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Original Research Article

Micro Hardness and Curing Depth of Bulk-Fill Composite Using New Generation of LED Device and Traditional Halogen Lamps: *In Vitro*

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Aim: The aim of this in vitro study was to investigate the effect of two different types of light curing using different modes on the microhardness and curing depth of a bulk fill dental composite. Materials and Methods: Forty (40) discs 4mm diameter ×4mm thick) of light-cured resin composite were prepared from (Tetric N-Ceram Bulk Fill, a nano-hybrid low-shrinkage resin-based composite from Ivoclar Vivadent. The specimens were divided into four groups of ten, according to the light curing units used. Before curing the specimens, the light intensity was measured using a radiometer (Bluephase meterfrom Ivoclar Vivadent). Results: The mean microhardness value of the top surface was highest for LED-high mode group (150.156±10.70109 nm) followed by halogen-continuous mode group (137.221±11.47567 nm), LED-low mode group (128.874±8.96043 nm), and lastly in LED-soft start group (112.530±5.19003 nm). The mean microhardness values of the bottom surface showed no statistically significant difference between different activation light curing units (p>0.05).However, the ratio of the mean microhardness top-to-bottom ratio was used to reflect the curing depth (or degree of conversion). Conclusions: LED curing light gives adequate curing depth when used for curing Tetric N-Ceram Bulk Fill at soft start or low mode for(10) seconds.

Keywords: Bulk-filled composite, Dental materials, Micro hardness

INTRODUCTION

Light-activated dental resin composites were, introduced in1970 and their use in restorative dentistry has increased significantly over the last several years, because of esthetic demands from patients and the improvements in these materials. In general, resin composites have many advantages regarding their physical properties such as durability, strength and good color matching (Parekh et al., 2012).

However, composites have many disadvantages, including, inadequate polymerization meaning full conversion of the monomers to polymers does not occur. This leads to a limited lifespan, loss of biocompatibility, degradation, retention loss, discoloration, breakage and microleakage (Parekh et al., 2012). In an attempt to solve these problems, much advancement has been made to improve the process of polymerization of the composite. One of the newest developments in composite materials is the bulk fill type (e.g.,Tetric N Ceram Bulk Fill,Ivoclar Vivadent) which the manufacturer claims has a high curing depth.

The potential advantages of the bulk fill resin composite technique compared to other methods are; easy application which is a less sensitive technique, less voids, less clinical time, technique and a high curing depth. Potential disadvantages of this method include; may be difficult to control during the placement, (especially in the contact areas), larger effects of shrinkage stresses, and may be inadequate polymerization of the resin in deep layers (Leprince et al., 2014).

In addition to the dental materials development of restoration techniques also include focuses in parallel on the only the light cure units. Recently, new-generation LED lights with dual/multi-peak technology were introduced into the light curing units by some manufacturers. To deliver the light energy in both spectral the blue and violet range, as they claimed this will lead to an increase of the polymerization of the resin composite (Santini, 2013; Santini et al., 2014).

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Therefore, the aim of this study was to evaluate the microhardness and the polymerization "curing depth" of one recently introduced bulk fill resin composite (Tetric N-Ceram) and the recently introduced light cure (bluephase N) with multi-peak technology "polyweave" with different modes.

NULL HYPOTHESIS

There is no difference between the microhardness and curing depth of the bulk fill resin composite using different modes of the light curing units.

LITERATURE REVIEW

History

Dental amalgam materials are still the most used in restorative dentistry for many situations, as they are cost-effective and have high durability and self-sealing properties (Bharti et al., 2010).The Chinese were the first to use amalgam as a medical material. In (659AD)Su Kung wrote about using amalgam it was a mixture of tin and silver (Ring,1985), as quoted in (Bharti et al., 2010).

In1528,a German physician, called Johannes recommended amalgam as a filling material(Hoffmann and Axthelm, 1981), as quoted in (Bharti et al., 2010). Later, in1578, mercury was added to amalgam which was introduced to America by Edward Crawcour and Moses Crawcour, and they used it to fill the teeth cavities after removing diseased tissue (Bhartiet al., 2010).

In1845 amalgam war initiated in the American society they considered the use of amalgam as a malpractice because they concern regarding the release of mercury from the amalgam restoration into the body and the environmental impact following its disposal (Ring, 1985). However, Flagg and G.V. Black changed the perception of dental amalgams by laboratory and clinical observation (Westcott, 1844, Evans and Messrs., 1849) as quoted by (Bharti et al., 2010).

Nowadays, there are many renewed concerns about the use of amalgam restorations. The none-aesthetic characteristic of amalgam, along with fears of mercury release, has led to many alternative materials being introduced into the field of dentistry (Muttereta l., 2004).

Silicate cement was the first esthetic restorative material; it was introduced in 1878 by Thomas Fletcher in the United Kingdom (Albers, 2002). This material is a combination of alumino-silicate glass and phosphoric acid which forms a silica gel matrix containing residual glass. Because of its tooth-matched ability and has anti-cariogenic feature due to fluoride release makes it a favorite material. Silicate cement has been used to restore small cavities in anterior teeth (Volker et al.,1944). Later, many of its drawbacks were noted, such as poor mechanical properties and solubility in the mouth, which limited its use (Bowen, 1962).

In the 1940s, unfilled acrylic resins based on polymethylmethacrylate (PMMA) were introduced in Germany to avoid the drawbacks of silicate cement (Anusavice, 1996).This material is similar to resins used in denture construction. It has a good esthetic appearance, insolubility in the oral cavity, and has a low cost. However, it has many disadvantages, including poor wear resistance and high polymerization shrinkage, that cause gaps that lead to micro leakage, recurrent caries, pulp damage and discoloration at the margin. Currently, it is used only for temporary indirect restorations (Ravi et al., 2013).

Later in 1962 resin composite technology was introduced as an alternative to unfilled acrylic resins, with the development of a high-molecular-weight monomer called bisphenol glycidyl methacrylate (Bis-GMA) reinforced with silica Along with the development of acid etching in 1955 by Michael G. Buonocore, when he used orthophosphoric acid to etching the enamel surface to improve the adhesion of acrylic resins.

These two discoveries were the impetus for the composite resin techniques used today(Bowen, 1963).The use of the esthetic filling material in restorative dentistry has increased significantly in the last several years because of esthetic the demands of patients and the improvement of these materials and their application techniques (Leevailoj et al.,2001;Stein et al., 2005).

Composite Resin Filling

Since the first resin composites were introduced in 1962 by Dr. Raphael Bowen, they have been used as a standard filling for direct restorations (Craig et al., 2006). A composite is defined as a material consisting of two or more chemically distinct constituents, with a distinct interface separating them. Ideally, the resulting material would have physical properties better than any of its constituents (Migliaresi and Alexander, 2004, Alsharif et al., 2010).

Dental composite can be considered as a three-dimensional combination of at least two chemically different materials, with an interface separating the components. They are divided into major and minor components (García et al., 2006).The major components are the resin matrix, fillers, and a coupling agent while the minor components include initiators, activators, and inhibitors(Parekh et al., 2012).Each component of composite plays a role in determining the final characteristics of the dental composite.

Major components of composite

Resin Matrix (Organic Phase)

The resin matrix is a chemically active component made up of mono-, di- or tri-functional monomers. The resin is the backbone of the composite and is responsible for the physical properties. The resin is converted from monomer in the liquid state into a rigid polymer by a radical addition reaction with dimethacrylate resin monomers that produces heavily cross-linked networks surrounding the filler particles (Noort, 2002, García et al.,2006). Bowen developed the high molecular weight2, 2-bis [4-(2-hydroxy-3methacryloyloxypropoxy) phenyl] propane called bisphenol glycidyl methacrylate, (Bis-GMA) a bifunctional monomer in 1962.

Until now it is still used as the standard monomer in dental composite. It constitutes around 20% vol% of composite resin compositions (García et al., 2006). Its high molecular weight (512 g/mol) and viscosity (1,200 Pas) result in superior mechanical properties and lower polymerization shrinkage than other types of monomers (Peutzfeldt, 1997; Moszner et al., 2008).

Another bifunctional monomer frequently used as the matrix for resin composites is urethane dimethacrylate (UDMA). This monomer was introduced in 1974and has a high molecular weight (470g/mol), and a viscosity of =23 Pas (Ogliari et al., 2008; Marchesi et al., 2010; Tarle et al., 2012)

Both Bis-GMA and UDMA are highly viscous monomers. To control the viscosity, low molecular weight diluent monomers such as bisphenol A dimethacrylate (Bis- DMA), ethylene glycol dimethacrylate (EGDMA), methyl methacrylate

(MMA), triethylene glycol dimethacrylate (TEGDMA) are added (Culbertson et al., 1997; Holter and Mulhaupt, 1997). These several monomers have different effects on the properties to the resin composite such as the polymerization shrinkage, viscosity, and water uptake (Moszner and Salz, 2001).

Inorganic Matrix' Fillers or Disperse Phase

The disperse phase of composite resins is made up of an inert inorganic filler material; which does not interfere with the polymerization process. Fillers are responsible for the mechanical and physical properties of the composite, such as compressive and tensile strengths, abrasion resistance, and radiopacity (Labella et al., 1999; Anusavice 2004; Callister and Rethwisch, 2007). Fillers are an important part of the resin composite, and they form around 50-80 wt% or (35 to 71 vol %) of composite resin compositions (Bayne et al., 1994;Tanimoto and Nemoto, 2004).

Various sizes and types of fillers give different properties of the composite. The primary composite filler used is silicon dioxide, while others fillers used such as quartz, boron silicates, and lithium aluminum silicates (García et al., 2006).

Lithium and aluminum ions make the glass filler materials easier to crash to form small particles, while the barium, zinc, zirconium, strontium, boron and yttrium ions provide the radio-opacity in the composite (Bouschlicheret al., 1998; Puckettet al., 2007). There are various ways to classify the composite according to filler size, type, and distribution of the fillers particles in the resin.

A high fillers concentration result in low water sorption of the resin, a lower polymerization shrinkage, and a smaller thermal expansion, in turn, providing better mechanical properties and optical properties such as color and translucency (Labella et al., 1999; Noort 2007).

Coupling Agent or Organic Silane

The mechanical properties of conventional composites are poor because of the lack of bond between the hydrophilic inorganic fillers and hydrophobic resin matrix (Albers, 2002).In 1963, Dr. Bowen showed that better mechanical properties (such as a lower water solubility and susceptibility to disintegration in water) were achieved after silanization of the inorganic fillers. Hence, surface modification of fillers with a coupling agent is essential to reduce the filler surface energy, enhanced the dispersion of the filler in the matrix, and form a chemical bond between the inorganic and organic phases (Labella et al.,1994; Crameret al.,2011).

Silane is a small synthetic hybrid inorganic-organic compound, used covalently to bond dissimilar materials. There are two kinds of silane coupling agents, vinyl trimethoxysilane(VTS)and gamma methacryloxypropyl trimethoxysilane (γMPTS), where the latter is the principle coupling agent used in dental composites (Santerre et al., 2001). It is a bifunctional molecule, with two ended one end of the molecule can bond to the hydroxyl groups of silica particles, and the other end is capable of copolymerizing into the polymer matrix. Therefore, silanization was a significant step forward with respect to material strength (Anusavice et al., 2004; Ikejima et al., 2003).

Minor Components

In addition to the major components, resin composites have minor components such as initiators, activator, and inhibitors.

Initiators and Activator

To start and promote the polymerization reaction in dental composite, initiators and activator materials are required. The resin composite can be a chemical or light-cured system. For chemical curing, benzoyl peroxide is added as initiators, while aromatic tertiary amines are added as activators, which are the source of free radicals (Ruyter, 1988).

There are two types of activator used NN-dimethyl-p-toluidine and NN-dihydroxyethyl-p-toluidine but the most common one is N-dihydroxyethyl-p-toluidine because it doesn't cause composite discoloration (McCabe and Walls, 2008). For light cure type camphoroquinone, a diketone photo-activator is used as a source of free radicals, conjunction with a tertiary aliphatic amine, such as4 NNdimethylaminophenythyl alcohol (Nadarajah et al., 1997).

Inhibitors

An inhibitors component is needed in resin-based composites; to prevent spontaneous polymerization under normal storage conditions and maximize the shelf life of the composite resin. Hydroquinone was previously used as an inhibitor, but it caused discoloration of the composite. Now, a monomethyl ether of hydroquinone or Butylated hydroxytolueneis typically used as an inhibitor (Nadarajah et al., 1997; Klapdohr and Mozner, 2005).

Other Components

There are other ingredients in composites like pigments and ultraviolet radiation absorbers. Iron oxides, aluminum oxide, or titanium dioxide are the most common pigments added to resin composite, to achieve color matching with the original tooth color. Ultraviolet radiation absorbers are added to improve the color stability of resin composite by absorbing the electromagnetic radiation that can cause discoloration. The most commonly used absorber is 2-hydroxy-4-methoxy benzophenone (Nadarajah et al., 1997; Kimand Shim, 2001; Yoshidam et al., 2001).

Classification of Resin Composites

In the1970s and 1980s, the need to classify composite systems arose because of the numerous developments in the field of resin composites. It is important to have a classification system to aid the dentist in his or her choice of resin composite to meet the needs of the therapy, aid in description and assist in the communication between the professionals, clinicians, researchers, and manufacturers.

There are many ways of classifying resin composite, according to their composition, matrix phases or concentration and properties of filler, and by their handling properties. The most common classification system is based on filler content (weight or volume percent), filler particles size, and method of filler addition. These properties as they influence the physical and mechanical properties of the composite resin.

The first classification system was introduced by Lutz and Phillips, in 1983, and it remains a very popular system, which is still in used today. It is based on filler particle sizes, where the resin composite is classified into three groups (Lutz and Phillips, 1983):

- Traditional macro filler (macro fill) composites particles (0.1 - 100 μm).

- Micro filler (micro fill) composites (0.04 µm).
- Hybrid composites, which area combination of micro fill and macrofill particles of different sizes.

Another method uses the terms macro, midi, mini, micro, and nano to represent different particle sizes, (Noort, 2002; Roberson et al., 1984). There are also other systems that have been suggested by several researchers (Leinfelder 1989; Roulet 1987; Marshall and Bayne 1988; Hosada el al. 1990; Willems 1992). In 1992, Willems proposed a system based on volume percentage of the inorganic filler.

Conventional' Traditional or Macro Filled Composites

Conventional composites contain glass fillers that form 60 – 80% of the resin composite. These are hard fillers with a large particle size (0.1 to 100 µm), produced by grinding or milling (Anusavice, 2004). In the 1980s the average particle size was approximately 8µm. The large filler particles with high give strength to the composite but have many disadvantages, including difficulties in finishing a high wear rate, and they can abrade opposing tooth.

Difficulties in finishing result in a rough surface that accumulates plaque, consequently leading to recurrent caries, and discoloration. This is due to filler particles protruding from the surface after resin removal (Lutz and Phillips, 1983; Noort, 2002; Ravi et al., 2013).

Microfilled Composites

In the1970s, microfilled composites were introduced to dentistry to avoid the disadvantage resulted to the macrofilled composite. The microfilled composites contain colloidal silica with particles size of 0.01 to 0.04 µm, and a low filler loading 30-60 wt% of the composite (Ravi et al., 2013). The small filler particle size facilitates easy finishing and polishing giving better esthetics results. However, a low filler loading means a higher concentration of resin matrix in the composite which results in a high viscosity and poor physical and mechanical properties, limiting the use of the resin composite to non-stress- bearing areas (Noort, 2002;Ferracane 2011).

Hybrid blended Resin Composite

Hybrid resin composites are a mixture of macrofill and micro fill material. Hence, they combine the physical and mechanical properties of conventional resin composites with the excellent esthetics of the microfilled composites. These materials contain only small amount larger particles of glass or quartz and colloidal silica. The average size of the larger filler particles is in the ranges of 15-20 µm, while the smaller particle started from0.01-0.05 µm. The silica added, to reduce viscosity and improve handling of resin composite. The filler loadings of hybrid composites are typically around75% macrofil size and 8% micro fill particles, where the total filler content is 83% or more of resin composite (Noort, 2002, McCabe and Walls, 2008).

Increasing the filler loading results in superior properties and improves the stress transfer between the particles in the composite (Ferracane, 1995). Hybrid resin composite are very popular for many reasons. They are available in a wide range of colors, for matching with the tooth structure. They also have less polymerization shrinkage, low water absorption, excellent finishing, lower abrasion and wear to opposing teeth than other composites. In addition, they have a similar thermal coefficient expansion to the tooth structures. It considered universal formulas for both the anterior and posterior teeth which have various degrees of opaqueness, translucency, and fluorescence (Wakefield et al., 2001; Braga et al., 2005).

Packable' Condensable' Resin Composites

Another method for classifying resin composite materials is by their flow characteristics; either packable or flow able resin composites. When resins composite were introduced in the 1970s, they were used only for restoration of the anterior teeth. The increase in patient demand and recent advances in esthetic restoration, led to the development of alternative to amalgam fillings.

Manufacturers have been trying to develop a form of resin composites that is easy to pack and use for restoring the posterior teeth. Packable resin composites were developed and marketed as amalgam alternatives. They are universal, can be packed using plastic instruments during placement before curing. As these are high viscosity composites, due to the high filler loading, they are primarily indicated for heavy stress-bearing areas, such as the posterior teeth (Christensen, 1993, Leinfelder et al., 1998).

Packable resin composites have similar physical, mechanical properties and application technique to the amalgam fillings. The goals for such composites are; easy of restoring inter proximal contact and better reproduction of the occlusal anatomy in posterior teeth, with esthetic results. When applying the packable composite, it is essential to use metal matrix bands and wooden wedges, a similar technique as that used for amalgam, to establish proper inter proximal contacts (Ravi et al., 2013).

The main disadvantages of packable composites are difficulties in adaptation between one composite layer and another, difficult handling and poor esthetics in anterior teeth (Suzuki, 2004;García et al., 2006).

Flowable Composite

Flowable composites have a low viscosity due to the low fillers content and the removal of some substances or rheological modifiers from the resin components added to improve the handling properties. The flowability imparts, many advantages; it can penetrate an irregular area, form layers with a minimum thickness, and eliminate entrapment of air (Olmez et al., 2004). Flowable composites are also, less likely to be displaced in the heavy stress-bearing areas of the teeth.

The main disadvantage of Flowable composites, high polymerization shrinkage that leads to inferior mechanical and physical properties compared with other types of resin composite. However, it has many uses including as pit and fissure sealants for repairing, the small class I cavities, as a liner under the composite and in class V restorations (Yacizi et al., 2003).

New Technology in Resin Composites

Since resin composites were introduced, many developments have been made to the material formulation, instruments, and application techniques. Nano composites and bulk-fill composites are recent developments in resin composite materials.

Nanocomposites

Nanotechnology has led to the development of a new type of resin composite in the market called nanocomposites, containing nanoparticles such as zirconium/silica or nano-silica. It's a universal form that can use for both anterior and posterior restorations and have a filler loading of79.5% and particle, sizes between 0.1and 100 nm (Geraldi and Perdigao; 2003, Beun et al., 2007; Ferracane, 2011). Due to the small size of filler particles, this material shows that means less curing shrinkage, easy finishing, which gives an excellent aesthetics result and less post-operative sensitivity compared to other composites. In addition, nano composites provide sufficient strength and durability (Meyer et al., 2003).

However, the drawbacks of this type of resin composite include the inferior optical performance, as the small size of fillers particles, do not reflect light. To solve this problem they are combined with larger-sized particles, with an average diameter corresponding to visible light wavelengths (i.e. around or below 1µm to act as reflectors (Garcíaet al., 2006).

Bulk-Fill Resin Composite

Bulk fill resin composite are a new class of resin composite introduced recently in order to reduce the treatment time. According to the claim of the manufacturers, these materials can be cured to a thickness of 4mm or more in one step instead of the incremental technique, without adverse effects on polymerization shrinkage, cavity adaptation, or degree of conversion (Xu, 1999; Geraldi et al., 2003; Furness et al., 2014). Two subgroupsof this material are available, low-viscosity (flowable) and high-viscosity (sculptable) composite types (Tarle et al., 2015).

Some potential advantages of bulk-filling are; faster technique, saves time of the clinician, better adaptation to the tooth, reduce chances of air entrapment, and better conformity to cavity walls. In addition, these materials show better marginal integrity, less shrinkage stress, and a better degree of polymer conversion (Xu, 1999; Geraldi et al., 2003; Furness et al., 2014; Jerri, 2015).

Recently, a new material was developed called Tetric N-Ceram. It is nano-hybrid low-shrinkage and light-cured resin composite suitable for use in direct restorations. It can be applied in bulk increments up to 4 mm without any adverse effect on the resin composite properties (according to the claims of the manufacturer. This technique can avoid unnecessary polymerization shrinkage, due to an advanced composite-filler technology, a pre-polymer shrinkage stress reliever, new photoinitiator Ivocerin® (polymerization booster), and a light sensitivity filter.

The monomers of Tetric N-Ceram are Bisphenol A-diglycidyldimethacrylate (Bis-GMA), Ethoxylated bisphenol A dimethacrylate (Bis-EMA) and Urethane dimethacrylate (UDMA). The fillers types are Barium aluminium silicate glass with two different mean particle sizes, an Isofiller“, ytterbium fluoride and a spherical mixed oxide 61% vol and 17% vol polymer fillers or Isofillers type.

Tetric N-Ceram uses three different initiators; camphorquinone plus an acyl phosphine oxide, together with a recently patented initiator Ivocerin which is dibenzoyl germanium derivative (Burtscher et al., 2008; Polydorou et al., 2008). Because of these initiators, the resin composite can be absorptive the maximum blue light that ranges from around 370 to 460 nm (Moszner et al., 2008).

Photoinitiators

Since the introduction of visible light activated composites, camphorquinone (CQ) has been widely used as the principal photoinitiator molecule (Taira et al., 1988, Alvim et al., 2007). It is a solid yellow molecule that forms a large amount of the resin composite composition with maximum energy absorption at 468 nm. Which is close to the emission spectrum of the light-emitting diode (LED - λ: 450-490 nm) in the light curing unit. One of the drawbacks of this photo initiator its effect on the final esthetic appearance of the resin composite, due to an undesirable yellowish color (Cook and Chong,1985; Ogunyinka et al., 2007). This led the manufacturer and researchers to find alternative photo initiators t replace or work synergistically with camphorquinone.

The photoinitiator 1-Phenyl-1, 2- Propanedione (PPD) was developed to solve the yellowing effect and improve the polymerization process (Park et al., 1999; Sun and Chae, 2000; Asmussen and Peutzfeldt, 2002).This photo initiator could be used alone or in combination with CQ. The absorption peak of these molecules is at shorter wavelengths within the ultraviolet spectrum the (maximum wavelength ≈ 410 nm) (Stansbury, 2000; Uhl et al., 2003).

Later Lucirin® (2, 4,6-trimethylbenzoyldiphenylphosphine oxide TPO),was introduced and used in some composites to restore bleached teeth. Because it is completely colorless after the light curing reaction, and the constituent polymers are less yellow than others in which the only Camphorquinone is used as a photo initiator. The absorption spectrum characteristic of this a shorter wavelength (ranging from 375 to 410 nm), (Stansbury, 2000;Uhl et al., 2003;Emami and Söderholm, 2005).

Polymerization

Polymerization is the chemical reaction that converts small molecules monomers such as that composite paste into large rigid polymer chains or networks. The conversion takes place by either an addition reaction or a condensation reaction. Increased conversion and cross-linking increases the polymerization shrinkage (Asmussen, 1975).

The intermolecular distances between the monomer are 3-4 Åangstroms, which are reduced to 1.5 Å angstromin the formed polymer after polymerization. This is due to the shrinkage during the polymerization process and covalent bond formation (Braga et al., 2005; Schneider et al., 2010).The total volumetric shrinkage may be observed during two phases: pre-gel and post-gel. Polymerization shrinkage starts immediately after light activation (Davidson and De Gee, 1984; Amore et al., 2003). The polymerization shrinkage is between around<1- 6 by volume, that depending on the formulation and curing conditions of the resin composite (Weinmann et al., 2005; Schneider et al., 2010; Narene et al., 2015).

This process forms significant shrinkage stresses that producing a powerful force that hinders the resin composite to confinement bond to the tooth (Bowen and Cobb 1983). Because of the concentration of stress inside the composite, this effect is observed clinically especially in heavy stress-bearing areas of the tooth, such as enamel fracture, micro-cracks, cracked cusps, cuspal deflection, failure of the cohesion and adhesive (Suliman et al., 1994; Jensen and Chan, 1985; Versluis et al.,1996; Meredith and Setchell 1997).

Microgap formation (10–15 µm), is the most effect of the polymerization shrinkage, especially when the margin of the resin composite is not on the enamel. This microgap allows fluid and bacteria to pass through the dentin-pulp complex from the oral environment. This causes sensitivity, pulpitis, and necrosis of the teeth. (Carvalho 1995; Amaral et al., 2004; Ferracane, 2005).

Polymerization is a critical factor determining the clinical performance of resin composites, especially in stress-bearing areas. Insufficient polymerization will affect the quality of the resin composite resulting in microleakages, and intrinsic discoloration (Moon et al., 2004;Silva et al., 2008).

Methods of Activation

Polymerization may be activated chemically, by mixing two components, or by the application of energy from an external source. The resin composite can be characterized into three categories according to the methods of activation; chemically activated, ultraviolet light-activated, and visible light-activated.

Chemically Activated

Early resin composites where two-paste system where the polymerization was initiated chemically. Each paste had a premixed resin and filler. One paste contained an aromatic tertiary amine activator such as N,N-diemthyl-p-toluidine or p-tolyl diethanolamine, and the other paste containing the 1% of benzoyl peroxide initiator. When the two pastes are mixed, the polymerization will start. The setting reaction is free radical addition polymerization. There are many disadvantages related to chemical curing composite. They contain porosity due to air incorporation during hand mixing. In addition, final polishing cannot be carried out before 24 hours after application, because the composite has not reached final polymerization. In addition, they are not stable at room temperature and require refrigerated storage below8ºC (Noort, 2002; McCabe and Walls, 2008; Mahn, 2013).

Ultraviolet Light Activated

In 1970, ultraviolet lamps were developed, emitting light with a wavelength 365 nm from mercury. Nuva Fil was the first commercial UV light used for curing resin composite. UV activated resin composites were made in a single paste that contained monomers, co monomers, filler, and an initiator such as benzoinmethyl ether. However, the UV light cured systems were soon replaced with visible light activators because of the harmful biological effect of UV, including altering oral micro flora and causing serious damage to the eye and soft tissue. Also, the UV system had a limited curing depth of1 to 2mm (Buonocore, 1970; Stansbury, 2000; Rueggeberg, 2011).

Visible Light-Activated

In 1975, Dart et al. introduced the first visible light system to dentistry. It was a visible light activated resin composite, in a single paste, which contained the initiator and co-initiator (Dart et al., 1978). An initiator that absorbs the visible light directly is Camphoroquinone (CQ). Which is coupled with a co-initiator such as N, N-dimethyl aminoethyl meth acrylate (DMAEMA) or ethyl 4-(dimethylamino) benzoate (4EDMAB)that does not absorb light but interacts with the activated photoinitiator to generate free radicals and initiates polymerization (Lee et al., 1993, Pires et al., 1993).

Camphoroquinone is used as typical visible light activated free radical photoinitiator in visible light composites, exhibits an absorbance range between 400 and 500nm and requires a reducing agent as an electron donor for efficient polymerization. Visible light activated resin composite have many advantages compared with chemically activated ones, as they do not need mixing, have less porosity, higher depth curing, controlled setting time, greater strength, better shade selection, better color stability and high polymerization conversion rates(Albers., 2002; Ogunyinka et al., 2007).

Types of Curing Lamps" Curing Units

There are many types of visible light unit available in the dental markets that belong to different generations. In 1976, Dr. Bassoiuny was the first to cure a resin composite using a visible light unit (Rueggeberg., 2011). Light curing can be accomplished using four main types of light sources: quartz-tungsten-halogen curing units (QTH), plasma arc curing units (PAC), light-emitting diode (LED) and laser curing units. Currently, halogen lights and LED units are the most frequently used in daily clinical practice (Jung, 2006).

There are many requirements for a good curing device, to achieve successful resin composite restoration. An ideal light curing unit should have a broad emission spectrum, sufficient light intensity, minimal loss of energy with distance, multiple curing modes, sufficient duration for multiple curing cycles, durability, large curing foot print and be easily repairable (Oyama et al., 2004; Mangat et al., 2014).

Quartz Tungsten Halogen Light

Quartz tungsten halogen lamp where developed in the 1980s.For several years it was the stander lamp used for curing resin composites. The light is produced from a thin tungsten filament in a lamp filled with halogen, iodine or bromine gas. When the lamp is connected to electricity, the tungsten filament heatsto2727°C, and emits, visible light and infrared radiation (Uhl et al., 2003). The visible white light is filtered to allow only the blue light through wave length ranges from 370-550 nm (Neumann et al., 2006). QTH can cure most types of resin composites (Malhotra and Mala, 2010).

However, QTH lamps have many drawbacks. Firstly, it is essential to have a cooling fan in this unit, due to the heat generated from the filament, which produces noise that is uncomfortable for the most patients. Even with cooling fans, the bulb reflector and filter degraded because of the high temperatures, requiring frequent monitoring and replacement for parts. In addition, the heat reduces the lifespan of the lamp, which operates 100 hours in approximately six months of clinical use (Thormann and Lutz, 1998).There is a reduction in the curing efficiency over time due to aging of the components, which increases the failure rate of resin composite restoration. To achieve adequate polymerization it is recommended to cure the resin composite each site for 40 seconds (Swartz et al., 1983; Rueggeberg et al., 1994; Meyer et al., 2002).

Plasma Arc Light

In the late 1990s, plasma arc lamps were introduced for use in dentistry, to shorten the curing time. The manufacturers claimed that polymerization could occur within 3 seconds, without affecting the mechanical properties of the resin composite. This lamp has a high-intensity light with a power density greater than2000 mW/cm2 (Rueggeberg, 1998; Tarle et al., 2002). The bulb contains two tungsten electrodes that ionize the xenon gas when a large voltage potential is applied. This plasma sequentially emits white light, which is filtered to allow only the blue light (380 to 500 nm) to pass through the units (Hao et al., 2015).Shorter curing times may lead to inadequate polymerization, increased micro leakage, and early failure of resin composite (Price et al., 2003, Jacinta et al., 2005).In addition, plasma arc lamps are expensive, bulky, and heavy (Malhotra and Mala, 2010).The original claims of the manufacturers regarding the short polymerization times have been rejected(Burgess et al.,2002;Kramer et al., 2008) and today the recommendations for plasma arc lamps lights are based on 3 x 3 seconds treatment (Katahira et al., 2004).

Argon Lasers Light

The first lasers lamps were developed in 1960 by Maiman. In1990, the seargon lasers lamps were recognized as a tool that could provide better care for the patients with short curing times. When a certain amount of energy is applied to an atom, electrons can be raised to a higher energy level. As this state is often unstable, later the electron will return to a stable level by releasing light through a medium of argon gas. Its high power densities blue light with a wavelength that ranges from450 and 500nm (Meniga et al., 1997). As the manufacturers claimed within 5 seconds; the polymerization can be achieved (Rueggeberg et al., 2000).

The advantages of this type; the emitted light cable to reaches deep area without dispersing that fastened the polymerization process which enhances physical properties of the resin composite. It's useful in class II composite, due to short curing time and easy to access because of its small fiber size. It has many of disadvantages large, heavy, not a portable unit, also its small tip, has a narrow light guide (or spot size), that mean multiple cure cycles is necessary.

Also, because this expensive unit, could not cure all types of resin composite, and it causes postoperative sensitivity due to its fast curing action which leads to increases in the temperature and causes shrinkage stress(Fleming and Maillet, 1999, Tarun et al., 2011). Therefore, it did not gain widespread use clinically (Knezevic et al., 2007).

Light Emitting Diode (LED) Lights

In 1995 Mills proposed using a light emitting diode as an alternative to halogen light for curing the resin composite. Its blue light is emitted from gallium nitride, when subjected to an electric current. No filters are needed in this type of light cure, due to narrower wavelength spectrum (range from 400-500nm) (Jandt et al., 2000).

It has gone through multiple generations. In the first generation, it was unable to cure all types of resin composite, only composite with, camphorquinone due to single peak – monowave technology that delivers light energy mainly in the blue spectral range (Santini, 2013).Many improvements have been made in the new generation technology that recently makes them the most popular curing unit. The current advantages include; it is a cheap unit, has a high curing depth, high energy efficiency, less heat generation and long life span more than 10,000 hours (Mills, 1995; Caughman and Rueggeberg, 2002; Ernst, 2004).

Recently, new-generation LED lights have been developed with higher light intensities that achieve wider spectrums. These deliver a greater power output that ranges from 500 to 1,400 mW/cm2. Therefore these units can offer better performance and shorter curing times (Price et al., 2003; Wiggins et al., 2004; Rahiotis et al., 2010). In addition, dual-multi peak technology i.e. Polyweave has been introduced by some manufacturers to their curing light devices that deliver light energy mainly in the blue and violet spectral range to increase the polymerization efficiency of materials containing initiators other than or in addition to camphorquinone. This unique feature of generating multiple wavelengths compared with the older generations of the single wavelength LED curing units may be able to produce resin composite restorations with better physical and mechanical properties (Santini, 2013; Santini et al., 2014).

Recently, a new LED curing unit called Bluephase N® was released which has this Polywave technology. This unit has high output and circumvents wavelength that utilizes dual/multi-peak i.e. polywave technology. This technology can cure resin composite with all current photoinitiator in types without restrictions, in the wavelength range between 385and 515 nm as manufacturer claims.

Radiometers

Periodic measurement and monitoring of the light curing unit intensity and its output is an essential step in the dental clinic using this technology. To monitor the curing unit for maintenance and replacement purpose, a portable or built-in chair-side unit called a radiometer. It is an inexpensive, simple unit that measures the number of emitted photons. The main disadvantage is that the accuracy of radiometers is sensitive to the diameter of the light tip. In addition, they only measure the irradiance from the emitting tip and not that from the light cure unit when held at a distance from the radiometer. The recommended output for resin composite curing is more than 300 mW/cm2 (Leonard et al., 1999; Rueggeberg, 2011; Aldossary and Ario, 2015).

Strategies to Reduce Polymerization Shrinkage

Polymerization shrinkage is one of the major problems with resin composite curing because it affects the tooth and success rate of the restoration (Moon et al., 2004). Different strategies have been developed to reduce the polymerization shrinkage by placement or curing techniques, or by the materials used (Narene et al., 2014).These strategies will be discussed in the following sections.

Light Curing Techniques

There are many modes for curing the resin composite. The conventional one is a continuous mode using constant irradiance. Researchers show using continuous high-intensity modes of curing light can negatively affect the integrity of the resin composite (Feilzer et al., 1995).Four new modes have been developed to reduce the polymerization shrinkage during curing of the resin composite; soft start, stepped, ramped, and pulse-delay curing modes.

Soft Start Polymerization

The soft start mode is a curing mode that initiates the polymerization with a low intensity and finishes with a high-intensity light. For example, starting with a radiance of 100mW/cm2 for 10 seconds followed immediately by an intensity resin of 600mW/cm2 for 30 seconds. This reduces the polymerization shrinkage by extending the time available for stress relaxation before the stiffness reaches the gel point. This technique allows for a slow initial rate of polymerization (Bichacho, 1994; Davidson, Davidson, 1998; Divakar et al., 2014). The soft start is dividing into three different techniques; stepped, ramped and pulse delay (Burgess et al., 2002)

Stepped' Staged' Delayed curing technique

In the staged curing mode, the resin is initially cured at low intensity for 10 seconds then contouring and shaping of the restoration, the occlusion is undertaken. Later, the maximum light intensity is applied to complete the curing of the resin restoration. This delay in the curing allows substantial relaxation of the polymerization stresses and lower generation of residual stresses due to longer period available for relaxation. This process also, allows better quality finishing of the composite restorations compared with the fully cured material (Rawls and Esquivel, 2003; Narene et al., 2014).

Ramped Curing Technique

The ramped curing mode gradually increases the intensity during exposure (Mehl et al., 1997). The intensity can be increased in many ways either by using a curing light designed to ramp up intensity or by bringing the light toward the tooth from a distance, or by curing through a cusp. The curing time with this mode is usually 30 sec. This mode can be used in stepwise, linear, or exponential modes. This type of curing mode reduces polymerization shrinkage without affecting the curing depth of the resin composite. The long processing time allows stress reduction during polymerization (Dennison et al., 2000; Divakar et al., 2014).

Pulse Delay Technique

The pulse delay curing mode is a technique where a series of exposure pulses are applied to cures the resin composite. The final increment of the resin composite will cure with a brief high intensity of energy for 2 to 3 seconds. Then a pause for3-5 minute is undertaken to allow the composite to flow and shrink while the restoration is finished and polished. After finishing, the restoration is cured again with high intensity to completely polymerize the material. This technique is mainly proposed for class I restorations. During the last increment of applying resin composite it is activated with a short pulse of light at a rather a low irradiance, 100 – 300mW/cm2 for 3 sec followed by a pause for 3 – 5 min and then a second pulse curing of greater intensity, 500 – 600 mW/cm2, for 30 sec (Kanca and Suh, 1999; Burgess et al., 2002).

Degree of Conversion (DC)

Effective polymerization is achieved when all monomers converse to polymers and form double bonds. However, during polymerization, not all monomers convert to a polymer, the degree of conversion is defined as the proportion of the remaining concentration of the aliphatic C=C double bonds in a cured sample compared to the total number of C=C bonds in the uncured material. The DC is an important factor that determines final properties of the resin composite such as, biocompatibility, dimensional stability, color change and solubility (Costa et al., 2010; Moraes et al., 2008; Rastelli et al., 2008).

A high degree of double bond conversion of resins composites yields favorable mechanical properties (Palin et al., 2003; Ferracane, 2006). However, the DC varies from 40% to 80% in polymerized resin composite (Ferracane, 1985; Davidson et al., 1997; Aldossary and Ario, 2015). The minimum required DC for successful composite restorations is at least 55% (Silikas 2000; Silva et al., 2008; Aldossary and Ario, 2015). Even when increasing the time of irradiance and the total energy level from the light curing units, the DC will never become 100%.Also, the resin composite properties will not get any improve once the maximum possible DC has been achieved (Lohbauer et al., 2005; Shin et al., 2009;Pelissier et al., 2011).Many factors affect the DC, such as the; type of curing light, light intensity, curing time, light tip size, quantity and distribution of the fillers, the quantity of photo initiator, distance between the light and resin, temperature and the shade of the resins composite(Albers,2002;Mills et al., 2002).

Curing Depth

The degree of curing in visible light-activated resin composites depends on the characteristics of the curing light. The curing light intensity output depends on many factors such as the light guide, battery power, condition of the bulb, irradiation time and distance of the light from the resin composite. The total irradiation energy determines the final mechanical properties of the resin composites (Aravamudhan et al., 2006; Silva et al., 2008; Lombardini et al., 2012).

The depth of cure is defined based on top and bottom hardness measurements, and it is common to calculate the ratio of the bottom to top hardness to give an arbitrary minimum value for this ratio (Moore et al., 2008; Poggio, 2012).This method is not an accurate reflection of the conversion degree bottom to top microhardness, according to Bouschlicher, regardless of composite composition.

This is because the percentage depth of cure can easily be misinterpreted specimen that could have been cured poorly throughout can give, ratio that exceeds 80%. This value can be helpful to indicate adequately cured composite samples, however, care should be taken not to misinterpret the results and not to make comparisons among groups, but only within groups (Dunn and Bush, 2002; Price et al, 2003;Bouschlicher et al., 2004).

Measuring the Degree of Conversion

There are many reliable methods for measuring the conversion rate of a composite resin specimen, such as Electron Spin Resonance (ESR) (Ottaviani et al., 1992; Burtscher, 1993; Tarle et al., 1995), Dynamic Mechanical Thermal Analysis (DMTA) (Iadr, 1992; Tarle et al., 1995),Infrared Spectroscopy (IR) (Peutzfeldt, 1994; Ruyterie and Gyorosip, 1976), Multiple Internal Reflection (MIR) (Ruyter and Svedsen, 1978), Attenuated Total Reflection (ATR) Infrared Spectroscopy techniques (Eliades et al., 1987; Tarle et al., 1995), Laser Raman Spectroscopy (Roberts and Shaw, 1984;Lundin and Koch1992), Fourier-Transform-Raman Spectroscopy(Shin et al.,1993; Tarle et al., 1995), Fourier-Transform Infrared Photoacoustic Spectroscopy (Spencer et al.,1992) and Fourier-Transform Infrared Spectroscopy (FTIR) (Ferracane and Greener, 1984; Rueggeberg and Craig ,1988).

In addition, someauthors analyzed the relationship between the DC and the surface hardness (Asmussen, 1982; Ferracane, 1985), thickness of a scraped sample (Baker et al.,1985), strength (Ferracane et al., 1982; Vankerckhoven et al., 1981) and translucency(Leung et al,1984). These methods can measure the DC with either direct or indirect techniques.

The most common direct techniques are vibrational (molecular) spectroscopy methods such as Fourier Transformed Infrared spectroscopy (FTIR) and Raman spectroscopy while the most common indirect technique is the hardness test (DeWald and Ferracane, 1987; Park et al., 2002; Mendesa et al., 2005; Aldossary and Ario, 2015). Other techniques those are less popular, include differential thermal analysis (DTA), differential scanning calorimetry (DSC) and nuclear magnetic resonance (NMR)(Rastelli et al., 2008; Aldossary and Ario, 2015).

The microhardness testis a more reliable method to study the DC according to many studies (Yap, 2000; Alaçam et al., 2004; Parekh et al., 2012).This is because spectroscopy is sensitive to changes in the first stages of curing, whereas microhardness is more sensitive for detecting small changes after the network is cross-linked (Santos et al., 2007; Parekh et al., 2012).

Composite Hardness

Hardness is an important factor that determines the behavior of the composite restoration in the oral cavity. It is defined as the ability of a material to resist the plastic deformation, penetration, indentation scratching, abrasion and machining (Yap, 2005; Callister, 2007; Poggio,2012).Unlike mass, length and time, hardness is not an intrinsic material property and cannot be precisely defined. The hardness value is determined by a well-defined measurement procedure. There are many methods to measure the hardness such as the Rockwell hardness test, Rockwell superficial hardness test, Brinell hardness test, Vickers hardness test, microhardness test, Moh's hardness test, Scleroscope measurements and others.

The four most common standard test methods are Brinell, Rockwell, Vickers, and Knoop. A hardness value is calculated from measuring the depth or area of an indentation that left by an indenter of a specific shape pressed into the sample with a specific force applied for a specific time. Each of these methods has unique hardness values based on scales, defined by the combination of the applied load and indenter geometry (Wang et al., 2003).

Brinell hardness test

The oldest hardness measurementmethod is the Brinell hardness test, which was developed to measure the hardness of metal and alloys. This technique uses a ball-shaped indenter made from steel or carbide with a 10 mm diameter.

Rockwell hardness test

The Rockwell hardness test is able to measure the hardness of plastic materials used in dentistry. It uses a diamond cone shape hardened steel ball indenter.

Vickers hardness test

In the Vickers hardness test, the test material is indented using a diamond indenter in the form of a square pyramid with an angle of 136 degrees between opposite faces and subjected to a load of 1 to 100 Kgf. The load is normally applied for 10 to 15 seconds. The two diagonals of the indentation left in the surface of the material after removal of the load are measured using a microscope and their average calculated. The area of the sloping surface of the indentation is calculated. This method is suitable to be applied to determining the hardness of small areas and for very hard materials (Wang et al., 2003).

Knoop Hardness Test

The Knoop hardness test is similar to the Vickers test but uses an indenter with different proportions. A diamond pyramid shaped indenter is used with a limited penetration depth. The length-to-width ratio of the indenter is, seven-to-one and respective face angles are 172 degrees for the long edge and 130 degrees for the short edge. The depth of indentation is about 1/30 of the indenter length. The indenter is applied to the surface with a known force and specified dwell time. The depth of the indentation is measured using a microscope (Parekh et al., 2012).

The Knoop hardness HK or KHN is then given by the formula:

$$HK = \frac{\text{Load (kgf)}}{\text{Impression area (mm2)}} = \frac{P}{CpL2}$$

L = Length of indentation along the long axis
Cp = Correction factor related to the shape of the indenter, ideally 0.070279
P = Load

The Knoop hardness test is more sensitive to surface characteristics of the material than other tests. It isfrequently used in studies concerning dental composite samples (Wald and Ferracane, 1987) and able to evaluate enamel and dentine structures. However, it is time consuming because of the need for highly polished flat surfaces and more care are needs to be taken compared to other tests (Noort, 2002; Wang et al., 2003).

For all these hardness test methods a microscope is needed for measuring the small size of the indentations (McCabe and Walls, 2008).These methods are not only used to measure the hardness of the material but also used to evaluate the degree of polymerization of resin composite and resin cement (Pereira et al., 1998; Shinkai et al., 2001; Wang et al., 2003). The hardening and depth of cure of these materials can be obtained using Vickers and Knoop microhardness tests known as micro-indentation-testing due to the size of their indenters. These methods allow the measurement of small, selected regions of a specimen, smaller than the filler particles or phases being measured (Wang et al., 2003).

The hardness of a resin composite is influenced by many intrinsic factors such as the type and amount of filler particles, the chemical structure of the organic matrix photo initiator concentration and the degree of conversion. The polymerization conditions are considered as extrinsic factors (Ferracane, 1985; Craig and Powers, 2002; Kim et al., 2002). Our goal in dentistry is to find a dental material that has the same mechanical and physical properties as tooth enamel and dentine. When researchers measure the hardness of enamel and dentine using the Knoop hardness test, they found microhardness values of 68for dentin and 343 for the enamel (Craig and Peyton, 1958).

These values give a reference for the required hardness for the dental restorations. A high-quality dental restoration should be hard enough to withstand mastication forces. Therefore, the hardness of the resin composite should have at least similar hardness of the dentine not only superficially but also in the deeper layers (Bouschlicher et al., 2004).

MATERIALS AND METHODS

Experimental design

This thesis presents a lab-based study aiming to evaluate the curing depth of a bulk fill resin composite, using a new-generation LED curing unit and a traditional halogen lamp. As an indirect method to determine the curing depth we have used micro-hardness test (Micromet 2100 series, Buehler, Lake

Bluff, IL, USA).Approval for the present project was obtained from the Research Center in Riyadh Colleges of Dentistry and Pharmacy. In our study forty (40) specimens of Tetric N-Ceram Bulk Fill (Ivoclar Vivadent, Schaan Liechtenstein) were prepared. These discs were divided into four groups of (10) specimens. The first group was subjected to conventional quartz tungsten halogen (QTH) QHL 75 (Dentsply, York, PA, United States of America) run in continuous mode. The second group was exposed to a LED light curing unit (Bluephase N) (Ivoclar Vivadent, Schaan Liechtenstein) in High mode. In same LED light unit was used for the third and fourth groups but with low and soft start modes respectively. This study was performed at the King Saud University in the (Physics lab) and took one month to prepare.

Materials and equipment

- The material used in this study was Tetric N-Ceram Bulk Fill, (Ivoclar Vivadent, Schaan Liechtenstein), the details of which are shown in Table.1 Figure.1.

To cure the resin composite two curing unit were used as shown in Table 2.

- 1-Conventional quartz tungsten halogen (QTH) QHL75 (Dentsply, York, PA, United States of America) in standard mode (continuous, constant light intensity) Figure2.
- 2-LED light-curing unit LED units (bluephase N) with polywave technology (Ivoclar Vivadent, Schaan Liechtenstein) used in three modes (high, low, and soft start) with wavelengths of (1200 - 650 - 650/1200 mW/cm2) respectively as shown in Figure 3.
- A radiometer (Bluephase meter, Ivoclar Vivadent, Schaan Liechtenstein) was used to measure the intensity output of the curing units Figure 4.
- A microhardness testing machine (Micromet 2100 series, Buehler, Lake Bluff, IL, USA) was used, as shown in Figure 5.

Specimens Preparation

- The experimental specimens in this study consisted of a total forty (40) of Tetric N-Ceram Bulk Fill composite discs with IVB universal B shade with a diameter of 4 mm and thickness 4 mm (Figure6), separated into four groups (n=10) for characterization. The composite discs made from Tetric N-Ceram Bulk Fill were prepared using custom stainless steel split molds to standardize the cavity dimensions. These molds were placed on a Mylar strip over a flat glass slab and then filled with the resin composites using a plastic instrument 44-396-79 and a condenser 44-380-04-07, both from (KLS-Martin, Germany).
- The resin composite was packed into the split mold holding the two parts of the mold together firmly between the thumb and the index finger. The composite was covered with another Mylar strip and gently pressed with another 1mm thick glass slide against the mold to extrude excess material. The top glass slide was removed and the specimens were then irradiated through the Mylar strip to prevent the formation of an oxygen inhibition layer. Curing was undertaken only at the top of the specimens with one of the two light curing devices as shown in Table 2.
- Before curing the specimens, the light intensity of the light cure unit was measured using the radiometer device (Bluephase meter from Ivoclar Vivadent, Schaan Liechtenstein).
- The tip of the curing devices was always in contact with the Mylar strips to standardize the distance. The light curing devices were used according to recommendations of the manufacturers. Immediately after light curing, the Mylar strips were removed from the mold.
- The top surfaces of each specimen were marked with a pen according to the group they belong to (red for halogen, black for high-intensity mode, green for low-intensity mode and blue for the soft start mode) Figure7.
- Then, the specimens were being removed by separating the split ends of the stainless steel mold. Both the top and bottom surfaces of the samples were finished with a wet 600 grit abrasive disc (Buehler, Lake Bluff, Illinois, USA) and polished with a 240 grit polishing disc (Buehler, Lake Bluff, Illinois, USA), with a constant speed for the same time Figure8.

After finishing and polishing, all the specimens were immersed in an ultrasonic bath with distilled water for 2 min to remove any remaining debris. The all specimens were kept inside an incubator at 37°C for 48 hours in a light-proof container to ensure complete setting.

Surface Hardness Test

- The surface hardness of each disc specimen was measured using the Knoop microhardness testing machine (Micromet 2100 series, Buehler, Lake Bluff, IL, USA. The specimens were placed on the platform of the machine and a rhombic-based pyramid indenter was used to apply a load of 300gram of mass (gm) to the surface for 15 seconds dwell time Figure 9.
- Three indentations were performed on both the top and bottom surfaces of each sample Figure10 and the hardness measured. Both the vertical and horizontal diameters of the pyramid were obtained from the machine.
- The mean of the vertical and horizontal Knoop Hardness Number (KHN) readings was calculated to get a single value per indentation. The mean of the sum of indentations per surface was calculated to have one representative reading for the bottom surface and one for the top surface hardness.

The hardness values measured on the bottom surface (i.e., 4mm from the top surface) were normalized considering the hardness value at the top surface was 100%.A value of 80% was used to indicate acceptable curing of the composite.

Pilot study

Prior to the final study, two samples from every group were subjected to a pilot study to ensure the accuracy of the study method.

Data Collection and Analysis

The micro hardness value of all samples was collected and recorded. The data were entered into the computer and analyzed using the SPSS Program version 20.0. The mean hardness levels and standard deviations were calculated. The data were analyzed using one-way analysis of variance (ANOVA). The average hardness values were calculated as described previously. A p-value of 0.05 or less was considered to indicate statistical significance.

RESULTS

This is a lab-based study comparing the microhardness values of Bulk fill resin composite Tetric N-Ceram (Ivoclar Vivadent, Schaan Liechtenstein) using two light cure units in four different activation modes (Appendix).

Table (1), Table (2) and figure (1,3) show the micro hardness values (Horizontal, Vertical, mean of horizontal and vertical) of both Top and Bottom surface of the Bulk fill composite using Halogen QHL 75 in continuous mode and the LED Bluephase N (high, low, soft start)modes. These data have been statistically analyzed and the following tables compare the average results.

Table (3) and (4) show the mean micrhardness values obtained for the top and bottom surfaces. It was found that the values for the top surface were higher than those for the bottom surface.

The means and standard deviation (SD) values from the top surfaces are shown in Table 3 and Figure 1. The mean of the microhardness value of the top surface was highest for the LED high mode group (150.156±10.70109 nm) followed by the Halogen-continuous (137.221±11.47567 nm), LED low (128.874± 8.96043 nm), and lastly LED soft start mode (112.530±5.19003 nm).

Considering the microhardness values at the top surfaces of the composite sample cured using different modes, there were statistically significant differences between the light cure units ($p<0.05$). The One-way analysis of variance (ANOVA) showed a statistically significant difference between the light curing units of p=0.000.

Scheffe post-hoc analysis revealed a statistically significant difference in the mean microhardness values between the Halogen-Continuous and LED-High (p=0.036), Halogen-Continuous and LED-Soft start (p=0.000), LED-High and LED-Low (p=0.000), and LED-High and LED Soft start (p=0.000), LED-Low and LED-Soft start (p=0.005).

The box plot in Figure 12 shows the spread in the microhardness data for all four groups through five statistics, minimum, first quartile, median, third quartile, and maximum. The box represents the inter-quartile range. The lower bound of the box represents the lower quartile, or quartile 1, and the upper bound of the box represents the upper quartile, or quartile 3. The line in the middle of the box is the median. The horizontal line on the far bottom is the extreme minimum value, and the horizontal line on the far top is the extreme maximum value. These are the smallest and the largest numbers in the data set, respectively.

Finally, the line that extends vertically from the extreme minimum to the extreme maximum represents the range of the data set. The means and standard deviation values of the hardness measured on the bottom surfaces are shown in Table (6) and Figure (3).

The mean of the microhardness value was highest for the Halogen-continuous mode (105.711±1.43867 nm) followed by the LED-High (105.617±2.36458 nm), LED-Low (104.768±0.87082 nm), and LED-Soft start mode (104.486±1.28529 nm).

When the bottom surface microhardness values were evaluated, no statistically significant differences were observed between the results from the different light curing units ($p>0.05$). One-way analysis of variance (ANOVA) results showed no statistically significant differences between the four modes of the light cure units (p=0.236).

The box plot in Figure 4 shows the spread of the microhardness for all the four groups through five statistics, minimum, first quartile, median, third quartile, and maximum. The box represents the inter-quartile range. The line that creates the bottom of the box represents lower quartile, or quartile 1, and the line that creates the top side of the box represents the upper quartile, or quartile 3.

The line in the middle of the box is the median. The horizontal line on the far bottom is the extreme minimum value, and the horizontal line on the far top is the extreme maximum value. These are the smallest and the largest numbers in the data set. Finally, the line that extends vertically from the extreme minimum to the extreme maximum represents the range of the data set.

Figure 5 shows the top and bottom hardness values along with a bottom-to-top hardness ratio. Table 8 and Figure 6 presented the bottom-to-top hardness ratio% for every sample, where the mean microhardness ratios above 80% are highlighted in bold to reflect adequate curing of the composite. The LED-Soft start mode achieved the highest curing values and surprisingly the LED-high mode showed the lowest ratio which is an indicator of cure depth or DC of the composite.

DISCUSSION

Resin composites are widely used in restorative dentistry. For the posterior restorations, 2mmincremental of the technique is common and widely accepted to reduce the polymerization shrinkage (Feilzer et al., 1995; Kinomoto et al., 1999; Fleming et al., 2008). However, this is a very sensitive and time-consuming technique. Therefore, to reduce the treatment time bulk fill resin composites have been introduced onto the dental market. Few randomized studies have assessed the physical and mechanical properties of this material. Dijken and Pallesen (2015) reported comparable annual failure Rate between bulk fill composites (class 1: 1.2%; class 2: 2.2%) and conventional composite (Class I: 1.0%; class 2: 1.6%) after three years of clinical function.

As mentioned previously, the degree of polymerization curing depth is important properties that play a significant role in determining physical and mechanical properties of resin composite materials. Accurate polymerization determines the longevity of composite resin restorations and reduces its cytotoxicity effects (Gupta et al., 2012).

In this study, the curing depth of a recently introduced material Tetric N-Ceram bulk-fill resin composite was assessed and the shade was specified (IVB) to standardized the spread of the curing light. In addition, the newly introduced Bluephase N LED light with unique polywave feature was tested in three different activation modes and compared to a traditional halogen light cure units with respect to the curing depth or degree of polymerization". There are many direct and indirect methods to measure the degree of polymerization. Indirect methods are more popular than direct methods as the former are time-consuming, complex and expensive.

Table 1. Composition of Tetric N-Ceram Bulk Fill

Name	Tetric N-Ceram Bulk Fill (Ivoclar Vivadent)
Shade	IVB
Type	Nano-hybrid Resin compoiste
Monomers	Bisphenol A-diglycidyldimethacrylate (Bis-GMA), Ethoxylated bisphenol A dimethacrylate (Bis-EMA) and Urethane dimethacrylate (UDMA)
Filler Type, size	Barium aluminium silicate glass with a mean particle size of 0.4 µm and 0.7 µm, ytterbium fluoride with a mean particle size of 200 nmand spherical mixed oxide with a mean particle size of 160 nm.
Filler content	75-77% by weight., 53-55% by volume
Photoinitiator	Camphorquinone plus an acyl phosphine oxide and Ivocerin®

Table 2. Modes and technical details of the light curing units

Groups	Light curing unit (Manufacturer)	Curing time	Type of light	Wavelength range	Light intensity
G1	QHL 75 (Dentsply)in continuous mode	40 sec	QTH	400 - 500nm	450mw/cm2
G2	Bluephase N (Ivoclarvivadent) in High mode	10 sec	LED	Polywave 380- 515 nm.	1200 mw/cm2
G3	Bluephase N (Ivoclarvivadent) in Low mode	10 sec	LED	Polywave 380- 515 nm.	650 mw/cm2
G4	BluephaseN (Ivoclarvivadent) in Soft start mode	10 sec	LED	Polywave 380- 515 nm.	650/1200 mw/cm2

Figure 1. Tetric N-Ceram Bulk Fill

Figure 2. Quartz halogen QHL 75

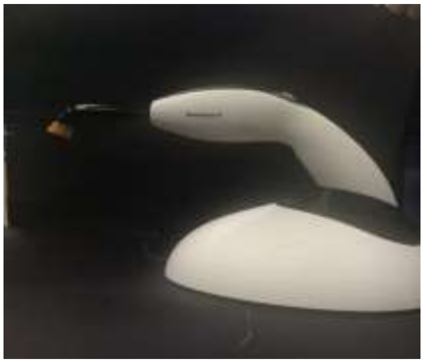


Figure 3. LED bluephase N

Figure 4. Radiometer Bluephase meter

Figure 5. Knoop microhardness machine

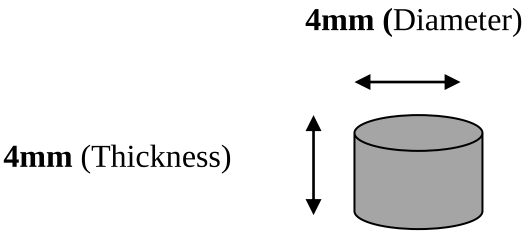


Figure 6. Specimen design

Figure 7. Specimen groups

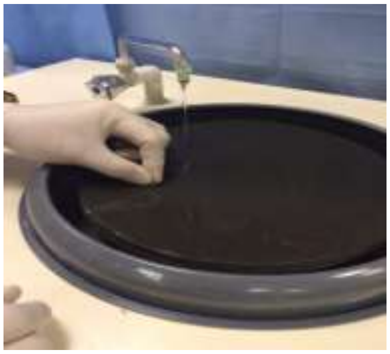


Figure 8. Finishing and polishing machine

Figure 9. Knoop indentations

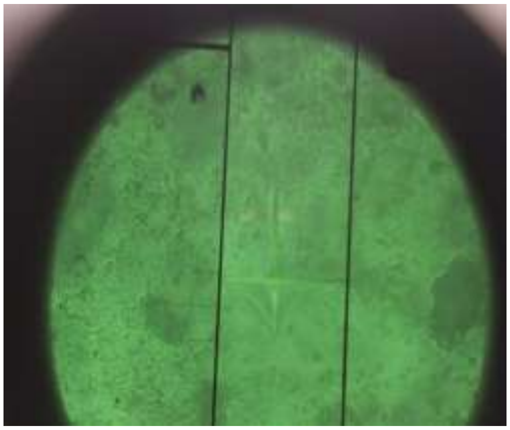


Figure 10. The appearance of the indentation

Table 3. Microhardness values of top surface

Halogen- continuous	LED-high	low-LED	LED-soft start
1+2+3HV	1+2+3HV	1+2+3 HV	1+2+3HV
130.61	160.98	133.48	110.33
127.16	159.85	118.85	109.15
138.73	157.66	134.41	120.41
158.38	154.65	119.88	120.03
148.50	142.53	139.50	110.51
121.35	155.58	136.73	112.95
128.38	142.38	137.20	111.68
130.96	158.28	129.83	105.31
144.18	140.25	113.68	117.50
143.96	129.40	125.18	107.43

Table 4. Microhardness values of Bottom surface

Halogen-Continuous	LED-High	LED-Low	LED-Soft start
1+2+3HV	1+2+3HV	1+2+3HV	1+2+3HV
106.95	107.48	105.45	102.46
108.20	104.38	102.81	105.51
107.00	104.93	104.40	104.40
103.53	103.26	104.85	103.03
104.78	108.8	104.58	106.60
105.93	105.33	105.10	105.96
105.40	104.61	105.60	104.30
105.48	109.71	104.03	103.56
105.96	105.41	105.68	104.36
103.88	102.26	105.18	104.68

Table 5. Mean (± SD) of microhardness value of the top surface

Descriptive Statistics

Dependent Variable:Top

List Modes	Mean	Std. Deviation	Std. Error
Halogen-continuous	137.2210	11.47567	2.972
LED-high	150.1560	10.70109	2.972
LED-low	128.8740	8.96043	2.972
LED-soft start	112.5300	5.19003	2.972

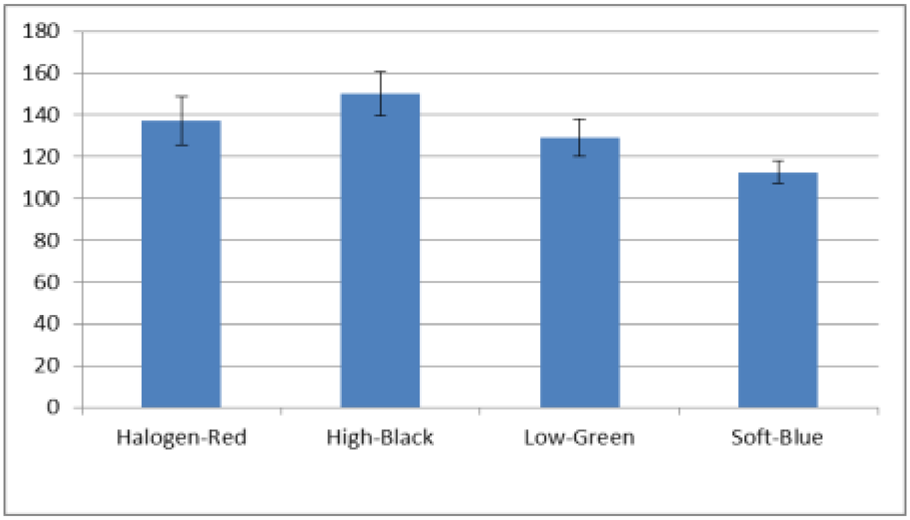


Figure 11. Mean (± SD) of microhardness value of the topsurfaces

Table 6. One-way analysis of variance (ANOVA) results of the top surface hardness values using the different light curing units.

Tests of Between-Subjects Effects

Dependent Variable:Top

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	7455.995[a]	3	2485.332	28.128	.000
Intercept	699023.365	1	699023.365	7911.308	.000
Groups	7455.995	3	2485.332	28.128	**.000**
Error	3180.870	36	88.357		
Total	709660.230	40			
Corrected Total	10636.865	39			

a. R Squared =0 .701 (Adjusted R Squared =0 .676)

Table 7. Scheffepost hoc analysis of the hardness values from the top surfaces.

Multiple Comparisons

Scheffe

(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Halogen- Continuous	LED-High	-12.9350*	4.20375	**.036**	-25.2619	-.6081
	LED-Low	8.3470	4.20375	.285	-3.9799	20.6739
	LED-Soft start	24.6910*	4.20375	**.000**	12.3641	37.0179
LED-High	Halogen- Continuous	12.9350*	4.20375	.036	.6081	25.2619
	LED-Low	21.2820*	4.20375	**.000**	8.9551	33.6089
	LED-Soft start	37.6260*	4.20375	**.000**	25.2991	49.9529
LED-Low	Halogen- Continuous	-8.3470	4.20375	.285	-20.6739	3.9799
	LED-High	-21.2820*	4.20375	.000	-33.6089	-8.9551
	LED-Soft start	16.3440*	4.20375	**.005**	4.0171	28.6709
LED-Soft start	Halogen- Continuous	-24.6910*	4.20375	.000	-37.0179	-12.3641
	LED-High	-37.6260*	4.20375	.000	-49.9529	-25.2991
	LED-Low	-16.3440*	4.20375	.005	-28.6709	-4.0171

Based on observed means.
The error term is mean Square (error) = 88.357.
* The mean difference is significant at the .05 level.

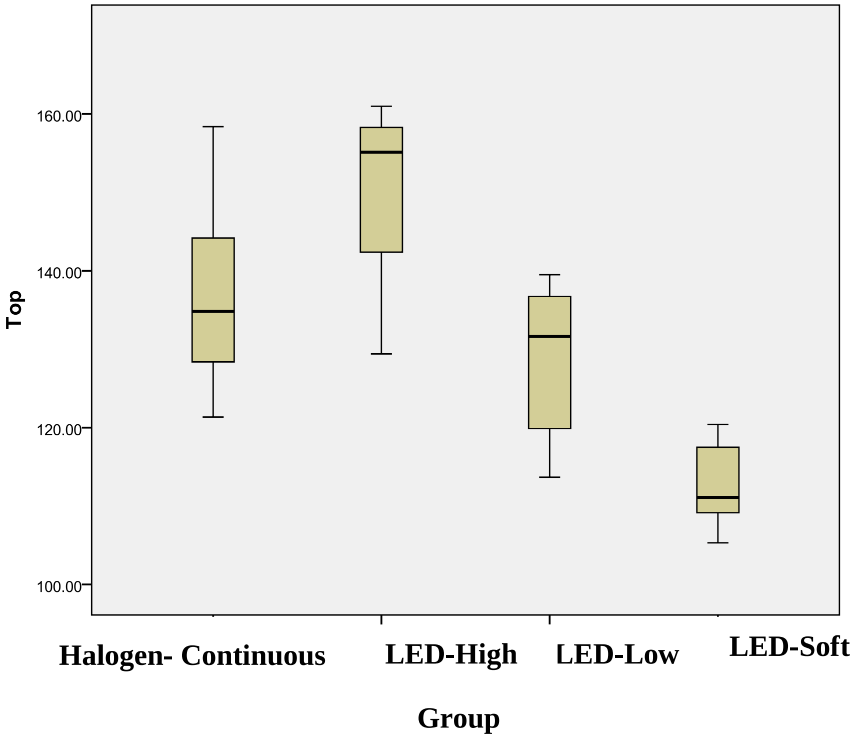


Figure 12. Box-plot of microhardness values of the top surfaces.

Table 6. Mean (± SD) of microhardness value from the bottomsurfaces

Descriptive Statistics

Dependent Variable:Bottom

Groups	Mean	Std. Deviation	Std. Error
Halogen- Continuous	105.7110	1.43867	0.502
LED-High	105.6170	2.36458	0.502
LED-Low	104.7680	.87082	0.502
LED-Soft start	104.4860	1.28529	0.502

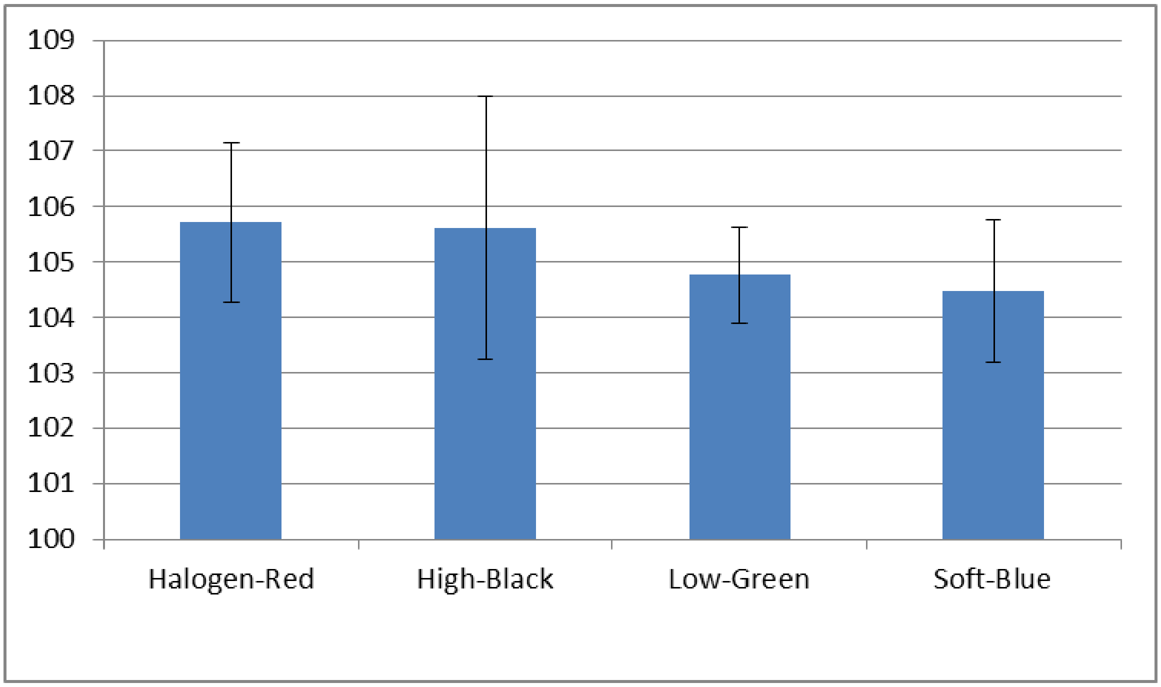


Figure 3. Mean (± SD) of microhardness value of the bottom surface

Table 8. One-way analysis of variance (ANOVA) results hardness values from the bottom surface using the different light cure units.

Tests of Between-Subjects Effects

Dependent Variable:Bottom

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	11.195[a]	3	3.732	1.482	.236
Intercept	442223.047	1	442223.047	175636.540	.000
Groups	11.195	3	3.732	1.482	.236
Error	90.642	36	2.518		
Total	442324.884	40			
Corrected Total	101.837	39			

a. R Squared = .110 (Adjusted R Squared = .036)

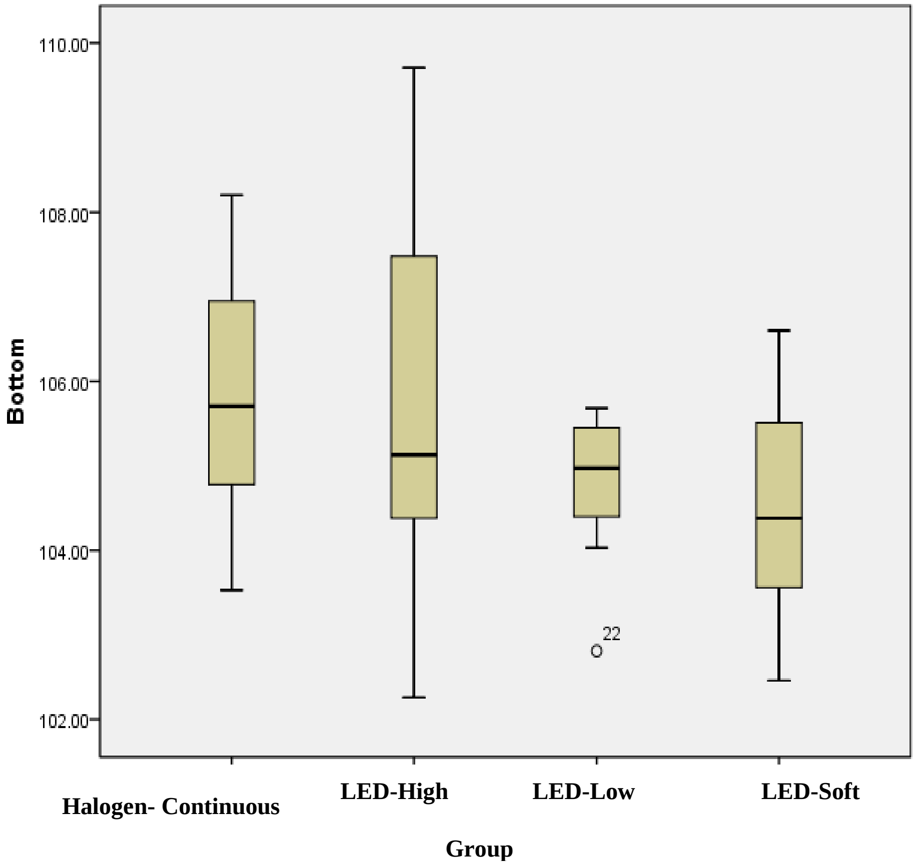
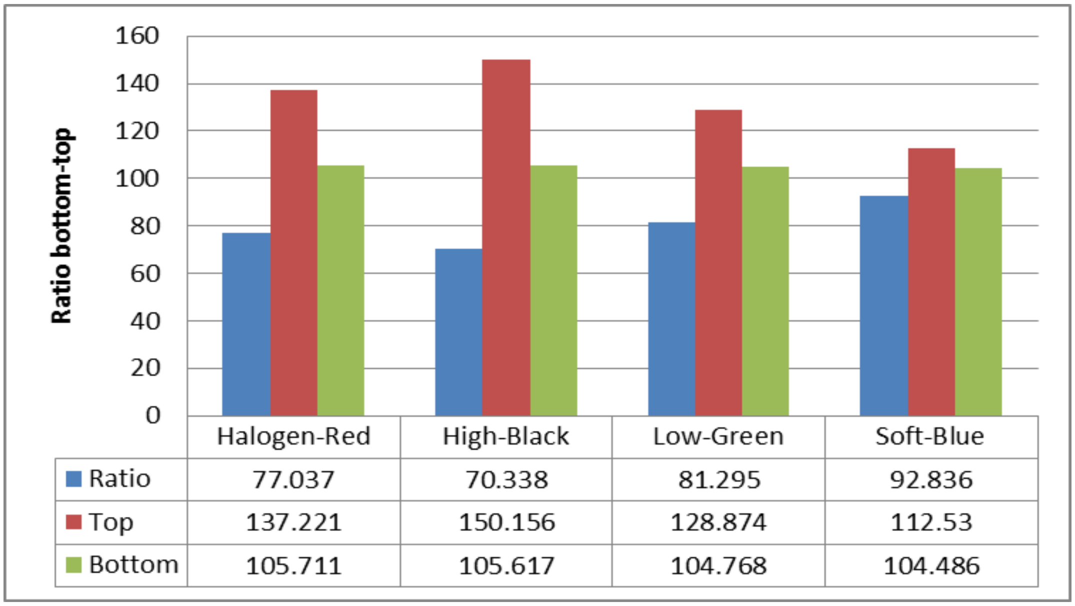


Figure 14. Box-plot of microhardness values from the bottom surfaces



	Halogen-Red	High-Black	Low-Green	Soft-Blue
🟦 Ratio	77.037	70.338	81.295	92.836
🟥 Top	137.221	150.156	128.874	112.53
🟩 Bottom	105.711	105.617	104.768	104.486

Figure 15. Means of hardness and bottom to top surface

Table 9: Mean hardness values for the bottom and top surfaces and bottom-to-top surface ratios (B/T)for every sample.

Halogen- Continuous			LED-High			LED-Low			LED-Soft start		
Top mean	Bottom Mean	T ratio/ B	Top mean	Bottom	T/ B	Top	Bottom	T/ B	Top	Bottom	T/ B
1+2+3HV			1+2+3HV			1+2+3HV			1+2+3HV		
130.61	106.95	**81.88**	160.98	107.48	66.76	133.48	105.45	79.00	110.33	102.46	**92.89**
127.16	108.20	**85.08**	159.85	104.38	65.64	118.85	102.81	**86.50**	109.15	105.51	**96.66**
138.73	107.00	77.12	157.66	104.93	66.55	134.41	104.40	77.67	120.41	104.40	**86.70**
158.38	103.53	65.36	154.65	103.26	66.77	119.88	104.85	**87.46**	120.03	103.03	**85.83**
148.50	104.78	70.55	142.53	108.8	76.33	139.50	104.58	74.96	110.51	106.60	**96.46**
121.35	105.93	**87.29**	155.58	105.33	67.70	136.73	105.10	76.86	112.95	105.96	**93.81**
128.38	105.40	**82.10**	142.38	104.61	73.47	137.20	105.60	76.96	111.68	104.30	**93.39**
130.96	105.48	**80.54**	158.28	109.71	69.31	129.83	104.03	**80.12**	105.31	103.56	**98.33**
144.18	105.96	73.49	140.25	105.41	75.15	113.68	105.68	**92.96**	117.50	104.36	**88.81**
143.96	103.88	72.15	129.40	102.26	79.02	125.18	105.18	**84.02**	107.43	104.68	**97.44**
		77.55			**70.67**			**81.65**			**93.03**

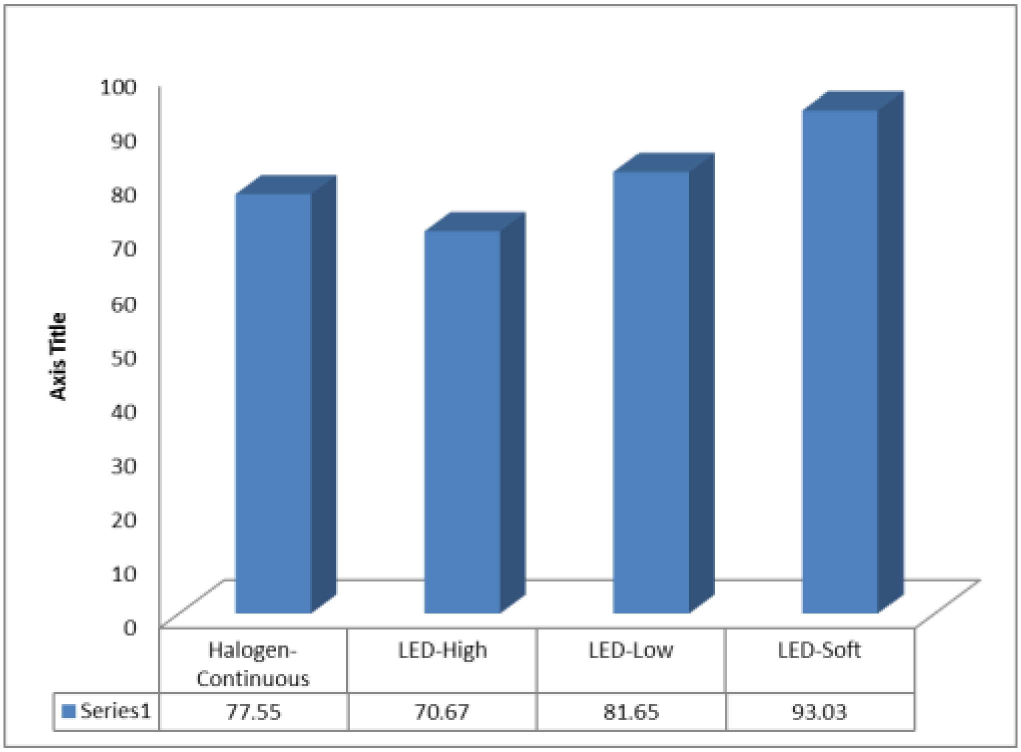


Figure 16. Means of hardness and bottom to top surface for every sample

Microhardness tests have been used as an indirect estimate of the curing depth. In fact, there is a good correlation between increasing hardness values and an increased degree of conversion (Ferracane, 1985).

We used this method here to investigate the degree of polymerization by evaluating the microhardness. The microhardness was measured on both the top and bottom surfaces of the specimens, and the curing depth was assessed by calculating the ratio of the bottom-to-top hardness values. We used the common benchmark of 80% ratio to define adequate polymerization (Ferracane,1985).

The hardness of a dental restoration is one of the most important factors that determine the prognosis of the dental treatment (Heys, 1981; Ruyter and Oysaed 1982). The magnitude of the load in microhardness tests (e.g., Vickers and Koop) has a significant effect on the microhardness results. The load should be in the range of 1grf to 1kgf, but the most common range is between 100-500 grf. With higher loads the indenter penetrates to a deeper layer in the composite, reaching the harder layer and therefore, measures a greater hardness (Uhl et al., 2004). Yoldaz et al. (2004), considered 15seconds dwell time, an acceptable time of load application for dental composites. In our study, the chosen load was 300 grf and the dwell time was 15 seconds. There are many variables that significantly affect the hardness and curing depth of composites such as curing time, light irradiance, and composition of the material (Halvorson et al., 2003).

Different curing times have an effect on the degree of curing; in our study, the manufacturers recommend different curing times for different light curing units in order to achieve adequate curing depths. For the QHL 75 halogen light in continuous modes the 40 seconds was recommended while 10 second was recommend for the Bluephase NLED light for all three activations modes (high, low, soft start).

When microhardness values were compared in this study, we observed a difference between the values measured for both the top and bottom surfaces according to the two different light curing units and different activations modes used; this leads to the rejection of the null hypothesis of this research. The microhardness value was higher for the top surfaces than the bottom surfaces in all groups with a statistically significant difference. This was because the top surface received the maximum energy from the curing light and the bottom surface received was less. This result is not in agreement with that of Pires, et al., (1993) who found that the hardness of the top surface of composites was less independent on the light intensity than the bottom surface. The top surface of the resin composite can be cured even with low-intensity light and gave similar hardness value when cured with high- intensity lights (Pires et al., 1993).

This lower microhardness values measured for the bottom surface can be explained by three different behaviors of the curing light; either the light beam passes through, is scattered, or absorbed by the resin composite material. The angle and the distance of the light curing units both with respect to the sample both effect on the light transmittance through the resin composite (Price et al., 2003; Emami et al., 2005).In our study, to minimize these factors, the curing devices tips were always kept in contact with the Mylar strips during resin curing to standardize the distance (zero distance).

The depth cure of the composites is critically dependent on the light intensity. As light passes through the heterogeneous composite consisting of resin and fillers. Passing the light beam is scattered at the resin-filler interface due to differences in the refractive indices of the individual component. The irregular shape of the fillers particles and an increase in the fillers content has been shown to decrease the light transmittance in a resin composite (Arikawa et al., 2007).This decrease in light transmittance is because of the increase in the specific surface area between the fillers and resin. In addition, an increase in the filler size (0.05–2μm)can lead to decreased light transmission(Fujita et al.,2011). This is due to the lower probability of light scattering at the resin-filler interface for particles that are smaller than the wavelength of the incident blue light.

In our study, the mean filler size of barium aluminum silicate glass range between 0.4 μm and 0.7μm. Thus, these larger filler particles may lead to a decrease in the light intensity passing through to the bottom surface. The other nano-sized ytterbium fluoride filler particles with a mean particle size of 200 nm and spherical mixed oxide particles with a mean particle size of 160 nm may have helped the light transmittance. These small particles are unable to scatter blue light at the resin-filler interface as they are smaller than the wavelength of the incident blue light. The mechanical properties are directly proportional to the filler content, while the light transmittance is inversely affected (Bucuta and Ilie, 2014). In addition, the light reduces in intensity during transmittance through the bulk of the restoration due to absorption by the composite resin (Ruyter, 1982;Tsai, et al., 2004; Aguiar 2005).This can also explain why darker shades have lower hardness values or degrees of cure as these materials have pigments that absorb more light. In our study the IVB, shade might be considered as a dark shade based on the findings of previous studies (Aguiar et al., 2005; Shortall, 2005)

However, in our study, the microhardness values significantly higher on the top surfaces than the bottom surfaces for all groups this disagrees with previous studies which found no significant difference between these surfaces (Peutzfeld et al., 1997; Leonard et al., 2001; Okte et al., 2005).

When comparing the microhardness values of the top surfaces for all groups, the highest values were for the LED high mode group followed by the Halogen-continuous group, LED-low mode and finally LED-soft start mode. This can be explained by the high-intensity light from the LED high mode1200 mW/cm2 that leads to more effective and faster conversion which increases the microhardness. The same result was found by Rahiotis et al., (2010); using LED curing units in a high-intensity mode with similar intensity to our study1100-1250 mW/cm2 gave the highest surface microhardness values.

In addition, heat generation during the curing procedures should be taken into consideration. A high light intensity leads to temperature increases within the composite, which improves the mobility of the monomer particles and increase the reaction rate to give greater double bond conversion (Lovell et al., 2003; Lu et al., 2005).

On the other side, Kurachi et al. (2001) found that the hardness values of samples treated with Halogen light were higher than those for LED light. In other studies, the microhardness values of resin composites gave similar results when cured by either Halogen light or LED light (Torre et al., 2003; Sabatini, 2013)

The second highest microhardness values of the top surfaces were found in the group treated with the halogen lamp, although it had a lower intensity of 450mw/cm2when compared with the LED curing unit. This can be explained by the increase curing time 40second compared with that of the LED light unit (10 second) according to the manufacture instruction this is may lead to a higher degree of polymer conversion and higher microhardness values compared to the other groups. Similarly, Soh et al. (2003) found that the hardness of the resin composite was higher when using a Halogen light compared with LED light. In their study, they used the same light output for both the Halogen and LED light groups but used different exposure times 10 s for LED group and 40 s for Halogen group as for our study.

When comparing the microhardness values from the bottom surfaces we observed some differences between the groups, but these were found to be not statistically significant. The highest microhardness was for the Halogen-continuous mode followed by the LED-High, LED-Low, and LED-Soft start modes.

In general, in our study, it was noted that, although the bottom surfaces had lower microhardness values than the top surface for all groups, they were still higher than that of dentin (68) KHN. In fact, all of the hardness values from both the top and bottom surfaces were higher than that of dentin. This result theoretically reflects that the Tetric N-Ceram Bulk Fill resin composite is expected to have acceptable clinical performance, bearing in mind that no dental restoration has achieved the high hardness of tooth enamel (Craig and Peyton, 1958).

When the mean Knoop Hardness values were calculated as a bottom-to-top ratio the highest value was (93.03%) for the LED-soft start mode followed by the LED-low mode (81.65%), Halogen-continues mode (77.55%) and finally the LED-High mode (70.67%). These values show that there is a difference in the depth of cure between the LED light and Halogen light, and between the different activation modes of the LED light. The results show that most of the LED light curing unit had a better curing depth compared with the Halogen light. Similar results were reported by Yazici et al (2007), while Ceballos et al (2009) found no influence on the curing depth from using Halogen or LED light to cure on conventional composites used in the bulk technique.

We can conclude that the soft-start polymerization technique has many advantages because this mode gradually increases the intensity of light, which may lead to an increase in the pre-gel polymerization phase. Theoretically, this may compensate for the polymerization contraction and relaxation of the shrinkage stresses, and thus, may improve the curing depth, and the mechanical and physical properties (Davidson and Feilzer, 1997; Bouschlicher et al., 2000; Emami et al, 2003).However, Lu et al. (2005) showed that the soft start activation mode might compromise the mechanical properties. In addition, the halogen light did not achieve an adequate curing depth (77.55%). Similar results were observed in many studies that reported curing with low-intensity light gave inadequate light curing of conventional composite resins, even when the time recommended by the manufacturers was followed and this may negatively influence the physical properties and clinical performance of these materials (Briso et al., 2006).

In addition, in our study, the LED in high-intensity mode showed similar performance to the halogen light and also did not achieve an adequate curing depth. This can be explained by rapid conversion in the superficial layer when using high-intensity light which may change the optical properties of this layer and inhibit light transmittance through the bulk of the resin material. These findings are in line with the results of Rahiotis et al. (2010) when they used the Blue phase unit with a light intensity of 1100 mW/cm2. Also, maybe the short curing time in this mode is not sufficient as suggested by Aguiar, et al. (2005) who showed that reduced polymerization times at high intensity provided unsatisfactory curing at the deepest layer of the composite resin. In addition, similar results were found by Correr et al., (2006) who showed that using short exposure times with high power intensity gave smaller curing depths than intermediate exposure times with intermediate light intensities. However, one of the disadvantages of using the bottom-to-top ratio as an analysis tool is that it does not give any quantitative, accurate information about the actual degree of conversion.

In our study, the results show that a 4mm increment thickness can achieve adequate curing depth (under in vitro conditions)when we used the low or soft start modes of a third-generation LED curing units. This feature, when associated with sufficient intensity and adequate shape and size of the light probe of the curing unit, may be able to reach the necessary peak and the required mechanical and physical properties (Rueggeberg, 2011).A recent study found that increasing the bulk thickness, significantly decreased the curing depth of resin when cured for 10 seconds which was in conflict with the manufacturer's recommendations (Tarle et al, 2015). Thus, to increase the curing depth and the microhardness value of the deeper layers, the curing time of the bulk fill resin composite could be increased up to20 seconds, which may lead to an increase in the curing depth (Tarle et al, 2015).

However, in the Tarle et al (2015) study they found that even when the curing time was increased to 30 seconds, some of the bulk fill resin composites did not attain the adequate curing ratio of 80 % from KHN. They observed a threshold at the depth of 4-mm.TheKnoop Hardness Numbers (KHN) and curing depth results should be carefully looked at together when choosing to use a bulk fill or incremental technique. Because not all high-viscosity bulk-fill materials reach the adequate curing depth, this might force clinicians to use the incremental technique with some bulk fill type composites.

In general, the exposure time plays an important role in the composite curing process. When it is increased, the surface hardness of the resin composite will increase significantly (Fujibayashi, 1998; Shortall and Harrington, 1996;Correret al., 2005).

Moreover, Caughman, et al. (1995) and Feilzer, et al. (1995) also agreed that light intensity, wavelength, and time of exposure are critical variables for achieving of maximum curing of composite resins.

However, there are many ways to increase the curing depth of resin composites either by optimizing the LED light source, the absorption spectrum or the reactivity of the initiator, or by increasing the translucency of the materials (Leloup et al., 2002; Rueggeberg FA 2011).

CONCLUSIONS AND RECOMMENDATIONS

Considering the limitations of this study, it can be concluded that:

1. The bulk fill type composite gave adequate microhardness values regardless of the type of light curing unit used.
2. LED curing light resulted in an adequate curing depth when used in soft start mode or low mode for 10 seconds.
3. LED curing light with high-intensity mode gave inadequate curing depth same as the traditional light cure unit.

Recommendation

1. The bulk fill composite is a promising material for dental restoration but it should be used with proper light cure method like soft start mode.
2. The high-intensity mode should not be used for the bulk fill composite.
3. More studies can be carried out others types of Bulk fill composite.
4. A different method of assessment is needed in combination with microhardness tests to give a complete description of the bulk fill composite properties.
5. A clinical assessment of the bulk fill is needed.

LIMITATIONS

The Knoop hardness test is an indicator of the curing quality but did not give an accurate reflection of the degree of conversion.

CONFLICT OF INTEREST

There is not conflict of interest among the authors with the publication of this study.

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APPENDIX

Table 1. Microhardness reading- 300GF, 15 second ofLED light-halogen-Red group on the top surface

Sample #	1st H	1st V	1st HV	2ndH	2nd V	2nd HV	3rdH	3rd V	3rd HV	1+2+3HV
1	132.5	135.5	134.00	131.5	130.3	130.90	127.8	126.1	126.95	130.61
2	131.4	126.3	128.85	128.6	121.5	125.05	130.3	124.9	127.60	127.16
3	133.4	138.3	135.85	137.4	139.5	138.45	143.1	140.7	141.90	138.73
4	157.2	145.0	151.10	162.0	159.4	160.70	163.5	163.2	163.35	158.38
5	147.3	141.4	144.35	146.4	139.2	142.80	155.0	161.7	158.35	148.50
6	120.0	115.5	117.75	117.6	118.1	117.85	123.5	133.4	128.45	121.35
7	132.4	149.2	140.80	119.0	125.1	122.05	118.9	125.7	122.30	128.38
8	130.4	131.0	130.70	127.1	136.4	131.75	126.4	134.5	130.45	130.96
9	150.8	142.2	146.50	139.1	146.2	142.65	141.5	145.3	143.40	144.18
10	134.9	143.5	139.20	146.5	149.0	147.75	141.4	148.5	144.95	143.96

H= Horizontal V= Vertical
1st=First Reading 2nd=Second Reading3rd = Third Reading

Table 2. Microhardness Reading- 300GF, 15 second for LED light-high-Black group on the top surface

Sample #	1stH	1st V	1st HV	2ndH	2nd V	2nd HV	3rd V	3rd H	3rd HV	1+2+3HV
1	172.6	174.0	173.30	164.5	165.8	165.15	145.3	143.7	144.50	160.98
2	155.3	164.5	159.90	162.5	165.6	164.05	156.7	154.5	155.60	159.85
3	156.9	161.3	159.10	153.4	154.2	153.80	161.2	159.0	160.10	157.66
4	160.1	159.5	159.80	149.1	146.8	147.95	162.0	150.4	156.20	154.65
5	142.4	138.9	140.65	150.0	143.5	146.75	140.7	139.7	140.20	142.53
6	150.0	152.0	151.00	153.2	157.0	155.10	164.1	157.2	160.65	155.58
7	124.7	136.5	130.60	134.5	141.3	137.90	161.8	155.5	158.65	142.38
8	150.4	157.1	153.75	156.0	161.1	158.55	163.1	162.0	162.55	158.28
9	146.7	151.3	149.00	146.0	146.5	146.25	126.5	124.5	125.50	140.25
10	125.9	132.9	129.40	129.0	136.5	132.75	128.7	123.4	126.05	129.40

1st=First Reading 2nd=Second Reading3rd = Third Reading
H= Horizontal V= Vertical

Table 3. Microhardness Reading -300GF, 15 second for Soft start light-Blue group on the top surface

Sample #	1stH	1st V	HV1	2ndH	2nd V	HV2	3rd H	3rd V	HV3	1+2+3HV
1	111.0	123.0	117.00	108.5	110.0	109.25	103.0	106.5	104.75	110.33
2	109.4	115.9	112.65	110.0	112.2	111.10	100.1	107.3	103.70	109.15
3	122.3	120.0	121.15	119.9	123.4	121.65	117.8	119.1	118.45	120.41
4	115.4	120.9	118.15	117.8	122.9	120.35	122.5	120.7	121.60	120.03
5	103.4	109.7	106.55	115.4	123.1	119.25	103.0	108.5	105.75	110.51
6	108.5	114.0	111.25	117.2	120.3	118.75	107.5	110.2	108.85	112.95
7	113.6	111.4	112.50	115.5	109.5	112.50	112.0	108.1	110.05	111.68
8	101.5	110.6	106.05	104.6	108.7	106.65	101.7	104.8	103.25	105.31
9	103.8	114.6	109.20	114.5	120.6	117.55	124.8	126.7	125.75	117.50
10	104.5	112.4	108.45	105.5	110.1	107.80	104.1	108.0	106.05	107.43

1st=First Reading 2nd=Second Reading3rd = Third Reading
H= Horizontal V= Vertical

Table.4. Microhardness Reading - 300GF, 15 second for LED light Low-Green group on the top surface

Sample #	1stH	1st V	1st HV	2ndH	2nd V	2nd HV	3rd H	3rd V	3rd HV	1+2+3 HV
1	120.0	130.1	125.05	127.4	130.3	128.85	143.6	149.5	146.55	133.48
2	118.4	122.5	120.45	115.3	124.1	119.70	118.5	114.3	116.40	118.85
3	129.8	131.7	130.75	125.0	136.1	130.55	142.0	141.9	141.95	134.41
4	120.5	121.7	121.10	118.3	121.5	119.90	118.0	119.3	118.65	119.88
5	136.0	137.4	136.70	141.4	134.8	138.10	147.0	140.4	143.70	139.50
6	134.8	136.7	135.75	137.0	134.9	135.95	139.8	137.2	138.50	136.73
7	137.4	141.6	139.50	133.4	137.3	135.35	132.4	141.1	136.75	137.20
8	131.4	132.5	131.95	132.3	133.2	132.75	123.4	126.2	124.80	129.83
9	102.5	107.4	104.95	118.0	126.0	122.00	109.0	119.2	114.10	113.68
10	123.6	125.0	124.30	115.3	126.7	121.00	128.2	132.3	130.25	125.18

1st=First Reading 2nd=Second Reading3rd = Third Reading
H= Horizontal V= Vertical

Table.5. Microhardness Reading - 300GF, 15 second forLED light-halogen-Red group on the bottom surface

Sample #	1stH	1st V	1st HV	2ndH	2nd V	2nd HV	3rd H	3rd V	3rd HV	1+2+3HV
1	101.6	106.9	104.25	104.6	108.1	106.35	108.4	112.1	110.25	106.95
2	108.5	106.3	107.40	104.5	107.8	106.15	111.9	110.2	111.05	108.20
3	105.4	107.3	106.35	103.8	107.1	105.45	108.6	109.8	109.20	107.00
4	101.6	106.5	104.05	101.8	105.9	103.85	102.5	102.9	102.70	103.53
5	102.6	103.8	103.20	105.9	103.8	104.85	106.7	105.9	106.30	104.78
6	102.1	104.8	103.45	106.7	107.8	107.25	107.2	107.0	107.10	105.93
7	106.7	109.7	108.20	108.1	106.5	107.30	101.2	100.3	100.75	105.40
8	101.9	108.7	105.30	105.1	108.1	106.60	101.7	107.4	104.55	105.48
9	106.1	105.9	106.00	109.0	105.1	107.05	105.9	103.8	104.85	105.96
10	100.9	106.2	103.55	100.9	106.4	103.65	103.5	105.4	104.45	103.88

1st=First Reading 2nd=Second Reading3rd = Third Reading
H= Horizontal V= Vertical

Table.6. Microhardness Reading -300GF, 15 second forLED light-high-Black group on the bottom surface

Sample #	1stH	1st V	1st HV	2ndH	2nd V	2nd HV	3rd H	3rd V	3rd HV	1+2+3HV
1	108.9	105.1	107.00	107.0	108.1	107.55	106.7	109.1	107.90	107.48
2	106.2	103.4	104.80	101.4	103.2	102.30	104.3	107.8	106.05	104.38
3	106.4	110.5	108.45	101.9	106.8	104.35	101.4	102.6	102.00	104.93
4	102.1	104.5	103.30	104.1	100.4	102.25	105.6	102.9	104.25	103.26
5	111.9	116.8	114.35	103.0	108.5	105.75	103.7	108.9	106.30	108.8
6	102.0	109.8	105.90	103.9	104.0	103.95	105.4	106.9	106.15	105.33
7	102.7	101.8	102.25	102.0	105.6	103.80	105.5	110.1	107.80	104.61
8	109.2	106.5	107.85	107.5	110.9	109.20	113.8	110.4	112.10	109.71
9	105.7	108.4	107.05	102.9	106.4	104.65	102.9	106.2	104.55	105.41
10	103.2	103.0	103.10	102.7	102.0	102.35	101.1	101.6	101.35	102.26

1st=First Reading 2nd=Second Reading3rd = Third Reading
H= Horizontal V= Vertical

Table.7. Microhardness Reading - 300GF, 15 second forSoft start light-Blue group on the bottom surface

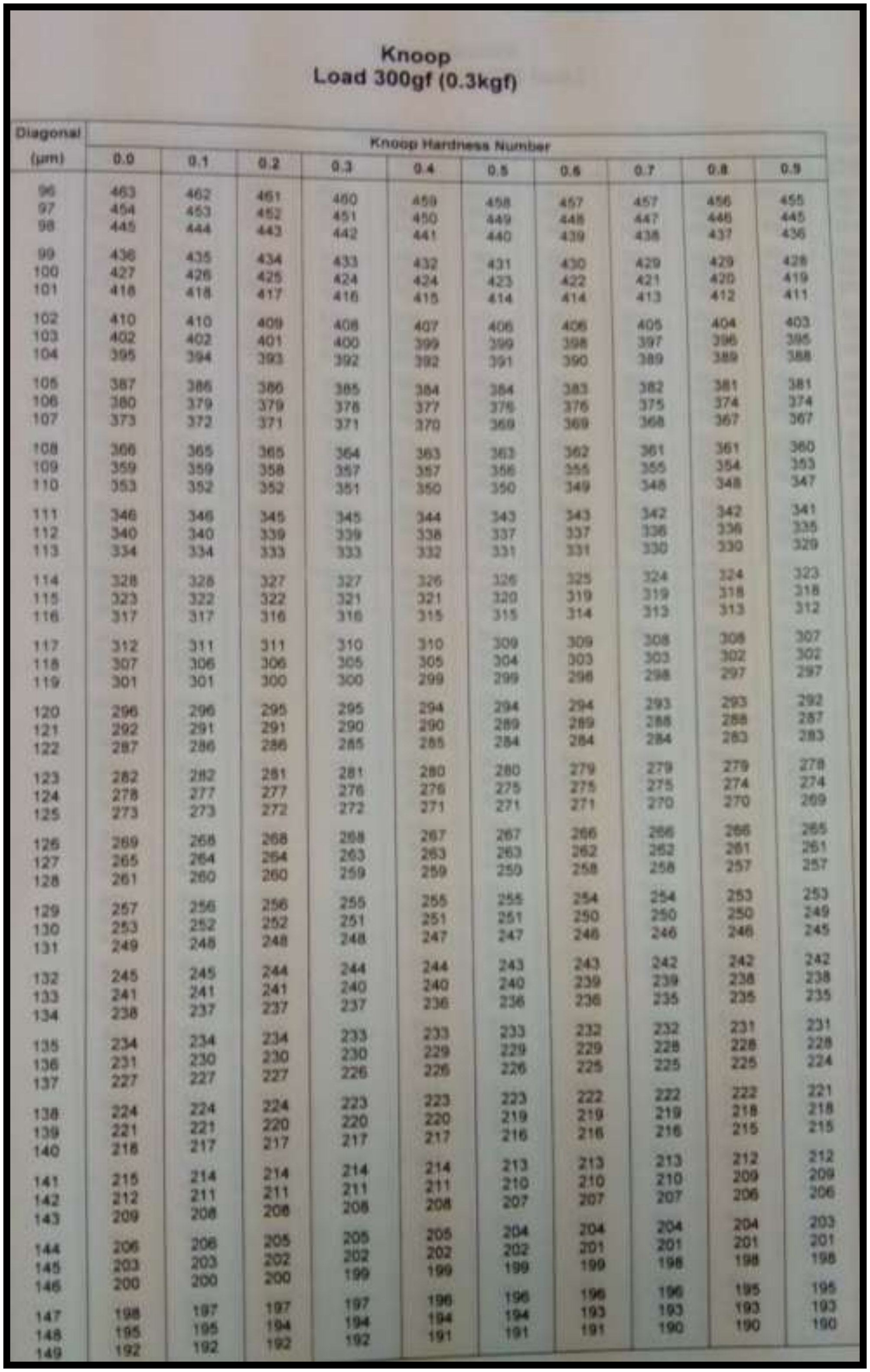
Sample #	1stH	1st V	1st HV	2ndH	2nd V	2nd HV	3rd H	3rd V	3rd HV	1+2+3HV
1	100.9	100.6	100.75	101.9	104.0	102.95	101.8	105.6	103.70	102.46
2	107.0	101.5	104.25	104.9	107.1	106.00	103.9	108.7	106.30	105.51
3	104.8	102.3	103.55	103.2	104.6	103.90	106.0	105.5	105.75	104.40
4	102.8	103.0	102.90	101.0	101.5	101.25	103.9	106.0	104.95	103.03
5	108.5	106.2	107.35	103.1	106.8	104.95	106.5	108.5	107.50	106.60
6	101.7	107.2	104.45	104.7	103.8	104.25	107.0	111.4	109.20	105.96
7	105.4	104.7	105.05	101.2	104.2	102.70	104.2	106.1	105.15	104.30
8	101.4	102.9	102.15	100.2	107.2	103.70	101.8	107.9	104.85	103.56
9	103.4	101.2	102.30	105.2	106.4	105.80	102.6	107.4	105.00	104.36
10	101.2	104.3	102.75	103.4	106.7	105.05	107.2	105.3	106.25	104.68

1st=First Reading 2nd=Second Reading3rd = Third Reading
H= Horizontal V= Vertical

Table 8. Microhardness Reading - 300GF, 15 second for LED light Low-Green group on bottom of the surface

Sample #	1stH	1st V	1st HV	2ndH	2nd V	2nd HV	3rd H	3rd V	3rd HV	1+2+3HV
1	107.9	106.3	107.1	107.9	105.0	106.45	102.4	103.2	102.80	105.45
2	101.4	106.0	103.70	101.2	104.3	102.75	102.2	101.8	102.00	102.81
3	103.4	106.4	104.90	100.7	103.2	101.95	104.6	108.1	106.35	104.40
4	106.2	104.3	105.25	104.0	108.9	106.45	103.2	102.5	102.85	104.85
5	102.1	106.2	104.15	106.4	107.9	107.15	101.5	103.4	102.45	104.58
6	103.4	107.2	105.30	103.7	102.3	103.00	107.2	106.8	107.00	105.10
7	102.5	104.3	103.40	105.6	107.2	106.40	106.1	107.9	107.00	105.60
8	101.2	103.6	102.40	100.1	104.2	102.15	106.9	108.2	107.55	104.03
9	100.5	107.2	103.85	106.9	109.4	108.15	102.7	107.4	105.05	105.68
10	103.5	108.5	106.00	104.1	108.7	106.40	101.2	105.1	103.15	105.18

1st=First Reading 2nd=Second Reading3rd = Third Reading
H= Horizontal V = Vertical



Knoop
Load 300gf (0.3kgf)

Diagonal (μm)	Knoop Hardness Number									
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
96	463	462	461	460	459	458	457	457	456	455
97	454	453	452	451	450	449	448	447	446	445
98	445	444	443	442	441	440	439	438	437	436
99	436	435	434	433	432	431	430	429	429	428
100	427	426	425	424	424	423	422	421	420	419
101	418	418	417	416	415	414	414	413	412	411
102	410	410	409	408	407	406	406	405	404	403
103	402	402	401	400	399	399	398	397	396	395
104	395	394	393	392	392	391	390	389	389	388
105	387	386	386	385	384	384	383	382	381	381
106	380	379	379	378	377	376	376	375	374	374
107	373	372	371	371	370	369	369	368	367	367
108	366	365	365	364	363	363	362	361	361	360
109	359	359	358	357	357	356	355	355	354	353
110	353	352	352	351	350	350	349	348	348	347
111	346	346	345	345	344	343	343	342	342	341
112	340	340	339	339	338	337	337	336	336	335
113	334	334	333	333	332	331	331	330	330	329
114	328	328	327	327	326	326	325	324	324	323
115	323	322	322	321	321	320	319	319	318	318
116	317	317	316	316	315	315	314	313	313	312
117	312	311	311	310	310	309	309	308	308	307
118	307	306	306	305	305	304	303	303	302	302
119	301	301	300	300	299	299	298	298	297	297
120	296	296	295	295	294	294	294	293	293	292
121	292	291	291	290	290	289	289	288	288	287
122	287	286	286	285	285	284	284	284	283	283
123	282	282	281	281	280	280	279	279	279	278
124	278	277	277	276	276	275	275	275	274	274
125	273	273	272	272	271	271	271	270	270	269
126	269	268	268	268	267	267	266	266	266	265
127	265	264	264	263	263	263	262	262	261	261
128	261	260	260	259	259	250	258	258	257	257
129	257	256	256	255	255	255	254	254	253	253
130	253	252	252	251	251	251	250	250	250	249
131	249	248	248	248	247	247	246	246	246	245
132	245	245	244	244	244	243	243	242	242	242
133	241	241	241	240	240	240	239	239	238	238
134	238	237	237	237	236	236	236	235	235	235
135	234	234	234	233	233	233	232	232	231	231
136	231	230	230	230	229	229	229	228	228	228
137	227	227	227	226	226	226	225	225	225	224
138	224	224	224	223	223	223	222	222	222	221
139	221	221	220	220	220	219	219	219	218	218
140	218	217	217	217	217	216	216	216	215	215
141	215	214	214	214	214	213	213	213	212	212
142	212	211	211	211	211	210	210	210	209	209
143	209	208	208	208	208	207	207	207	206	206
144	206	206	205	205	205	204	204	204	204	203
145	203	203	202	202	202	202	201	201	201	201
146	200	200	200	199	199	199	199	198	198	198
147	198	197	197	197	196	196	196	196	195	195
148	195	195	194	194	194	194	193	193	193	193
149	192	192	192	192	191	191	191	190	190	190