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YEDITEPE UNIVERSITY

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DEPARTMENT OF RESTORATIVE DENTISTRY

EVALUATION OF THE DEPTH OF CURE AND SURFACE MICROHARDNESS OF VARIOUS BULK FILL COMPOSITE RESINS POLYMERIZED WITH DIFFERENT LIGHT SOURCES

MSc Master Thesis

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ABSTRACT

Aim: To compare the the microhardness of composite sample with different thikness following polymerization with different light sources.

For this purpose, the microhardness values of the top and bottom surfaces of the composite samples were measured and the microhardness of composites at different depths were compared using the values obtained from the top and bottom surfaces.

Materials & Methods: Effectiveness of cure sources was determined by measuring the top and bottom surface hardness (VHN) of 4 and 2-mm composite specimens. One microhybrid composite (Z250, shade A2) as control group and two bulk fill composite (SDR bulk fill composite and Tetric evoceram bulk fill composite) were used to prepare 10 samples for a total of 120 samples. The samples were made up in 8 mm diameter circular black polypropylene molds, with 4 and 2mm thickness. Each sample was prepared in the same manner by the same operator and cured maintaining a distance of 2mm between the specimen and light tip. After 24 hours' storage in distilled water , Vickers micro-hardness measurements were obtained on both sides of the samples, with a load of 50 grams for 10 seconds. Three indentations were performed on each surface of each sample and the Vickers hardness values were obtained.

Data analysis: Two Way Anova test was used, for the evaluation of the effect of different material, application thickness of the material and also the type of light curing device on the hardness ratio means. In comparison, the parameters between more than two groups, One-way Anova Test; and during the determination of the group that caused the differences Tukey HDS test was used. Also, in comparison the parameters between the two groups, Student t test was used.Significance was evaluated on the level of $p < 0,05$.

Result: When halogen light was used, statistically significant differences were found between the hardness ratio means of the materials which had 2 mm thicknesses($p = 0,015$; $p < 0,05$) and statistically significant differences were found between the hardness ratio means of the materials which had 4 mm thicknesses ($p = 0,001$; $p < 0,01$) When LED light unit was used, no statistically significant differences were found

between the hardness ratio means of the materials which had 2 mm thicknesses but statistically significant differences were found between the hardness ratio means of the materials which had 4 mm thicknesses ($p = 0,001$; $p < 0,01$)

Conclusion: All composites with 2 mm or 4 mm thickness (except Tetric Evo Ceram 2 mm) when cured with LED showed lower hardness ratio means than the materials cured with halogen light

Keywords: Bulk fill composite, Microhardness test, Depth of cure, Light cure sources

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LIST OF ABBREVIATIONS

mm.	Millimetre
min.	Minute
μm.	Micromiter
nμ.	Nanomicro
nm.	Nanomiter
Co.	Company
TEGDMA.	triethylene glycol dimethacrylate
EBADMA.	ethoxylated bisphenol-A-dimethacrylate;
Bis-GMA.	bisphenol-A-glycidyl dimethacrylate;
Bis-EMA.	ethoxylated bisphenol-Adimethacrylate
UDMA.	urethane dimethacrylate
et al.	et alii
cont.	Continue
SD.	standard deviation
ANOVA.	analysis of variance
n.	number of specimen
VHN .	Vicker's hardness number
Vol% .	volume percentage
Wt% .	weight percentage

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1. THE AIM OF THE STUDY

Restorative dentistry is the study, diagnosis and integrated management of diseases of the teeth and their supporting structures and the rehabilitation of the dentition to functional and aesthetic requirements of the individual. Improvements in tooth-coloured restoratives and bonding technology have made dental procedures more acceptable and feasible. Nowadays, patients are attracted to a restoration that matches the colour of natural teeth. So, resin composites have become the most frequently used aesthetic material in dentistry (1,2).

The composition of resin-based dental composites has developed significantly since the materials were first introduced to dentistry. Until recently, the most important changes have involved the reinforcing filler, which has been purposely reduced in size to produce materials that are more easily and effectively polished and demonstrate greater wear resistance. Most of the changes are focused on the polymeric matrix of the material, but near these changes, the reducing the polymerization shrinkage stresses is very important (3).

During the polymerization of resin-based composites, stresses due to resin composite's contraction is occurred. Clinically, these stresses may be transferred to the margins of the restoration and affects marginal quality (4). When the marginal quality is not adequate, problems like microleakage, recurrent caries and pulpal irritation may occur (5,6).

Restoration placement techniques are widely recognized as a major factor in the decreasing of shrinkage stresses (7). Incremental filling techniques are usually preferred to avoid the clinical consequences of polymerization shrinkage and effective marginal seal can be obtained (8,9). Incremental techniques have been suggested to compensate

the polymerization shrinkage of composites, by reducing the stresses developed within the tooth-restoration system (10-12).

When restoring cavities with light-curing resin composites, it has therefore been regardedas the gold standard to apply and cure the resin compositein increments of limited thickness. The maximal increment thickness has been generally defined as 2 mm (13,14). Although, restoring cavities, especially deep ones, with resin composite increments of 2 mm thickness is important for adequate light penetration, its disadvantages are the time-consuming and impliesa risk of incorporating air bubbles or contaminations between the increments. Bulk application technique is simpler than incremental one, and also it makes the work quicker by reducing the number of clinical steps (15).

Thus, various manufacturers have recently introduced new types of resin composites, so-called “bulk - fill”materials, which are claimed to be curable to a maximal increment thickness of 4-5 mm in one step (16-18). Bulk-fill resin based composites are also marketed as restoratives that are particularly well suited for patients with limited compliance.

So in the present study, evaluation of the depth of cure and surface microhardness of two bulk-fill and a microhybrid composite cured with a halogen and a LED light units were purposed.

2. INTRODUCTION

The aim of restorative dentistry is to restore oral and dental tissues to normal functionality whilst simultaneously meeting the patient's aesthetic requirements. Restorative dentistry can be instrumental in improving the aesthetic appeal of a person's smile as well as helping to maintain good oral health. Missing and damaged teeth can also lead to malocclusion which is the misalignment of teeth of the upper and lower dental arches which can effect eating and even talking.

Dental restorations are used to repair the damaged surfaces of the teeth. Dental filling materials may be used to even out tooth surfaces for better biting and chewing. Nowadays for the purpose of aesthetic approach, composite resins are the most popular restorative materials used for the rehabilitation of damaged teeth.

2.1. COMPOSITE RESINS

During the past 50 years, the use of composite resin for direct restorations in anterior and posterior teeth has increased significantly, largely due to the esthetic demands of patients and concerns regarding mercury in amalgam fillings (19). Composite resins require little preparation, minimally invasive procedures can be used during the cavity preperation and tooth structure can be preserved and natural-looking results can be obtained after the restorations. So, composite resin also may eventually replace silver amalgam for direct restorations (20,21).

Composite resins require a bonding procedure for durability and reliability, so they must be biocompatible and bond well to both enamel and dentin. Direct restorative materials are also required to resist masticatory forces and demonstrate mechanical

properties similar to those of natural teeth. Composite resins must also be easy to use if they are to replace silver amalgam for direct fillings (22).

A composite material may be defined as a compound of two or more distinctly different materials, with properties that are superior or intermediate to those of the individual constituents (23).

Composite resins have been introduced into the field of restorative dentistry to minimize the drawbacks of the acrylic resins that replaced silicate cements in the 1940s. In 1955, Buonocore (24). used orthophosphoric acid to improve the adhesion of acrylic resins to the surface of the enamel. In 1962 Bowen developed the Bis-GMA monomer in an attempt to improve the physical properties of acrylic resins, as their monomers only allowed linear chain polymers to be formed (3). These early, chemically cured composites required the base paste to be mixed with the catalyst, leading to problems with the proportions, mixing process and colour stability (1,17).

From 1970, composite materials polymerized by electromagnetic radiation appeared, doing away with mixing and its drawbacks. At first, an ultraviolet light source (365 nm) was used to provide the required light energy, but its shallow polymerization and iatrogenic side-effects led to its replacement by visible light (427-491 nm), which is currently in use and undergoing further development (25). Composite development has been and continues to be unceasing, making it necessary to keep abreast continually.

2.1.1.Advantages and uses of current composites

Resin composites are used for a variety of applications in dentistry, including but not limited to restorative materials, cavity liners, pit and fissure sealants, cores and

buildups,inlays, onlays, crowns, provisional restorations, cements for single or multiple tooth prostheses and orthodontic devices, endodontic sealers, and root canal posts. It is likely that the use of these materials will continue to grow both in frequency and application due to their versatility. The rapidity by which the materials have evolved suggests a constantly changing state of the art (3).

In addition to their use in anterior teeth, aesthetic composite resin restorative materials are increasingly being used to restore shape and function in posterior teeth. Posterior composite resin restorations, however, are submitted to very large masticatory forces. Therefore the mechanical properties of a composite resin material become even more important in determining long term clinical performance under occlusal forces.

2.1.2. Composition of current composites

The most important factors that influence the mechanical properties are the composition of the composite resin itself and its degree of cure (17). While the composition of light cure composites, including the quantity and size of the fillers, the amount and type of photoinitiators, and resin matrix are determined by the manufacturer, the degree of final cure depends on the quality of the curing light and the duration of cure (18).

Basically, dental compositesare composed of four major components: organic polymer matrix(usually a dimethacrylate), an inorganic matrix (reinforcing fillers, typically made from radiopaque glass), a coupling agent (a silane for binding the filler to the matrix), and the initiator-accelerator system (26). also several chemicals and other components are added to enhance the composite material, for example pigments are added to achieve an acceptable shade and/or opacity. (3,26).

2.1.2.1. Organic Matrix

The predominant and most commonly used base monomer in commercial dental compositesare the high-molecularweight monomers Bisphenol A glycidyl methacrylate (Bis-GMA), which due to its high viscosity, it is mixed with other dimethacrylates, such as TEGDMA, UDMA or other monomers (23, 27).

Diluents (for example TEGDMA) are therefore added to attain high filler levels, but to retain usable handling consistencies. UDMA is similar in molecular weight to Bis-GMA but is considered more flexible (23). Most companies add a Bis-GMA/TEGDMA or Bis-GMA/UDMA/TEGDMA combination to their composites (28).

Methacrylate monomers react via an addition polymerization reaction to form a highly cross-linked structure when light of appropriate wavelength and intensity is applied. Therefore the resin matrix has an important influence on the chemical and physical properties of composite resins as it also contains the initiator system(s) for polymerization (3, 26, 28).

2.1.2.2.Inorganic Matrix

Inert fillers are added to the resins to improve mechanical properties such as compressive and flexural strength and hardness. Improved physical properties include a reduction of polymerization shrinkage and an increase in the modulus of elasticity (23,29,30).

The physical and mechanical properties of composite resins are also influenced by the characteristics of the fillers itself, for example their size, distribution and content per volume of the filler particles (31). The filler particles used in dental composites vary widely in their chemical composition, morphology and dimensions. Most filler particles are silicon dioxide based and are either a) crystalline silica (quartz), b) silica with metals (silicate glass), or c) amorphous silica (colloidal silica) (23).

Boron silicates and lithium aluminum silicates are often used. In many composites the quartz is partially replaced by heavy metal particles such as barium, strontium, zinc, aluminum or zirconium to impart radiopacity (28).

Colloidal silica particles are also known as microfillers. A disadvantage of microfillers is that they aggregate to form fibrous, chainlike secondary structures which limits filler loading resulting in lower mechanical properties (32). To improve the filler load, commercial microfills often contain a mixture of silica microfillers and prepolymerized resin particles produced from fumed silica. The larger filler particles are produced by milling or grinding dense, large particles (mined quartz, melt glasses, ceramics) to produce smaller particle sizes varying from 0.1μm to 100μm. Milling procedures, however, cannot reduce filler particle size below 100nm(32).

The latest development in filler technology is nanoparticles and nanoclusters. Nanoparticles and nanoclusters are being manufactured using synthetic chemical processes to produce building blocks on a molecular scale. Progressively larger structures are assembled and transformed into suitable nanosized fillers (32). Aqueous colloidal silica sols are being used to synthesize dry powders of nanosized silica particles 20nm and 75nm in diameter. These particles are treated to prevent aggregation.

Two types of nanoclusters with a cluster size range of 0.6 – 1.4 microns have also been developed. One type consists of loosely-bounded agglomerated silica particles and is being used in the translucent shades. The other type consists of agglomerated zirconia/silica particles that are radiopaque and is being used in the enamel, body and dentin shades (32).

2.1.2.3. Coupling Agent

The role of the coupling agent is to form a bond between the inorganic filler particles and the organic resin matrix phase of the composite. Bonding is accomplished by treating the surface of the fillers with a coupling agent before mixing it with the unreacted oligomer.

The most common coupling agents are organic silicon compounds called silanes. The silane accomplishes coupling as follows: the methoxy groups on the silane hydrolyse to hydroxy groups and react with the adsorbed moisture (-OH groups) on the filler, to form a film on the surface of the filler. During the setting reaction of the organic resin matrix the carbon double bonds of the silane react with the resin and hence form a bond between the filler and resin (26).

The coupling agents play an important role in the mechanical and chemical properties of a resin composite, especially its durability.

2.1.2.4.Photoinitiator

In a light cured resin composite, a diketone type of photo initiator system is included in the resin, which when activated by light of a specific wavelength causes polymerization and hence curing/hardening of the resin. This is achieved through the release of radicals, which start converting the oligomers into a cross linked polymer (33). After this reaction has taken place the resin composite should be cured tosuch a degree that it will display the typical physical and chemical properties that areexpected of a restorative material of this type.

The most common photoinitiator system is camphoroquinone, accelerated by a tertiary amine, typically an aromatic one (34).

2.1.2.5. Optical Modifiers

Shading of composite materials is achieved by the addition of minute amounts of inorganic metal oxide pigments (26). Shades can range from very white bleaching shades to yellow to gray. Translucency or opacity is provided to simulate enamel or dentin, for example, when an opacitier is added light will not pass through the restoration but be reflected back and the restoration will look whiter. Titanium dioxide and aluminum oxide are examples of effective opacifiers (23).

2.1.3. Types of dental composites and their development

Dental composites can be distinguished by differences in formulation tailored to their particular requirements as restoratives, sealants, cements, provisional materials,

etc.These materials are similar in that they are all composed of a polymeric matrix, typically a dimethacrylate, reinforcing fillers, typically made from radiopaque glass, a silane coupling agent for binding the filler to the matrix, and chemicals that promote or modulate the polymerization reaction.

A useful way to classify dental composites is according to their filler content's size and amount as summarized in Table 1(35).

Table 1: The classification of Resin Based Composites

Type of Resin Composite	Size of inorganik filler	Percentage of inorganic filler (by weight)
Megafill	50 – 100 nμ	
Macrofill	10 – 100 nμ	70 – 80 %
Midifill	1 – 10 nμ	70 – 80 %
Minifill	0,1 – 1 nμ	75 – 85 %
Microfil	0,01 – 0,1 nμ	35 – 60 %
Hybrid	0,04 – 1 nμ	75 – 80 %
Nanofill	0,005 – 0,01 nμ	

Also, according the polymerization promoting systems, most composites are categorized as light-activated, either as the sole polymerization initiator or in a dual cure formulation containing a chemically cured component.

2.1.3.1. Hybrid Composite Resins

These composites are so called because they are made up of polymer groups (organic phase) reinforced by an inorganic phase, comprising 60% or more of the total content, composed of glasses of different compositions and sizes, with particle sizes ranging from 0.6 to 1 micrometers, and containing 0,04 micrometer sized colloidal silica. They make up a large majority of the composites currently used in dentistry.

The characteristic properties of these materials are summerized as availability of a wide range of colours and ability to mimic the dental structure, less curing shrinkage, low water absorption, excellent polishing and texturing properties, abrasion and wear very similar to that of tooth structures, similar thermal expansion coefficient to that of teeth, universal formulas for both the anterior and posterior sector, different degrees of opaqueness and translucency in different tones and fluorescence (36, 37).

2.1.3.2.Flowable Composites

These are low-viscosity composite resins, making them more fluid than conventional composite resins. The percentage of inorganic filler is lower and some substances or rheological modifiers which are mainly intended to improve handling properties have been removed from their composition.

Their main advantages are listed as high wettability of the tooth surface, ensuring penetration into every irregularity; ability to form layers of minimum thickness, so improving or eliminating air inclusion or entrapment (38), high flexibility, so less likely to be displaced in stress concentration areas (cervical wear processes and cavitated dentine areas); radio-opaqueness and availability in different colours. The

drawbacks are high curing shrinkage, due to lower filler load, and weaker mechanical properties (39). Some of the indications for these materials can be listed as below (39),

- applications in class V restorations,
- cervical wear processes
- minimal occlusal restorations
- as liner materials in class I or II cavities
- areas of cavitated enamel.

2.1.3.3.Bulk-Fill Composite Resins

Bulk-fill restorative resins are not a new idea. Numerous bulk-fill products have come and gone from the market over the past two decades.Instead of an oblique incremental layers this material can be applied as a one bulk up to 4-6 mm.

One of the problems connected with photo-polymerized resin composites is the depth of cure limitation and the possibility of insufficient monomer conversion at depth (40). Since photo-polymerized resin composites were introduced, the degree of conversion was acknowledged as vital to the clinical success of these materials (41). Photo-cured resin composites polymerize only to a certain depth. This depends on the penetration of visible light through the bulk of the material (42). It has been shown that the insufficient polymerization may lead to a decrease in the physical/mechanical (43) and biological (44) properties of resin composites.

The class of bulk-fill resin based composites revealed similar flexural strength values as the class of nanohybrid and microhybrid resin based composites, and significantly higher values when compared to flowable composites. The modulus of elasticity (Eflexural), the indentation modulus (YHU), and the Vickers hardness (HV) classify the bulk-fill compositess as between the hybrid and the flowable composites; in

terms of creep, bulk-fill and the flowable composites perform similarly, both showing a significantly lower creep resistance when compared to the nanohybrid and microhybrid resin based composites (5,45).

2.1.4. Application Techniques of Composite Resins

During the clinical applications, composite resins are generally applied to the cavities by two ways.

- Incremental techniques.
- Bulk techniques.

Layering is the standard of care for placement of dental composites in cavity preparations exceeding 2mm. This procedure is based on the desire to ensure as complete a cure as possible by virtue of sufficient exposure of the entire increment to the curing light, as well as to reduce the volume of contracting material to mitigate to some extent polymerization shrinkage stresses. Various techniques have been proposed in the literature (46, 47) and many variations on the theme can be expected.

The bulk curing of composite, considering that ample light energy was able to be transferred to the material, has been suggested for large preparations, but the evidence seems largely against this approach due to concerns over elevated stress generation and tooth deformation (48).

2.1.4.1. The potential advantages of bulk-filling

• Fewer voids may be present in the mass of material.

• The technique would be faster than placing numerous increments.

• It may be easier than placing numerous increments.

2.1.4.2. The potential disadvantages of bulk-filling

•More voids may be present in the mass of the material, since it may be difficult to control the mass placement.

• Making adequate contact areas may be challenging.

• Shrinkage stress may be more pronounced when bulk-filled than when placed in increments.

• Polymerization of resin in deep preparation locations may be inadequate.

2.2.Polymerization and Light Sources

Full polymerization of the material is determined by the degree of conversion of monomers into polymers, indicating the number of methacrylate groups that have reacted with each other during the conversion process. The factors that influence the degree of conversion of the composite are shown in Table 2 (1).

The shrinkage suffered by the composite during curing ranges from 1.35% to 7.1%. This, together with curing stress, leads to cohesion and adhesion failures, which are joined by the degree of monomer to polymer conversion as the main causes of composite resin restoration failures (1).

Shrinkage depends solely on the organic matrix and, within this, on the number of reactions that take place. It rises with the degree of conversion and falls with increasing monomer molecular weight. The manufacturers try to develop light sources that will give the greatest conversion with the least curing stress, as this helps to improve the functional and aesthetic results of composite materials; using “soft-start”

lamps (whether halogen, conventional or high intensity, or LED curing lights), which gradually increase the light intensity, is very useful for reducing composite shrinkage (49,50).

Nowadays, a number of sources for photo-initiating composite resins are available:

- Tungsten halogen lamps.
- Plasma arc lamps.
- Laser
- Light-emitting diode (LED) lights.

The most-used are tungsten halogen and LED lamps. LEDs are a promising alternative for photo-curing dental materials.

Their use in dentistry has been discussed ever since blue diodes were developed in the 1990's. Research has shown that at a 100 mW/cm2 intensity, the curing depth and the resin monomer conversion range is significantly better with an LED than with a halogen lamp (51).

Table 2: Factors that influence the composite resin polymerization process.

Factor	**Clinical repercussions**
Curing time	It depends on: resin shade, light intensity, box deep, resin thickness, curing through tooth structure, composite filling.
Shade of resin	Darker composite shades cure more slowly and less deeply than lighter shades (60 seconds at a maximum depth of 0.5 mm).
Temperature	Composite at room temperature cure more completely and rapidly.
Thickness of resin	Optimum thickness is 1-2 mm
Type of filler	Microfine composites are more difficult to cure than heavily loaded composites.
Distance between light and resin	Optimum distance < 1 mm, with the light positioned 90 degrees from the composite surface.
Light source quality	Wavelength between 400 to 500 nm. A power density about 600 mW/cm2 is required to ensure that 400 mW/cm2 reaches the first increment of composite in a posterior box.
Polymerization shrinkage	Depends on the amount of organic phase.

The LED lamps that are commercially available nowadays are very similar in power to halogen lamps (about 755 mW/cm2). Studies show that the curing light quality is not exclusively due to the intensity of the light, as initiator system absorption must also be taken into account, so the spectrum emitted is an important determining factor in the performance of a curing lamp. The camphoroquinone absorption curve covers a range from 360 to 520 nm, with a peak at 465 nm. The optimum emission spectrum of a polymerisation source therefore lies between 440 and 480 nm. In conventional curing units 95% of the light is emitted in wavelengths between 400 and 510 nm, whereas 95% of the spectrum emitted by blue LEDs lies between 440 and 500 nm with a peak at 465 nm, identical to the camphoroquinone peak, so a photon emitted by an LED curing lamp is more likely to be absorbed by the camphoroquinone than that of a halogen lamp (49).

2.3. MICROHARDNESS

The resistance of a material to indentation or penetration is called hardness (52). Most of the methods for measuring hardness consistofmaking a dent in the surface of a material with a specified force in a controlled and reproducible manner and measuring the size of the dent (52). Hardness is commonly correlated to physical properties of composite resins like mechanical strength, rigidity and resistance to intra-oral softening (53).

Hardness testing has been widely used in the study of optimum cure of composite resins and includes Knoop and Vickers hardness testing. The Knoop and Vickers tests are classified as microhardness tests in comparison with the Brinell, Rockwell macrohardness tests (54).

Hardness is commonly correlated to physical properties of composite resins like mechanical strength, rigidity and resistance to intra-oral softening (53).

The hardness of composites is influenced by several factors, for example organic matrix composition, type and amount of filler particles and degree of conversion (55).

Several direct and indirect methods can be used to evaluate the degree of polymerization of resin composites.

As the direct methods are complex and expensive, the indirect methods such as visual, scrape and hardness testing are more popular (56,57) compared four of these methods and found that the visual and scraping methods correlated well, but severely overestimated depth of cure as compared with hardness tests or a degree of conversion analysis.

The hardness tests involve the use of a static diamond tip under a specific load, over a tested material and over a specific period of time, which forms anindent after removal of the load. This indent is microscopic and in a Vickers hardness test, the shape resembles a pyramid-square shaped impression (58).

The Vickers hardness number (VHN) is calculated by dividing the load by the surface of the indentation. The lengths of the diagonals of the indentation are measured and means values are obtained and the VHN is read from a table. The limitation of this test is that it is not suitable for the measuring of materials that are resilient, as they tend to recover rendering the indentation inaccurate (54, 58).

The Knoop hardness test is the most commonly used method for the evaluation of resin composites because it minimizes the effect of elastic recovery. When the Knoop and Vickers hardness methods were compared in a study on placement techniques of composites, it was reported that both the Knoop and Vickers hardness measurements showed statistically similar results and good correlation, although Vickers values were higher: VHN = 14.7 + 0.954 x Knoop hardness number (KHN) (58).

3. MATERIALS AND METHODS

This in vitro study in which evaluating the depth of cure and surface microhardness of two bulk-fill and a microhybrid composite cured with a halogen and a LED light units was performed at the Hard Tissue Laboratory in Yeditepe University Faculty of Dentistry.

The materials used in the study are shown in Table 3 and Figure 1.

Table 3: Materials used in the Study

Brand	***Manufacturer (Lot no.)***	***Type***	***Matrix composition***	***Inorganic filler content***
Surefil SDR	Dentsply, USA (101006)	Bulk-fill Flowable Composite	TEGDMA, EBADMA	Barium borosilicate glass 68 wt%, 44 vol%
Tetric EvoCeramBulk Fill	Ivoclar Vivadent, VA, P48872	Bulk-fill Packable Composite	Bis-GMA, UDMAn,	Barium glass filler 80 wt%, 60 vol%
Filtek Z250 (CONTROL)	3M/ESPE St. Paul MN, USA (8RX)	Universal Microhibrid Composite	Bis-GMA, Bis-EMA, UDMA	zirconia 78 wt%, 60 vol%

Figure 1: Materials used in the Study

3.1. Preparation of the Samples

In the study, total of 120 specimen were prepared by using three resin based composites. Two of them were bulk-fill composites (SDR flowable Bulk-Fill and Tetric Evo-Ceram packable Bulk-Fill) and one of them was an universal microhybrid composite which was used as a control group (Filtek Z 250).

The test samples were prepared using circular polypropylene molds with a 8 mm diameter and heights of 2 and 4 mm. Each mold was put on a glass slide to obtain a smooth surface on the resin composite. A piece of black cardboard was placed under the glass slide in order to avoid light reflection from the bottom. The resin was inserted into

the different sized polypropylene molds with a single increment, completely filling the mold cavity (for each thickness, the different mold was used). To smooth the surface where the light was applied, a Mylar strip was used with a glass slide over it. The glass slide was removed prior to polymerization. The resin composite was polymerized with two different light curing units. The tungsten halogen unit used for polymerization for 20 seconds was the Optilux 501 (Kerr Corporation, Middletown, USA) light-curing unit (Fig 2). The LED curing light was Woodpecker LED (Woodpecker Medical Instrument Co, Guilin, China) was also used for polymerization for 20 seconds, in accordance with the manufacturer's recommendations (Fig 3). The thicknesses of the cured samples were measured using calipers(Absolute Coolant Proof Calliper, Mitutoyo Corp, Kawasaki, Japan) (Figures 4,5).

The upper surface of each sample was marked, because during the hardness tests, top and bottom of the samples are evaluated separately to find the hardness ratio (bottom/top ratio) of the sample.

The surfaces of the prepared samples were polished with a polishing machine (Phoenix Beta Grinder/Polisher; Buehler, Dusseldorf, Germany) (Fig 6), and stored in distilled water for 24 hours at 37°C before the microhardness test.

Figure 2: Tungsten halogen curing light

Figure 3: Light emitting diodes (LED) curing light

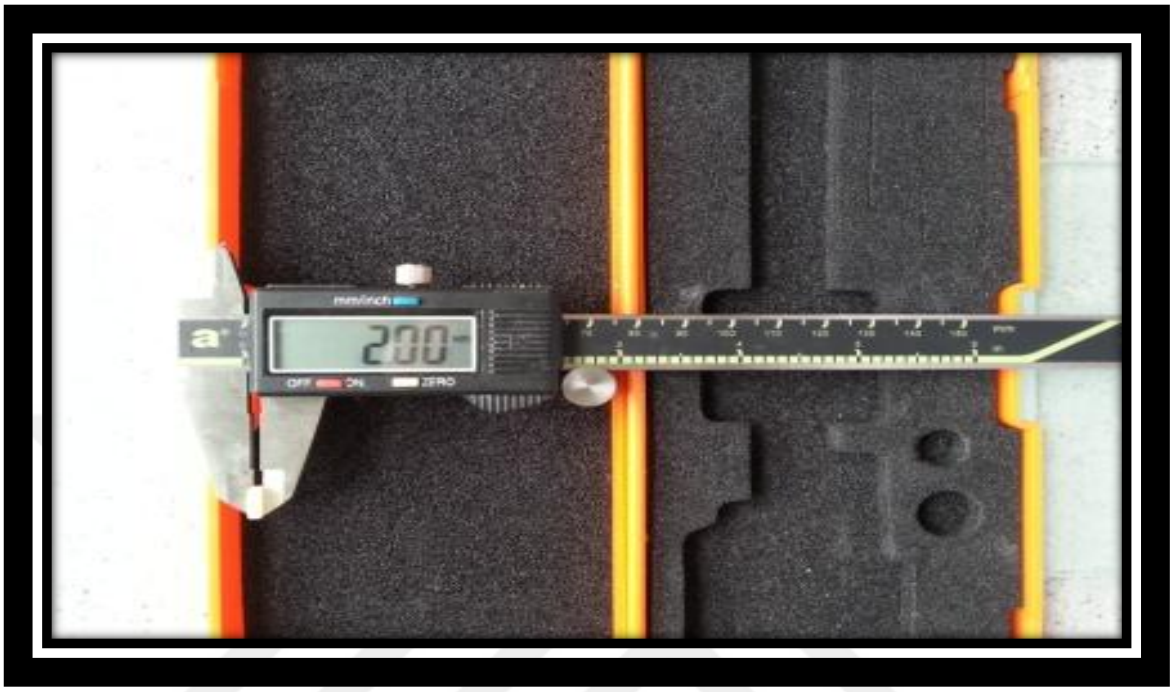

Figure 4: Measuring of the samples

Figure 5: Measuring of the samples

Figure 6: Grinding/Polishing Machine

3.2. Designing the experimental groups

Twelve groups (n=10 for each group) were designed. These groups were shown in Table 4.

Table 4: Summary of experimental groups, (number of samples, sample thicknesses and the type of cuing device used)

Groups	***Resin Based Composites***	***Sample thickness***	***Curing Device***	***Number of samples***
Group 1	SDR Flowable Bulk-Fill	2 mm	Tungsten Halogen	n = 10
Group 2	SDR Flowable Bulk-Fill	4 mm	Tungsten Halogen	n = 10
Group 3	SDR Flowable Bulk-Fill	2 mm	LED	n = 10
Group 4	SDR Flowable Bulk-Fill	4 mm	LED	n = 10
Group 5	Tetric Evo-Ceram Packable Bulk-Fill	2 mm	Tungsten Halogen	n = 10
Group 6	Tetric Evo-Ceram Packable Bulk-Fill	4 mm	Tungsten Halogen	n = 10
Group 7	Tetric Evo-Ceram Packable Bulk-Fill	2 mm	LED	n = 10
Group 8	Tetric Evo-Ceram Packable Bulk-Fill	4 mm	LED	n = 10
Group 9	Filtek Z 250 Universal	2 mm	Tungsten Halogen	n = 10
Group 10	Filtek Z 250 Universal	4 mm	Tungsten Halogen	n = 10
Group 11	Filtek Z 250 Universal	2 mm	LED	n = 10
Group 12	Filtek Z 250 Universal	4 mm	LED	n = 10

3.3. Vickers Microhardness Test

The Vickers microhardness tester (Figure 7) was assembled and connected (Model BUEHLER,USA/ number MICROMET 5114) and the reading objective of 40 X magnification was put into view.

A metal stage micrometer was placed on the stage of the microscope and the draw tube of the microscope adjusted until 0.1mm on the stage (1 block) was equal to seven and a half divisions of the fixed scale of the filar eye piece. The microscope was hence calibrated at a magnification of 75 X.

Figure 7: Vickers microhardness tester used

A test measurement using a preformed indent on the metal stage was carried out.This was done by focusing the microscope as well as the moving the stage of the microscope forwards, backwards and sideways.

The indent was adjusted next to lie between a vertical line of the fixed scale and the other vertical line of adjustable scale of the filar eyepiece.The span of the indent was consequently measured by counting the number of vertical lines of the fixed scale to denote the first digit. The other 2 digits would be noted as it appeared on the adjusting knob of the filar eyepiece.

3.3.1. Vickers Indentation of Samples

Each sample was placed on the stage of the microscope and a lower magnification of 10X was used to adjust and bring into focus the centre of the resin based composite material in the disc to identify a smooth surface, devoid of voids or other irregularities (Figures 8, 9).

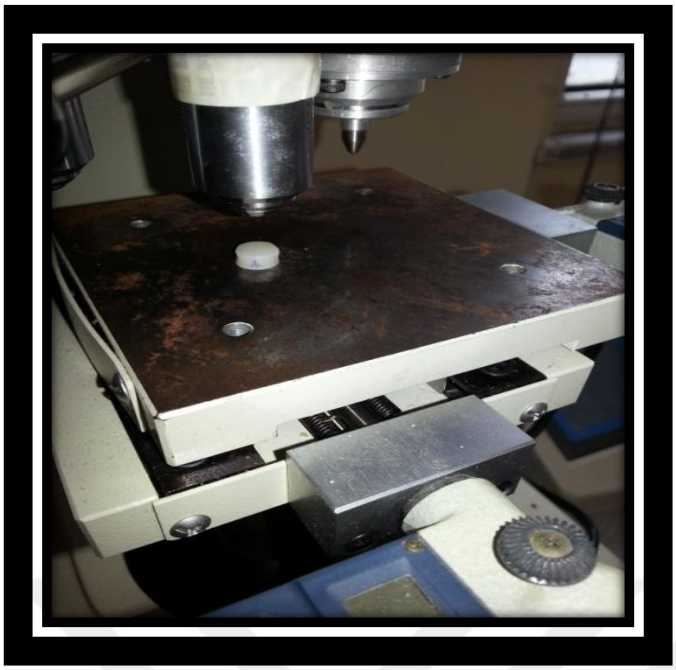

Figure 8: Bringing the surface of the sample into focus at a low magnification

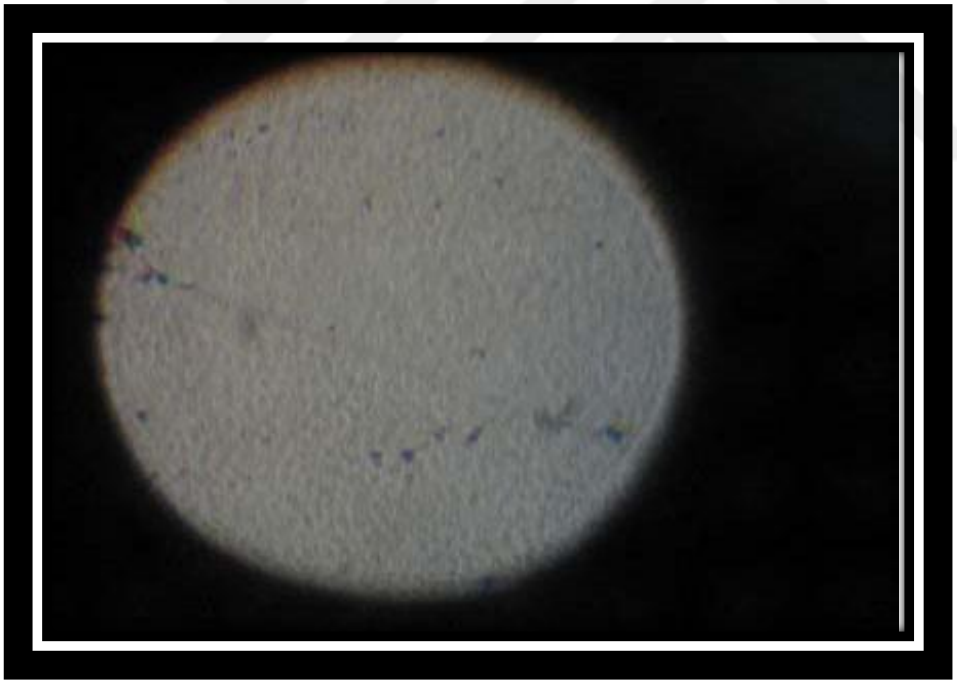

Figure 9: Identification of a smooth surface devoid of voids and other irregularities

The Vickers hardness tester was adjusted to a load of 50 g and the Vickers objective , was turned into place, above the specimen disc (Figure 10).

The lever on the main Vickers hardness tester was pushed down for 10 seconds and the duration timed accurately using a stop watch.

The activation of the lever caused an indenter on the objective to push into the resin based composite material to create the diamond shaped indent. After the 10 seconds, the lever was pushed back up releasing the indenter from the material.

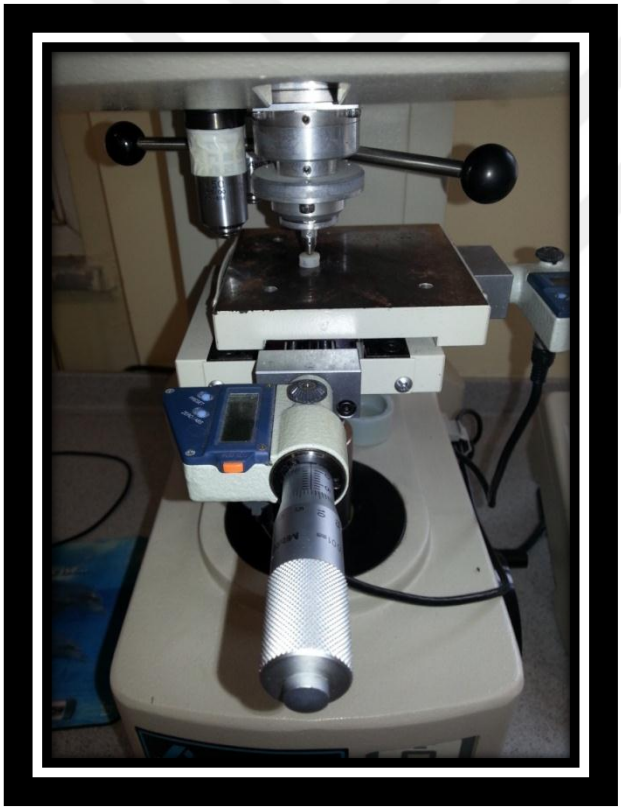

Figure 10: Vickers hardness indenter

3.3.2. Measurement of the Vickers Indents

A higher magnification objective of 40X was next put into view, since the calibration of the microscope was done at this magnification and the indent was brought into focus with the adjusting knobs. One edge of the indent was adjusted to lie against a vertical line on the fixed scale (Figure 11).

The filar eyepiece knob was adjusted to bring the movable vertical line to lie against the opposite edge of the indent, as well as lie parallel to the vertical line on the fixed scale.The number of vertical lines in between the fixed scale and movable filar lines were counted to denote the filar micrometer divisions. Each line would denote a hundredth of that number, for example two lines would mean 200. The scale on the filar eyepiece knob was then checked, which would denote the second and third digit of the readings and calculation by hardness testing machine (Figures 12,13).

A total of 3 indents were made on each side of each specimen disc, totaling 6 indents per disc/sample. Each indent were measured, the Vickers hardness number obtained and tabulated using an Excel spreadsheet.

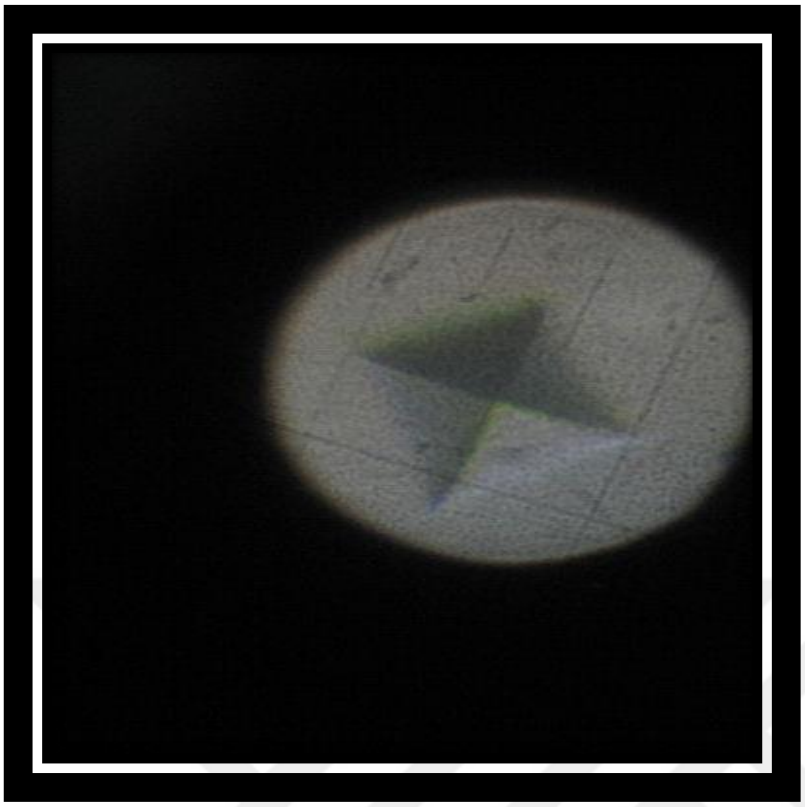

Figure 11: Focusing onto the indent.

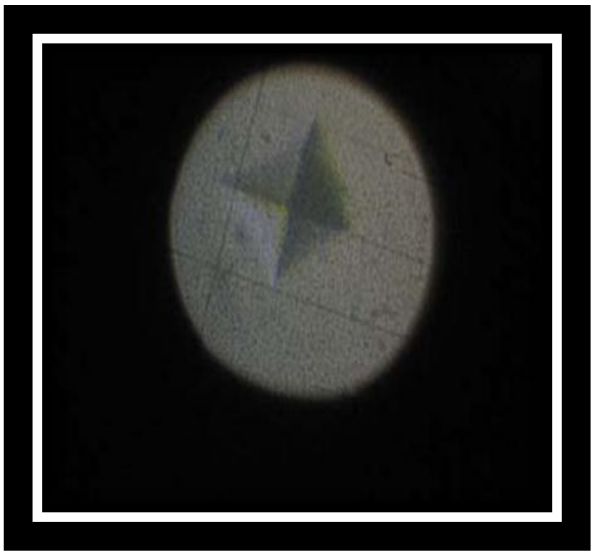

Figure 12: Example of correctly aligned indent

. **Figure 13:** Readings of the measurement

3.4. Data Analysis

The top and bottom hardness means of the materials were compared according to the experimental conditions including all composite types, two different thickness (2mm, 4 mm), and 2 different curing units. The information about upper and lower was further evaluated by the Hardness Ratio (100*Lower/Upper).

While the results of the study was evaluating, IBM SPSS Statistics 22 programme was used for statistical analysis.

In assessing the data of the study, complience of parameters to normal distrubition was evaluated by Kolmogorov-Smirnov Test, and it was observed that the parameters had normal distrubition.

Two Way Anova test was used, during the evaluation of the effect of material's type, application thickness of the material and also the type of light curing device on the hardness ratio means.

In comparison the parameters between more than two groups, One-way Anova Test; and during the determination of the group that caused the differences Tukey HDS test was used.

Also, in comparison the parameters between the two groups, Student t test was used.

Significance was evaluated on the level of $p < 0,05$.

4.RESULTS

All the results according to the experimental groups in the study, were shown in Table 5.

Table 5: Vicker's Microhardness means and standard deviation values of the sample's top and bottom surfaces and also The Hardness Ratio means of the samples.

Groups	Top surface of the samples	Bottom surface of the samples	Hardness Ratio (Bottom /Top)
Group 1 (SDR – 2 mm – Halogen)	67,28±6,5	59,16±7,5	0,88±0,09
Group 2 (SDR – 4 mm – Halogen)	59,59±7,1	49,97±2,1	0,85±0,09
Group 3 (SDR – 2 mm – LED)	72,01±4,8	55,46±7,3	0,78±0,13
Group 4 (SDR – 4 mm – LED)	78,76±8,4	59,28 ± 6,2	0,76 ± 0,11
Group 5 (Tetric – 2 mm – Halogen)	99,12 ± 9,6	74,67 ±5,2	0,76 ± 0,12
Group 6 (Tetric – 4 mm – Halogen)	84,52 ±7,0	64,30 ±8,7	0,77 ±0,18
Group 7 (Tetric – 2 mm – LED)	97,44 ±6,4	78,80 ±3,5	0,82 ±0,11
Group 8 (Tetric – 4 mm – LED)	93,94 ±6,3	66,19 ±5,2	0,72 ±0,10
Group 9 (Z 250 – 2 mm – Halogen)	178,88 ±14,2	156,70 ±13,0	0,88 ±0,07
Group 10 (Z 250 – 4 mm – Halogen)	133,58 ±10,7	67,87 ±3,4	0,52 ±0,08
Group 11 (Z 250 – 2 mm – LED)	176,66 ±14,9	136,07 ±4,6	0,78 ±0,08
Group 12 (Z 250 – 4 mm – LED)	158,12 ±9,6	74,93 ±5,7	0,48 ±0,11

Table 6: Statistical analysis of the hardness ratio means of several resin based composite materials with different thicknesses (2 mm, 4 mm) and cured with various light units (Tungsten Halogen and LED)

		SDR	**Tetric**	**Z250**	
		Hardness ratio means ± S.D.	Hardness ratio means ± S.D.	Hardness ratio means ± S.D.	p
Halogen	2 mm	0,88±0,09 (Group 1)	0,76±0,12 (Group 5)	0,88±0,07 (Group 9)	0,015*
	4 mm	0,85±0,09 (Group 2)	0,77±0,18 (Group 6)	0,52±0,08 (Group 10)	0,001**
LED	2 mm	0,78±0,13 (Group 3)	0,82±0,11 (Group 7)	0,78±0,08 (Group 11)	0,661
	4 mm	0,76±0,11 (Group 4)	0,72±0,10 (Group 8)	0,48±0,11 (Group 12)	0,001**
Oneway ANOVA test		** p<0.05*	*** p<0.01*		

When halogen light was used, statistically significant differences were found between the hardness ratio means of the materials which had 2 mm thicknesses ($p = 0,015$; $p < 0,05$). To determine which material caused the differences, post hoc Tukey HSD test was applied. According to this test, Group 5 showed significantly lower hardness ratio means from Group 1 ($p = 0,028$; $p < 0,05$) and Group 9 ($p = 0,032$; $p < 0,05$). But, there was no statistically significant differences between the hardness ratio means of Group 1 and Group 9 (Table 6) (Figure 14).

When halogen light was used, statistically significant differences were found between the hardness ratio means of the materials which had 4 mm thicknesses ($p = 0,001$; $p < 0,01$). To determine which material caused the differences, post hoc Tukey HSD test was applied. According to this test, Group 10 showed significantly lower hardness ratio means from Group 2 ($p = 0,001$; $p < 0,01$) and Group 6 ($p = 0,001$; $p < 0,01$). Also, the hardness ratio means of Group 6 was lower than Group 2, but there was no statistically significant differences between the hardness ratio means of Group 2 and Group 6 (Table 6) (Figure 14).

When LED light unit was used, no statistically significant differences were found between the hardness ratio means of the materials which had 2 mm thicknesses. Although, the hardness ratio means of Group 7 showed the highest values,there were no statistically significant differencesbetween Group 3, Group 7 and Group 11 (Table 6)(Figure 14).

When LED light unit was used,statistically significant differences were found between the hardness ratio means of the materials which had 4 mm thicknesses ($p = 0,001$; $p < 0,01$). To determine which material caused the differences, post hoc Tukey HSD test was applied. According to this test, Group 12 showed significantly lower hardness ratio means from Group 4 ($p = 0,001$; $p < 0,01$) and Group 8 ($p = 0,001$; $p < 0,01$). Also, the hardness ratio means of Group 8 was lower than Group 4, but there was no statistically significant differences between the hardness ratio means of Group 4 and Group 8 (Table 6)(Figure 14).

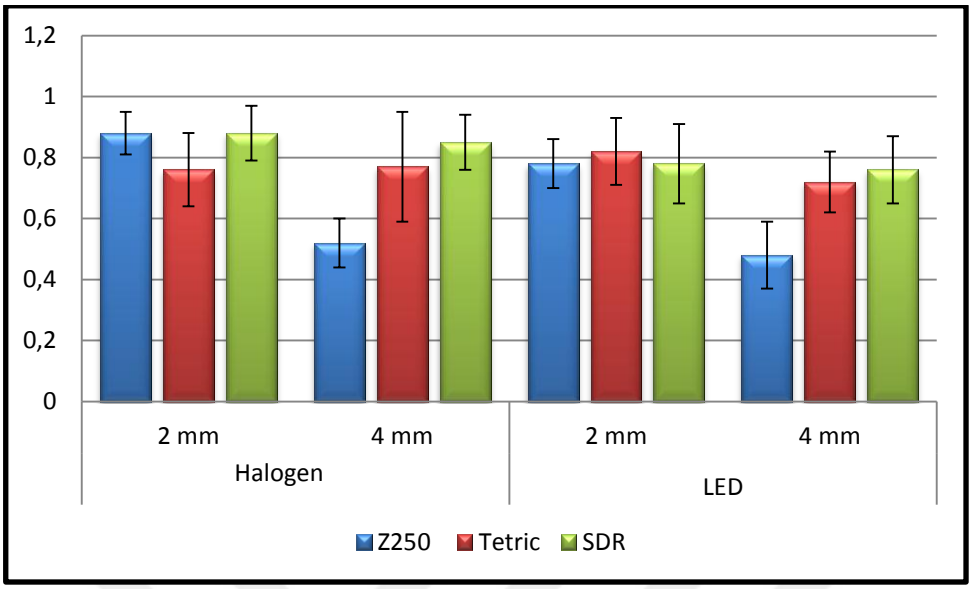

Figure 14: Showing the hardness ratio means and standard deviation of three resin based composite materials with different thicknesses (2 mm, 4 mm) and cured with two light units (Tungsten Halogen and LED).

Table 7: Evaluation of the effect of different light sources on the hardness ratio means according to used materials and thicknesses.

		Halogen	LED	
		Hardness ratio means± S.D.	Hardness ratio means ± S.D.	p
Z250	2 mm	0,88±0,07 (Group 9)	0,78±0,08 (Group 11)	0,047**
	4 mm	0,52±0,08 (Group 10)	0,48±0,11 (Group 12)	0,478
Tetric	2 mm	0,76±0,12 (Group 5)	0,82±0,11 (Group 7)	0,311
	4 mm	0,77±0,18 (Group 6)	0,72±0,10 (Group 8)	0,434
SDR	2 mm	0,88±0,09 (Group 1)	0,78±0,13 (Group 3)	0,055
	4 mm	0,85±0,09 (Group 2)	0,76±0,11 (Group 4)	0,065

Student t test *** p<0.05*

When 2 mm thickness SDR was used, there was no statistically significant difference between the hardness ratio means of Group 1 and Group 3 (p = 0,055; p > 0,05) (Table 7) (Figure 15).

When 4 mm thickness SDR was used, there was no statistically significant difference between the hardness ratio means of Group 2 and Group 4 ($p = 0,065$; $p > 0,05$) (Table 7) (Figure 15).

When 2 mm thicknessTetric Evo-Ceram Bulk-Fill was used, there was no statistically significant difference between the hardness ratio means of Group 5 and Group 7 ($p = 0,311$; $p > 0,05$) (Table 7) (Figure 15).

When 4 mm thicknessTetric Evo-Ceram Bulk-Fill was used, there was no statistically significant difference between the hardness ratio means of Group 6 and Group 8 ($p = 0,434$; $p > 0,05$) (Table 7) (Figure 15).

When 2 mm thickness Filtek Z 250 was used, the hardness ratio means of Group 9 was significantly higher than the hardness ratio means of Group 11($p = 0,047$; $p < 0,05$) (Table 7) (Figure 15).

When 4 mm thickness Filtek Z 250 was used, there was no statistically significant difference between the hardness ratio means of Group 10 and Group 12 ($p = 0,478$; $p > 0,05$) (Table 7) (Figure 15).

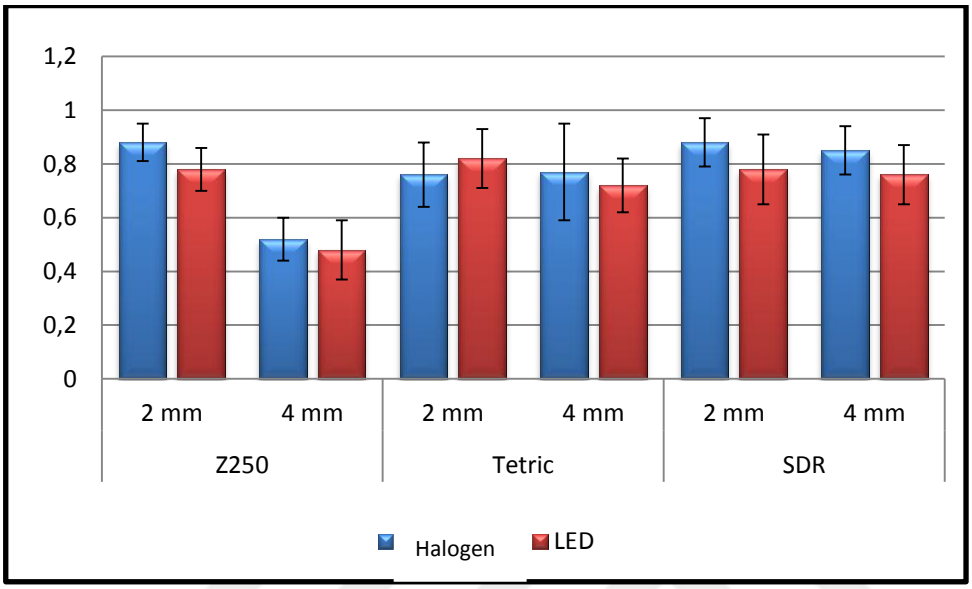

Figure 15: The effects of two different light sources on the hardness ratio means of each material applied two different thicknesses.

Table 8: Evaluation of the effect of different thicknesses on the hardness ratio means of each material cured with halogen or LED

		2 mm	4 mm	
		Hardness ratio means ± S.D.	Hardness ratio means± S.D.	p
Z250	Halogen	0,88±0,07 (Group 9)	0,52±0,08 (Group 10)	0,001**
	LED	0,78±0,08 (Group 11)	0,48±0,11 (Group 12)	0,001**
Tetric	Halogen	0,76±0,12 (Group 5)	0,77±0,18 (Group 6)	0,876
	LED	0,82±0,11 (Group 7)	0,72±0,10 (Group 8)	0,056
SDR	Halogen	0,88±0,09 (Group 1)	0,85±0,09 (Group 2)	0,447
	LED	0,78±0,13 (Group 3)	0,76±0,11 (Group 4)	0,761

Student t test *** p<0.01*

When SDR Bulk-Fill composite material cured with a halogen light, there was no statistically significant difference between the hardness ratio means of Group 1 and Group 2 (p = 0,447; p > 0,05) (Table 8) (Figure 16).

When SDR Bulk-Fill composite material cured with a LED light unit, there was no statistically significant difference between the hardness ratio means of Group 3 and Group 4 ($p = 0,761$; $p > 0,05$) (Table 8) (Figure 16).

When Tetric Evo Ceram Bulk-Fill composite material cured with a halogen light, there was no statistically significant difference between the hardness ratio means of Group 5 and Group 6 ($p = 0,876$; $p > 0,05$) (Table 8) (Figure 16).

When Tetric Evo Ceram Bulk-Fill composite material cured with a LED light unit, there was no statistically significant difference between the hardness ratio means of Group 3 and Group 4 ($p = 0,056$; $p > 0,05$) (Table 8) (Figure 16).

When Filtek Z 250 composite material cured with a halogen light, Group 9 showed statistically higher hardness ratio means than Group 10 ($p = 0,001$; $p < 0,01$) (Table 8) (Figure 16).

When Filtek Z 250 composite material cured with a LED light unit, Group 11 showed statistically higher hardness ratio means than Group 12 ($p = 0,001$; $p < 0,01$) (Table 8) (Figure 16).

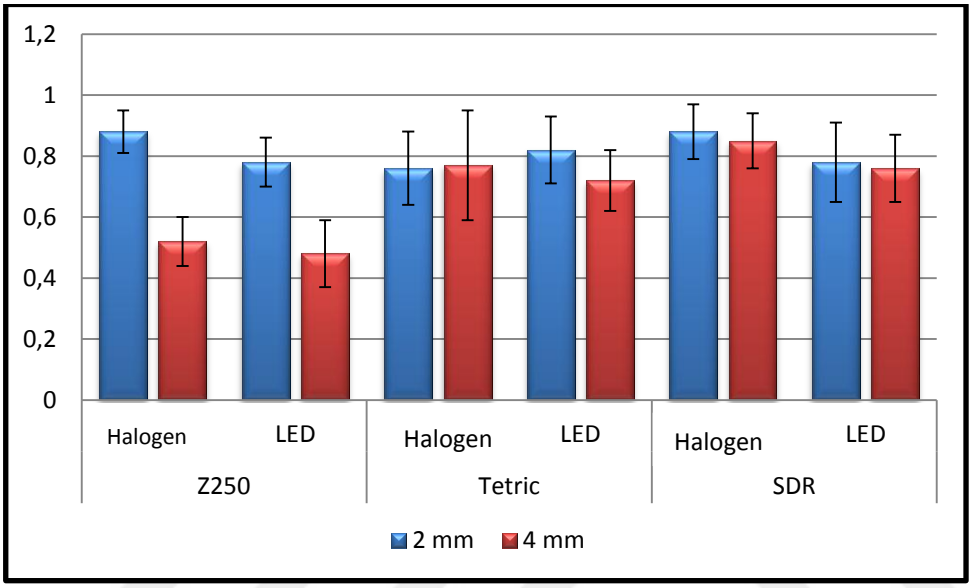

Figure 16: The effects of different thicknesses on the hardness ratio means of each material cured with halogen or LED.

5. DISCUSSION

In the previous studies, it was shown that the degree of cure of resin based composite materials is very important for the physical properties, bonding ability to dental hard tissues and also clinical success of the restorations (5,43,59-64).When bonding performance is inferior or the decreases in degree of conversion compromise physical properties, then it is possible that both initial and residual polymerization stresses lead to gap formation, microleakage, recurrent caries, pulpal irritation or may be retention loss (6,41,65-70). One of the aim of this study is to evaluate the depth of cure of visible light activated resin based composite materials.

As the clinicians are requested the resin based composites inserted into the deep cavities in a single increment quickly and easily, many manufacturers have recently introduced new types of resin composites which can be applied to the cavities with bulk-technique. For this reason, in the recent comparative studies, the application of bulk-technique and conventional incremental technique was evaluated (5,15,71-73). Second aim is to evaluate both the materials which are applied with the bulk- technique and also the application procedure.

As the effectiveness of light curing units is very important on the ideal polimerization of light cured composites, the effect of various curing devices were investigated in the previous studies (62, 67,74-81).

In addition to the type of curing device used, several factors may interfere in the polymerization depth of resin based composites, such as exposure time, resin shade, type of resin composite, quality of light emitted and location of the light (82,83).

So, the third and the last aim of the study is to evaluate the performance of different light curing units used in dental clinics, and also to compare the effects of curing units according to the type and thickness of composite used.

The studies in which clinically important points discussed independently, were contributed establishing the parameters of this study.For these reasons, in the present study, evaluation of the depth of cure and surface microhardness of two bulk-fill and a microhybrid composite cured with a halogen and a LED light units was planned.

Recently, new restorative materials have been advertised as bulk-fill composites. In light of recent marketing efforts promoting this type of composites, the clinicians and the reserchers had wondered what has changed that now allows composites to be placed in increments exceeeding 2 mm thickness. Because several disadvantages (inability to cure composite adequately to depths greater than 2 mm, challanges related to preperation design on C-factor, or the polymerization shrinkage and shrinkage-induced stress associated with composite polymerization) of bulk-filling preperations with light cured composites are recognized (84-88).

Insufficient polymerization may result in the degradation of the resin composite, poor physical properties and adverse biological reactions owing to the leaching of the monomeric components of the unset resin composite (50). There are various disadvantages associated with incremental techniques, such as incorporating voids or contamination between composite layers, failures in bonding between layers, placement difficulty owing to limited access in small cavities and an extended treatment time for placement of layers and their polymerization (89).

So, the concept of ‘bulk-filling’ a preperation has been evaluated numerous times in the literature by several investigators (5, 90-93).

Manufacturers claim that bulk-fill materials have greater depth of cure and lower polymerization shrinkage stress. In the new technology, polymerization modulators are used which are allowed a certain amount of flexibility and optimized network structure during polymerization (16,17,18).

In the recent studies, some comparable physical and mechanical properties among bulk-fill and traditional composite materialsare evaluated in terms of clinical importance (45, 94-97). In most of these studies, it was seen that SureFil SDR and Tetric Evo-Ceram Bulk Fill were used more than the others as an investigated materials (5,15,73,90,95, 97-100). So, to make a comparison with other studies' results, these two bulk fill resin based composites were evaluated in this study.

SureFil SDR flow (or SDR on the European market), is one of the first bulk-fill materials on the market, and requires an additional final capping layer made of regular resin based composites, while other materials in the same category (SonicFill, Tetric Evo Ceram Bulk Fill, andx-tra fil) can be placed without capping layer made of regular resin based composites. This different application of materials belonging to the same material class confuse many practitioners since they assume the materials' behavior would be similar.

In SureFil SDR flow, the organic matrix also contains a patent-registered urethane dimethacrylate with incorporated photoactive groups able to control polymerization kinetics (SDR technology =stress decreasing resin) (16, 101).

In Tetric EvoCeram BulkFill, the manufacturer states that, besides having a regular camphorquinone/amine initiator system, it has introduced an ‘‘initiator booster’’ (Ivocerin) able to polymerize the material in depth (18).

Because of these, SDR and Tetric Evo Ceram that introduced as bulk-fill materials with different functional properties were prefered in the study.

Filtek Z 250 which is an universal resin based composite, is prefered as a control material. It is a microhybrid composite that has acceptable mechanical and optical properties in the clinic.

Since the introduction of light-cured resin-based composites,the quality of polymerization has now become one of the great concerns of researchers. Although new light curing units are already being used clinically, there is still a need for these units to undergo laboratory testing, since insufficient polymerization of resin composites can result in restoration failures.The physical properties of resin composites polymerized by these curing units can be analyzed and studied by several means, such as microhardness tests and analysis of the degree of conversion (74-80).

The conventional curing units for light cured resin composites present several advantages. However, although the polymerization rate has improved with the newer units, the rate achieved has still not attained ideal levels. With the aim of enhancing the properties of light cured resin composites, reducing the activation time and diminishing the working time, various types of light curing units have been suggested (49,74). Currently, the dental professional has a variety of light curing units available on the market, such as conventional halogen, plasma arc, light emitting diodes (LEDs) and Argon ion laser light units.So, in the study, two of them, a conventional Tungsten halogen and a LED ligth curing devices were used to polimerize the composite samples.

One of the most frequently used indirect methods for verifying the degree of resin composite polymerization is the microhardness test (78,82, 102-104). However, the direct method of degree of conversion analysis by means of vibrational spectroscopy has also been used to verify the degree of resin composite polymerization (105,106).

Most commonly, Knoop and Vickers hardness methods have been used to determine the depth of cure of restorative materials (71,72,107,108). In this study, Vickers hardness method was used to determine the depth of cure of restorative materials used.

Recently, to define depth of cure of restorative materials based on top and bottom hardness measurements, it is common to calculate the ratio of bottom/top hardness, and give an arbitrary minimum value for this ratio. As an accepted minimum standard, many authors have claimed that a ratio of 0,80 is clinically acceptible (109-111).

Results of this study taken numerically, when the materials cured 2 mm thickness with a halogen light unit, although the hardness ratio means of SDR (Group 1) and Filtek Z 250 (Group 9)was almost the same (0,88), the hardness ratio means of Tetric Evo-Ceram Bulk fill (Group 5) showed lower means than these groups (0,76). This ratio was near the ratio of 0,80 which is clinically acceptible.

But, when the composites cured 4 mm thickness with a halogen light unit, it was shown that SDR (Group 2) had the best hardness ratio means (0,85), Tetric Evo-Ceram Bulk fill (Group 6) was the second row (0,77), and Filtek Z 250 (Group 10) showed the lowest hardness ratio means which was not clinically acceptible (0,52).

When the materials cured 2 mm thickness with a LED light unit, although the hardness ratio means of SDR (Group 3) and Filtek Z 250 (Group 11) was almost the same (0,78), the hardness ratio means of Tetric Evo-Ceram Bulk fill (Group 7) showed higher means than these groups (0,82). All the ratios were near the ratio of 0,80 which is clinically acceptible.

But, when the composites cured 4 mm thickness with a LED light unit, it was found that SDR (Group 4) had the best hardness ratio means (0,76), Tetric Evo-Ceram Bulk fill (Group 6) was the second row (0,72), and Filtek Z 250 (Group 10) showed the lowest hardness ratio means which was not acceptible clinically (0,48).

When the results of the study evaluated statistically, it has been found that, when the materials cured 2 mm thickness with a halogen light unit, Group 5 has significantly lower hardness ratio means than Groups 1 and 9.

The groups in which materials cured 4 mm thickness with a halogen light device, while the hardness ratio of Group 2 and 6 were close values to each other, and no statistically significant differences were found between these groups, Group 10 showed significantly lower hardness ratio means than Groups 2 and 6.

When the materials cured 2 mm thickness with a LED light unit, no significant differences were found between the Groups 3, 7, and 11.

The groups in which materials cured 4 mm thickness with a LED light device, while the hardness ratio of Group 4 and 8 were close values to each other, and no statistically significant differences were found between these groups, Group 12 showed significantly lower hardness ratio means than Groups 4 and 8.

In some of the studies which evaluated the bulk fill materials, were stated that the degree of cure and also the micromechanical properties were shown to remain constant within a 4 mm layer, it can be assumed that under proper polymerization conditions, a 4 mm increment placed with these materials in bulk or by using an

incremental technique would present similar properties (71,73).These outcomes, support the result of this study.

The study in which influences of increment thickness on Vickers microhardness investigated, Flury et all (15), reported that regarding microhardness at increasing depths, Filtek Supreme XTE (control material) showed the most drastic decrease along the microhardness profile and hardness ratio dropped below 80% of the maximum microhardness value at depths of 4 mm. They also noted that, while Tetric Evo Ceram Bulk Fill was showing a certain decrease in microhardness at decreasing depths, however, up to a depth of 4 and 6 mm microhardness did not drop below 80%; SDR showed no decrease in microhardness at incresing depths. Between the results of Flury et all's and the results of this study shows similarities. In this study, only SDR showed a slight decrease in microhardness means at 4 mm compared to 2 mm (15).

Due to Filtek Z 250 is an universal composite and is suitable for curing 2 mm thickness, when it was cured 4 mm with a bulk technique, both Group 10 and also Group 12 showed the lowest hardness ratio means in this study. Tsai et all (112) noted in their study, hardness at the resin surface (Z 250) was not significantly different between LED and conventional curing lights, however, below the surface, hardness reduced more rapidly for the LED lights, especially at depths beyond 3 mm. The results of this study shows the similar results of this study for Filtek Z 250 material.

In this study, also the effect of different light sources on the hardness ratio means according to used materials and thicknesses were evaluated. The LED groups showed lower hardness ratio means than the halogen light groups, except Group 5 (Group 3< Group 1; Group 4 < Group 2; Group 8 < Group 6; Group 11 < Group 9; Group 12 < Group 10; only Group 7 > Group 5).

But, according to the statistics, only the hardness ratio means of the group Filtek Z 250 cured with LED in 2 mm thickness (Group 11) showed significantly lower means from the group Filtek Z250 cured with halogen in 2 mm thickness (Group 9). No statistically significant differences were found between the other groups (Table 7).

There are lots of studies evaluating the performance of LED's with halogen lights, some of them declared that, LED's show superior results. On the other hand, some of them reported that LED showed better or similar performance with conventional curing lights (76,81,112-114).

Rueggeberg et al (81) detected that, there were no significantly differences in microhardness up to a depth of 2 mm independently of curing units in their study.

Asmussen and Peutzfeldt (76), reported that, when compared with halogen light, LED's present either similar or inferior results, depending on the properties of the light cured resin composite.These outcomes, also support the result of this study.

In addition to the type of light source used, several factors may interfere in the polymerization depth of resin composites, such as exposure time, resin shade, type of resin composite, quality of light emitted and location of the light (82,83).

6. CONCLUSIONS

1. In case, the composite materials which are recommended to be applied by incremental technique, are cured more than 2 mm thickness with a bulk technique, bottom/top ratio (hardness ratio) drops below the clinically acceptible ratio (80% of the top surface microhardness).

2. The manufacturers' indication to finish a bulk-fill restoration by adding a capping layer made of universal resin based composites is a necessity, since the top surface hardness of these materials (especially SDR) were considerably below the mean values measured of universal composite (Filtek Z 250).

3. Independently from the curing device, hardness ratio means decreased with increasing increment thickness (4 mm) for SDR, but only Group 6 (Tetric Evo-Ceram 4 mm thickness) showed higher hardness ratio means than the Group 5 (Tetric Evo-Ceram 2 mm thickness), when the halogen light used for curing.

4. All composites with 2 mm or 4 mm thickness (except Tetric Evo Ceram 2 mm) when cured with LED showed lower hardness ratio means than the materials cured with halogen light.

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