COMPARATIVE EVALUATION OF MARGINAL ADAPTATION AND DEPTH OF CURE OF COMPOMERS USING CONVENTIONAL LIGHT CURING AND PULSE ACTIVATION – AN IN-VITRO STUDY

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CERTIFICATE

This is to certify that this dissertation titled **"Comparative Evaluation of Marginal Adaptation and Depth of Cure of Compomers using Conventional Light Curing and Pulse Activation – An Invitro Study"** is a bonafide record of work done by **Dr. Jolly Mathews** under my guidance during her postgraduate study period between 2003-2006.

This Dissertation is submitted to THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY, in Partial fulfillment for the Degree of **Master of Dental Surgery in Branch VIII –Pedodontics & Preventive Dentistry.**

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

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Introduction

Light activated composite resin introduced in 1970 has revolutionized clinical dentistry by maximizing working time and minimizing the setting time.[62] Thus the clinician has sufficient working time to sculpt the material to achieve the desired contour to mimic the morphology of the tooth structure.

In the recent years the popularity of esthetic tooth colored restoration has led to a rapid increase in use of composite resins. The initially introduced dental composites were chemically cured through amine / peroxide chemistry. The limitation with the above technique has led to the development of single component resin composite activated by visible light[33].

Visible light curing units are an integral part of modern adhesive dentistry. Visible light activated resin system use a diketone absorber to create free radical that initiate polymerization. Most dental photo initiator systems use camphoroquinone as the di-ketone absorber with the absorption maximum in the blue region of the visible light spectrum at a wave length of 450 – 490nm[58]. Any source of light that operates in the blue spectrum of visible light can be employed as a curing source.

Currently there are different technologies for light curing of materials used in dental practice. The most popular medium for delivering blue light has been halogen based light curing units. In halogen lamps the light is generated when electric energy heats a small tungsten filament and emits electromagnetic radiation in the form of visible light. Conventional composite curing lamps operate in the blue region of the visible spectrum. The major

drawback of the halogen lamp is decline of irradiance over time due to the ageing of the bulb and filter[33].

In the past few years more advanced method of light curing have been introduced such as plasma arc-curing lamp, lazers and light emitting diodes.

Modifications to the conventional quartz tungsten halogen units have led to the development of pulse activation technique and soft start polymerization.

Soft start polymerization, a two-phase curing technique that utilizes an initial period of low intensity followed by high intensity curing has been shown to achieve a better marginal integrity. This technique was designed to obtain a slow continuous conversion during polymerization of light cured materials using a gradual increase in light intensity. The pulse activation technique is characterized by a waiting interval of 2-3 minutes between the initial low intensity pulse and a final exposure to a high intensity light. This is one of the most recent methods for minimizing polymerization shrinkage of light activated composite resins, by allowing flow during setting by means of controlled polymerization, which is done by pre-polymerization at low intensity followed by final cure at high intensity. This polymerization could result in smaller marginal gap and increased marginal integrity[54,31].

Esthetic restorative materials have increasingly been used to replace missing tooth structure as well as modify tooth color and contour. Composite resins have been the material of choice for aesthetic restoration because of

high mechanical properties, lower coefficient of thermal expansion and higher resistance to abrasion than silicates and acrylic restorative resins[8].

However adhesive properties of glass ionomer have led to their use as alternatives to composites, due to their moisture sensitivity and low mechanical properties. Hybrid versions such as resin modified glass ionomer cements and polyacid modified resin composites commonly known as Compomers have been developed. Commercially the term compomers (composite – ionomer) is used to reflect its resin composite and glass ionomer derivation. It is a one paste restorative materials introduced in the early 1990s.They are recommended for use in the restoration of primary teeth and non-stress bearing cavities in permanent teeth. They could be used in class V and III restoration including early childhood caries and class I and II restoration in primary teeth[23]. Poly acid modified resin composite are essentially resin composite in which filler is glass similar in many ways to ionomer glass. They have also variable quantity of dehydrated polyalkenoic acid incorporated with the filler that does not react with filler until the material absorbs water.

As with other light curing restorative resin, microleakage is a problem in poly acid modified resin composite. The excellent physical characteristics of this new category of restorative materials include esthetic, easy handling, adhesion to tooth structure, fluoride release, improved physical and mechanical properties, biocompatibility, radiopacity and ease of finish .

A new light–cured single component **P**oly **A**cid **M**odified **R**esin Composite (PMRC), Dyract AP (Dentsply De Trey) was introduced compared to its earlier version (Dyract). Dyract AP has higher compressive and flexure strength and its wear resistance is similar to that of resin composite. Therefore Dyract AP is recommended by the manufacture for use in all cavity types in anterior and posterior teeth including the occlusal stress-bearing surface of permanent teeth[11, 34].

The manufacturer recommends use of Prime and Bond NT (Dentsply De Trey) with Dyract AP compomers in stress bearing class I and class II permanent restoration. Prime and Bond NT is a self-priming dental adhesive that combines primer and adhesive in a single bottle. It is designed to bond Dyract AP compomer or resin composite material to enamel and dentin.

In resin composite restorations the physical properties are closely related to the degree of polymerization and measurement of hardness is an effective way to evaluate the degree of polymerization.

Hardness is defined as a resistance of a material to indentation. Curing, scratching or abrasion can be used as indicator for the completeness of polymerization[33]. Surface hardness is an indirect measure of degree of conversion and information can be obtained by comparing hardness values at the top and bottom surface. **Vickers** hardness is the suitable test for measuring surface hardness of restorative dental material. Hardness evaluation is the test widely used to examine curing of material.

Aims & Objectives

The aim and objective of this study is

The aim of this study

1) To test the influence of pulse activation system and conventional light curing system on the marginal adaptation of polyacid modified composite resin (compomer) in class V cavity preparation

2) To find the degree of cure and depth of cure while using two different curing modes by measuring VHN at three different heights (2mm, 3mm, 4mm) and three different loads (50g, 80,110g)

The objective of the study

To recommend the best curing method that could result in adequate resin polymerization with improved mechanical properties of the set material.

Review of Literature

Davidson C.L and DeGee A.J et all [1984][11] his study evaluate competition between composite – dentin bond strength and polymerization contraction stress. The influence of contraction stress developed during the polymerization of composite, on adhesion to dentin treated with a dentin adhesive was studied for a chemically and light activated microfilled composite in both linear and 3-d models. The composite materials used were the chemically –initiated composite. Chemically initiated composite- Sliar, the light –initiated composite- Silux and the dentin adhesive, Scotchbond. In the linear model throughout the composite polymerization process, the adhesion survived the contraction stress, which is explained by flow relaxation, which could occur sufficiently in this configuration. In the three-dimensional model, composites are attached to more than two dentin walls. In this situation flow is severely limited and contraction stress values can exceed the bond strength, leading to separation. This was seen in class V cavities. The shape of cavity is considered to be of great importance in conservation of composite – dentin bond.

UnoShigera and Asmussen Erik et al [1991][57] *investigated the effect of reduced rate of polymerization on the marginal adaptation of composite resin inserted in dentin cavities treated with simplified Gluma system. The effect on bonding strength to dentin and compressive strength was also investigated. The light intensity of the polymerization unit was lowered by the use of transformer and thus the polymerization of composite resin. When the resin was irradiated for 30 sec at 110v*

followed by 30sec at 220 v, the marginal adaptation was significantly improved and it also resulted in acceptable values of bonding strength to dentin and diametral compressive strength. So it was suggested that the reduced rate of polymerization may allow for increased flow of the material, decreasing the contraction stress in the restoration.

Rueggeberg FA and Caughman WF et al (1994)[48] investigated the effect of light intensity and exposure duration on cure resin composite. Thin wafers of composite were obtained from simulated cylindrical restorations such that the wafer could be removed from the top or from a distance of 1,2 & 3 beneath the surface. The composite used in this study were microfil and hybrid of universal and gray shade specimens, which were cured using various source intensities for different durations at each level within the cured specimen. A Quartz tungsten halogen lamp was used as the light source. The cure of the specimen resulting from the different treatments was determined using infrared- spectroscopy. The result showed that at depths greater than 2mm, poor cure results and polymerization is very susceptible to changes in light intensity and exposure duration. From this study it was recommended that routine exposure time of 60 sec having intensity of 400 mw/cm^2 could resulted in optimal cure. Incremental layer thickness should not exceed 2mm and 1mm being ideal. Sources and intensity 233 mw/cm^2 should not be used because of the poor cure characteristics.

Attin Thomas and Buchalla wolfgang et al (1996)[3] evaluated enamel bond strength of restorative materials containing both glass ionomer and

composite components. Three resin modified glass ionomer restorative materials,[Fuji II LC, Vitremer, Photac –Fil] three polyacid – modified composite,[VariGlassVLC, Dyract,Ionosit Fil], a hybrid composite[blend-a-lux] and a chemical cured glass ionomer cement[ChemFil Superior] were tested for enamel tensile bond strength with and without conditioning of the tooth surface. The tensile bond strength was tested with a universal-testing machine. The result showed that except for the enamel bond strength of chemfil superior all materials showed greater adhesion to conditioned tooth surface than to unconditioned specimens. Superior bond strength to enamel was obtained for polyacid- modified composites, which are attached with phosphoric acid etching technique and there by resemble the adhesion patterns of composites.

Cortes Olga and Gercia Carlos PerezLeonor et al (1998)[8] did a study to evaluate the marginal micro leakage of two compomers placed in enamel and cementum. The buccal and lingual surfaces of twenty human premolar teeth were used. Materials used were Dyract and Compoglass. Teeth were divided into 4 groups of 5 teeth each. Class V cavities were prepared with enamel and cementum margins. The groups were gp[1] Dyract, gp[2]etching and Dyract, gp[3] Compoglass, gp[4] etching and compoglass. All gps were light cured for 40 sec. 2 % fuchsin was used for microleakage study. Results showed that microleakage in enamel were significantly less than in cementum. No significant differences in micro leakage were seen between the two materials or between etched and unetched surfaces.

Ferrari Marco ,Vichi Alessandro et al (1998)[22] This in - vivo study was done to evaluate the marginal seal of two compomers in-vivo. Dyract with Dyract – PSA Primers, grp 1; Dyract with prime and bond grp 2; compoglass with SCA primer grp 3: compoglass with system single component grp4. The restoration was made in a standardized shaped cavity across the cementoenamel junction. The specimen were kept in a solution of 2% methylene blue for 24 hrs.The examination of the dye was made with a microscope at a maginification of x 20.These restoration systems did not completely prevent leakage either at the incisal or the cervical margins. Therefore the use of an enamel dentin bonding system in combination with proprietary compomer is recommended.

Hannig M, Bott .Bet al (1999)[28] did a study to measure the pulp chamber temperature increase during composite resin polymerization with various visible light curing units. Measurement of pulp temperature changes during polymerization was performed with K-type thermocouple positioned at the pulp-dentin junction. It was concluded that light polymerization with curing units characterized by high energy output causes significantly higher pulp chamber temperature changes as compared to the conventional curing light.

Lowell L.C, Newman S.M, and Bowman C.N (1999)[36] examined the effects of light intensity, temperature and composition on the polymerization behaviour of BisGMA/TEGDMA copolymerization. It was found that the maximum rate of polymerization was significantly affected by intensity of the light, and temperature of the polymerization affected the conversion at which

the maximum rate occurred. When the composition of the mixture was varied it was discovered that viscosity played a significant role in polymerization and reaction diffusion.

Manabe Atsufumi,Itoh Kazuo and Hisamitsu Hisashi et al (1999)[40] studied the role of the functional monomers in dentin bonding agents of an experimental dentin bonding system by measuring the wall – to – wall contraction gap and tensile bond strength measurement. The value of the contraction gap was significantly different between the commercial dentin bonding agents and these agents without functional monomers. It was concluded that the functional monomers were essential to obtain the marginal integrity of the resin composite in dentin cavities.

Sano.H ,T Yoshikawa T, P.N.R.Pereira et al (1999)[51] evaluated the long term durability of bonds between adhesive resin and dentin bonds which is of significant importance for the longevity of bonded restorations. They carried out an in-vivo study in a one year time in the oral cavity as well as to test the hypothesis at the adhesive interface would show morphological changes in vivo over time. Very shallow saucer-shaped dentin cavities were prepared in 12 intact teeth of one Japanese monkey. The cavities were restored with Clearfil Linear Bond II and Clearfil Photo Posterior resin composites. All restorations were retained in teeth during the testing period. No specimen broke during preparation and shaping for the micro tensile bond testing. The surfaces of failed bonds were observed under a field emission scanning electron microscope. Bond strength measurements in this study were successfully performed and were stable at 19Mpa during one year testing.

Long time bonds can be assessed in-vitro by the combined evaluation of the microtensile bond strength and SEM morphological examination of the adhesive interface.

Crisp R.J et al (2000)[10] in his study evaluated the in-services performance of compomer [F2000] restoration after 1 year, placed by 10 general practitioners as part of handling evaluation of this material. Eighty-two restorations were intact. No secondary caries was detected. All patients reported satisfaction with the restoration, both in appearance and surface texture and no symptoms were reported. The F2000 compomer restorations placed in conjunction with its bonding system were found to be performing satisfactorily.

Dennison B Joseph,Yaman Peter et al (2000)[15] investigated the effect of sequentially increasing light intensity on the polymerization shrinkage of 2 composites, a hybrid and micro fill. A Knoop hardness test was used to evaluate effectiveness of the cure with each intensity increase. Polymerization shrinkage was measured by using a linometer. Light intensity curing sequences were as follows: full intensity control (100 % intensity for 40 sec), low intensity control (25% intensity for 40 sec) for test group 1 (25% intensity for 20 sec, 50% intensity for 10 sec, 10% intensity for 10 sec) and test group 2 (25% intensity for 10 sec, 50% intensity for 10 sec, 100% for 20 sec). The results showed a significant difference in linear shrinkage between the full intensity control group and the other three consequences for both composites. So Curing composites for 10 sec at 25% intensity, 10 seconds at

50% and 20 sec at 100% significantly reduced polymerization shrinkage while not compromising depth of cure.

Luo Y and C.M.L Edward, Fang T S Daniel et al (2000)[38] evaluated the clinical performance of a new compomer restorative system, Dyract AP placed in combination with Non-Rinse conditioner and Prime and Bond NT in permanent posterior teeth [occlusal stress bearing areas]. Fifty class II and 41 class I restoration were placed in 39 patients by 1 dentist. The restorations were directly evaluated with modified US Public Health Service criteria and indirectly evaluated with color slides [clinical color slides taken for color match, marginal staining and surface porosity] and polyvinyl siloxane impressions at baseline and six months and 1 year placement. Preoperative and 1 year postoperative bitewing radiographs were also taken. No postoperative sensitivity or pulpal signs and symptoms were reported. The excellent handling characteristics, the good clinical performance and the improved wear resistance suggest that this compomer will provide reliable direct tooth colored restoration in stress bearing areas.

Tyas MJ (2000)[55] did a study to evaluate the retention of polyacid modified resin composite in cervical non-stress bearing areas.41 Dyract restorations were placed (36 in non carious cervical cavities and five in anterior approximal cavities and assessed for 3 yrs. The results showed that retention rate was 97 % for cervical restorations, however 16 restorations showed some degree of marginal discoloration. Color match and surface integrity were highly satisfactory throughout the trial. Dyract AP has now

superseded Dyract and manufactures should consider recommending mandatory enamel etching.

Yap AUJ (2000)[61], in his study was to see the impact of cavity depth and light source exposure time upon the effectiveness of polymerization of two bulk placement composite restorations ,assessed indirectly using hardness testing. The composite material used was Ariston pHc and Surefil of shade A2.The composite was placed in plastic molds with cylindrical cavities 2-4 mm deep and 5 mm in diameter. They were cured for 40 sec using intensity of 421.33 mw/cm^2. Knoops hardness number of the top and bottom surface were taken. The specimens were irradiated for 20 sec increments upto 120 sec from the top surface through the glass slide. The results showed that the effectiveness of polymerization decreased significantly with increased cavity depth regardless of exposure time. Increased exposure time increased the extent of polymerization at cavity depths of 3-4 mm. To conclude that increments of composite should be no greater than 2 mm to provide uniform and maximum polymerization.

Agostini F.G., Kaden Crhistoph et al (2001)[2] did an invitro study to evaluate the tensile bond strength of three self-etching primers to human primary enamel and dentin. Forty extracted primary molars were sectioned bucco-lingually and embedded in self-curing acrylic resin with the facial or lingual surface exposed. The materials tested were, Prompt L –Pop, Clearfil SE bond, Etch and Prime 3.0 and a control Prime and Bond NT. The adhesive systems were applied according to manufactuers instructions. The specimens were debonded in tension using a universal testing machine (instron) at a

crosshead speed of 0.5 mm/min. The result show that the four adhesive systems tested, bonded effectively to enamel of primary teeth, but only clearfil-SE bond achieved adequate bond strengths to dentin.

Hasegawa T and Yukitani W et al [2001][29] evaluated the marginal adaptation of 4 resin composite Clear APX, Estelite, Silux Plus and Z-100 cured with two irradiation methods ,soft start and high power start of a commercial soft start halogen lamps unit [Elipar Highlight] by measuring the wall to wall contraction gap width. 160 cylindrical cavities, 3mm in diameter and 1.5 mm in depth were prepared in extracted human molars. The 80 cavities were treated with megabond system and each 10 fillings were irradiated by the soft start method i.e. soft power light for 10 sec followed by high power light for 30 sec or high power light for 40sec. The other cavity walls were treating with an experiment bonding system consisting of 0.5m EDTA as a conditioner, 35% glycerl mono-methacrylate as a primer and clearfil Photobond as a bonding agent. The cavities were restored with the 4 resin composites and two irradiation methods, the same as the megabond group. The contraction gap was measured with a light microscope and expressed in % of the cavity diameter. The curing capability of the two light sources was evaluated by measurement of the curing depth of 4 resin composite using a spilt Teflon mold 4mm in inner diameter and 8mm in height. The result showed that marginal gap formation of clearfil APX, Estelite and Silux Plus with experiment bonding system was completely prevailed regardless of the kind of irradiation methods used. The deterioration

of marginal adaptation caused by megabond system could not be improved by the use of soft start method.

Hasegawa T, Itoh K, Yukitami W et al (2001)[28] evaluated the marginal adaptation of four resin composites(Clearfil APX, Estelite, Silux Plus and Z-100) cured with two Xenon lamp units (plasma are curing system/Apollo 95E) or a halogen lamp unit by measuring the wall to wall contraction gap width. A cylindrical dentin cavity (3mm diameter x 1.5) were prepared on extracted molar teeth treated with Megabond system or experimental bonding system consisting of 0.5 M EDTA, 35 % GM and Clearfil Photo Bond prior to composite filling and was irradiated for 3 sec (Xenon lamp) or 40 sec (halogen lamp) The contraction gap was measured with a light microscope. The curing capabilities of the three light sources used was evaluated by measuring the curing depth of composite filled in a split teflon mold (4mm x 8mm). There was no marginal gap formation for Clearfil APX, Estelite and Silux Plus treated with experimental bonding system regardless of the type of light sources. The curing depth of Xenon lamp was significantly higher than the halogen lamp while marginal adaptation did not suffer any deterioration.

Kurachi Christina, Aparecida M et al (2001)[34] did a study to evaluate the hardness ratio of a composite resin cured by five LED (Light Emitting Diodes) based devices and a comparison with a conventional curing unit. The composite resin (Z100, shade A3) was cured for 20,40,60120,180 sec with LED based devices and 40 sec with the halogen lamp. The composite samples were prepared with 0.35, 1.25 and 1.8 mm of thickness. Five samples of each set of parameters were done. The microhardness of the samples were

measured with mhp 160 microhardness tester with the marker for Vickers units.Three readings were taken at random position around the center of non-illuminated area. The indentation was made with a 50 g load for 30 sec. All the samples cured by LED based devices showed inferior hardness values when compared with halogen lamp at the typical curing time of 40 sec.

Lovell G.Lale and Lu Hui (2001)[37] This study investigates the effect of cure rate on the mechanical properties of common dimethcrylate dental resin formulation. The monomer mixture used in this investigation consisted of (bis-GMA), (TEGDMA).Initiators used in this study – UV light and visible light initiating system. Study shows that high cross- linkage dimethacrylate system, such as bis – GMA/TEGDMA exhibit similar network structure and properties, as a function of double bond conversion regardless of the method of rate cure.

Okada K, Tosaki et al (2001)[42] investigated the effect of saliva used as a storage liquid and length of storage effect on surface hardness of Fuji IX, Dyract, and Z100 and Estio LC. The materials were mixed and immersed in distilled water or human parotid saliva at 37°C .The materials were placed in acrylic molds having an internal diameter of 6mm and height of 1mm.Vickers hardness numbers was measured 1,7,20 and 40 days after the material were mixed. VHN was calculated from the indentation diameter after 100 or 300 g loading on either surface for 15 sec. Electron Probe microanalysis was used for depth profile analysis. The study concluded that only in Fuji IX did Vickers hardness number increase with time at storage conditions, distilled water and saliva. The results suggest that neither composite resin nor the poly

acid modified composite resin reacted with Ca 2^{+} and PO4 ions from saliva as did GIC.

Sharkey Seamus , Ray Noel et al (2001)[52] studied the micro hardness values of upper and lower surface of 3 commercially available resin composites – Herculite RV, Glacier Enamel, Silux Plus which were cured using both the traditional halogen source and a plasma arc lamp. 2O samples of each composite were cured using halogen lamp protocol and 10 samples each were cured with plasma lamp protocol. Surface hardness measurements were carried out using a calibrated Vickers indenter on both the top and bottom surface after 7 days of storage in air at 20^{o} C. The results showed that the plasma lamp yielded lower hardness values for all surface compared with halogen sources, so the possibility of reduced surface microhardness values may reflect a reduced % conversion of monomers to polymers.

Yoshikawa Takako and Burrow F Michael et al (2001)[67] evaluated the method of light curing that could influence the [a] marginal sealing and resin composite adaptation to the cavity wall (b) polymerization contraction rate (c) hardness at the top and bottom surface of a body of resin composite. Cylindrical cavities 1mm deep and 3mm in diameter were prepared on flat superficial dentin surface and teeth were bonded with one of two adhesive systems [Clearfil Photo Bond and SuperBond D liner and cavities filled with hybrid resin composites. The resin composites were cured using three intensities of 600, 270 and 20mw/cm^2 and various curing times. For evaluating the hardness the specimen made of Teflon molds having the same dimensions on that of prepared cavity, KH measurement were taken at the top

and bottom surface of resin specimens. It was concluded that that when composite was light cured with initial light intensity of (270mw/cm^2) for 10 sec followed by high intensity light (600 mw/cm^2) for 50 sec provides the best adaptation of resin composite to cavity walls and possibly the least polymerization contraction stress.

Yap AUJ and Seneviratne C et al (2001)[62] investigated the influence of light energy of composite cure in view of the curing profiles of new – light polymerization units. This investigation used digital microhardness tester to evaluate the hardness of the top/bottom surface and hardness ratio of 2mm thick composite after exposure to different light energy densities. The composites were placed in black Derlin molds with square cavities 2 mm deep and 4 mm wide confined between two opposing acetate strips to ensure smooth surface and to minimize inhibition of polymerization by oxygen (Finger and Dreyer Jorgensen 1976) The parameters included five light intensities [200,300,400,500 and 600 mw/cm^2] and nine irradiation time [10,20,30,40,60,80,100,120 and 180 sec] Knoop hardness and the hardness ration obtained with 40 sec and 400mw/cm^2 was used as control. Effective cure was not achieved with low intensities (200 to 300 mw/cm^2) but could be achieved with high intensities (500 and 600 mw/cm^2) after 30 sec of irradiation. Optimal cure at the bottom surfaces was possible with 30 and 20 sec irradiation at 500 and 600 mw/cm^2 respectively.

Demirci M and Erser H et al (2002)[14] This invivo study, which evaluated the three-year clinical performance of a Polyacid, modified resin composite material, Dyract in class III cavities. Sixty- two class III cavities in

30 patients were restored with Dyract used along with Primer Adhesives and intensity of 450mw/cm^2. The restoration depth were made more than 2mm then applied using incremental technique. After application of first layer cured for 40 sec then second layer and again cured for 40 sec. Restoration were clinically evaluated at baseline, one, two three years recalls according to modified Ryge criteria. It was concluded that after 3 years the retention rate was 96.7%. At the end of three years marginal discoloration was statistically significant but did not require replacement of any of the restoration. Dyract exhibited significant marginal discoloration after three-year clinical performance in class III cavities.

Fan P.L and Schumacher M R Yan et al (2002)[20] investigated the depth of Cure of several shades of five commercially available resin based composites irradiated via light with an intensity of 300mw/cm^2 with irradiation time of 20, 30 & 40. The materials [composite] were designated as A.B.C.D&E. A total of five samples for each shade were taken. The depth of cure for each sample were determined using the method described in the 2000 ISO standard for polymer- based filling restorative materials. The scraping method was used i.e. at the end of the irradiation period the composite sample were removed from the mold [steel molds 6mm high & 4mm in diameter] and the uncured material at the bottom of the sample were removed by scraping it away with a plastic spatula. Using a micrometer, the length of the remaining used specimens were measured to the nearest of 0.01mm.The result showed that thirteen [62%] of 21 composite material met the ISO standard depth of cure requirement of 1.5 millimeter. Six of the eight remaining materials met

the depth – of – cure requirements, when the authors doubled the irradiation times recommended by the product manufactures.

Hackman ST, Pohjola RM , Rueggeberg FA (2002)[26] investigated the extend of cure [monomer conversion into polymer) of a variety of photo-initiated resin composite and different shades. The composite resins used in this study are Herculite VRV, Pyramid and Z100. Cure values were measured at the top surface and at simulated lighting conditions 0.5,1.0and 2.0 mm below the top. The curing source used in this study was quartz-tungsten halogen unit [VIP]. The exposure methods used were continuous output at 600mw/cm^2 [10,20,or 40 sec], initial component the pulse technique pulse [3 sec at 200mw/cm^2] and the entire pulse delay technique [pulse, 3min delay, 10 sec at 600mw/cm^2] Results showed that conversion values using the pulse delay technique and a 20sec continuous exposure were significantly lower than those obtained using continuous 40 sec exposure.

Luo Y, Lo ECM, Wei SHY (2002)[39] investigated the effect of two factors, conditioning methods and light cure techniques on the marginal adaptation of Dyract AP. 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 different protocols. Cylindrical cavities 3mm in diameter were prepared in 60 extracted human molar teeth. They were restored with Dyract AP using Prime & Bond NT.Cavities were etched with conditioner 36 [GrpI], Non-Rinse Conditioner [GrpII] and [PBNT] only [Grp III]. The results showed that with conventional curing technique, enamel fracture margin were frequently observed. Marginal

gaps were found along the compomer – dentin interface irrespective of the conditioning protocol. A significantly lower % of gap containing margin were found in cavities that were found conditioned with 36 % phosphoric acid. With the pulse activation technique no marginal gap was found along the compomer dentin interface that were etched with either conditioner 36 or NRC. The use of Prime &Bond without etching is not recommended as marginal gaps are present irrespective of the curing techniques.

Obici AC and Sinhoreti MAC et al (2002)[41] measured the gap that resulted from polymerization shrinkage of seven restorative resin composites after curing by three different methods. The composite was placed in a circular brass model 7mm in diameter and 2mm in height. Photoactivation was performed by a) continuous light (500mw/cm^2) for 40sec b) stepped light with low intensity [150mw/cm^2] for 10sec and high intensity [500mw/cm^2] for 30 sec; c) intermittent light (450mw/cm^2) for 60 sec. The top and bottom surfaces were polished and contraction gap was measured by SEM. The results showed continuous light method presented the greatest gap values, while the other methods demonstrated lower polymerization shrinkage values. The stepped light and intermittent light techniques showed an effective reduction in polymerization shrinkage.

Park SH, Krejci I, Lutz F et al (2002)[44] evaluated the effectiveness of the plasma arc curing [PAC] for composite curing unit. To compare its effectiveness with conventional quartz tungsten halogen [QTH] light curing units, the microhardness of two composites [Z100 and Tetric Ceram] that had been light cured by the PAC or QTH units were compared according to the

depth from the composite surface. Two resin composites were used to measure microhardness. Two mm thick samples were light cured for three sec [Group I], six sec [Group II], or 12 sec [Group3] with conventionally light cured with optilux 500 for 30sec[Group4] or 60 secs [Group5]. The microhardness of the upper and lower surface were measured with a Vickers hardness-measuring instruments under load. Results of microhardness indicated that there was no statically significant difference in microhardness between groups for the upper surface. However the lower surface when composite were light used with Apollo 95 E for 3sec the microhardness was usually lower than that of the upper surface and did not cure sufficiently. It was concluded that when compared with conventional QTH unit, the PAC unit did not properly cure the lower composite surface when the layer thickness exceeds 2mm.

Yap AUJ, Soh MS, Siow KS et al (2002)[63] investigated the effectiveness of composite cure with pulse activation and soft start polymerization. The six light cure modes examined were:

Control (c)-400 mw/cm^2 (40sec), Pulse delay 1 PDI –100 mw/cm^2 (3 Sec)- DELAY [3 mins]-500 mw/cm^2 [30 SEC], Pulse Delay II [PDII]-200mw/cm^2 [20 sec] ----delay [3 mins] ---500mw/cm^2 [30 sec], Soft Start [SS]- 200mw/cm^2 [10 sec]-----600mw/cm^2 [30 sec], Pulse Cure1 [PCI] ----400 mw/cm2 [10 sec] ----delay [10secs] ---- 400mw/cm^2 [10sec] -----delay [10sec] --400mw/cm^2 [20sec]; and Pulse cure II [PCII]—400mw/cm^2 [20sec] --- delay [20sec] --- 400 mw/cm^2 [20sec]. Effectiveness of cure was determined by measuring the top and bottom surface hardness of 2mm thick

composite [Z100] specimens using a digital microhardness tester. The effectiveness of cure of the bottom surface of the composite was measured by Fourier Transform Infrared [FTIR] spectroscopy. No significant differences in top Knoops hardness was observed except for PDI and PD11. At the bottom surface Knoop Hardness obtained with the control was significantly greater than with PDII, SS and PCII. FTIR RESULTS ranked well with the hardness of the bottom surface.

Yap AUJ, Soh MS et al (2002)[64] evaluated the influence of pulse activation and soft start polymerization regimens on the post-gel shrinkage of a visible light activated composite resin [Z100]. The six light cure modes examined were:

Control (c)-400 mw/cm^2 (40sec), Pulse delay 1 PDI –100 mw/cm^2 (3 Sec)-DELAY [3 mins] -500 mw/cm^2 [30 SEC], Pulse Delay II [PDII]-200mw/cm^2 [20 sec] ----delay [3 mins] ---500mw/cm^2 [30 sec], Soft Start [SS]-200mw/cm^2 [10 sec]-----600mw/cm^2 [30 sec], Pulse Cure1 [PCI] -- - 400 mw/cm^2 [10 sec] ----delay [10secs] ---- 400mw/cm^2 [10sec] ---- delay [10sec] -- 400mw/cm^2 [20sec]; and Pulse secure II [PCII]—400mw/cm^2 [20sec] ---delay [20sec]--- 400 mw/cm^2 [20sec]. Post gel shrinkage associated with PDI was significantly lower than with PDII. At one-minute post light polymerization PDI had significantly lower shrinkage compared to PDII and SS. Significant differences in shrinkage were observed between PDI and SS only at 10,30 and 60 minutes. At all times no significance in post-gel shrinkage was observed between the control and all pulse activation/soft-start polymerization regimens.

Uno Shigeru, Tanaka Toru and Natsuizaka Asuka et al (2003)[57],evaluated the the effect of a new intensity – changeable light source Curetron 7(CT-7) devised for slow curing on cavity wall adaptation in the adhesive composite restoration as well as the microhardness of cured composite. Microhardness of both top and bottom surface was measured by an indentation method for 2mm thick cylindrical cavities. The result proved the efficacy of the slow curing method combined with the interval between two irradiation with low intensity and high intensity.

Calheiros, C Fernando, Brag R Roberto et al (2004)[35] verified the relationship between contraction stress and degree of conversion in different compositions of composites. [Filtek Z250, FiltekA110, Tetric Ceram And Heliomolar]For the contraction stress test composite (2mm thick) was applied between two 5mm-diameter glass rods. Mounted in a tensilometer. Degree of conversion was determined by infrared photoacoustic spectroscopy, with different energy densities. At higher energy levels, degree of conversion had a tendency to level off earlier than contraction stress values. Using high energy densities may cause a significant increase in stress values, without producing a significant increase in conversion.

Koupis S Nikolaos and Vercruysse J W Chris, Marks AM Luc et al (2004)[33] compared the curing depth of polyacid modified composite resins (PAM-C) and composite resins as a function of shade and post cure using a scraping method and a penetrometer. The curing depth of the PAM-C Hytac, F2000, Glasiosite, Dyract, DyractAP, and compoglass and of the composite resin Durafill VS and Z100 were determined for shade A2 and A4. Samples

were light cured in bulk in split stainless steel molds 10 mm ht and 4mm diameter at 800mw/cm^2 at 40 secs. It was concluded that the scraping and penetrometer method are equally well suited for the evaluation of curing depth of PAM-C, though small differences but significant difference can be found depending on the material and shade. Compared to microfill composite [Durafill] some PAM-C [f2000, Glassiosite] cured to a greater depth like hybrid and Hytac had a curing depth smaller than that of microfilled composite resin. Also shade A2 results in significantly greater values for the curing depth compared to shade A4 i.e. lighter shades cured to greater depth than darker shades.

Chye CH, Yap AUJ, Laim YC et al (2005)[7] compared the post gel polymerization shrinkage associated with five different- light curing regimens of similar light energy density. The five regimen investigated were pulse delay (PD), soft start (SS), pulse cure (PC), turbo cure [TC] and standard continuous cure[C]. Pulse delay or pulse activation 100mw/cm2 for 10 sec

Delay 3min 500mw/cm2 for 30 sec

1. Soft start [ss] 200mw/cm^2 for 20 sec → 600mw/cm^2 [20 sec]

2. Pulse cure [PC] 400mw/cm^2 for 20sec → Delay 20 sec 400mw/cm^2 [20 sec]

Turbo cure 600mw/cm^2 for 27 sec and Standard continuous cure 400mw/cm^2 for 40 sec.

With exception of TC, the light energy density for all curing regimens was at 16 J/cm^2.A strain-monitoring device and test configuration were used to measure the linear polymerization shrinkage of 2mm thick composite specimens [Z100, 3M ESPE] during and post-light polymerization up to 60 minutes. No significant differences in shrinkage was observed between PC, TC

and C at all time intervals. The use of pulse delay and soft start regimes resulted in significantly lower post-gel polymerization compared to continuous, pulse and turbo cure.

Okte Z ,Villalta P et al (2005)[43] compared the Vickers hardness of the top and bottom surface of two compomers (Compoglass F and Dyract AP) polymerized for 20 and 40 seconds with two different light curing systems. Five samples for each group were prepared using Teflon molds (95 2 mm) and were light cured with a conventional lamp (Optilux 501) or LED light .VHN were obtained from the top and bottom surface of each sample. The results showed that there was no significant difference in the microhardness of both surfaces of compoglass F and Dyract AP cured for either 20 or 40 seconds using LED. With Optilux 501 the microhardness of samples cured for 40 seconds was significantly higher than 20 seconds.

Materials & Methods

This study was done in the Department of Pedodontics and Preventive Dentistry, Ragas Dental and Hospital, Chennai and in collaboration with Central Leather Research Institute and Nuclear Physics Department (Anna University) Chennai, India

MATERIALS USED

- **COMPOMER (DYRACT AP B2 SHADE)**

  UDMA resin

  TCB resin

  Strontium flouorosilicate glass

  Strontium fluoride

  Photoinitiators

  Stabilisers

- **PRIME AND BOND NT** (Bonding agent)

  Di- and trimethacrylate resin

  Amorphous silica

  PENTA

  Photoinitiators

  Stabilisers

  Cetylamine hydrofluoride

  Acetone

- ETCHANT (36% phosphoric acid)
- *EXTRACTED PREMOLARS*
- GLASS SLIDE
- **SAINLESS STEEL MOLD OF**

  2 × 6 mm

  3 × 6 mm

  4 × 6 mm

- Quartz tungsten halogen based conventional light curing unit (SATELEC ACTA)
- Quartz tungsten halogen based conventional light curing unit with variable intensities (300 mw/cm² - 800 mw/cm²) (SPECTRUM 800 DENTSPLY)
- Glass slab
- Plastic instrument
- Radiometer (CURE RITE, DENTSPLY)
- Scanning electron microscope
- Microhardness tester (Reitchert MD 4000 E ultra microhardness tester)

METHODOLOGY

Marginal adaptation

30 extracted caries free premolars are used for the study. All teeth are carefully cleaned to remove plaque and calculus. Teeth are randomly divided into 2 subgroups with 15 specimens in each group

Class V cavities 2mm deep and 3 mm in diameter is prepared on the buccal surface of extracted teeth using burs and copious water irrigation. Cavity depths are standardized by using a small piece of stainless steel wire inserted into the cavity, which has markings on it.

The cavities are first etched with 36% phosphoric acid (conditioner 36,Dentsply DE Trey) for 20sec .The cavity is left moist after rinsing and then dried and a layer of Prime and Bond NT is applied to the etched enamel and dentin and cured for 20 seconds.

The restorative material is placed in bulk according to the manufacturers instructions

Two light cure units are used

1) Quartz tungsten halogen based conventional light curing unit **(SATELEC ACTA)**

2) Quartz tungsten halogen based conventional light curing unit with variable intensities (300 mw/cm² - 800 mw/cm²) **(SPECTRUM 800 DENTSPLY)**

Group I specimens are cured with SATELEC ACTA

Group II specimens are cured with SPECTRUM 800

For group I the conventional polymerization technique is used

The restoration is polymerized using constant light intensity of 400 mw/cm² for 40 sec

For group II the pulse activation polymerization technique is used.

The restoration is initially light cured for 4 sec at 100 mw/cm² .It is then allowed to relax for 3 minutes followed by a final light cure phase at 400 mw/cm² for 36 seconds.

The intensities of the power output (i.e. 100 and 400 mw/cm²) are measured with light meter that is incorporated in the halogen light-curing unit. These are checked prior to use during the period in which 30 teeth are restored.

After the final curing phase finishing of the restored specimen are performed using sof-lex polishing disks 3M, Dental product).

Then all the specimens are aged in distilled water at 37°C for 24 hrs. Unlike resin composite there is evidence that hygroscopic expansion of

compomer material is significantly greater than that of conventional composites. This may result in closing of the marginal gap during the aging period.[31]

A 1mm thick section was prepared with a slow speed diamond disc under water cooling along the longitudinal axis of the tooth passing through the center of the restoration. After sectioning the section was then again polished so that no visible scratches could be seen under the microscope.

The sections were then loaded on stubs and the compomer – dentine interface were viewed and were recorded as gap free or gap containing for all specimens. Through image analyzing system the maximum width of gap were measured in terms of millimeters.

DEPTH OF CURE

For evaluating the depth of cure the methodology is as follows

STAINLESS STEEL MOLD

42 stainless steel ring molds with dimensions of 2mm, 3mm and 4 mm height and 6 mm diameter (14 numbers with each dimension) were prepared from non-magnetic stainless steel rod.

PREPARATION OF THE SAMPLE

42 specimens were prepared and were divided into 2 groups with 21 specimen in each group. Each group was subdivided into 3 categories with 7 specimen in each category. Category ‘a’ represents samples of 2 mm height, category ‘b’ represents samples of 3 mm height, and category ‘c’ represents samples of 4 mm height.

The compomer used in this study was DYRACT AP, B2 shade. To prepare each specimen the stainless steel mold was placed on a clear glass slab and the compomer was placed in the mold in a single increment. Glass slide was placed on the mold and excess material was extruded out by applying pressure.

The extruded material was removed with a plastic instrument and the glass slide was placed in such a way that the exposed surface of the compomer was flat and parallel to the surface of the mold. The top surface of the specimen was exposed to the light source.

All the 21 specimens in group I (a, b, c) were light cured with Satelec ACTA Quartz tungsten halogen based light curing unit with light intensity of 400 mw/cm² for 40 sec. Curing was done on one surface and the cured surface was marked as top surface.

The group II specimens were light cured by pulse cure technique with spectrum 800 (DENTSPLY) a halogen based light curing unit. In the pulse cure technique the initial pulse of 4 sec with light intensity of 100 mw/cm²

and a waiting period of 3 minutes and a final cure of 400 mw/cm²for 36 sec was done to cure the specimens

Prior to light curing the intensity of the light source was checked before start of each session with a radiometer and, the light curing tip was placed as close to the specimen while the curing was done. After curing all the specimens were stored in the dark for 24 hours and the hardness measurements were carried out with a microhardness tester for Vickers Hardness Number

Vickers hardness readings were undertaken using loads 50, 80 and 110 g. Three indentations were made at random on each specimen and the mean hardness ratio was calculated.

ANOVA, Scheffe and T- test were used to evaluate the statistical significance of the results at 0.05 significance level.

CONSTRUCTION AND FUNCTIONS OF THE MICROHARDNESS TESTER

1. OPTICAL VIEWING SYSTEM

The microscope has a wide and bright field of view and provides images

2. OBJECTIVE LENS

The measuring objectives are available in 4 types - x 10, x 20, x100 and x 150. A x 10 lens is used for observation exclusively, other lenses available are x 8, x 12.5 and x 20.Combining the eyepiece (x 10) with these objectives provides a magnification range from x 80 – x 3000.The images are sharp in any magnification

3. INDENTER

A Vickers indenter tip is ideally finished and the indenter is held at the right angle to the specimen surface

4. DISPLAY

The microscopic image is captured through the Aver media EZ Capture card that is then displayed on the television

5. KEYBOARD

All the instructions for the entire operation are given via these touchpad keys

6.INDENTATION MEASURING UNIT (OPTICAL HEAD)

A clear-cut image of the indentation is seen in a bright and large field to view. The diagonal length of an indentation is measured by individually setting two contrast lines to it

7. LOAD SELECTION, LOADING AND UNLOADING IN AUTOMATED SEQUENCE

After testing parameters such as testing load and the load duration time, are entered via the keyboard, the test is carried out in automated sequence. Exceptionally high efficiency is obtained when the specimens are measured under the same set of testing conditions

8. REVOLVER

The revolver has the standard indenter and two objective lenses, which are always positioned, at the right place.

9. STAGE

The stage can be finely shifted both in the X and Y directions over a range of 25 mm. The minimum division of the micrometer is 0.01 mm.

10. FOCUSING KNOB

A single knob is used for coarse focusing and for fine focusing. Its movement is very smooth

The specimens cured under conventional light cure unit group I (a,b,c) was mounted on the stage of the microhardness tester. Three indentations were made randomly on the top surface and three indentation were made on the bottom surface with a load of 50, 80 and 110 gms for 2 seconds and were visualized in the monitor with the help of EZ Capture card for the depth of cure and recorded. All the 21 specimens of group I were tested by the above mentioned manner. The specimens cured under pulse cure technique (group II) were mounted on the stage of the microhardness tester. Three indentations made at the top surface and bottom surface were visualized in the monitor. All the 42 specimens were tested and the data was calculated as Vickers hardness number (VHN)

$VHN = C \times P / d^2$

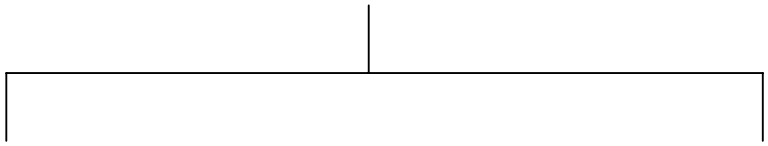
P - applied load in kgs

d - length of diagonal

C - constant for each indenter based on angle (c) = 1.8544

COMPOMER SPECIMEN

Total Sample Size – 42



Group 1 (conventional)

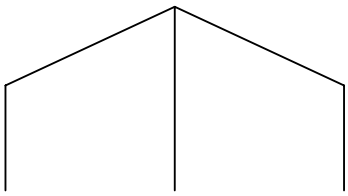
Group II (pulse activation)

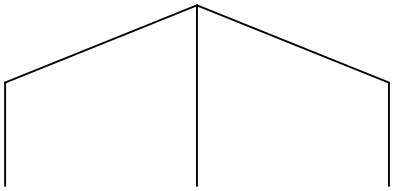
Sample Size 21

Sample Size 21

SATELEC – ACTA
400 mw/cm^2, 40 s

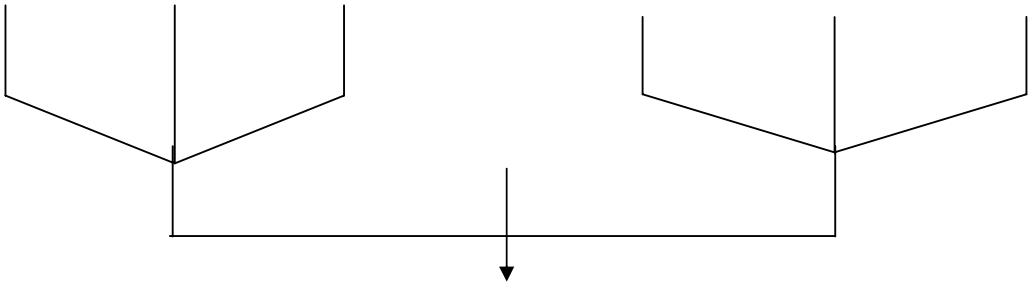
SPECTRUM 800
INITIAL CURE : 100mw/cm^2, 4s
FINAL CURE : 400 mw/cm^2, 36s





(a) 2m (b) 3mm (c) 4mm

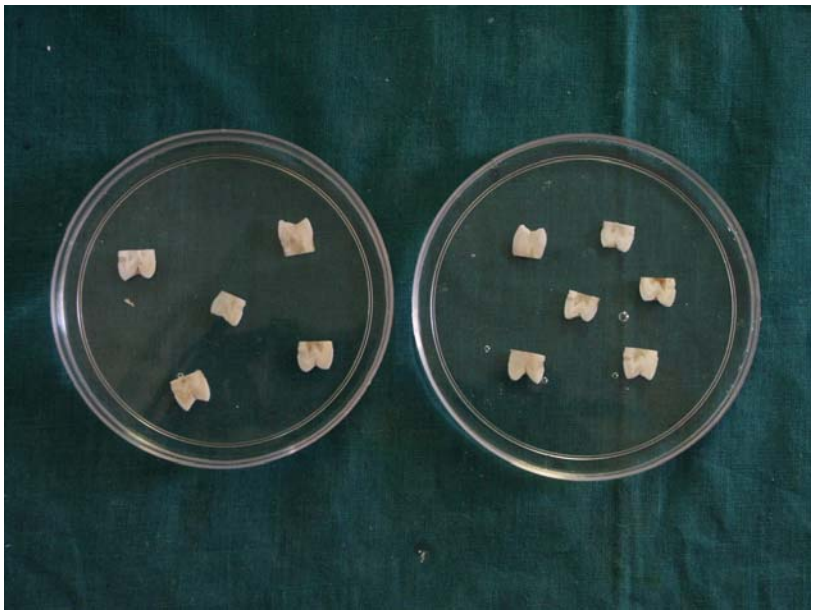
(a) 2mm (b) 3mm (c) 4mm



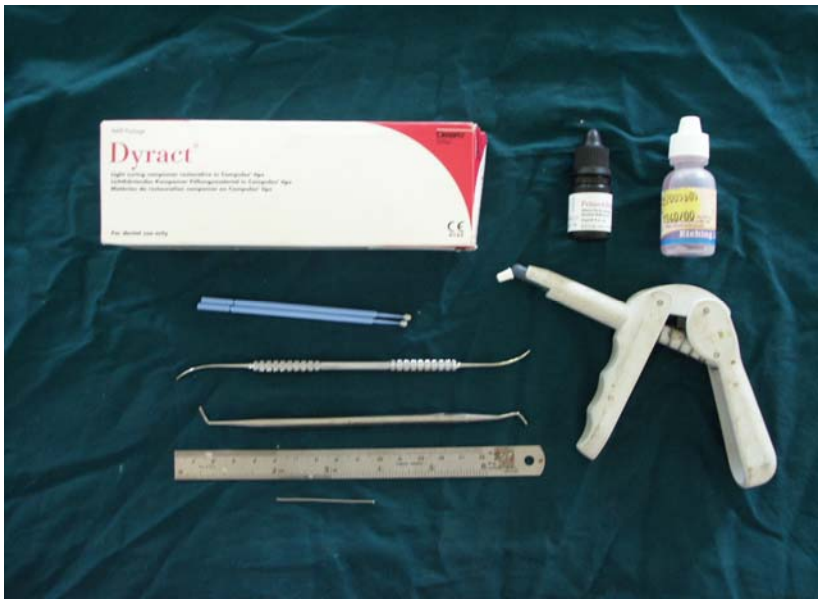
MICRO HARDNESS TESTER

(Fig.1) Satelec Light Cure Unit

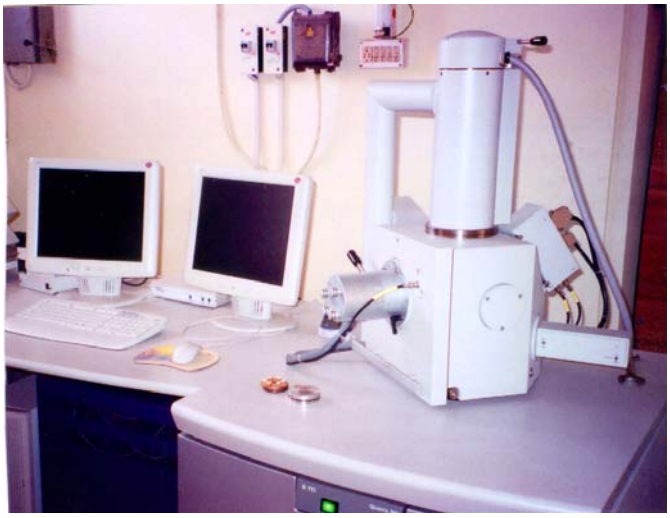
(Fig.2) Spectrum – 800 (Dentsply)



(Fig.3) Specimen for SEM study



(Fig. 4) Materials and Instruments



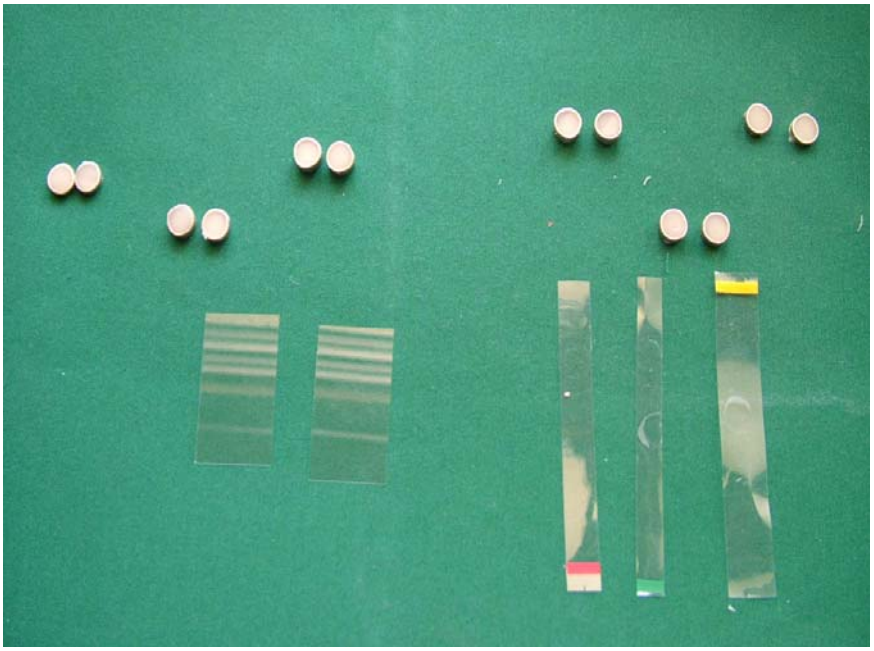
(Fig. 5) Scanning Electron Microscope

A

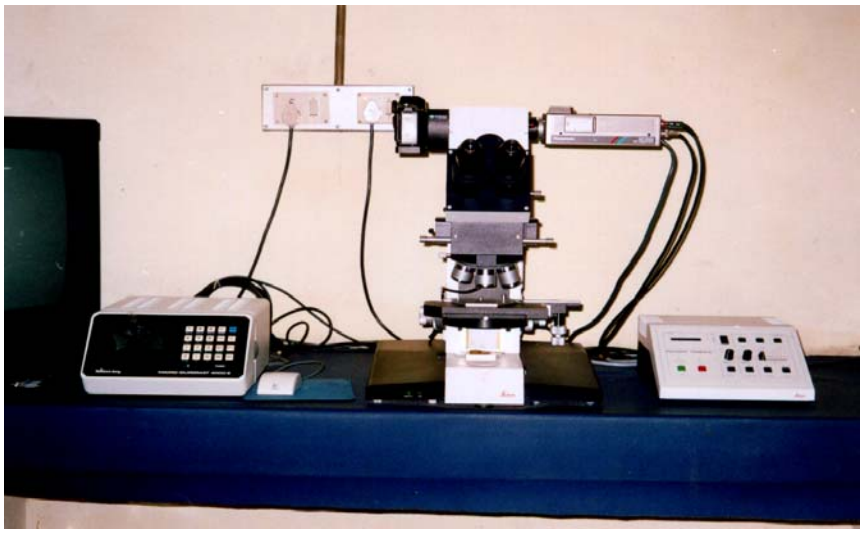
B

C

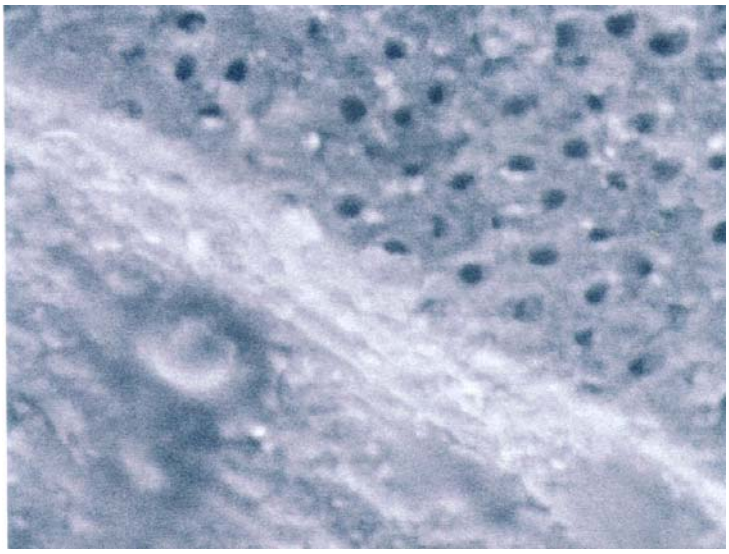
(Fig. 6) Stainless steel molds



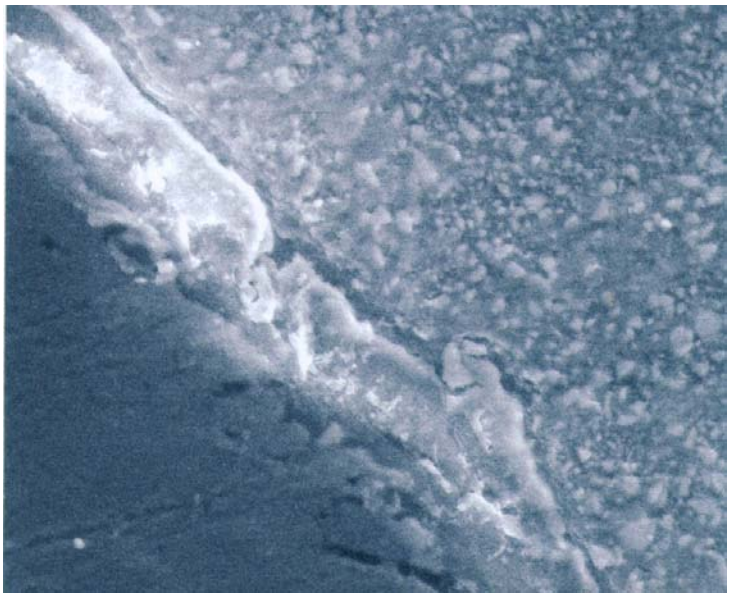
(Fig.7) The prepared compomer specimen



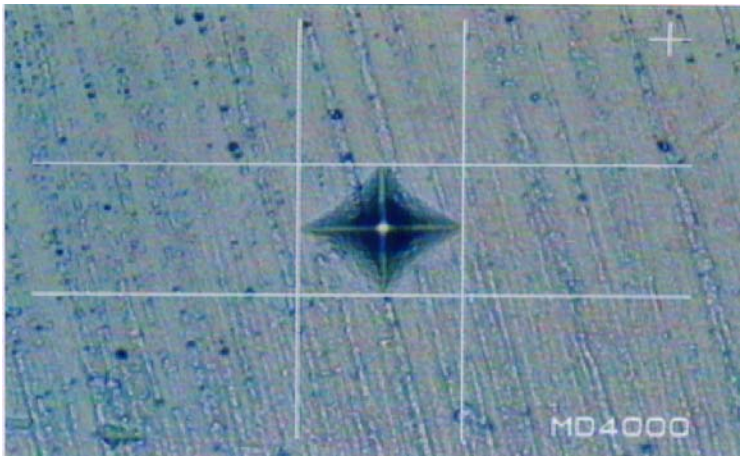
(Fig. 8) Photomicroscope with Hardness Tester



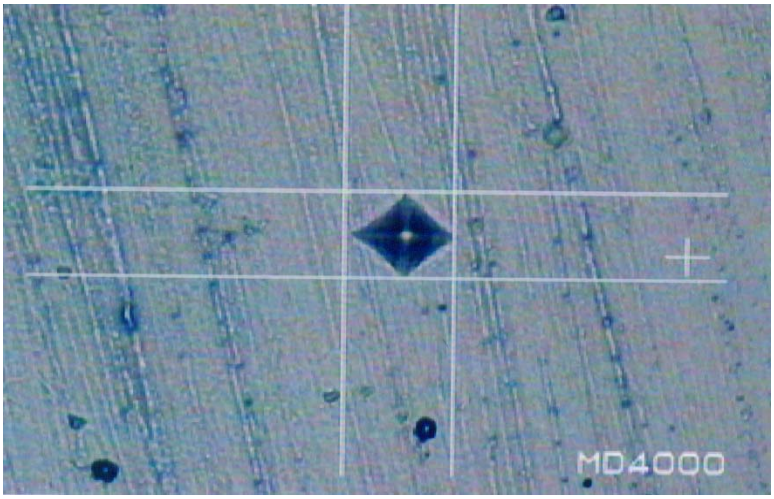
(Fig 9) showing perfect adaptation without any gap for sample cured with pulse activation system



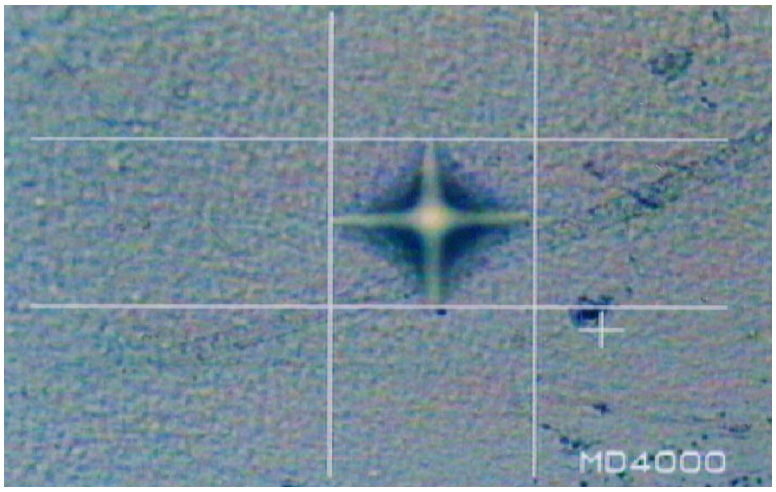
(Fig. 10) showing gap formation for sample cured with conventional system



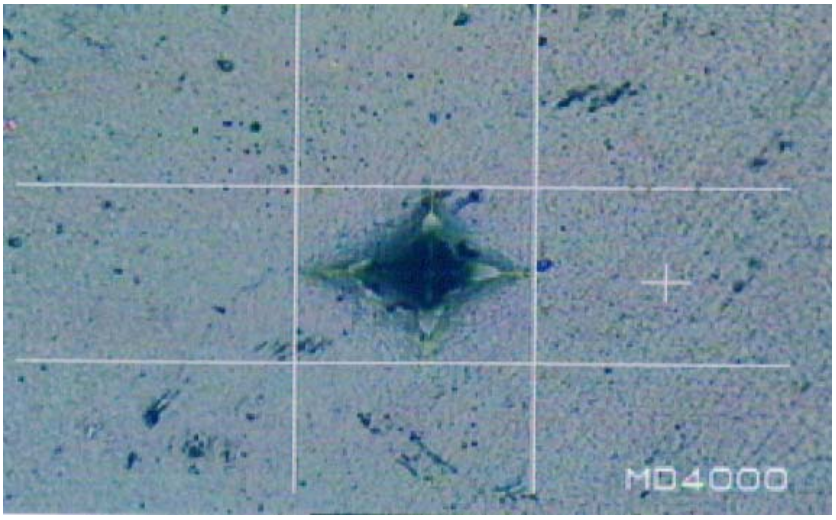
(Fig 11) showing indentation at 50 load at 2mm height of conventional cured sample



(Fig 12) showing indentation at 50 load at 2mm height of pulse activated sample



(Fig. 13) Pulse activated sample showing indentation at 110 load 2mm height



(Fig. 14) Conventional cured sample showing indentation at 110 load 2mm height

Results

The present study was carried out to evaluate the marginal adaptation of compomer and also the depth of cure of compomers using two different curing protocols- conventional (group I) and pulse activation system (group II)

I. For evaluating the influence of light activation system (conventional and pulse activation) on the marginal adaptation of compomers

Here group I used conventional system i.e. using constant light intensity of 400mw/cm^2 for 40 sec

Group II used pulse activation system i.e. using initial low intensity of 100 mw/cm^2 for 4 sec followed by final cure at 400 mw/cm^2 for 36 sec.

Comparison was made between the groups (I and II) with heights 2mm, 3mm and 4mm.

Observations from Table 1

Table 1 describes the marginal adaptation of the two cured systems.

In group I (15 specimens) which was cured with conventional system 8 had gap free margins (53.3%) and 7 were found with gap (46.6%).

In group II (15 specimens) which was cured with pulse activation system 11 had gap free margins (73.3%) and 4 specimens were found with gap (26.6%)

Chi-square test- Two-tailed Fischer Exact Test was used to evaluate the statistical significance and no statistical significant difference was seen between the two groups ($p= 0.265$)

Observations from Table 2

Table 2 describes the mean gap width of 30 teeth cured with the two groups (I and II)

Mean value for group I is 3.333 and for group II is 0.08067.

Mann-Whitney –U Test was used to calculate the statistical significance, which showed that there was only borderline significance ($p= 0.08$) between the two groups.

II. For evaluating the depth of cure

In this study to find the depth of cure of compomers cured with two curing protocols (group I and II) 42 stainless steel mold were taken with different heights 2mm, 3mm and 4 mm (a, b and c). So group I was divided into group Ia Ib and Ic containing 7 specimens each and group II divided into group IIa, II b and II c with 7 specimens in each group. Each of which was subjected to three different loads (50, 80 and 110).

OBSERVATION FROM TABLE 3

The mean top surface hardness for group Ia using 50, 80 and 110 load was 55.69, 56.76, 59.87 respectively and for group II was 48.17, 50.87 and 51.51 with a p value (p= 0.000) which was highly significant. (As shown in figures 11,12,13 and 14) Samples cured with conventional system had significantly higher hardness than pulse activation, with load 110 having the highest hardness value

The mean bottom surface hardness of group I using 50 and 80 load was 45.31 and 43.14 and for group II was 39.07 and 38.13 and (p= 0.000) which was highly significant. But with 110 load it was seen that for group I hardness value was 0 .00 and group II a was 37.29 and (P=0.000) which was highly significant

Hence samples cured with conventional system had higher bottom surface hardness values than pulse activated samples with load 50 and 80 but pulse activated samples showed better bottom surface hardness for 110 load.

The mean hardness ratio for group I a using 50 and 80 load was 0.81 and 0.75 and group II was 0.81 and 0.75 (p= 0.651, 0.667) respectively. Hence there was no statistical significant difference between the two groups. The mean hardness ratio for group Ia using 110 load was .00 and group II was 0.72 and (p= 0.000). So group II showed significantly higher hardness ratio than group I.

OBSERVATION FROM TABLE 4

The mean top surface hardness for group I b using 50, 80 and 110 load was 52.33, 53.55, 59.04 respectively and for group II b was 47.36, 49.76 and 51.31 and (p= 0.124) which was not significant. Samples cured with conventional system had significantly higher hardness than pulse activation, with load 110 having the highest hardness value

The mean bottom surface hardness of group Ib using 50 and 80 load was 34.31 and 32.74 and for group II b was 31.80 and 30.56 and (p= 0.000) (p= 0.002) respectively which was significant. But with 110 load it was seen that for group I b hardness value was 0 .00 and group II b was 28.97 and (p=0.000) which was highly significant.

Hence samples cured with conventional system had higher bottom surface hardness values than pulse with load 50 and 80 but pulse showed better bottom surface hardness for 110 load than conventional.

The mean hardness ratio for group I b using 50 and 80 load was .66 and .61 and group II was 0.67 and 0.61 and (p value = 0.000, 0.836)

respectively. Hence for 50 load pulse showed significantly higher hardness ratio than conventional but for 80 load there was no significant difference. The mean hardness ratio for group Ib using 110 load was 0.00 and group II b was .56 and (p=0.000). So group IIb showed significantly higher hardness ratio than group I b for 110 load but for 50 and 80 load there was no statistical difference between the two groups (I and II).

OBSERVATION FROM TABLE 5

The mean top surface hardness for group Ic using 50, 80 and 110 load was 48.54, 49.91,52.84 respectively and for group II c was 37.67,40.01and 41.53 and (p= 0.000) which was highly significant. Samples cured with conventional system had significantly higher hardness than pulse activation, with load 110 having the highest hardness value

The mean bottom surface hardness of group I c using 50 and 80 load was 25.60 and 24.13 and for group II c was 19.57 and 18.63 and (p=0.000) which was highly significant. But with 110 load it was seen that for group I c hardness value was 0.00 and group II c was 17.27 and (p= 0.000) which was highly significant.

Hence samples cured with conventional system had higher bottom surface hardness values than pulse with load 50 and 80 but pulse showed better bottom surface hardness for 110 load than conventional.

The mean hardness ratio for group I c using 50 and 80 load was 0.53 and 0 .48 and group II c was 0 .55 and 0 .47 and (p = 0.527, 0.267)

respectively. So there was no significant difference between the two groups at 50 and 80 load The mean hardness ratio for group Ic using 110 load was 0.00 and group II c was 0.42 and (p= 0.000). So group II c showed significantly higher hardness ratio than group I c.

It has been suggested that the top to bottom surface hardness gradient should not exceed 10-20 % (i.e. hardness ratio should be greater than 0.8) for adequately polymerized photo activated resin composite.

So the specimens of both the groups (I and II) at 2mm level at 50 load had an optimum hardness ratio of > 0.8.

The 3mm and 4 mm specimens with load 80 and 110 did not have optimum hardness ratio of > 0.8.

TWO TAILED FISCHER EXACT TEST : TABLE -1

Curing Protocol	No.	Gap free	%	Gap containing	%	P-value
Conventional	15	8	53.3	7	46.6	0.265
Pulse activation	15	11	73.3	4	26.6	

MEAN VALUE FOR GAP WIDTH: TABLE - 2

Group	No.	Mean	Standard deviation	P-value
Conventional	15	3.333	3.7125	0.08
Pulse activation	15	.08067	1.3992	

$P<0.05$ is statistically significant

TABLE – 3

LOAD	I A		GP		II A	P-value
	CONV.			PULSE		
	MEAN	SD		MEAN	SD	
50 TOP	55.69	.97		48.17	.69	.000
BOTTOM	45.31	.87		39.07	.51	.000
HR	.81	.02		.81	.01	.651
80 TOP	56.76	1.02		50.87	1.53	.000
BOTTOM	43.14	.81		38.13	.85	.000
HR	.75	.02		.75	.03	.667
110 TOP	59.87	.58		51.51	.72	0.000
BOTTOM	0.00	.00		37.29	.41	0.000
HR	0.00	0.00		.72	0.01	0.000

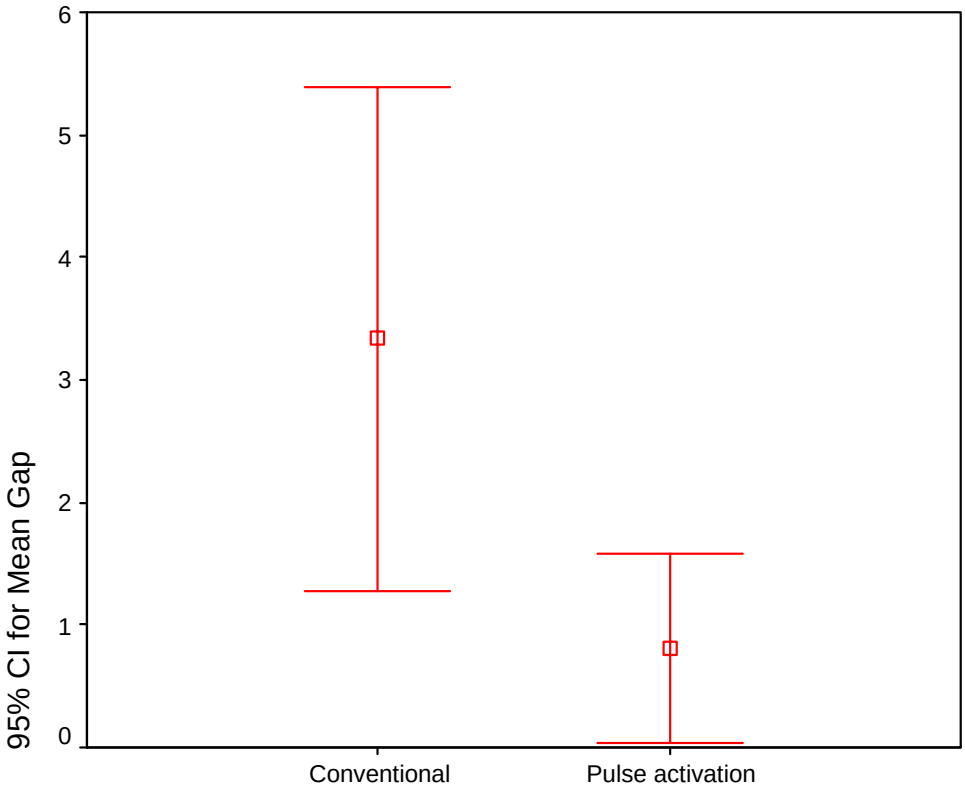
TABLE - 4

LOAD	I B		GP		II B	P-value
	CONV.			PULSE		
	MEAN	SD		MEAN	SD	
50 TOP	52.33	1.01		47.36	.40	0.000
BOTTOM	34.31	.97		31.80	.80	0.000
HR	.66	0.02		.67	0.02	0.124
80 TOP	53.53	.71		49.76	.55	0.000
BOTTOM	32.74	1.07		30.56	1.00	0.002
HR	.61	0.02		.61	0.02	0.836
110 TOP	59.04	1.26		51.31	.49	0.000
BOTTOM	0.00	0.00		28.97	.95	0.000
HR	0.00	0.00		.56	0.02	0.000

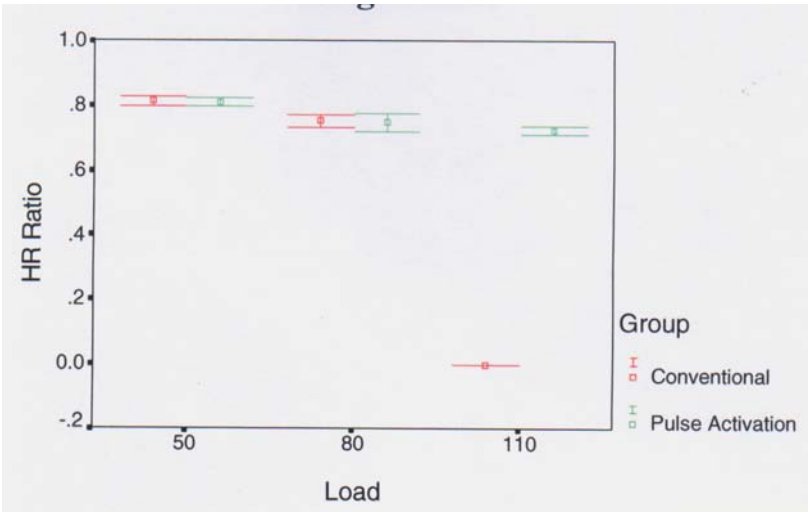
TABLE - 5

LOAD	I C		GP		II C	P-value
	CONV.			PULSE		
	MEAN	SD		MEAN	SD	
50 TOP	48.54	.82		37.67	.75	0.000
BOTTOM	25.60	1.04		19.57	1.18	0.000
HR	.53	.01		.55	0.09	0.527
80 TOP	49.91	1.03		40.01	.72	.000
BOTTOM	24.13	1.22		18.63	1.29	.000
HR	.48	0.02		.47	0.04	0.267
110 TOP	52.84	1.96		41.53	.70	0.000
BOTTOM	0.00	0.00		17.27	.48	0.000
HR	0.00	0.00		.42	0.02	0.000

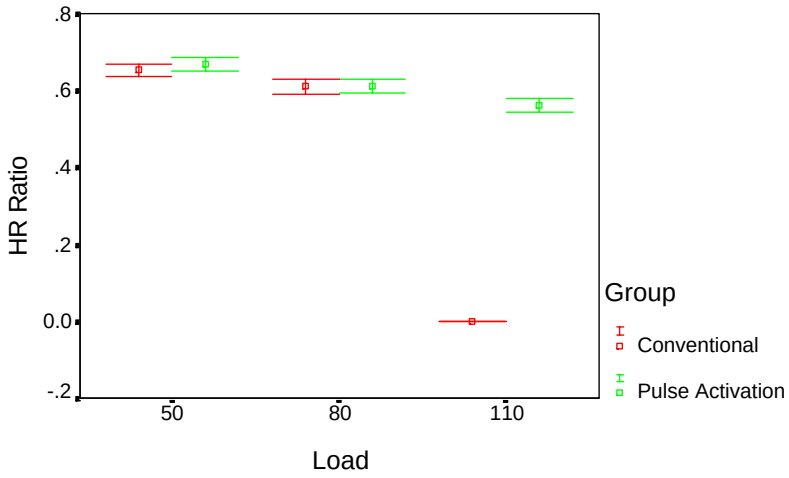
Graph 1



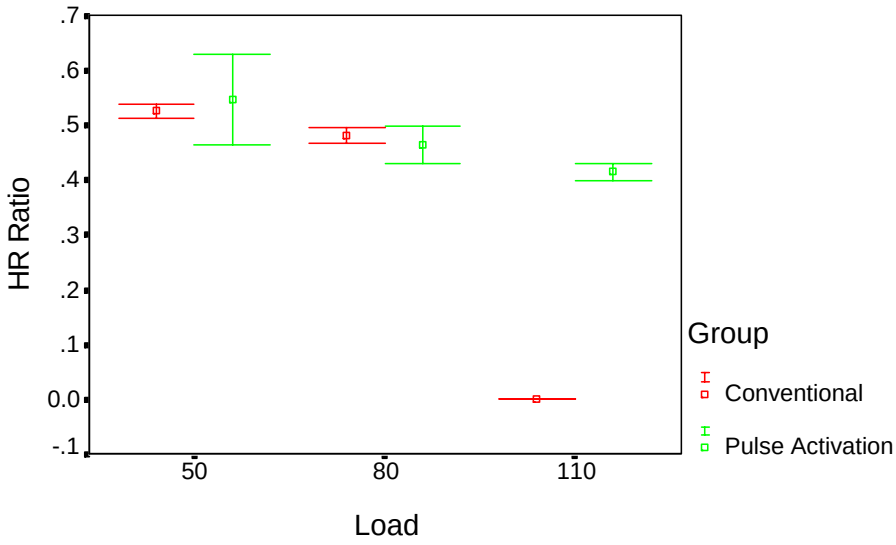
Graph 2
Height 2mm



Graph 3
Height 3 mm



Graph 4
Height 4 mm



Discussion

Visible light curing system has become an integral part of modern adhesive dentistry. Light activated resin introduced in the 1970 revolutionized clinical dentistry by maximizing working time and minimizing setting time. These are generally based on camphoroquinone/amine activation and are usually cured through a constant – intensity extended exposure by suitable quartz halogen light source. This light initiates polymerization with absorption maximum in the blue region of visible spectrum at a wavelength of 450-490 nm[6].

For many years conventional quartz tungsten halogen light curing units have been widely used. Modifications were done to the conventional QTH units to overcome the polymerization shrinkage of light cured composite. One such modification is the pulse cure technique (pulse delay technique). In the pulse cure technique the composite resin was cured with an initial low intensity pulse for few sec, a waiting period of 3 – 5 minutes followed by final cure with high intensity light.

The hardening of dental composite (conversion of monomer to polymer network) results from chemical interaction between dimethacrylate resin monomers that produce a rigid and heavily cross-linked polymer network surrounding the inert filler particles.[21] The extent of this reaction often referred to as the degree of effectiveness of cure is very important in that it dictates many physical and mechanical properties of composite restoration.[1]

Hence the purpose of this study was to

1) Evaluate the marginal adaptation of compomers cured with two different light curing systems- conventional and pulse activation.

2) To determine the effectiveness of cure (depth of cure) of compomers by performing the Vickers hardness test on both top and bottom surface of the prepared compomer specimens by varying depths (2mm, 3mm, 4mm)and three different varying loads(50 , 80 ,110) with the two different curing protocols.

In this study a commercially available curing unit (QTH and Spectrum 800 was used as the curing units for conventional and pulse activation systems .The material used is Dyract AP (poly acid modified composite resin. The cavity design chosen resembled most closely the clinical situation resulting in C-factor of 5, where relatively high shrinkage stress can be expected as in class V and class I, which is supposed to have the maximum value followed by class II and III having C values of 1 and 2 (Feilzer A.J et al 1987). Hence in this study class V cavities were prepared to see if the light curing system could minimize the shrinkage stresses.

Polymerization shrinkage has been a perennial problem with dental composites. Modern composite undergoes volumetric polymerization shrinkage of 1% to 5% (Davidson and Feilzer 1997)[12] can be divided into 2 phases: the pre-gel and post –gel phases. During pre-gel polymerization the composite flows and stresses within the structure are relieved (Davidson and De Gee 1984). Flow ceases after gelation and cannot compensate for

shrinkage stresses. As a result post-gel polymerization causes significant stresses in the surrounding tooth structure and affects the composite –tooth bond. One of the recent methods for minimizing polymerization shrinkage of light activated composite resin is to allow flow during setting by means of controlled polymerization[56]. This can be achieved with the application of pulse activation (short pulses of energy) or soft –start techniques (pre-polymerization at low intensity followed by final cure at high intensity). These curing modes have been shown to result in lower shrinkage, smaller marginal gap, increased marginal integrity and improved mechanical properties.[56,30]

The use of pulse activation and soft- start polymerization regimens reduced the effectiveness of cure at the bottom surface of composite restoration (Yap AUJ et al 2002)[64] . But in his study the use of high intensity during the initial cure (200 mw/cm^2) for soft-start and pulse –delay which he stated could be the reason for decrease / adverse effectiveness of cure as also suggested by (Yap and Seneviratne 2001)[62] Some studies have found no significant difference in shrinkage when compared to continuous modes.[63, 47, 32, 65] There are many factors influencing the transmission of light, including the thickness of restorative material, the presence and size of filler particle, shade of restorative material and distance of light tip to the restoration surface.[52] All these factors were standardized in this study, and any reduction in polymerization shrinkage may be attributed to the light curing regimen used.

The restorative material used is a one component system and consists of matrix made of combination of resins and polycarboxylic molecules that are light cured and filler, which is always glass component and capable of ion release. As these materials consists of a modified composite resin reinforced with glass ionomer, it is assumed adhesion to enamel increased by previous acid – etching and in this way achieving better marginal sealing and consequently reducing microleakage.[45]

An initial application of high intensity radiation may cause increased level of strain at the restoration / preparation interface, which resulted in gap formation. This could probably be the reason for increased gap formations in group I specimens, which used the conventional system (400 mw/cm^2]. A light intensity of 400 mw/cm^2 is suggested for routine polymerization according to Rueggeberg and Caughman[48]. This light intensity together with the manufactures recommendation, a curing time of 40 sec was used for group I.

Pulse delay mode or 'pulse activation' which is similar to soft-start curing method but is different from soft – start in that it is characterized by a waiting interval between the initial low intensity pulse, which may last, for 3-5 min and final exposure to the high intensity light. A waiting period of 3-5 min was found to reduce the residual microstrain in the polymerized resin.[53] This could be the reason for lesser shrinkage and better adaptation. Luo Y et al (2002) also concluded that improved adaptation of Dyract AP was obtained when conditioner 36/Prime and Bond NT were used with the pulse activation system.[39]

The methodology for evaluating the marginal adaptation was similar to that done by Luo et al[39] except that resin replica technique was used for evaluating the adaptation but in this study the specimens were directly viewed under SEM for

evaluating marginal adaptation. Marginal gap formation was significantly reduced or even completely absent in compomer-dentin interface in specimens that were polymerized with the pulse activation curing technique (group II). This suggested that with the use of pulse activation polymerization technique dentin was able to resist polymerization shrinkage and prevent marginal gap generation. But there was no significant difference between the two groups in this study.

Effectiveness of composite cure (depth of cure) may be directly or indirectly assessed. Direct methods that assessed the degree of conversion such as infrared spectroscopy and Laser Raman spectroscopy have not been accepted for routine use because these methods are complex, expensive and time consuming. Indirect method includes visual, scrapping and hardness testing.[1] Hardness is defined as the resistance to permanent indentation or penetration. It is a good indicator of conversion of double bonds.

Hence in the second part of the study to find the depth of cure, indirect method was used i.e. Vickers Hardness Test was used to determine the depth of cure and cure depth profiles were obtained using microhardness machine.

The hardness testing methodology used to asses the effectiveness of cure was based upon that used by Yap (2000)[61], but here compomers were placed on stainless steel mold instead of derlin molds. The bottom of the molds were blacked out to prevent transmission of light. A glass slide was placed on the molds and excess was extruded by pressure application. The compomer was then irradiated through the glass slide and the molds were placed centrally beneath the indenter of the digital microhardness tester to asses the VHN of the top and bottom surface. Loadings of 50, 80 and 110 were applied through the indenter with a time of 5 seconds. The VHN corresponding to each indentation was computed by measuring the dimension

of each indentation using the formula VHN = C6P/d2 where P is applied load, D is the length of diagonal C is the constant (1.8544). Three readings were taken for each specimen and averaged to form a single value for that specimen .The mean VHN and hardness ratio was calculated using the following formula, hardness ratio = VHN of bottom surface/ VHN of top surface. The study compared the microhardness values of both the upper (top) and lower (bottom) surfaces of 42 specimens which were subdivided into 3 groups, corresponding to three different heights 2mm, 3mm and 4 mm cured with two different curing regimen. Samples of 2 mm and 3 mm were prepared due to their clinical relevance. Samples of 2mm were chosen in order to approximate the depth of cure in class I cavities and 3 mm were chosen in order to approximate the depth of cure in class II cavities. 4 mm were taken in order to see the extent of cure to which it can get adequately polymerized and to see if there is any variation between the two curing methods used.

In the ideal situation, the degree of composite polymerization should be the same throughout its depth and hardness ratio should be 1:1 or very close to it as the hardness of bottom surface should be identical to that of top surface. As light passes through bulk of resin, light intensity is greatly reduced due to light scattering thus decreasing the effectiveness of cure (Ruyter and Oyssed 1982)[50]. This scattering of light accounts for the difference in hardness between the top and bottom surface. The hardness ratio should not exceed 10-20 % that is hardness ratio should approximately > / = 0.8 for visible cured resin to be adequately polymerized (Pilo and Cardash 1992)[46]. In this study hardness ratio > 0.8 was found in specimens of 2mm height for both the groups. The 3mm and 4 mm specimens of both groups did not have optimum hardness ratio > 0.8. It has been suggested that composite increments should never be placed more than 2 mm by Rueggeberg et al[48]. With the new bulk placement materials, manufacturers have

claimed that their high density composites be sufficiently polymerized upto depths of 4-5 mm with a single 40 sec exposure using a curing light output greater than 300 mw/cm^2. [16]

Polymerization of resin composite generally decreases from the surface of the restoration inwardly. As a result apparent hardness of top or external surface is not an indicator of complete material polymerization (Tate, Porter and Dosch 1997)[54]. The top surface hardness of composite was dependent on light intensity than the bottom surface.

The result of this study showed that top surface hardness was significantly higher than bottom surface hardness which is also similar to other studies but however in this study an additional finding was that at higher loads (after 110, 140 etc) pulse activation group took up higher loads than conventional group at the bottom surface, but conventional showed better values at the top surface than pulse activation. One possible explanation for this could be that the initial low energy density used with pulse activation resulted in soft surface that resulted in less hardness than conventional system. Chye et al 2005)[7] also concluded that the use of pulse delay and soft-start regimens decreased post –gel polymerization when compared to standard continuous cure.

The reason why the top surface has higher hardness value when compared to the bottom surface is because at the top surface of compomers there is no overlying compomer layer which interferes with light transmission.[49] As the light passes through the bulk of compomer the light intensity is greatly reduced by scattering, thus decreasing the polymerization of bottom surface.

The study also showed that as the load increased from 110 –140 pulse activation showed better hardness values than conventional group, so better

conversion of monomer to polymer is seen in pulse activation than the conventional group. But it was observed that hardness ratio of 2mm samples were more than the hardness ratio of 3mm and 4mm. The effectiveness of polymerization decreased significantly with an increase in the height of specimens.

So from this study it is observed that for 2 mm specimens both conventional and pulse activation group showed no significant difference with all 3 loads. As the load increased from 110, pulse showed better hardness or better cure than conventional system .So in clinical practice if the depth of cavity is higher or in areas of greater stress it is better to use pulse activation system. Although it is time consuming, since the benefits are better pulse activation system will be a better choice than conventional according to the inference of this study. Further research is required before establishing new curing profiles with different light sources.

Conclusion

This in-vitro study was done in the Department of Pedodontics and Preventive Dentistry, Ragas Dental College and Hospital, Chennai and in collaboration with Central Leather Research Institute and Nuclear Physics department (Anna University) Chennai, India.

The following conclusions were drawn from this study

1) Pulse activation group, grp II showed comparatively better marginal adaptation than conventional group, grp I.

2) There was no significant difference between the two groups for loads of 50 and 80 gm. But the top surface hardness was higher for conventional system than pulse activation system for all the groups

3) When subjected to higher loads (110 g) pulse activation group showed better hardness ratio than conventional for all heights. In other words pulse activation group could withstand or take up higher loads than conventional. Thus pulse activation can be a better choice than conventional for curing compomers (light activated resins) and could be used for restoration in stress bearing areas of cavities as well. Hence a few manufacturers' instructions of using Dyract AP in stress bearing areas when cured with pulse activation holds good from the inference of this study.

4) The practice of curing light activated resins in increments of not more than 2mm still holds good

Since this is an in-vitro study, an in-vivo study should be carried out to ascertain the longevity of restorative resins cured with different light curing protocols.

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MASTER CHART

DATA

MAXIMUM WIDTH OF GAP

S.NO.	CONVENTIONAL	PULSE
1	6.6	3.1
2	6.8	3.6
3	7.2	2.8
4	7	3.6
5	6.4	0
6	8.1	0
7	7.9	0
8	0	0
9	0	0
10	0	0
11	0	0
12	0	0
13	0	0
14	0	0
15	0	0

MEAN AND STANDARD DEVIATION OF VICKERS HARDNESS OF DIFFERENT STUDY GP (GP I & II)
GROUP 1 CONVENTIONAL

DATA

GROUP	HEIGHT	LOAD					
		50		80		110	
		MEAN	SD	MEAN	SD	MEAN	SD
I A	2mm						
	TOP	55.686	.974	56.757	1.016	59.871	.579
	BOTTOM	45.314	.871	93.143	.812	0.000	.000
	HR	.813	0.016	.754	0.021	0.000	.000
I B	3mm						
	TOP	52.329	1.011	53.529	.713	59.043	1.255
	BOTTOM	34.143	.965	32.743	1.066	0.000	0.000
	HR	.655	0.017	.611	0.020	0.000	0.000
I C	4mm						
	TOP	48.543	.824	49.914	1.027	52.843	1.956
	BOTTOM	25.600	1.042	24.129	1.218	0.000	0.000
	HR	.527	0.014	.483	.483	0.000	0.000

GROUP II (PULSE ACTIVATION)

GROUP	HEIGHT	LOAD					
		50		80		110	
		MEAN	SD	MEAN	SD	MEAN	SD
II A	2mm						
	TOP	48.171	.695	50.871	1.535	51.514	.715
	BOTTOM	39.071	.509	38.129	.850	37.286	.414
	HR	.810	.014	.748	0.028	.724	0.013
II B	3mm						
	TOP	47.357	.395	49.757	.550	51.314	.488
	BOTTOM	31.800	.796	30.557	.996	28.971	.953
	HR	.671	0.019	.614	0.018	.563	0.021
II C	4mm						
	TOP	37.671	.752	40.014	.715	41.529	.697
	BOTTOM	19.571	1.179	18.629	1.292	17.271	.479
	HR	.549	0.089	.465	0.036	.416	0.016

MASTER CHART

SAMPLES CURED WITH PULSE ACTIVATION

			S.No.	Top	Bottom	H/R
Group II A	**Ht. 2 mm**	Load 50	1	48	39.6	.825
			2	48.8	39	.799
			3	48.9	39.6	.8
			4	47.8	39.5	.826
			5	47.6	38.3	.804
			6	48.9	38.7	.791
			7	47.2	38.8	.822
			S.No.	**Top**	**Bottom**	**H/R**
		80	1	50.2	38.2	.76
			2	50.1	38.9	.767
			3	50.2	38.7	.776
			4	49.8	38.9	.776
			5	52.2	37.8	.724
			6	49.8	36.5	.732
			7	53.8	37.9	.704
			S.No.	**Top**	**Bottom**	**H/R**
		110	1	51.9	37.2	.716
			2	52	37.6	.723
			3	52.1	37.9	.727
			4	50.2	37.6	.749
			5	51.2	36.9	.72
			6	51.1	36.9	.722

			S.No.	Top	Bottom	H/R
Group II B	**Ht. 3 mm**	50	1	47.6	31.3	.657
			2	47	31	.659
			3	46.8	33	.705
			4	47.3	32.5	.687
			5	47.5	31.7	.667
			6	48	32.2	.67
			7	47.3	30.9	.653
			S.No.	**Top**	**Bottom**	**H/R**
		80	1	49.2	29.9	.607
			2	50.2	30.8	.613
			3	49.5	32.1	.648
			4	49.9	31.2	.625
			5	49.6	29.9	.602
			6	50.7	30.9	.609
			7	49.2	29.1	.591
			S.No.	**Top**	**Bottom**	**H/R**
		110	1	50.7	27.8	.548
			2	51.9	28.9	.55
			3	50.9	30.6	.601
			4	51	29.8	.584
			5	51.2	28.6	.558
			6	51.9	28.9	.556
			7	51.6	28.2	.546

			S.No.	Top	Bottom	H/R
Group II C	**Ht. 4 mm**	Load 50	1	38.6	20.4	.735
			2	37.5	20.3	.541
			3	36.5	21.2	.58
			4	38.2	19.8	.518
			5	37.6	19	.505
			6	37	18.3	.494
			7	38.3	18	.469
			S.No.	**Top**	**Bottom**	**H/R**
		80	1	40.2	19.9	.495
			2	39.9	19.6	.491
			3	39.1	20.3	.519
			4	41.2	18.2	.441
			5	39.5	18	.455
			6	39.6	17.2	.434
			7	40.6	17.2	.423
			S.No.	**Top**	**Bottom**	**H/R**
		110	1	41	16.8	.409
			2	41.2	17.5	.424
			3	40.9	18.1	.442
			4	42.9	17.1	.398
			5	41.2	17.6	.427
			6	41.6	16.9	.406
			7	41.9	16.9	.403

MASTER CHART

SAMPLES CURED WITH CONVENTIONAL LIGHT CURE

			S.No.	Top	Bottom	H/R
Group I A	**Ht. 2 mm**	Load 50	1	56	45.3	.808
			2	57.2	45.9	.8024
			3	55.8	45.1	.808
			4	54.9	46.4	.845
			5	56.4	45.5	.806
			6	54.3	43.6	.802
			7	55.2	45.4	.822
			S.No.	**Top**	**Bottom**	**H/R**
		80	1	57.9	42.1	.727
			2	58.2	43.9	.733
			3	56.9	42.9	.76
			4	55.7	43.9	.788
			5	55.8	43.9	.759
			6	55.9	42.1	.753
			7	56.9	43.2	.759
			S.No.	**Top**	**Bottom**	**H/R**
		110	1	59.9	0	0
			2	60	0	0
			3	60.1	0	0
			4	59.5	0	0
			5	59.9	0	0
			6	60.8	0	0
			7	58.9	0	0

			S.No.	Top	Bottom	H/R
Group I B	**Ht. 3 mm**	Load 50	1	53.5	35.3	.659
			2	51.2	34.8	.679
			3	52.6	33.9	.644
			4	52.8	33.6	.636
			5	51	34.1	.668
			6	53.4	35.6	.666
			7	51.8	32.9	.635
			S.No.	**Top**	**Bottom**	**H/R**
		80	1	54	32.9	.609
			2	52.9	33.9	.64
			3	53.9	31.8	.589
			4	53.9	32.1	.595
			5	52.8	33.4	.632
			6	54.5	33.9	.622
			7	52.7	31.2	.592
			S.No.	**Top**	**Bottom**	**H/R**
		110	1	57.5	0	0
			2	58.7	0	0
			3	57.2	0	0
			4	60	0	0
			5	59.9	0	0
			6	60.2	0	0
			7	59.8	0	0

			S.No.	Top	Bottom	H/R
Group I C	**Ht. 4 mm**	Load 50	1	49.3	26.3	.533
			2	48.6	25.8	.53
			3	47.9	24.9	.519
			4	48.8	25	.512
			5	49.2	26.5	.538
			6	49	26.8	.546
			7	47	23.9	.508
			S.No.	**Top**	**Bottom**	**H/R**
		80	1	50.8	24.8	.488
			2	49.9	23.9	.478
			3	48.7	23.2	.476
			4	49.1	24.1	.49
			5	50.9	25.1	.493
			6	51.1	25.7	.502
			7	48.9	22.1	.451
			S.No.	**Top**	**Bottom**	**H/R**
		110	1	50	0	0
			2	51.5	0	0
			3	51.9	0	0
			4	52.1	0	0
			5	54.5	0	0
			6	54	0	0
			7	55.9	0	0