rueggeberg F.A. & Jordan D.M. (1993)[62] The inability to place the light tip in close approximation to a resin restoration in effect the resultant polymerization and clinical durability of the restoration. This research measured light intensity at the surface of resin composite, as well as 2 mm within its bulk, as the tip to resin distance is more from 0 to 10 mm. The polymerization of a resin composite at both locations was

measured for various tip differences using exposure duration's of 10, 20, 40 & sec. Light intensity did not decrease with the inverse square of the tip distance. The polymerization on the surface was greatly dependent upon the duration of exposure. The extent of polymerization 2 mm below the surface was still dependent primarily upon exposure duration, but intensity had a significant effect. For exposure duration's of 10, 20 & 40 sec., a tip distance greater than
4 mm demonstrated a significant decrease in resin polymerization 2 mm below the resin composite surface.

Flower C.S. et al. (1994)[28] studied the efficacy testing of visible light curing units to evaluate reduction in output of using lights on depth of cure of various resins and to compare the hardness of top and bottom surfaces of resin cements. In their conclusions, the known reduction in the emission of curing lights impairs depth to cure of composite resins. To compensate the loss of light output they recommended a cure time of 60 seconds over 30 seconds. Since a longer exposure to the light can compensate for some reduction in light output.

M. Kawaguchi et al. (1994)[39] evaluated the relationship between the transmission coefficients and depth of cure on eight light activated resin composites. The transmission coefficient, ranging from 0.042 to 0.263 was dependent upon the shade of the resin. There was a good correlation between the transmission coefficient and depth of cure for different shaded of composite resin.

Frederick A. Rueggeberg et al. (2000)[64] stated that the rate at which composite cure and development of stress from polymerization shrinkage at the tooth interface as well as within the tooth structure are clinical concerns. To minimize shrinkage the light intensity is lowered in order to reduce the rate at which the free radicals are formed and the rate at which the

polymerization occurs. A low initial rate of cure is intended to allow composite to flow from the unbonded surfaces to relieve stresses prior to attaining a gel point. Step - cure units generate an initial low - level output for a predetermined time into the curing exposure. Immediately following this phase, the unit generates full output for the remainder of the exposure. The initial light intensity can be slowly increased during exposure and then maintained at a fixed level. Such modification of light output is called ramping.

Joseph B. Dennison et al. [2000][35] stated polymerization shrinkage is a critical limitation of dental composites and may contribute to postoperative pain microleakage, secondary caries. The purpose of this study was to investigate the effect of sequentially increasing light intensity on polymerization shrinkage of 2 composites. Knoop hardness was used to evaluate effectiveness of the cure with each intensity increase. Results showed a significant difference (p<05) in mean linear shrinkage between the full intensity control group and other 3 sequences for both composites curing composites for
10 seconds at 25% intensity / 10 seconds at 50% intensities, and 20 seconds at 100% significantly reduced polymerization shrinkage while not compromising the depth of cure.

William J. Dunn et al. (2000)[73] The authors investigated the adequacy of cure of LED light curing units or LCV's. They concluded that the light output of commercially available diodes for resin based composite polymerization still requires improvement to rival the adequacy of cure of halogen based LCV and additional studies are necessary.

Christina Kuruchi et al. (2000)[16] The main goals of this study was the hardness of a composite resin cured by five LED based device and a comparison with conventional light curing unit besides the differences of

irradiance. When compared with halogen lamps, LED based devices show to be a promising alternative curing instrument further development in instrumentation may result in devices even more efficient than conventional lamps on temperature transfer. Through resin composite and dentin.

Anne Peutzfeldt (2001)[2] stated that numerous in vitro studies have reported the effect of additional or secondary cure on the properties of composite resins. All studies found a positive influence on the degree of conversion as a result of an additional cure. The degree of conversion increased by 6-44%.

Auj Yap et al. (2001)[7] stated that surface hardness is dependent on the percentage of filler volume besides the hardness of the filler particles of the composite resin.

C. Porko & E.L. Hietala (2001)[58] The purpose of this study was to measure the heat transference to pulp chamber during light curing. The temperature of the pulp was 2.2EC. Thereafter, standard occlusal cavities were prepared in all 10 teeth and filled with composite resin filling material in three parts. The dental adhesive was light cured for 20 seconds and each composite increment for 40 seconds. An extra cycle of was a post cure. The maximal temperature difference during the total procedure was 7.2 degree centigrade. The heating effect of the light curing should thus be taken into account when restorations are cured.

D.L. Leonard et al. (2001)[45] performed an in vitro study that determines the minimum irradiance value required for adequate polymerization of a microfill and hybrid resin composite when cured for 40 and 60 seconds. The effect of resin composite composition on the minimum irradiance required to adequately polymerize a 2 mm increment of the composite was evaluated. The results of this study indicate a significant difference between the

minimum irradiance required to adequately polymerize the hybrid resin composite and the microfilled composite resin. The generally accepted value of 300 mW/cm appeared to be adequate for proper polymerization of the hybrid resin composite resin used in this study. However, the microfill resin composite required twice the irradiance as that of the hybrid for adequate polymerization.

K. Okada et al. (2001)[56] investigated the effect of saliva as storage liquid and the length of storage effect on surface hardness of Fuji IX, Dyract, 2100, Estio. They observed only Fuji IX had increased in HVN with time at both storage conditions distilled water and saliva.

Lale G. Lovell et al. (2001)[41] The main objective of this study was to investigate the effect of cure rate on the mechanical properties of a common dimethyacrylate dental resin formulation. Copolymer specimens were cured with UV and visible light initiating system. UV light intensities that varied by over four orders of magnitude and cure temperature that differed by 60EC. Even though the polymerization rates for resins were vastly different, similar T_2 and modulus were measured for specimens cured to the same final double bond conversion. The significance of this study shows that highly cross-linked dimethyl acrylate systems, such as bis.GMA / TEGDMA, exhibit similar network structure and properties as a junction of double bond conversion, regardless of the method or rate of cure.

S.S. Davidson et al. (2001)[21] conducted a study on the effect of curing light variations on bulk curing and wall to wall quality of two types and various shades of resin composites. They suggested that slowing the rate of conversion can maintain good mechanical and physical properties and conversion while achieving good adaptation of composite preparation walls. The degree of conversion appears to depend more on irradiation time than on

intensity. This low-intensity cure also provided better adaptation of composites to preparations because it allowed the material to flow from the unbonded surface, thus compensating for contraction stress.

Seamus Sharkey et al. (2001)[68] compared micro hardness values of upper and lower surface of 3 composites resin cured by both traditional halogen source and plasma arc lamp and found the results for both top and bottom surfaces. The plasma arc yielded lower hardness values for all surfaces compared with halogen source. The amount of difference depended on the composite.

AUJ Yap et al. (2002)[12] This study investigated the influence pulse activation and soft start polymerization regimens on the post gel shrinkage of a visible light activated composite resin. When compared to a continuous, one level method, pulse activation and soft start polymerization, regimens did not significantly reduce post-gel shrinkage.

A.U.J. Yap & Byy Mok (2002)[6] investigated the effects of professionally applied topical fluorides on the surface hardness of a composite. The effects of topical fluoride application on surface hardness was material dependent for all materials. Treatment with APF gel and foam significantly reduced surface hardness when compared to the control.

Au. J. Yap et al. (2002)[8] In their study investigated the effects of cyclic temperature changes on surface hardness of four commercial composite resins. They concluded under the condition of their vitro study. The effect of cyclic temperature changes on hardness was material dependent.

P.I. Fan et al. (2002)[26] concluded that several factors control the light curing of a resin-based composite. The composition of the resin, the shade of the composite, the wavelength of the curing unit, the bandwidth, the distance of the curing light from composite the light intensity of the unit and curing time. The authors investigated depth of cure of five brands of resin-based

composite irradiated with light in 450 - 515 nm wavelength bandwidth. At ISO recommended intensity of 300 mw/cm^2 to recommended curing time be manufactures. The results concluded that intensity of 300 mw/cm^2 appear to effectively cure most resin based composite when an appropriate curing times are used.

R.W. Loney RBT Price (2002)[47] Light curing units used for polymerizing restorative resins produce heat during operation. Newer curing units with concentrating light guides or different light sources may require shorter curing times. However, the effect of such modifications on temperature transfer to the pulp is unknown. This study examined the effect of high output light curing units.

S.H. Park et al (2002)[57] In this study evaluated the effectiveness of the plasma arc-curing (PAC) unit for composite curing. To compare it's effectiveness with conventional halogen curing unit (QTH). The micro hardness of Z100 and tetric cream and the concluded. When compared with conventional light curing unit, the PAC unit, Apollo 95E did not properly cure the lower surface when the layer thickness exceeded 2 mm. In addition, 3 seconds of curing time, which the manufacturer recommend was insufficient for optimal curing of composites.

W.F. Caughman, F.A, Ruggeberg (2002)[65] The light curing protocol from 10 years ago may not be valid today. Today's clinician must choose among several types of curing lights and select from numerous composite systems that were not available when published. Today's lights vary in their special emission and power density and modern composite differ greatly in their ease of polymerization. Therefore to optimize clinical success, the polymerization protocol must be appropriate for given light and composite system. This manuscript outlines curing light/composite choices and supplies a clinical protocol to ensure adequate polymerization.

Y. Luo et al (2002)[48] The objective of this study was to investigate the effect of two factors : conditioning methods and light curing techniques on the marginal adaptation of Dyract. The pulse activation curing technique was compared with a conventional light curing technique for their effectiveness in reducing marginal gaps in restoration that were conditioned with three protocols. The significance of the pulse activation curing technique is it improves the marginal integrity of Dyract Ap when conditioner Prime & Bond NT and NRC are used as conditioning. The use of prime & bond NT without etching is not recommended, as marginal gaps are present irrespective of the curing techniques employed.

F.A. Ruggerberg W.F. Caughman (2000)[65] In this study investigated the degree of monomer conversion of four commercial dual - cure resin cements. The results demonstrated a wide range of potential cures among the various brands regardless of brand; chemical component of cure was always lower than when the specimens were exposed to any lighting condition.

A.D. Obici et al (2002)[43] Measured the gap that resulted from polymerization shrinkage of seven restorative resin composites after curing by three different method. The photo activation methods were a continuous light for 40 seconds at 500 mw/cm^2. Stepped light with initial intensity of 150 mw/cm^2 10 seconds and high intensity of 500 mw/cm^2 for 30 seconds. Intermittent light (450 mw/cm^2) for 60 seconds.

Results demonstrated the continuous light method presented the greatest shrinkages valves than other methods. Composite shrunk more at the bottom than at the top surface.

Auj. Yap. C. Senevirtanae (2001)[13] In this study investigated the influence of light energy density of (intensity x time on the effectiveness of composite cure in view of the curing profiles of new light polymerization

units hardness measurements were done on top/bottom surface and hardness ratio measured to different light energy densities.

Results showed that effective cure was not achieved with low intensities (200 to 30 mw/cm^2) but it could be achieved with high intensities 500 and 600 mw/cm^2) after 30 seconds of irradiation.

L.V. Stockton et al (2002)[69] In their study evaluated the effect of four different packing times on the knoop hardness number of three composites (Surefil, Z100, and spectrum TPH). Photomicrographs were made to determine whether the indentations had routinely been made on porosity free sites. Statistically analysis by 2 way ANOVA re.... The increasing the packing time for clinical composite may result in a lower KHN and increased clinical wear which would further increase if also associated with porosit....es within the composite.

The dental adhesive was light cured for 20 seconds an each composite increment for 40 seconds. An extra cycle of curing was given as post cure. The maximal temperature difference during the total procedure was 7.2°C. The heating effect of light curing should thus be taken into account when restorations are cured.

S. Hackman RM Pohojola : FA Ruggeberg (2000)[30] Investigated the extent of cure of a variety of phoinitiated resin composites and different shades. Cure valves were measured at the top surface and at simulated lighting conditions 0.5, 1.0 and 2.0 mm below the top. The exposure methods were continuous (10, 20 or 40 sec) at 600 mw/cm^2 and pulse delay technique. The results showed very little difference in conversion between A2 and D2 shades of the same composte with respect of depth. Conversion valves using the pulse delay technique and a 20 sec continuous exposure were significantly lower than those obtained using continuous 40 seconds exposure.

SUMMARY

This study evaluated the effectiveness of composite cured by standard mode of curing and soft start polymerization

The light cure unit [Translux Energy, KULZER] that used in this study consisted of both standard mode and soft start mode of curing. The composite used in this study was Venus [Kulzer] nanofill hybrid composite of shade A2. Samples were categorized into two groups. Group I were cured with soft start mode and group II were cured with standard mode of curing. The degree of conversion was determined by measuring absorbance peak using F.T.I.R. before curing. After curing samples were pulverized with mortar and pestles and mixed with infra red grade Potassium bromide to make a disc by KBr technique. The absorbance peak compared between before and after curing to obtain the value of degree of conversion. Effectiveness of composite cure was also established by measuring the surface microhardness using a microhardness tester.

Data obtained was analysed using Student's t test. The degree of conversion of group II cured by standard mode of curing was significantly greater than group I cured with soft start mode. Results of microhardness test also ranked well with the F.T.I.R. study. Vicker hardness number of group II was higher than the group I.

CONCLUSION

Adequate polymerization is a crucial factor in obtaining optimal physical properties and clinical performance of composite resin restorative materials. Problem associated with inadequate polymerization include inferior

mechanical properties, increased solubility in the oral environment which can compromise the biocompatibility of the final restoration.

From the result of the present study it can be concluded :

1. Degree of conversion with standard mode is higher than the degree of conversion with soft start mode.
2. Surface microhardness value obtained in microhardness study also higher in standard mode of cured group compared to soft start mode of cured group.

Further studies can be conducted by comparing various other methods of soft start curing (pulse delay, ramp) with standard mode evaluating the double bond conversion by other method like differential thermal analysis or magnetic resonance micro imaging.

BIBLIOGRAPHY

1. Ac Obici, Mac Sinhoreti, MF de Goes, S. Consani, LC Sorbinto. Effect of the photo - activation method on polymerization shrinkage of restorative composites. Operative Dentistry 2000; 27: 192-198.

2. Anne Peutz Feldt. Indirect resin and ceramic systems. Operative Dentistry, Supplement 2001; 6: 153-176.

3. Antony JM and Toth E. Extent of polymerization of dental resin by differential scanning calorimatry. Journal of Dental Research 1983; 62: 121-125.

4. Atmadja G. Bryant RW. Some factors influencing the depth of cure of visible light activated composite resins. Australian Dental Journal.

5. Auj Yap. Effectiveness of polymerization in composite restoratives claiming bulk placement: impact of cavity depth and exposure time. Operative dentistry 2000; 25: 113-120.

6. Auj Yap, Byx Mok. Effects of professionally applied topical fluorides on surface hardness of composite based restorations. Operative Dentistry 2002; 27: 576-581.

7. Auj Yap, C.L. Chew, S.H. Teoh, L.K.L.F. Ong. Influence of contact stress on occlusal contact area wear of composite restorations. Operative Dentistry 2001; 26: 134-144.

8. Auj Yap, KEC Wee, SH Tech. Effects of cyclic temperature changes on hardness of composite restorations. Operative Dentistry 2002; 27: 25-29.

9. Auj Yap, HB Wang. Polymerization shrinkage of visible light cured composite restorations. Operative Dentistry 2002; 27: 25-29.

10. Auj Yap, MS Soh. Influence of curing light and modes on cross-link density of dental composite. Operative Dentistry 2004; 29: 410-415.

11. Auj Yap, M.S. Shah. K.S. Siow. Post gel shrinkage with pulse activation and soft - start polymerization. Operative Dentistry 2002; 27: 81-87.

12. Auj Yap, MS Shah. Effectiveness of composite cure with pulse activation and soft start polymerization. Operative Dentistry 2002; 27: 44-49.

13. Auj Yap, C. Seneviratne. Influence of light energy density of effectiveness of composite cure. Operative Dentistry 2001; 26: 460-466.

14. Auj Yap, SCNg. Soft start polymerization influence on effectiveness of cure and post gel shrinkage. Operative Dentistry 2001; 26: 262-266.

15. Caughman. W.F., Ruggerberg FA. Shedding new light on composite polymerization. Operative Dentistry 2002; 27: 636-638.

16. Christina Kurachi, Aparecida M. Tubay, Daniel. V Magalhaes, Vanderlei. S. Bagnato. Hardness evaluation of a dental composite polymerized with experimental LED - based devices. Dental Materials 2000; 17: 309-315.

17. Chung K and Greener EH. The degree of conversion seven visible light cured posterior composite. Journal oral rehabilitation 1988; 15: 555-560.

18. Clark. M. Stanford, P.L. Fan, Ralph. L. Leung, Ray Kno-eppel, John. W. Stanford. Polymerization of composite by sequential and continuous irradiation with visible light. Operative Dentistry 1986; 11: 51-54.

19. Darance Tantbiro JN et al. Tooth deformation patterns in molar after composite restorations. Dental Materials 2004; 20: 535-542.

20. Davidson CL, AJ Gee. Relaxation of polymerization contraction stress by flow in dental composite. Journal of Dental Research 1984; 63: 146-148.

21. Davidson S.S., C.L. Davidson, A.J. Feilzer, A.J. DeGhee, N. Erdilek. The effect of curing light variation of bulk curing and wall to wall quality of two types. Journal of Esthetic & restorative dentistry 2001; 13: 205-206.

22. De wald and Ferracane J.L. A comparison of four models of evaluation depth of cure of light activated composites. Journal Dental Research 1987; 66(3): 727-730.

23. Dewald J.P, Ferracane J.L. A comparison of modes of evaluating depth of cure of light activated composites. Journal of Dental Research, 1987; 66(3): 727-730.

24. Elides GC et al. Degree of double bond conversion in light cured composite. Dental Materials 1987.

25. Erick Asmussen, Anne Peutz Feldt. Twp-step curing influence on conversion and softening of a dental polymer. Dental Material 2003; 466-470.

26. Fan PL, Ryan M. Schumacher, Kristy Azzolin, Richard Geary, Fredrick C. Eichmiller. Curing light intensity and depth of cure of resin based

composites tested according to international standards. Journal of American Dental Association 2002: 133: 429-433.

27. Ferrance JL, EH Greener. Fourier transformation infrared analysis of degree of polymerization in unfilled resin – Methods comparison. Jouranl of Dental Research 1989; 63: 1093-1095.

28. Flower CS, Swartz ML, Moore BK. Efficacy of testing visible light curing units. Operative Dentistry 1994; 19: 47-52.

29. Frederick Rueggeberg, Krishnan. Resin cure determination by polymerization shrinkage. Dental Materials 1988; 11: 265-268.

30. Hackman ST, RM Phojola, Ruggerberg FA. Depths of cure and effect of shade using pulse delay and continuous exposure photo-curing techniques. Operative Dentistry 2002; 27: 593-599.

31. Hansen EK, Asmussen E. Correlation between depth of cure and surface hardness of a light activated resin. Scandinavian Journal of Dental Research 1993; 101: 62-64.

32. Imazato S, JF Mc Cabe. Degree conversion of composite measured by DTA and FTIR. Dental Materials 2001; 17: 178-183.

33. Jeffery W Stansbury. Curing dental resin composite by photopolymerization. Journal of Esthetic Dentistry 2000; 12: 300-308.

34. Jose Antonia, F. Pires, Elizabeth Cuitko, Gerald E. Denehy, Edward J. Swift. Effect of tip distance on light intensity and composite resin micro hardness. Ouintessence International1993; 24(7): 517-521.

35. Joseph B. Dennison, Peter. Yaman < Ricardo Sier, James C. Hamelton. Effect of variable light intensity on composite shrinkage. Journal of Prosthetic Dentistry 2000; 499-505.

36. Joshua Freidman, Roland Hassan. Comparison of visible light curing units and hardness of light curing units and hardness of light cure restorative materials. Journal of Prosthetic Dentistry 1984; 504-505.

37. JL Ferracane and EH Greener. Fourier transfomarion infrared analysis of degree of polymerization in unfilled resin – Methods comparison. Journal of Dental Research 1984; 63: 1093-1095.

38. Kanca, B.I. Suh. Pulse activation reducing resin based composite contraction stresses at the enamel cavo surface margin. Journal of Esthetic Dentistry 2001; 18(3): 202-203.

39. Kawaguchi M, T. Fukushina, Mayazaki. The relation between the cure depth and transmission co-efficient of visible light. Journal of Dental Research 1994; 516-521.

40. Kelsey W.P. The effects of wand positioning on the polymerization of composite resin. Journal of American Dental Association 1986; 112: 533-553.

41. Lale C. Lovell, Hui Lu, Jeannine. E. Elliot, Jeffery. W. Stansbery, Christopher. N. Bowman. The effect of cure rate on the mechanical properties of dental resin. Dental materials 2001: 504-511.

42. Lale C. Lovell, Shelden. The effect of light intensity on double bond conversion and flexural strength of model, unfilled dental resin. Dental Materials 2003; 19: 458-465.

43. Lee S.Y, CH. Chiu, A. Bhoghosian, E.H. Greener. Radiometric and spectrometric comparison of power outputs of five visible light cure units. Journal of Dentistry 1993; 21: 373-77.

44. Tantbirogn et al. Tooth deformation pattern in molar after composite restorations. Dental Materials 2004; 20: 535-545.

45. Leonard DL, Charlton DG, Hilton TJ. Effect of curing tip diameter on the accuracy of dental radiometers. Operative Dentistry 1999; 24: 31-37.

46. Leonard D.L., D.G. Charlton, H.R. Roberts, T.J. Hilton, A. Zionic. Determination of the minimum irradiance required for adequate polymerization of hybrid and microfil. Operative Dentistry 2001; 26: 176-180.

47. Loney RW, RBT Price. Temperature transmission of high-output light curing units through dentin. Operative Dentistry 2001; 26: 516-520.

48. Luo. Y, E.C.M. Lo, Shy Wei, F.R. Tay. Comparison of pulse activation vs conventional light on marginal adaptation of a compomer - conditioned using a total - etch or a self etch technique. Dental Materials 2002; 18: 36-48.

49. Majorie. L. Swartz, Ralph R. Phillips. Visible light activated resin-depth of cure. Journal of American Dental Association 1983; 109: 634-637.

50. Matsumoto H, JE Gres, V.A. Marker, T. Okabe, J.L. Ferracane, G.A. Harvey. Depth of cure of visible light cured resin. Clinical Simulation 1986; 55: 574-578.

51. Mc Cabe J.F, Carric T.E. Output from visible light activation units and depth of cure of light activated composites. Journal of Dental Research 1989; 68(11): 1534-1539.

53. Miyazaki M, Hottori T, Ichilsh Y, Kondo M, Moore HBK. Evaluation curing units used in dental offices. Operative Dentistry 1998; 23: 50-54.

54. Mosley H. Strang, R. Stephen K.W. An assessment of visible light polymerization sources. Journal of Oral Rehabilitation 1986; 13: 215-224.

55. Marry R, Bouschlier, Frederick A Rueggeberg. Effect of stepped light intensity polymerization force and conversion in photoactivated composite. Journal of Esthetic Dentistry 2000; 12: 22-32.

56. Okada K, S. Tosaki, K. Hirota, W.R. Home. Surface hardness change of restorative filling materials in saliva. Dental Materials 2001; 34-39.

57. Park SH, J. Krejci, F. Luiz. Microhardness of resin composite polymerized by plasma arc or conventional visible light curing units. Operative Dentistry 2002; 27: 30-37.

58. Porko C, E.L. Hretala. Pulpal temperature change with visible light - curing. Operative Dentistry 2001; 26: 181-185.

59. Richard B Price. Effect of distance on the power density from two light guide. Journal of Esthetic Dentistry 2000; 12: 320-327.

60. Richard J. Blankenau, W. Thomas Cavel, K. Patric, Paul Blankenau. Wavelength and intensity of seven sytes for visible light curing composite resin. Journal of American Dental Association 1983; 106: 471-474.

61. Rueggerberg et al. Noble approach to measure composite conversion kinetics during exposure with stepped or continues light curing. Journal of Esthetic Dentistry 1999; 11: 198-201.

62. Rueggberg et al. Calibration of FTIR conversion analysis of contemporary dental resin composite. Journal of Dental Materials 1990; 6: 241-249.

63. Ruggerberg F.A, Jordan D.M. Effect of light tip distance on polymerization of resin composite. Journal of Prosthetic 1993; 6: 364-370.

64. Ruggerberg F.A, Janet. W. Ergle, Donald J. Mettenberg. Polymerization depths of contemporary light curing units using micro hardness. Journal of Esthetic Dentistry 2000; 12(6): 340-349.

65. Ruggerberg F.A, Caughman W.F. The influence of light exposure on polymerization of dual cure resin cement. Operative Dentistry 1993; 18: 48-55.

66. Ruggerberg F.A, Caughman W.F. The influence of light exposure on polymerization of dual cure resin cement. Operative Dentistry 1994; 19: 26-32.

67. Rueggerberg and Krishnan Tamilselvi. Dental Materials 1995; 11: 265-268.

68. Sakaguchi RL, WH Douglas. The curing performance and polymerization of composite restorative materials. Journal of Dental Research 1992; 20: 183-188.

68. Seamus Sherkey, Noel Ray, Francis Burke, Hassan Ziadia, Aillish Hannigan. Surface hardness of light activated resin composites cured by two different visible light sources: An vitro study. Dental Materials 2001; 32: 401-405.

69. Stockton L.W, PT. Williams, C. Ahtallah. The effect of prolonged packing on the surface hardness of posterior composites. Operative Dentistry 2002; 27: 266-270.

70. Takamizu T. Moore KB, Setcos JC, Phillips RW. Efficacy visible light generators with changes in voltage. Operative Dentistry 1998; 13: 173-180.

71. Theodore M. Robertson et al. Studevant's art and science and operative dentistry 4th edition.

72. Versules D Tanbiro JN, WH Dauglas. Do Dental composite shrinkage towards light. Journal of Esthetic Dentistry 2000; 12: 54-55.

73. William. J. Dunn: Anneke C, Bush. A comparison of polymerization by light emitting diode and halogen based light curing units. Journal of American Dental Association: 2002; 133: 335-341.

74. Yearn JA. Factors affecting cure of visible light activated composites. International Dental Journal 1985; 35: 218-225.