

UNIVERSITY OF THE WESTERN CAPE



***An in-vitro* evaluation of the physical properties of a new bulk-fill composite**

A mini thesis submitted in partial fulfilment of the requirements for the
degree of Master of Science in Restorative Dentistry at the Faculty of

Dentistry

University of the Western Cape.

Aziz Eltayeb

Student number: 3205028

Supervisor: Dr Naren Patel

Co-Supervisor: Dr Desi Moodley

DECLARATION

I hereby declare that, “*An in-vitro evaluation of the Physical Properties of a new Bulk-fill Composite*” is my personal work, that it has not been submitted previously in its entirety or in part for any degree or examination at any other university, and that all the sources I have used or quoted have been indicated and acknowledged by a complete list of references.



Aziz Eltayeb

October, 2017



Keywords

Composites

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Microleakage

Surface hardness



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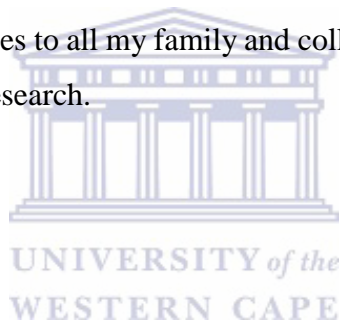
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DEDICATION

I dedicate this thesis to my parents and my lovely wife and daughter for their understanding, endless patience and encouragement when it was most required. May Allah bless them all.

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The Prophet Muhammad (peace be upon him) said: “One who treads a path in search of knowledge has his path to Paradise made easy by God...”

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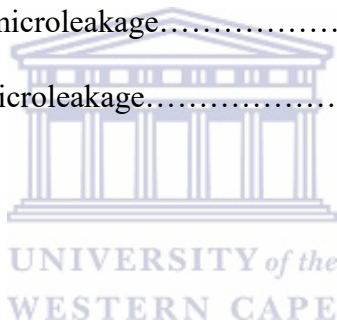
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Chapter 1

Literature Review

1.1 Introduction

Dental composite is a synthetic resin that is used as a tooth coloured restorative material in dentistry. It became the material of choice in the dental field due to its superiority in strength and aesthetics (García *et al.*, 2006). Composite resin has favourable physical properties such as high wear resistance and shade stability. The main disadvantages are as follows: polymerization shrinkage which leads to marginal leakage; discoloration of the filling; postoperative sensitivity; and recurrent caries (García *et al.*, 2006). In order to decrease the application time of incremental layering techniques in conventional resin composite restorations, bulk-fill composites were introduced to the dental market with modifications in physical and mechanical properties. BulkFill composite can be applied in a single one-step increment layer of 4 - 5mm, saving considerable time during the clinical procedure when compared to the conventional composite layering technique of 2 mm (Leprince *et al.*, 2014).

Nowadays, research has concentrated on improvement of physical and mechanical properties like polymerization shrinkage, microleakage, as well as compressive and flexural strengths, by developing the filler in both size or shape as well as in the amount of filler particles in the filling material (Kavei, 2015). Research has shown that the filler content of resin composites plays an important role in the physical and mechanical properties of a composite. An increase in filler content decreases the volume of the resin matrix for polymerization, leading to increased strength and hardness (Leprince *et al.*, 2014).

El-Damanhoury & Platt (2013) found that the decrease in the intermolecular distance from 0.3-0.4 nm to 0.15 nm which occurred during polymerization of the composite, created stresses due to the contraction of the restorative material that consequently lead to failure of the bond and an increase in microleakage of the composite restoration. Other researchers showed that a bulk-fill composite ensured better polymerization shrinkage and decreased cuspal deflection when compared with a conventional composite (Moorthy *et al.*, 2012).

In order to reduce polymerization shrinkage in a conventional composite, a Class II sandwich restoration technique was used, comprising of placement of a layer of glass ionomer cement or resin modified glass ionomer between the dentin cervical margins and the occlusal composite filling. Both materials showed a low ability to seal the margins. In recent times, flowable composites with low filler and low viscosity were suggested as liners at the cemento-enamel junction margins in Class II composite fillings to ensure better marginal integrity and reduce the incidence of microleakage, post-operative sensitivity and pulp irritation. Flowable composite materials, at the gingival floor of the cemento-enamel junction of Class II composite restorations, provide a superior marginal seal and are a better choice compared to the use of the sandwich technique (Ozgunaltay *et al.*, 2005).

Bulk fill composites are considered useful for restoration of posterior teeth due to their mechanical and physical advantages in application and ability to reduce polymerization shrinkage (Moorthy *et al.*, 2012). Recently, efforts have been directed at reducing the amount of increments for composite restorations and encouraging the use of a bulk-fill technique. Numerous manufacturers have developed bulk-fill composites, with a thickness of 4mm, superior curing and controlled polymerization shrinkage, which can be applied to the cavity.

Flowable composite resins have been marketed as cavity base materials for bulk filling technique (Czasch & Ilie, 2013). Cavity based flowable composite resins for bulk filling technique can fill the most part of the cavity in one bulk, and can reduce clinical steps and treatment time compared with conventional incremental filling. However, polymerization shrinkage is a serious problem for flowable resin composites. Flowable resin composites generally show higher polymerization shrinkage than conventional restorative resin composites. The increase of filler content in flowable resin composite is limited in order to maintain its flowability. This decrease of inorganic filler content corresponds with an increase of monomer content, leading to the increase of polymerization shrinkage. The occurrence of polymerization shrinkage in a restoration can lead to secondary caries, pulpal damage, and debonding of restorative appliances due to gap formation between restorative materials and cavity walls (Czasch & Ilie, 2013).

Jose-Luis (2010) suggested that bulk-fill composite materials should display important characteristics, namely: low polymerization shrinkage; flow-ability for good cavity adaptation; easy application with minimal handling; higher physical characteristics; increased depth of cure (minimum 4mm); and translucency to allow light transmission. Composite restorative material's translucency is considered an important visual property, which strongly affects the appearance of the composite restorative material. The light cure transmission through the resin composite is mainly influenced by the inorganic matrix (filler) size. A mismatch between refractive indices and the filler will lead to reduced translucency of the composite whereby the filler will increase light scattering in the resin filler interface and produce opaque materials (Fujita *et al.*, 2011).

1.2 History of dental composites

In order to reduce the shortcomings of the acrylic resin that replaced the silicate cement which was the only aesthetic material used in the 1940s, composite resin was introduced in the field of dentistry to enhance the bond of acrylic resin to the enamel surface of the tooth. Buonocore (1955) used orthophosphoric acid and Bowen (1963) improved the physical properties of acrylic resin by using a Bis-GMA monomer, as these monomers only permitted the formation of linear chain polymers. These chemically cured composites had a problem with proportions, the mixing process and color stability, which required the base paste to be mixed with a catalyst (Kinomoto *et al.*, 1999).

Composite material, polymerized by electromagnetic radiation, was introduced since 1970 which showed excellent properties. The blue light emitting diode (LED) lights and halogen used for curing the composite material was introduced in 1990. Kinomoto *et al.*, (1999) showed that the LED light cure provides better curing depth than the halogen light.

Leprince *et al.*, (2013) found that several factors may affect the success of the composite resin restoration. One of the most important factors is the photo-polymerization effectiveness of the composite material. Photo-polymerization of a resin composite can be defined as the reaction process in which free radicals are created by irradiation of a light sensitive initiator and exposure of the double bonds of methacrylate groups (figure 1) (Leprince *et al.*, 2013). This process occurs in three steps:-

1. Initiation: the formation of a free radical to begin the polymerization process.
2. Propagation: occurs by the radical attack on methacrylic monomers leading to chain growth of larger molecules by stabilizing the free radical.

3. Termination: designated by several mechanisms to break the polymerization progression which leads to formation of C-C double bonds (figure 2) (Leprince *et al.*, 2013).

Many factors can affect photo-polymerization. The extrinsic factors include the following: the technique of light curing; light spectrum; light guide tip setting; and irradiation procedures, while the intrinsic factors include: the photo-initiator type; percentage and the size of the filler; comonomer composition; and ratio (Leprince *et al.*, 2013).

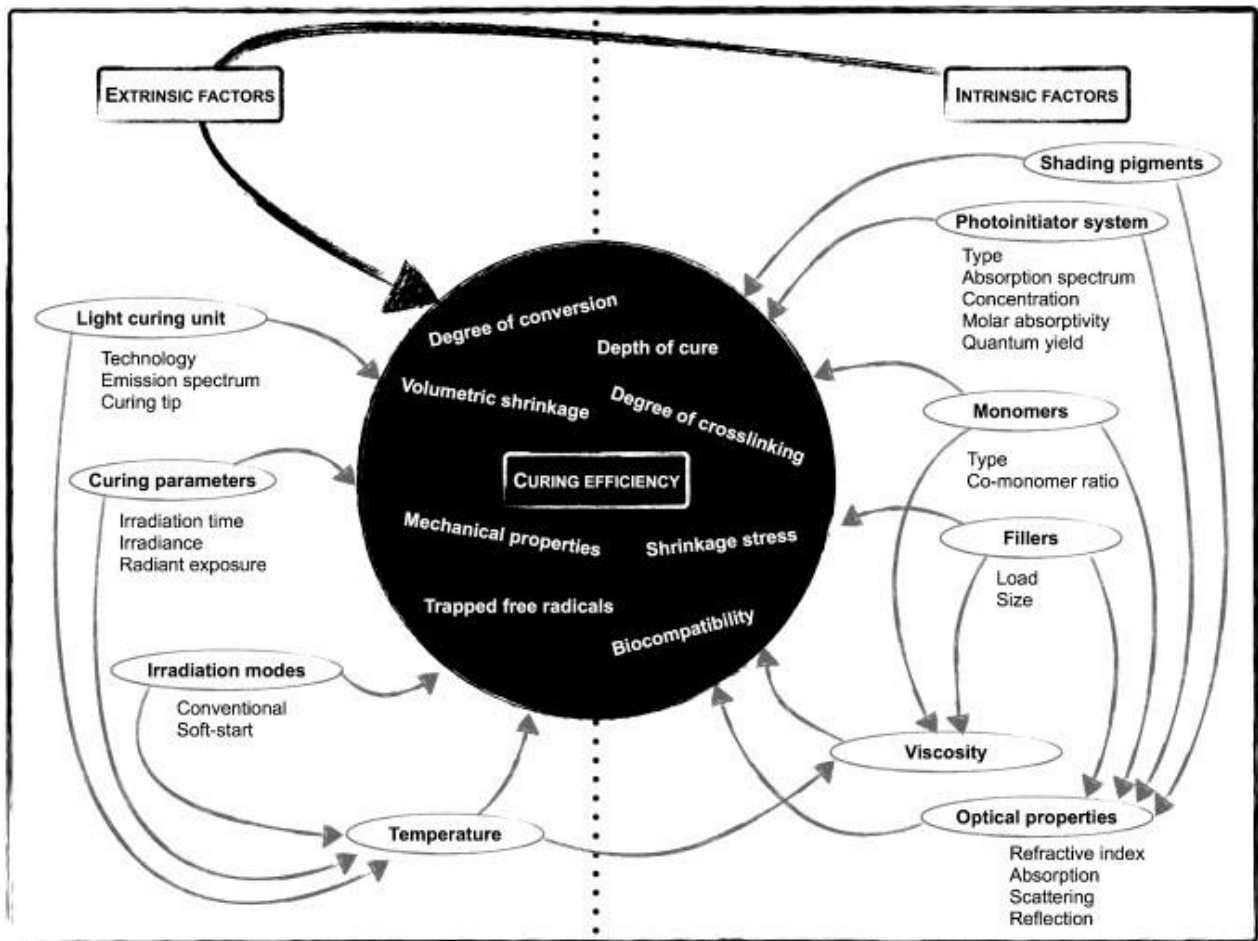


Figure 1: Diagram shows the different properties used to assess photo polymerization efficiency, and numerous extrinsic and intrinsic factors that affect the process (Leprince *et al.*, 2013).

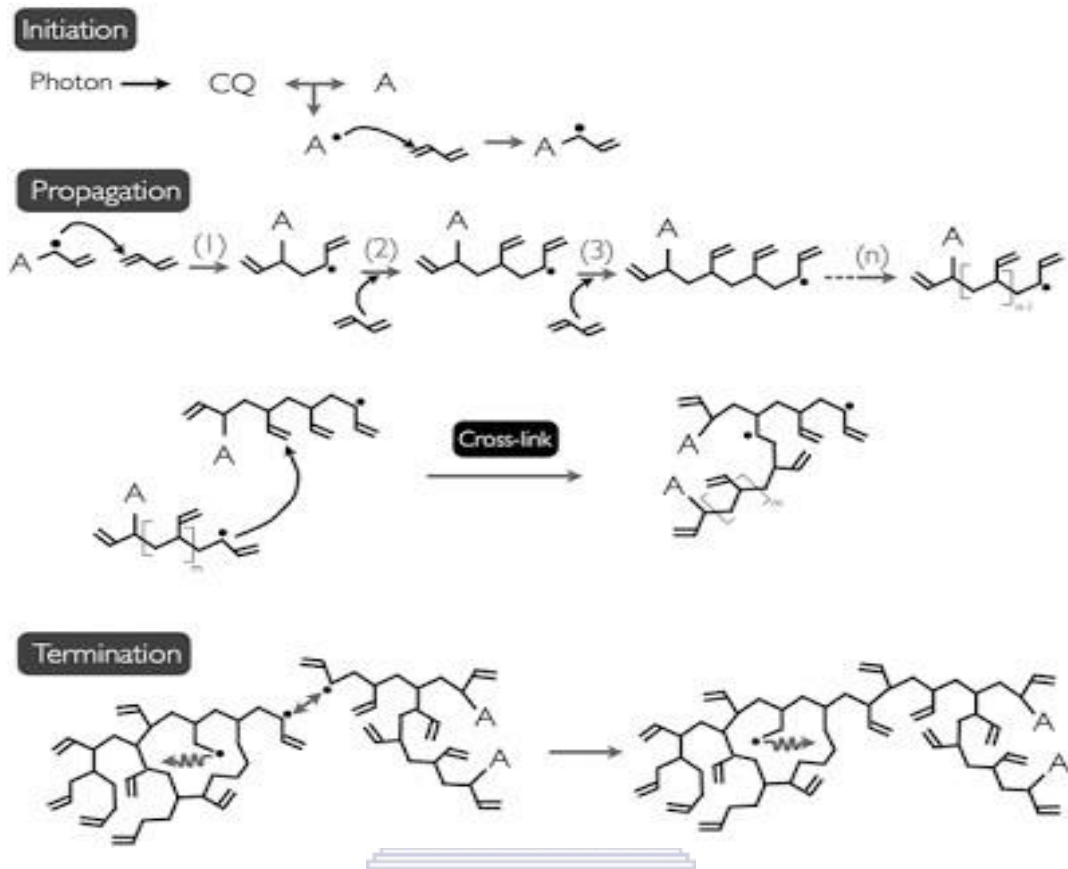


Figure 2: Diagram shows the three steps of the photo-polymerization process (Leprince *et al.*, 2013).

1.3 Constitutes of composite resin

The dental composite resin contains three chemical materials: the organic matrix or the organic phase; the inorganic matrix known as the filler or disperse phase; and the organosilane or coupling agent (Garcia, *et al.*, 2006).

Organic matrix

It is a mixture of monomers and the initiator activator system. The most commonly used monomer is Bis-GMA for composite manufacturing, which is mixed with other chemical products such as dimethacrylate (triethylene glycol dimethacrylate TEGDMA). Due to the high viscosity of the resin it can be watered down with low viscosity monomers like bisphenol A dimethacrylate (BisDMA), ethylene glycol dimethacrylate (EGDMA) and methyl methacrylate (MMA) (Ferracane, 2014). The organic matrix is also mixed with the initiator activator system which allows the polymerization reaction by releasing the free radicals. It also contains photo-initiators like camphoroquinone, the most regularly used photo-initiator, which are activated by blue specific light cures with wavelengths of approximately 470nm to cure the resin composite by releasing the free radicals. Other components like pigments and stabilizers are also found within the structure of the organic matrix (Anusavice, 2012). The physical properties of the composite material are influenced by the chemical composition of the monomers, the amount of polymerization, and the quality of the highly cross-linked network (Ferracane *et al.*, 2014).

Inorganic matrix

The inorganic matrix known as the filler system is usually added to the organic phase to give a high mechanical outcome, decrease the thermal expansion and polymerization shrinkage and improve aesthetic appearance. Fillers usually consist of silica dioxide and sometimes the quartz is changed by heavy metal particles like zinc, strontium, and zirconium (Labella, 1999). Lutz and Phillips (1983) classified the composite into three types according to the filler size, namely: macro filler composites (0.1 to 100 μ); micro filler composites (0.04 μ); and hybrid composites, which are different sized particles. Recently the resin composites that are commonly used contain filler particles, (50 - 86 %) by weight and (35 to 71 %) by volume. Flowable bulk-fill composites have

irregular and spherical shaped filler particles according to the material brand. The aim is to reduce the inter particle spacing, which increases strength, hardness and wear resistance of the resin composite by reducing the volume of the organic matrix by interlocking the smaller particles into spaces between the larger particles (Jain *et al.*,2013).

Physical and mechanical properties of resin composites are affected by filler particles (Karabela & Sideridou, 2011). The study by Fortin and Vargas (2000) showed that the chemical composition of the filler affects the structure of the composite. The mechanical properties of resin composites are generally determined by the filler component. Highly filled composites are more resistant to degradation in solvents, such as ethanol. Recently improvements have been done on resin composites by decreasing the particle size range from conventional composite to nano-hybrid composite.

Composite resin is classified according to Lutz and Phillips (1983) as follows: macro filler which contains particles from 0.1 to 100 μm ; micro filler which has 0.04 to 0.4 μm particles; and hybrids which contain different size fillers (Table 1) (Garcia, *et al.*, 2006). Another classification by Zimmerli *et al.*, (2010) classified the composite according to the matrix components (Table 2).

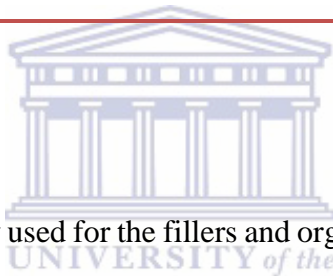
Sideridou & Karabela (2011) found that depth of cure was affected by the size of the nanocomposites, showing that depth of cure was reduced by 4% due to increased particle size from 7 to 40 nm. Ferracane *et al.*, (2014) found that large particle size lead to increased surface roughness and strength of the resin composite and decreased surface gloss.

Table 1: Classification of composites (Lutz & Phillips, 1983)

Type of Filler	Composite	Size of the particles
Macrofiller (ground silica)	Macrofilled composite	1-50 μm
	Hybrid composite	1-20 μm glass/ 0.04 μm silica
Microfiller (pyrogenic silica)	Hybrid midifilled composite	0.1-10 μm glass/ 0.04 μm silica
	Homogenous microfilled composite	0.04 μm silica
	Heterogeneous microfilled composite	Composite 0.04 μm silica Prepolymerised resin particles containing 0.04 μm silica
Microfiller-based complexes	Heterogeneous microfilled composite	0.1-2 μm glass / 0.04 μm silica

Table 2: Classification of composite according to matrix component (Zimmerli *et al.*, 2010)

MATRIX	CHEMICAL SYSTEM	GROUP
Conventional matrix	Pure Methacrylate	Hybrid composite Nano composite
Inorganic matrix	Inorganic Polycondensate	Ormocers
Acid modified methacrylate	Polar group	Compomers
Ring opening epoxide	Cationic polymerization	Silorane



Coupling agent

The coupling agent most commonly used for the fillers and organic matrix is gamma methacryloxy propyl trimethoxy silane (Labella, 1999). The quality and concentration of the inorganic matrix, the polymer complex forming monomers, and the coupling agent that links the inorganic matrix to the resin organic matrix to maintain stress transmission from the weaker polymer to the stronger inorganic matrix, have an effect on the properties of resin composites (Ferracane *et al.*, 2014).

1.4 Types of composite resin

Hybrid composite resin

This type contains an organic matrix which is reinforced by an inorganic matrix. An inorganic matrix contains different particle sizes ranging between (0.6 and 1.0) micrometer with (0.04) micrometer colloidal silica. It is widely used in the dental field. The advantages of this type are:

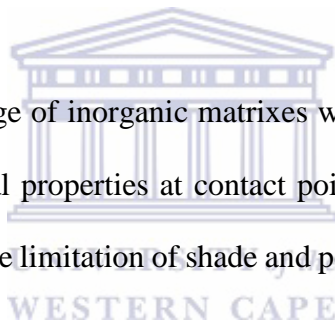
less polymerization shrinkage; low water absorption; different types of shades; good finishing and polishing; and wear resistance similar to the natural tooth (Wakefield and Kofford, 2001).

Flowable composite resin

Flowable composite is a material with low viscosity which is more fluid when compared to conventional composites. The consistency of the inorganic matrix is low. The advantages of the material are: high wettability; good attachment to all irregular tooth surfaces; wide shade selection; and high flexibility. It is usually used in class V cavities and as base liner in class I or II due to its superior marginal seal (Perdigao, *et al.*, 2004).

Condensable composite

This type contains a high percentage of inorganic matrixes which behave like silver or amalgam with good mechanical and physical properties at contact points and are usually used in class II cavities. The main disadvantages are limitation of shade and poor aesthetic appearance (Wakefield & Kofford, 2001).



Nano composite

Nano composite is defined as a multiple solid material where one of the phases has one, two or three dimensions less than 100 nm. It consists of one or more inorganic or reinforcing materials that are distributed in one organic matrix. Nano composites are classified into polymer based and non-polymer based composites. Polymer- based nano composites are more unique due to their excellent properties (Ferracane, 2011).

Recently dental companies produced composites with a combination of nanomer-sized particles and nano-cluster formulations that resulted in a reduction of the interstitial space of the inorganic filler matrix. The strong bond between filler and matrix created by the silane coupling agent and

the use of finer inorganic particles, resulted in good physical and mechanical properties (Ilie & Hickel, 2009).

The main advantages of nano composite material are superior polishing, wear resistance, low polymerization shrinkage, highly translucency and thermal stability (Ilie & Hickel, 2009).

Bulk-fill Composites

The new composite technology allows directly placed posterior restorations with bulk-fill resin bonded composites to be placed in single increments. Bulk-fill composite products have been introduced to the dental market as packable or condensable composites. The condensable composites have higher viscosity, do not stick to the dental instruments like the conventional composites and can be packed into the cavities without slumping (Leinfelder *et al.*, 1999).

Bulk-fill composites are designed to decrease chairside time by application of a single increment of the material. It is also intended to minimize the shrinkage and the resulting stress by using the same exposure time and light intensity used for the normal conventional composites, which can be achieved by decreasing the filler content (Bulk-fill flowable composites resin), changing the filler matrix structure to increase the translucency or by changing the photoinitiator scheme (Ferracane *et al.*, 2014). The main advantage of the bulk-fill composites is that they can be placed in larger increments (Christensen, 2012). Bulk-fill composites, when compared with conventional composites packed in an oblique incremental layering technique, showed less cuspal deflection.

The marginal integrity evaluation of bulk-fill composites showed better marginal integrity than conventional composites (Alrahlah *et al.*, 2014).

The basic properties of bulk-fill composite resins are: reduced polymerization shrinkage which diminishes the chance of failure due to microleakage; a reasonable depth of cure up to 4-5 mm; and the ability to be placed in larger increments (Leinfelder *et al.*, 1999).

The main drawbacks associated with the conventional layering technique of composites are as follows: bonding failure; contamination of the composite layers; difficulty to access the small cavities leading to difficulty during composite placement; and more time required to place the composite in increments (Alrahlah *et al.*, 2014).

Some bulk-fill resin composites chemically contain ceramic fibre combined with an elongated filler complex which is about 100nm in length (Rao Kilaru, 2012). This chemical complexity improved the composite depth of cure up to 5mm. It is mainly composed of light activated, dimethacrylate resins with a higher ratio of irregular fillers. The bulk-fill composites contain a high filler percentage, which varies from 60-80% by volume (Fortin & Vargas, 2000). The main disadvantage of the bulk-fill resin composite is shrinkage stress. Bulk fill composite polymerization may be inadequate in the case of a very deep cavity, resulting in poor contact areas (Fortin & Vargas, 2000).

Ratios of filler in the bulk-fill resin composites were found to be higher than conventional composites (Garcia, 2006). Bulk-fill composites' advantages are: fewer voids due to application of the material into the cavity in one step; time saving because there is no need to place the bulkfill composite in increments as in the layering technique; interlocking particle technology, which is one of the main advantages of the bulk-fill composites in which mixtures of different sized filler particles are found; and mechanical interlock which takes place when large particles are packed together with small particles (Christensen, 2012).

Bulk-fill composites are classified into high viscosity and low viscosity composites. The high viscosity composites include larger amounts of filler particles when compared to the low viscosity type. The low viscosity type has better adaptation to the cavity but shows higher polymerization shrinkage and lower mechanical properties when compared to the high viscosity type. For this reason it is suggested that a high viscosity type should be applied with a 2mm thickness when restoring areas that are exposed to high occlusal stresses (Dionysopoulos *et al.*, 2016).

In a previous study by El-Safty *et al.*, (2012), bulk-fill composites, conventional composites and flowable composites were compared. The conventional resin composites showed greater surface hardness and modulus of elasticity. Leprince *et al.*, (2014) found that bulk-fill composites had higher mechanical properties when compared to the conventional composites. Ferracane *et al.*, (2014) found that the mechanical properties of bulk-fill composites behave like the conventional composites or worse, even when cured at 2mm increments.

Denser increments of bulk-fill composites are due to improvement of photo-initiator dynamics and increased translucency which lead to extra light penetration allowing deeper cure of the bulk-fill composite. Besides the recent improvement in the depth of cure, bulk-fill composites show lower polymerization shrinkage, stress and contraction rates than other types of hybrid and flowable composites. With bulk-fill composites it is difficult to predict marginal gaps and cuspal deflection due to the high modulus of elasticity (Ilie & Hickel, 2011).

Recently, a new bulk fill composite material, SonicFill™ 2, was launched for posterior dental restorations. The Sonic Fill™ 2 system allows the dentists to complete dental restorations in a onestep technique that is meant to offer a reliable bulk restorative filling (Kachalia *et al.*, 2011). Sonic Fill™ 2 shows perfect adaptation during placement of restorative material, gives great depth

of curing, and shows low polymerization shrinkage as well as high strength properties and aesthetic dental restorations and it can be used up to 5mm as a single increment (Kachalia *et al.*, 2011).

The SonicFill™ 2 composite combines a highly filled proprietary resin with superior modifiers that respond to sonic energy. The sonic energy is applied by the hand-piece. The modifier leads to a decrease in the viscosity (to 84%) and after the sonic energy has stopped, the composite becomes viscous and non-slumping, which facilitates carving and contouring of the material (Kachalia *et al.*, 2011).

1.5 Activation of Resin Composites

In the past composite was chemically cured by mixing two pastes. The first paste contained the aromatic tertiary amine activator (N, N-dimethyl-p-toluidine) and the second paste contained the benzoyl peroxide initiator. This technique had many disadvantages: the working and finishing time was uncontrolled and the possibility of discoloration of the chemically cured composite existed. A new activated light curing system was presented in the 1970s, with a wavelength of 365 nm and polymerization only started when the composite was activated by (UV) light. The light from the curing system split the benzoin methyl ether into free radicals. This process occurred without the tertiary amine activation (Neeraj Malhotra & Mala, 2010).

Problems associated with the (UV) light are: damaging of the eye, soft tissue burns and poor penetration of the light through the tooth structure to complete curing of the filling. Due to these disadvantages the UV light cure system was changed to a visible blue light cure activated system (Neeraj Malhotra & Mala, 2010). The most commonly used photo-initiator is a combination of camphoroquinone which is sensitive to light with a wave-length of about 420-490nm and a source of free radicals which is essential for the curing process with a co-initiator or an electron donor which are generally different types of tertiary amines (Neeraj Malhotra & Mala, 2010).

While the camphorquinone is used as standard light photo-initiator, there are other photo-initiators which absorb light at shorter wavelengths. Camphorquinone reactivity was developed by the addition of an amine-reducing agent such as dimethylamino ethylmethacrylate (DMAEMA), ethyl-4-dimethylaminobenzoate (EDMAB), and N-cyanoethyl-methylaniline (CEMA). Camphorquinone and amine concentrations differ according to the manufacturers of the composite materials usually found in a range of 0.2-1.2 by weight. An alternative photo-initiator that can be used is 1- phenyl-1, 2-propanedione (PPD) with a high absorption peak of 410nm (Uhl, Mills & Jandt, 2003). The photo-initiator system in bulk-fill resin composites is camphorquinone, like the conventional resin composite, except for Tetric N Ceram (Ivoclar Vivadent), which contains a new photo-initiator known as Ivocerin (figure 3) (Moszner *et al.*, 2013).

Ivocerin increases the depth of cure due to its high absorption of light and was reported to be better than camphorquinone (Moszner, 2013). In the polymerization process the Ivocerin photoinitiator allows two radicals to start the polymerization compared to only one radical in camphorquinone, which makes it more effective to initiate polymerization (Ilie & Stark, 2014).

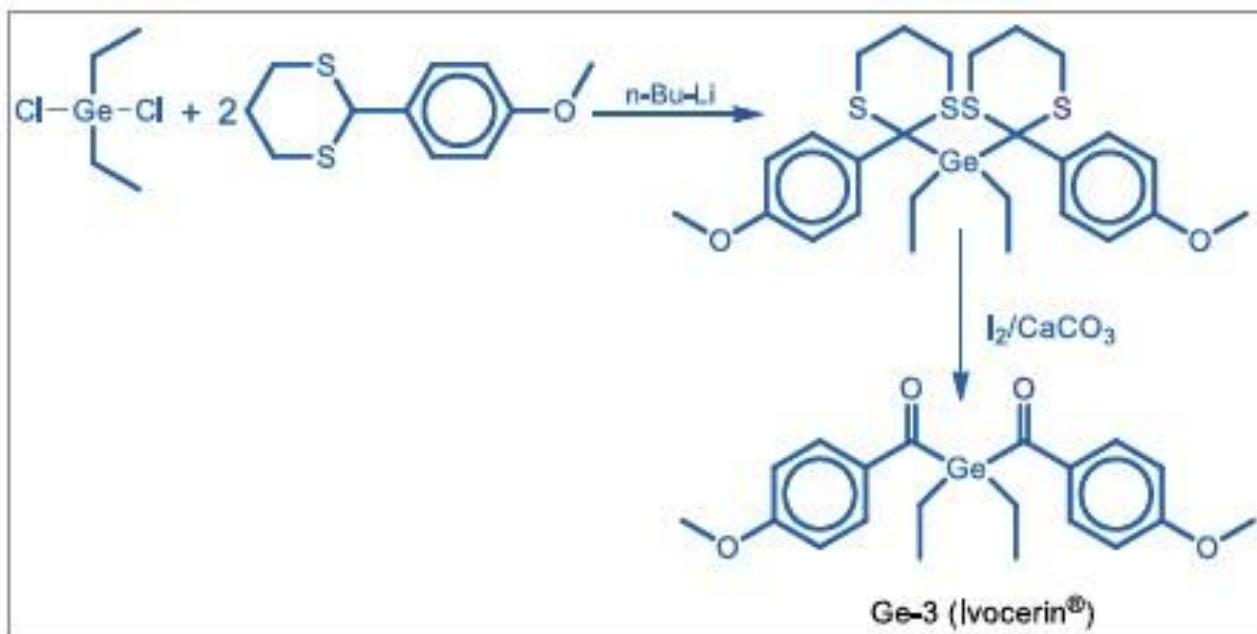


Figure 3: Ivocerin with formation of two free radicals (Moszner, 2013)



1.6 Depth of curing and micro-hardness

Depth of cure is defined as the maximum thickness of each cured composite layer (Leprince *et al.*, 2013). The problems with photo-polymerized resin composites are insufficient depth of curing and monomer conversion. The visible light extends through the photo-cured composite resin which controls the depth of curing. The amount of light output that extends to the photoinitiator limits the depth of curing (Alrahlah *et al.*, 2014). An increase in the thickness of the material results in a decrease in the depth of cure. This affects the mechanical properties of the composite and leads to release of monomers that affect the soft tissue (Moore *et al.*, 2008).

Many factors affect the depth of cure, for example: the type of resin composite and its shade; the thickness of the increment or layers; distance of the tip of the light from the material; the

wavelength of the curing light used for polymerization; and its intensity and irradiation type (Alrahlah *et al.*, 2014).

A previous study showed that the use of an incremental layering technique with a 2mm thickness reduced the polymerization shrinkage and resulted in a suitable depth of cure (Abbas *et al.*, 2003). However, the use of layering or incremental techniques has disadvantages which include the following: contamination between composite layers; microleakage; difficulties with handling and placement of the material in the small cavities; and it is time consuming. Bulk-fill composites are meant to overcome the disadvantages and allow packing of the material in 4-5mm thickness (Abbas *et al.*, 2003).

Microhardness, visual inspection and the penetrometer technique are the indirect methods commonly used to measure depth of cure. Anusavice (2013) defined micro-hardness as the resistance to indentation, while Poskus *et al* (2004) described micro-hardness as the resistance to long-lasting deformation which is only produced by indentation after load. Organic matrix composition, filler type and particle size play a major role in affecting the micro-hardness of a composite (Correr & Sinhoreti 2005). The micro-hardness of composites has been used to assess the effectiveness of the light cure and extent of polymerization indirectly (Alrahlah *et al.*, 2014).

Additional techniques include measuring the hardness of the top and bottom of the composite specimen surfaces, the degree of conversion and visual microscopy where there is an optical margin between cured and uncured composite resin. The International Organization for Standardization (ISO 4049) presented the protocol for studying the depth of curing of composite resin. In this process a cylindrical mould is used which is filled with the material to be tested and light cured, and the uncured material at the bottom surface is scraped away. The length of the residual cured composite is then measured (Flury *et al.*, 2012).

Choi *et al.*, (2000) stated that composite resin, when tested in layers greater than 2 mm thickness, showed no acceptable depth of cure and the polymerization shrinkage of the packable composites was related to or greater than the normal composites. Another study showed that sufficient cure of the bulk-fill composites varied between 2.5-3.5 mm (Choi *et al.*, 2000). The depth of cure of bulkfill composite resin was shown to be significantly greater than other conventional dental composites (Manhart *et al.*, 2000).

1.7 Microleakage of composites

Microleakage is defined as the clinically detectable passage of bacteria, fluids, molecules or ions between a cavity wall and the restorative materials, most commonly due to shrinkage, which is one of the main problems in clinical dentistry (Radhika *et al.*, 2010). The main disadvantage of composite shrinkage is formation of the gap between the filling material and tooth cavity which leads to microleakage, thus allowing a path for microorganisms and oral fluids, resulting in postoperative sensitivity, pulpal irritation, and secondary caries (Going,1972) .

Different techniques were suggested to reduce the shrinkage in composites, which include use of a resin liner before placing the composite restoration, use of the incremental technique and by increasing the filler volume (Ymazaki *et al.*, 2006).

Microleakage evaluation is the most common technique for evaluating the sealing efficiency of a restorative material. There is no gold standard for this method which is usually done by staining with 1% methylene blue for 24 hours (Blackwood *et al.*, 2002). Gogna *et al.*, (2011) showed that loading of the material did not affect microleakage outcomes when using the bulk filling technique, because the internal stresses established when the resin composite is positioned in bulk are already

high and the fatigue applied in the restoration interface did not lead to a higher degree of leakage (Gogna *et al.*, 2011).

Some studies showed that bulk -fill materials have the ability to adapt to cavity walls especially at the cervical margins apical to the cemento-enamel junction. These bulk-fill materials are appropriate for applying 4 mm bulk of material in one step due to their low polymerization stress and high reactivity when curing. Poggio *et al* (2013) found that bulk-fill restorative material with a 4mm thickness must be covered by a single layer of standard composite. El-Damanhoury *et al* (2013) found that during the polymerization process, the volumetric shrinkage of the composite with the active bonding to tooth dentin resulted in excessive stress transfer which leads to internal deformation on the walls of the cavity. Therefore, the incremental technique used to fill the cavity leads to less stress generation on the cavity walls and thus the incremental technique is normally considered the most appropriate placement technique. Patel *et al* (2016) found that bulk-fill composites guarantee suitable marginal adaptation on the tooth enamel, but not on dentin and cementum.

Geerts *et al* (2010) found that thermo-cycling was the only test that can be performed *in vitro* for stimulating thermal stress between the filling and the tooth cavity. Thermo-cycling is a hydrolytic and thermal combination test that simulates the temperature of the tooth cavity through rapid changes in temperature (Souza *et al.*, 2010).

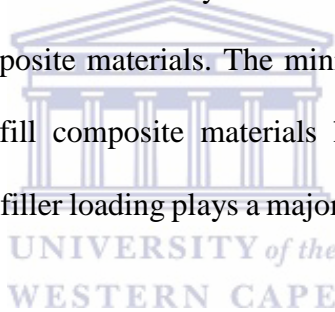
1.8 Flexural strength

Anusavice *et al.*, (2013) defined flexural strength as the amount of force per unit area at the instant of fracture in a sample subjected to flexural loading. Flexural strength shows the longevity of the composite restoration against the mastication pressure and occlusal force, and is important because the ISO usually use the flexural strength test for screening the resin based materials. The bulk-fill

composite shows high flexural strength (above the minimal requirement of the ISO standard) when compared with a conventional composite (Didem & Oztas, 2014).

Mechanical properties are very important in determining the superiority of the material, which include: compressive and diametric tensile strength; fatigue resistance; and flexural strength. Flexural strength is the most substantial mechanical property of the material because in the flexural strength test the material is subjected to tension, shear load and compression, simulating the load in the oral cavity during mastication (Anusavice, 1993).

Flexural strength controls the permanency of a composite restoration against mastication and occlusal forces. The flexural strength test is used by the ISO for determination of the mechanical properties in the screening of composite materials. The minimal flexural strength should be 80 MPa (Julian *et al.*, 2014). Bulk fill composite materials have higher flexural strength than conventional composites, while the filler loading plays a major role in the determination of flexural strength (Julian *et al.*, 2014).



There is a direct connection between the flexural strength and the filler loading by weight, the higher the filler volume the greater the composite mechanical properties. Didem & Oztas (2014) found that high flexural and compressive strength was related to high amounts of filler volume in the material. The flexural strength determines the fracture resistance of bulk-fill materials, which shows defects in materials which may have a possibility of failure after subjected to occlusal load (Rodrigues *et al.*, 2008). The flexural strength test is used to assess the strength of the bulk-fill materials and the extent of alteration expected under bending stress. Of the several mechanical properties, flexural strength is important because bulk-fill materials replace a bulky area when used in cavity fillings. Flexural strength ensures resistance of bulk-fill composite materials to

compressive and tensile forces created by intraoral function and parafunction (Jyanthi & Vinod, 2013).



Chapter 2 Aims and Objectives

2.1 Aims

The aim of this study was to evaluate and compare the flexural strength, surface hardness and microleakage of three bulk-fill composites.

2.2 Objectives

1. To determine and compare the surface hardness of three bulk-fill composite namely SonicFill™ 2 (Kerr), Filtek bulk-fill (3M ESPE), and TetricN Ceram Bulk-Fill (Ivoclar Vivadent) composite materials, based on the top and bottom surface micro-hardness using an LED Curing Light (3M™ Elipar™ DeepCure-S LED Curing Light).
2. To evaluate and compare the depth of cure of three bulk-fill composite namely SonicFill™ 2 (Kerr), Filtek bulk-fill (3M ESPE), and Tetric N Ceram Bulk-Fill (Ivoclar Vivadent) composite materials.
3. To evaluate and compare the flexural strength of SonicFill™ 2 (Kerr), Filtek bulk-fill (3M ESPE), and Tetric N Ceram Bulk-Fill (Ivoclar Vivadent) composite materials.
4. To evaluate and compare the microleakage of SonicFill™ 2 (Kerr), Filtek bulk-fill (3M ESPE), and Tetric N Ceram Bulk-Fill (Ivoclar Vivadent) composite materials.

2.3 Null hypothesis

There is no difference in the depth of cure, polymerization shrinkage and microleakage between SonicFill™ 2 (Kerr), Filtek bulk-fill (3M ESPE) and Tetric N Ceram Bulk- Fill (Ivoclar Vivadent).

2.4 Ethical considerations

The study was presented to the Dental Research and Senate Research Ethics committees of the University of the Western Cape for approval and permission to conduct the study (Ethics Reference Number BM/16/3/30). Patient consent was sought from patients who attended the Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, UWC. Teeth meant for routine extractions were used in this study and all patients were informed using consent forms and patient information sheet. No financial or personal gain will be received from this study. There was no vested interest in any of the materials used.

Extracted teeth were collected from the Department of Oral and Maxillofacial Surgery. After the study the teeth were placed in a hazardous waste container for biomedical waste.

2.5 Conflict of interest statement

No conflict of interest was declared.

Chapter 3

Review of the Materials

3.1 Filtek Bulk- Fill (3M ESPE)

Filtek bulk-fill posterior restorative material is a light-cure activated, visible, radiopaque restorative composite for posterior restorations and according to the manufacturer the material shows high strength and low amounts of wear and shrinkage. The material enables up to 5mm depth of cure with a good polish surface. The material can be used for direct anterior and posterior restoration, splinting, core build up and indirect restoration such as inlays, onlays and veneers. The composition of the filtek bulk-fill composite comprises aromatic dimethacrylate (AUDMA), nonagglomerated 20 nm silica filler, non-agglomerated 4 - 11 nm zirconia filler and a ytterbium trifluoride filler comprising agglomerate 100 nm particles, and 76.5% inorganic filler by weight. Flexural strength of Filtek™ Bulk Fill Posterior composite is high when compared to other bulkfill materials. Table 3 shows the chemical composition provided by the manufacturer.

3.2 Tetric N Ceram (Ivoclar Vivadent)

Tetric N Ceram is a nano-hybrid bulk-fill composite considered as a bulk-filling restorative material for posterior restorations which is applied in one increment and allows up to 4mm in thickness. This material contains a light activator, Ivocerin, which allows complete cure of the material. Tetric N-Ceram includes different types of filler (barium aluminium silicate glass with two different mean particle sizes, an Isofiller, Ytterbium fluoride and spherical mixed oxide) in

order to comply with the standard properties for composite restorative material. Ivocerin allows the material to absorb the maximum amount of the blue light range from around 370 to 460 nm. The new photoinitiator, Ivocerin (in Tetric N Ceram) works with camphorquinone and 2, 4, 6 trimethyl benzoyl diphenylphosphine oxide, to provide the required depth of cure and to increase the material properties (Vogel, 2013). Tetric N Ceram contains filler, 75% by weight and 53% by volume. Table 3 shows the chemical composition provided by the manufacturer.

3.3 SonicFill™ Sonic 2 (Kerr)

Sonic Fill™ 2 contains a new filler system which is a nano-scale zirconium oxide with silica oxide particles which provides colour matching, wear resistance and strength. The new Sonic Fill™ 2 allows curing up to 5mm on a single step composite posterior restoration. The material has low shrinkage stress. The viscosity of the material is reduced by 84% optimally which is applied by an air driven hand-piece with sonic vibration. This produces good adaptation, while the mechanical and physical properties of the material show high flexural strength and fracture toughness. Table 3 shows the chemical composition provided by the manufacturer.

Table 3: Composition of composites provided by manufacturers

Property	Filtek Bulk-fill	Sonic Fill™ 2	Tetric N Ceram
Filler level wt%	76.5%	83.5%	75%
Filler level vol%	58.4%	83.5%	53%
Filler type	Zirconia/silica, Ytterbium trifluoride	SiO ₂ , glass, oxide	Barium aluminium silicate glass, Ytterbium fluoride, spherical mixed oxide
Resin matrix type	AUDMA, BIS- CMA, UDMA, BISEMA	Bis-GMA, TEGDMA	BIS-GMA, UDMA, BIS-EMA
Compressive strength (MPa)	390	253.6	203
Flexural strength (MPa)	154	163.47	135.16
Tensile strength (MPa)	79	87	
Depth of cure	5mm	5mm	5mm

Chapter 4 Materials and methods

4.1. Study design

This was an *in-vitro* study to test and compare the depth of cure, flexural strength and degree of microleakage of three bulk-fill composite materials.

4.2. Materials

Three types of Bulk-Fill materials were used in this study, namely SonicFill™2 (figure 4), Filtek Bulk-Fill (figure 5), and Tetric N Ceram Bulk-Fill (figure 6).



Figure 4: SonicFill™2 (Kerr)



Figure 5: Filtek bulk-fill (3M ESPE)



Figure 6: Tetric N Ceram Bulk-Fill (Ivoclar Vivadent)

4.3 Methodology

A. Evaluation of depth of cure

The methodology of the study included five steps and preparation according to ISO 4049 for depth of cure determination (ADA, 2003).

Light cure setting → Preparation of composite bulk-fill specimens → curing the composite specimens → Vickers hardness machine setting and Indentation of composites → Measurement of the Vickers hardness after 24hrs for the top and bottom surfaces.

Light cure setting

The light cure used in this study was 3M™ Elipar™ DeepCure-S LED Curing Light (figure 7).

According to the manufacturer, the light cure wavelength is 430–480 nm, the light intensity of the Elipar is 1,470 mW/cm² and the power source is a Lithium-ion battery with 120 min battery life (~720 10-sec. cures) with constant light output.



Figure 7: 3M™ Elipar™ DeepCure-S LED Curing Light

Preparation of composite bulk-fill specimens

Thirty specimens were used in this study, divided into three groups with ten specimens of each type of bulk-fill composite (n=10). A Teflon cylinder-shaped mould with a central cavity, 6mm in diameter and 4mm in thickness, was prepared. The cylindrical mould was placed on a Mylar strip (3M ESPE) resting on a transparent glass slab. The mould was filled with the three types of bulk-fill composites placed directly into the cavity of the mould using a flat plastic instrument. The first group of ten specimens was filled with SonicFill 2 which was injected into the mould

cavity using sonic energy that was applied through the hand-piece (figure 8) and excess material was removed with a plastic instrument from the entrance of the mould.



Figure 8: Sonic fill hand-piece

The second group was filled with Filtek™ Bulk Fill and the third group was filled with Tetric N Ceram directly into the cavity of the mould using a flat plastic instrument. The excess material was removed from the entrance of the mould with a plastic instrument (figure 9).



Figure 9: Material after filled within the mould



Curing the bulk-fill composite specimens

Photo-polymerization with a LED curing light (Elipar, Deep Cure-S, 3M ESPE) at $>1,470\text{mW}/\text{cm}^2$ was used according to the manufacturer's instructions (table 4): for SoniFill 2, ten seconds; for Filtek Bulk-Fill, twenty seconds; and for Tetric N Ceram, ten seconds (figure 10). All specimen moulds with the filling materials were covered with a Mylar strip and cured in the centre using the LED 3M curing light. Thome *et al.*, (2007) found that the light cure intensity decreased when the distance from the light cure tip end was increased. The LED light cure tip had to be kept in contact with the Mylar strip to control the procedure and after curing each specimen at one end only, it was clearly marked as the top part (figure 11).

All specimens were removed from the mould and stored in dry and sterile containers in an incubator for 24 hours at 37°C . The top and bottom surface hardness was measured using a Vickers hardness machine (Zwick, Germany), which was adjusted to a load of 300g for 15 seconds according to ISO

4049 (ADA,2003). All measurements were repeated three times. Depth of cure was calculated after 24 hours for each specimen by calculating the top to bottom ratio from the measured Vickers hardness mean values.

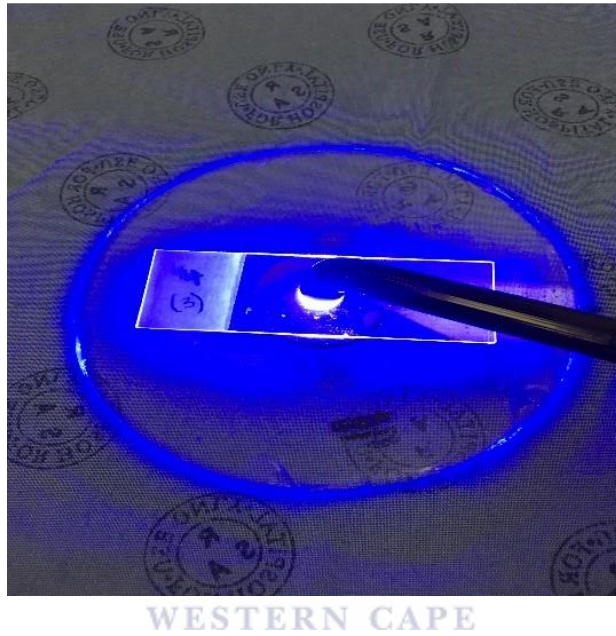


Figure 10: Curing process of Bulk-fill materials



Figure 11: Specimen after removal from the mould showing marked top surface

Table 4: Curing time, thickness, and shade of bulk-fill composites used

MATERIAL	Filtek bulk-fill	SonicFill 2	Tetric N ceram
TYPE			
Specimens	10	10	10
Thickness	4mm	4mm	4mm
The LED curing time	20sec	10sec	10sec
Colour	A2	A2	A2



Vickers hardness machine setting and Indentation of bulk-fill composites

The Vickers hardness machine (Zwick, Germany) (figure 12) was used for testing micro-hardness and depth of cure. The machine was set to a load of 300g for 15 seconds according to ISO 4049 (ADA, 2003). All samples were placed on the platform of the machine, the magnification 40X on the machine was adjusted to the centre of the bulk-fill specimen to recognize a smooth surface. Voids, air bubbles and irregular surfaces were avoided and the indenter of the Vickers machine was automatically moved to begin the indentation. Three indentation readings were taken on the top and bottom surface of all specimens. The mean values of the three indentation readings on the top and bottom were evaluated for statistical results.



Figure 12: Vickers hardness machine

B. Evaluation of the flexural strength

Laboratory putty and cold cured acrylic resin were used for a rectangular mould fabrication (25 ± 2 mm x 2.0 ± 0.1 mm x 2.0 ± 0.1 mm) according to ISO 4049:2009 (figure 13). Thirty six ($n=36$) specimens were prepared, twelve specimens ($n=12$) from each Bulk-fill material, Filtek Bulk-Fill (3M ESPE), Tetric N Ceram Bulk-Fill and SonicFill 2, according to the manufacturers' instructions. The moulds were filled with the materials and covered with transparent film. A glass slab was placed over the film and pressure was applied to remove all the excess material (figure 14).



Figure 13: Mould used for flexural strength evaluation

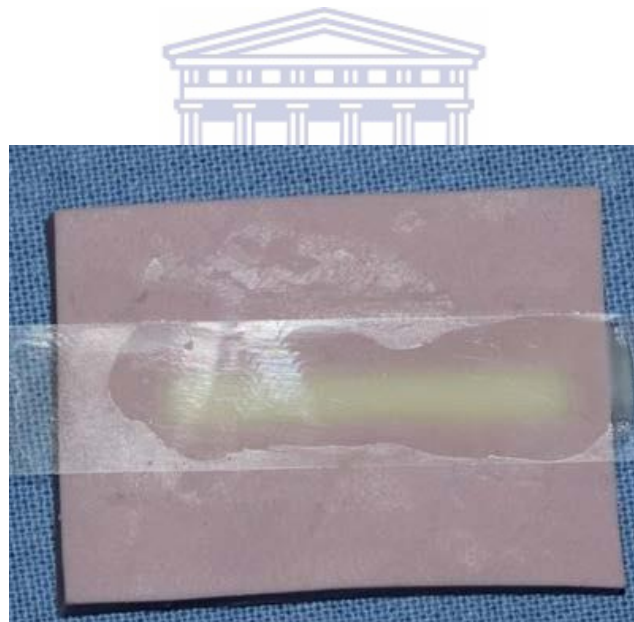


Figure 14: Material in the mould with excess material after pressure was applied

All specimens were cured according to the manufacturer's instructions. The light used was a 3M™ Elipar™ DeepCure-S LED Curing Light and it was checked after every ten samples using a Cure Rite light meter (Dentsply, USA) (figure 15). All specimens were placed in distilled water at 37 °C in three sterile containers for each type of bulk fill material, for 24 hours before testing.

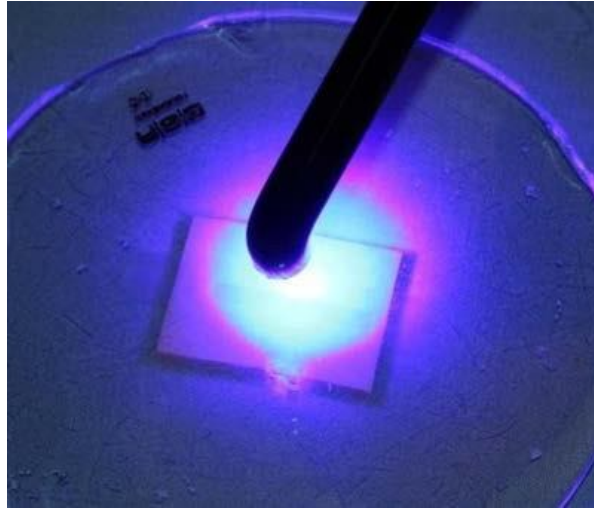


Figure 15: Specimens curing

A Tinius Olsen H10KT Universal testing machine (Horsham, USA) (Figure 16) was used for testing all the bulk-fill specimens. All specimens were located and secured in a jig (Figure 17). The load angle for the specimens was set at 90° to the long axis with the point of pressure at the midpoint of the specimen length. The load was applied at a speed of 1 mm/min on the core of the bulk-fill material until fracturing of the specimen occurred. The force applied at the time of fracture of the specimen was noted in Newton.

Flexural strength was calculated according to ISO using the following equation and recorded in mega-pascals (MPa): ISO 4049:2009

$$\sigma = \frac{3PL}{2bw^2}$$

- (P) Maximum load exerted on the specimen
- (L) Distance between the supports ± 0.01 mm

- (W) Width of specimen measured immediately
- (T) Thickness of specimen measured immediately



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Figure 16: Tinius Olsen H10KT Universal testing machine (Horsham, USA)

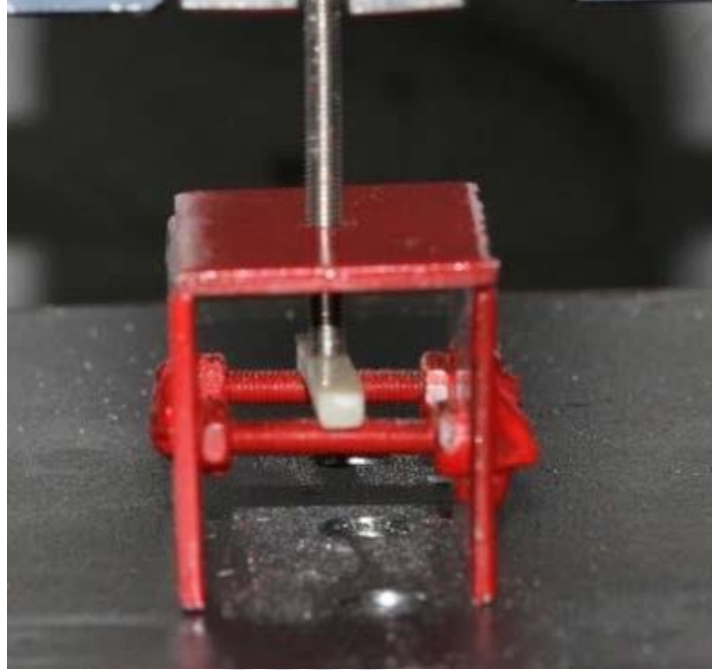


Figure 17: Specimen secured in the jig

3. Evaluation of microleakage

Thirty (n=30) sound human premolars were randomly divided into three groups of ten (n=10) teeth to test for microleakage. The apices of the roots were cut off and small circular cavity preparations were made using round diamond bur, and sealed off with amalgam. Cavities were prepared on the buccal surfaces of premolars at the cemento-enamel junction which was 4mm deep and 3mm in diameter, half of the cavity preparation lies on the enamel side and half lies on dentine side. A total of 30 standard cavities were prepared using a carbide fissure bur (SS White FG-331) with a cavosurface angle of 90° and a water-cooled high speed hand-piece.

All cavity preparations were carefully washed with an air/water spray. Group A was filled with SonicFill™ 2, group B was filled with Filtek™ Bulk-Fill and group C with Tetric N Ceram bulkfill according to manufacturers' instructions (figure 18).

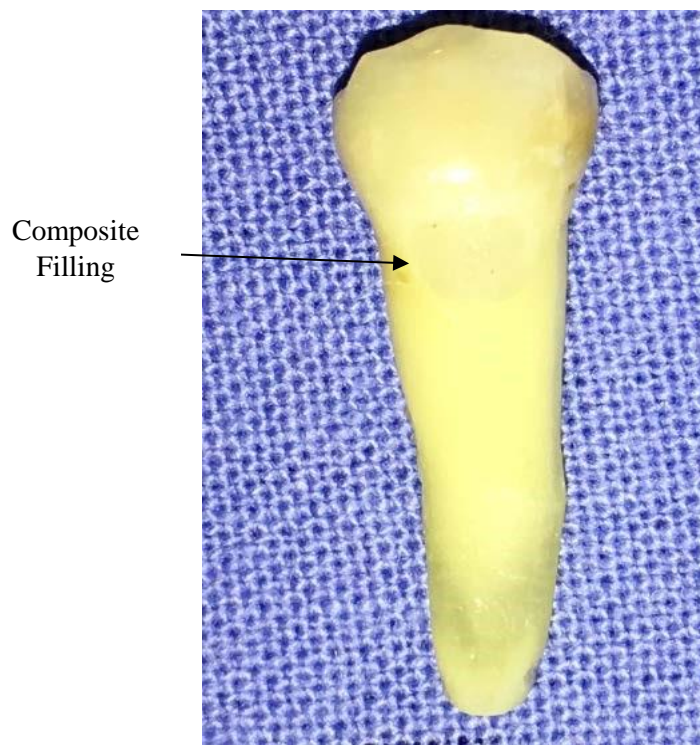


Figure 18: Extracted premolar with filling

All teeth were coated with two layers of nail varnish leaving a 1mm window free of varnish around the restorations (figure 20). All 30 specimens were cycled in 2% basic fusion solution for 500 cycles in a thermo-cycling machine at a temperature ranging from 5 °C to 45 °C and a dwell time of 15 seconds (figure 21). The nail varnish was cleaned off and samples were embedded in resin and sectioned with a diamond disc cutter (Struers Minitom).

The microleakage of the specimens was evaluated using a light microscope at x60 magnification for the presence of any dye penetration (figure 22). Scoring was done according to Grobler's criteria, and described by Grobler *et al*, (2000) in the diagram below (Figure 19).

- (0) No penetration of dye
- (1) Penetration to one third of the cavity depth
- (2) Penetration to two thirds of the cavity depth
- (3) Penetration up to the cavity floor
- (4) Penetration into the cavity floor

The dye penetration into enamel and dentin were recorded separately and scored by two examiners.

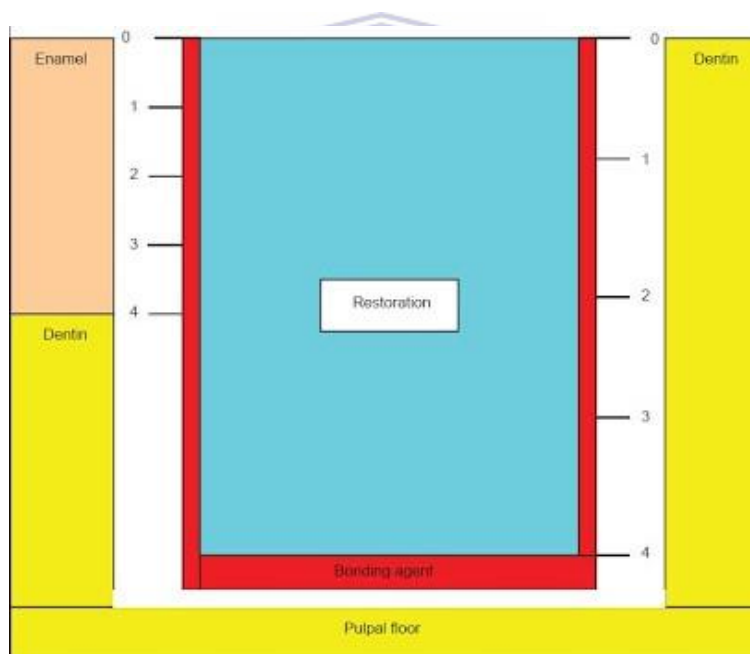


Figure 19: Diagram shows scoring criteria



Figure 20: Tooth with nail varnish leaving 1mm window around the restoration

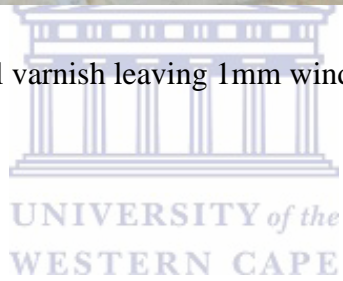
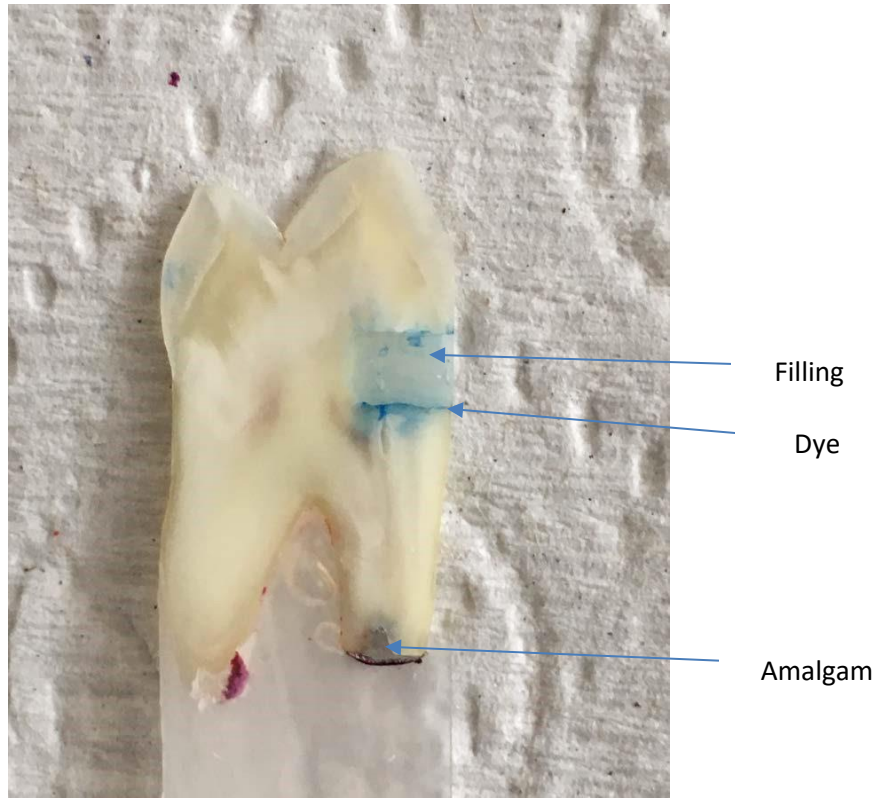


Figure 21: Thermo-cycling machine



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Figure 22: Section of tooth **Chapter 5**

Results

5.1 Data Analysis

The results were recorded in an Excel spreadsheet (Microsoft 2010, USA). The data was imported into statistical package for the social science (SPSS) version 21 (IBM, UAS) for windows to perform statistical analysis. A One Way analysis of variance (ANOVA) was carried out to examine if statistically significant differences occurred between the bulk-fill composite materials at a significance level of $p < 0.05$.

5.2 Results

The ANOVA test was used to compare the mean values of the micro-hardness of top surfaces, micro-hardness of bottom surfaces, and depth of cure of the three restorative materials after 24 hours, microleakage and flexural strength. An analysis was completed at a significance level of $p < 0.05$ to compare the depth of cure, microleakage and flexural strength of the three types of bulkfill materials for significant differences.

5.2.1 Micro-hardness measurements after 24 hours

Thirty specimens were used in this test, divided into three groups with ten specimens of each type of bulk-fill composite ($n=10$) to evaluate the depth of cure based on the top and bottom surface micro-hardness.

5.2.2 Micro-hardness measurements after 24 hours top surface

There were statistically significant differences (ANOVA $p < 0.05$) between the mean values of the top surface with SonicFill 2 showing higher hardness values at the top surface and Tetric N Ceram showing the lowest values. SonicFill 2 showed the highest top surface hardness values followed by Filtek bulk-fill and Tetric N Ceram bulk-fill showed the lowest values. However, no significant difference was found in top surface hardness between the two types of bulk-fill composite materials, namely, SonicFill 2 and Filtek bulk-fill ($p > 0.05$). A significant difference was found between Sonic Fill2, Tetric N Ceram ($p < 0.05$) and Filtek bulk-fill, and Tetric N Ceram ($p < 0.05$), (figure 23).

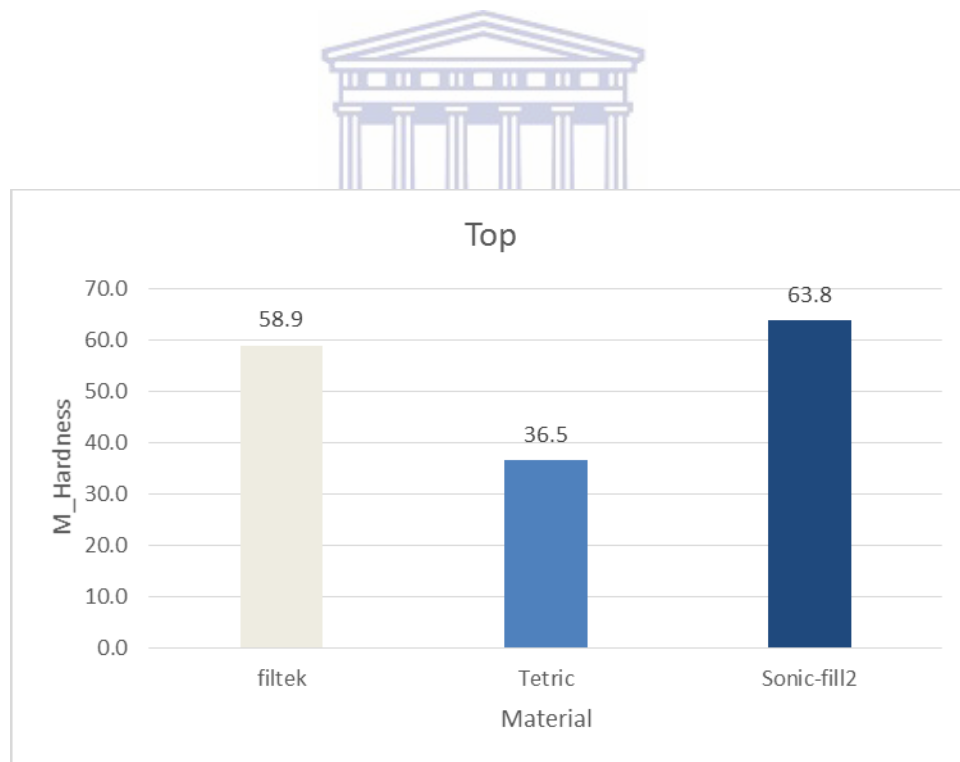


Figure 23: Comparison between the mean values of the micro-hardness top surfaces of the materials (24 hours) with LED curing light.

5.2.3 Micro-hardness measurements after 24 hours bottom surface

There were significant differences (ANOVA $p < 0.05$) between mean values of the bottom surface hardness of SonicFill 2 when compared to the other materials. SonicFill 2 showed the highest bottom surface hardness values and Tetric N Ceram bulk-fill showed the lowest. However, no significant difference was found on the bottom surface hardness between two types of bulk-fill composites materials, namely, SonicFill 2 and Filtek bulk-fill ($p > 0.05$). A significant difference was found ($p < 0.05$) between SonicFill 2 and Tetric N Ceram and also between Filtek Bulk-Fill and Tetric N Ceram (figure 24).

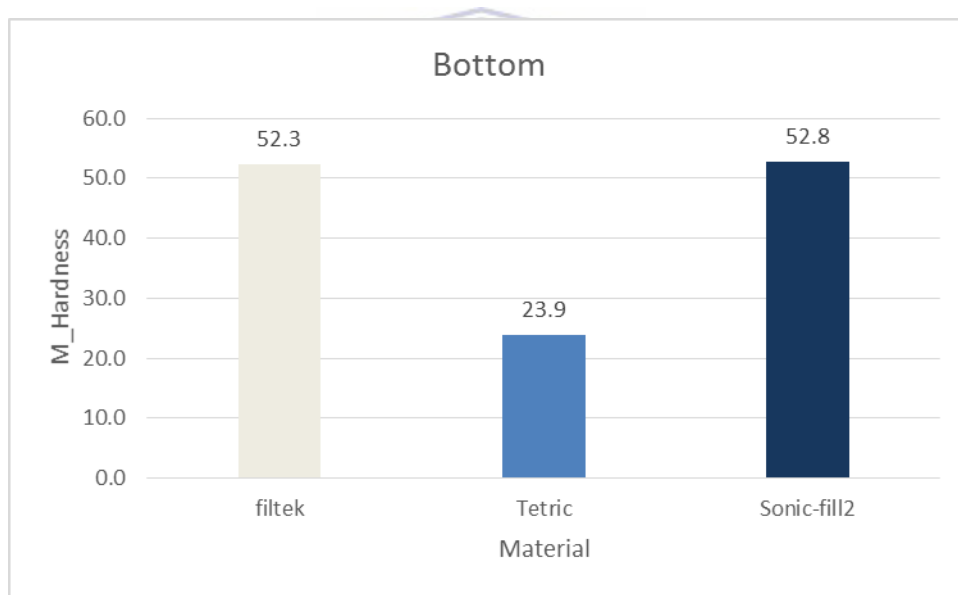


Figure 24: Comparison between the mean values of the micro-hardness bottom surfaces of the materials (24 hours) with LED curing light.

5.2.4 Top versus bottom surface after 24 hours for micro-hardness

There were statistically significant differences between the values (ANOVA $p < 0.05$). The values of the bottom surface of bulk fill materials were found to be lower than those of the top surface for LED curing lights after 24hrs (figure25).

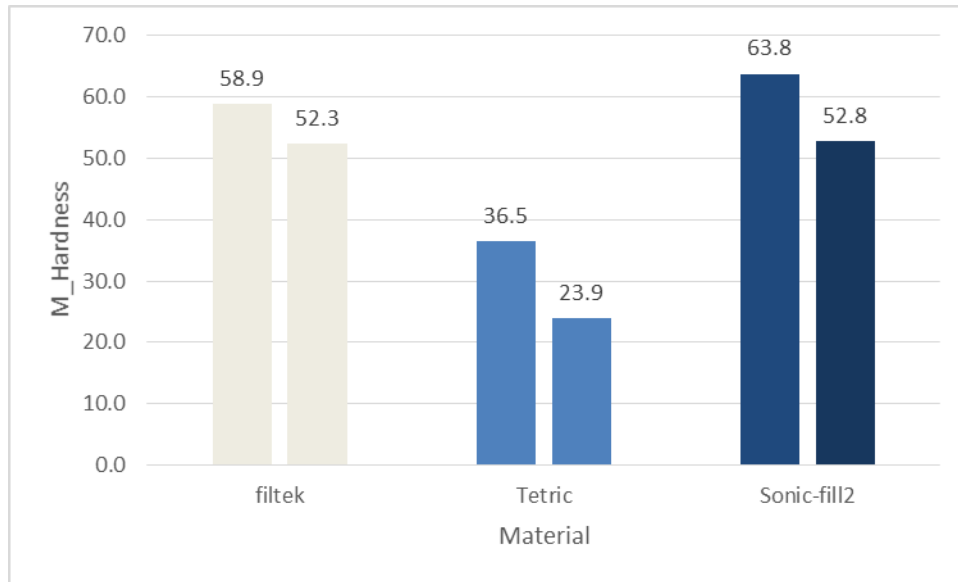


Figure 25: Comparison between the micro-hardness of the top and bottom surface of bulk-fill materials after 24 hours with LED curing light

5.2.6 Depth of cure measurement

The micro-hardness mean values were used to determine a bottom to top hardness ratio and (figure 26) shows the mean values of the top and bottom micro-hardness of the three bulk-fill materials. A ratio higher than 80% has often been suggested as a minimum acceptable value. Clinically the bottom surface can be about 80% of the upper hardness value (Watts *et al.*, 1984).

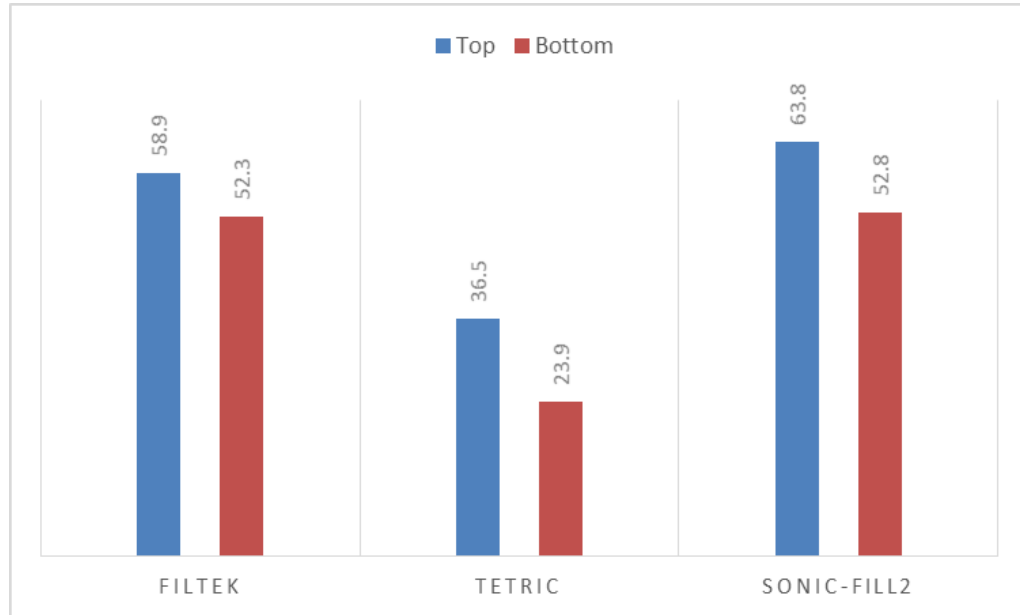


Figure 26: The mean values of top and bottom micro-hardness of the three bulk-fill materials

There were significant differences (ANOVA $p < 0.05$) between the mean values of the top and bottom micro-hardness the three bulk-fill materials. Filtek bulk-fill (88.8%) and SonicFill 2 (82.8%) showed the highest depth of curing and Tetric N Ceram (65.5%) showed the lowest values (Figure 27). However, there was no significant difference between Filtek bulk-fill and SonicFill 2 ($p > 0.05$).

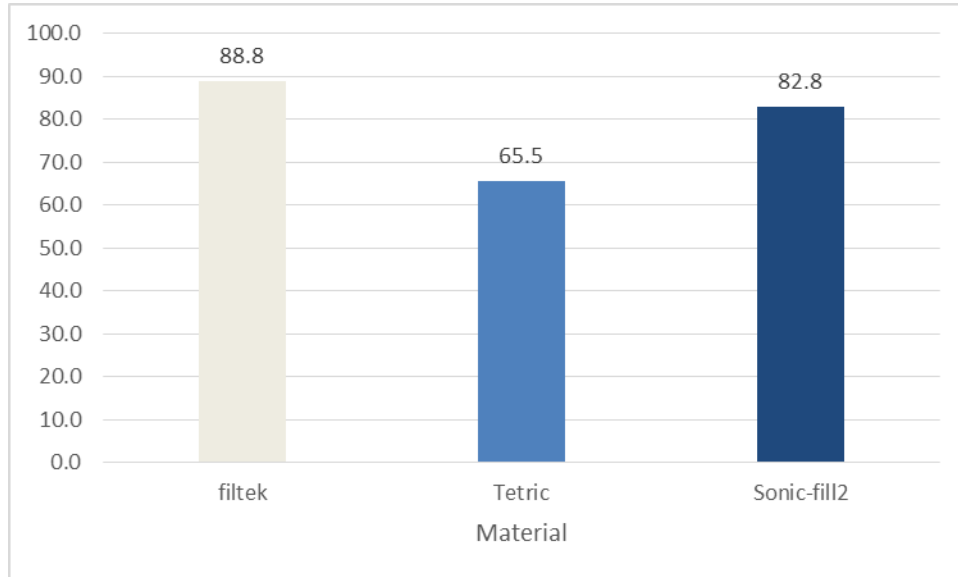


Figure 27: Depth of cure values for the different materials with LED curing light after 24 hours



5.2.7 Flexural strength

Thirty six (n=36) specimens were prepared, twelve specimens (n=12) from each Bulk-fill material: Filtek Bulk- Fill (3M ESPE), Tetric N Ceram Bulk-Fill (Ivoclar Vivadent) and SonicFill 2 (kerr). The mean values of the flexural strength was highest for SonicFill 2 followed by Filtek Bulk Fill and the lowest was Tetric N Ceram. A significant difference in flexural strength was observed between the materials (One-way ANOVA, Kruskal-Wallis) ($p < 0.05$) (figure 28).

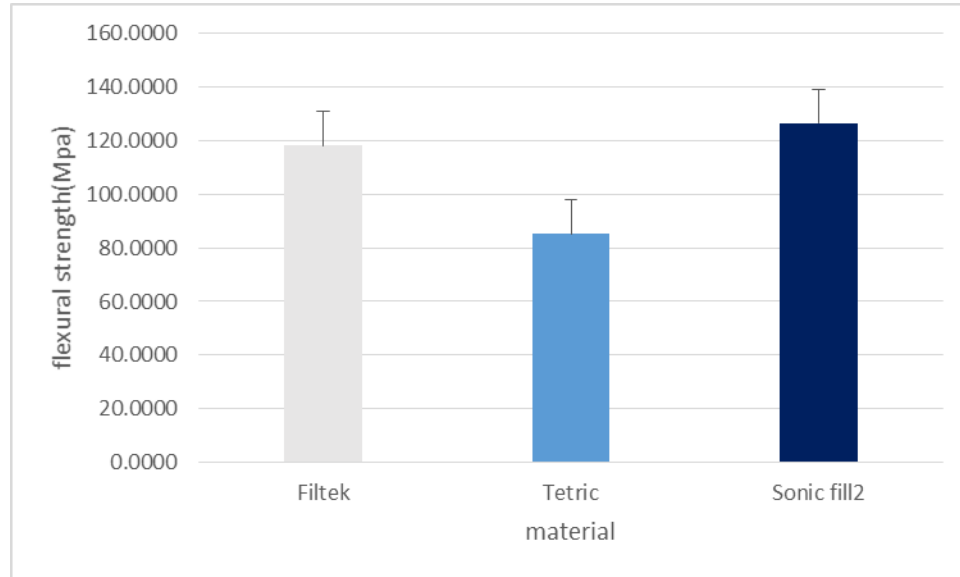
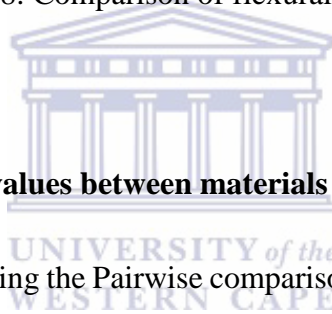


Figure 28: Comparison of flexural strength.



5.2.7.1 Comparison of the mean values between materials

Multiple comparisons were done using the Pairwise comparison test to determine if there were any significant differences in flexural strength between the materials tested. No significant difference in flexural strength was found between the Filtek Bulk-Fill and SonicFill 2 materials ($p > 0.05$) (Kruskal-Wallis). A significant difference was found between Filtek Bulk-Fill and Tetric N Ceram ($p < 0.05$). A significant difference was also found between SonicFill 2 and Tetric N Ceram ($p < 0.05$).

5.2.8 Microleakage

Thirty (n=30) sound human premolars were randomly divided into three groups of ten (n=10) teeth to test for microleakage. The dye penetration into enamel and dentine were recorded separately. The occurrences of the leakage categories per material for Enamel and Dentine are shown in (Tables 5, 6).

Table 5: The occurrences of the leakage categories (Enamel)

		Enamel				Total
		0	1	2	3	
Mat.	Filtek	2	8	1	0	10
	Sonic	3	6	0	0	10
	Tetric	1	1	4	4	10
Total		6	15	5	4	30

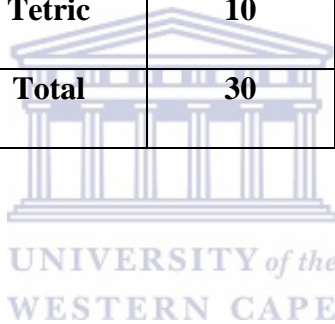
Table 6: The occurrences of the leakage categories (Dentine)

		Dentine					Total
		0	1	2	3	4	
Mat.	Filtek	0	5	4	3	0	10
	Sonic	2	2	3	1	0	10
	Tetric	0	1	2	3	4	10
Total		2	8	9	7	4	30

A nonparametric One Way Anova (Kruskal-Wallis test) was used to analyse the differences between the materials (Table 10). The mean rank was the highest for Tetric N Ceram in both enamel and dentine, the mean rank for Filtek was higher in dentine than enamel, while the mean rank for Sonic Fill2 was higher on dentine than enamel.

Table 7: Description of Kruskal-Wallis per material

Ranks			
	Material	N	Mean Rank
Enamel	Filtek	10	11.85
	Sonic	10	11.55
	Tetric	10	22.75
	Total	30	
Dentin	Filtek	10	13.00
	Sonic	10	11.90
	Tetric	10	21.95
	Total	30	



When microleakage in enamel was analysed using the One-way ANOVA, Kruskal-Wallis test (figure 29), there were significant differences between the bulk-fill materials: Sonic Fill2, Tetric N Ceram, ($p < 0.05$) and Filtek bulk-fill, Tetric N ($p < 0.05$). No significant difference in microleakage of enamel was found between Sonic Fill2 and Filtek bulk-fill ($p > 0.05$).

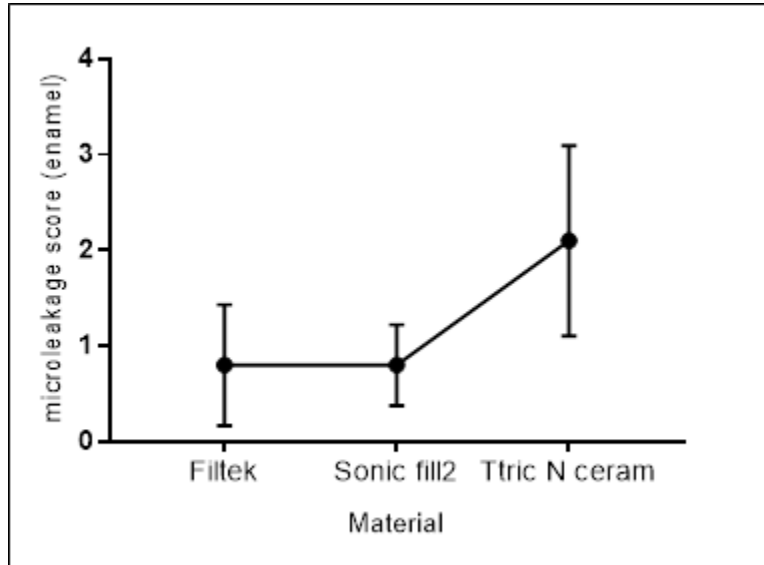


Figure 29: Comparison of enamel microleakage

When microleakage in dentine was analysed using the One-way ANOVA, Kruskal-Wallis test (figure 30), there were significant differences between the bulk-fill materials: Sonic Fill2, Tetric N Ceram, ($p < 0.05$) and Filtek bulk-fill, Tetric N ($p < 0.05$). No significant difference of microleakage in dentin was found between Sonic Fill2 and Filtek bulk-fill ($p > 0.05$).

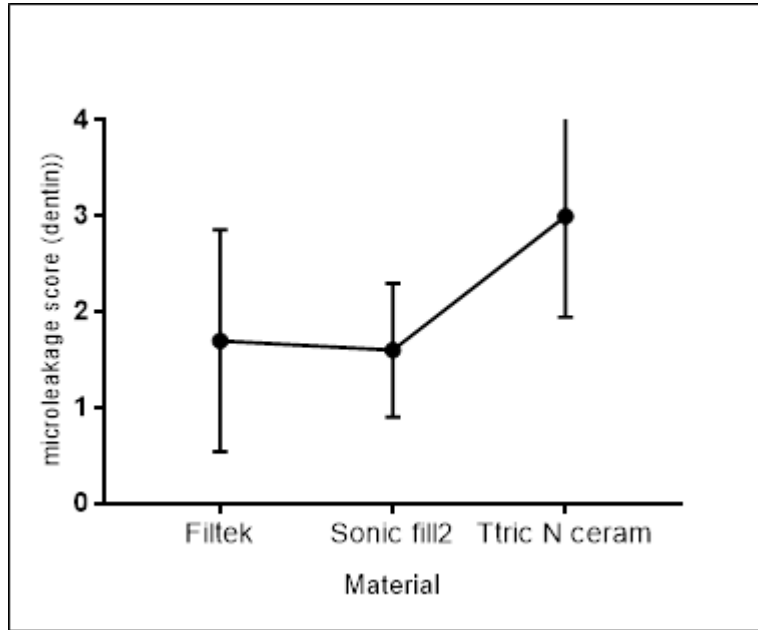
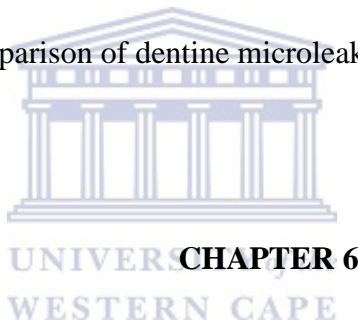


Figure 30: Comparison of dentine microleakage



Discussion

6.1 Evaluation of depth of cure

6.1.1 Introduction

Depth of cure and micro-hardness are one of the most important physical properties of composite resin and play an important role in the evaluation and comparison of the restorative materials. Micro-hardness is usually used for assessment of depth of cure and effectiveness of the curing lights (Yaman *et al.*, 2011). The possibility of inadequate monomer conversion and insufficient

curing depth are two of the main difficulties associated with photo-polymerized composites (Yaman *et al.*, 2011). The depth of cure readings showed clear relevance to the clinical aspects of composite curing (Hubbezoglu *et al.*, 2007). Evaluation of the degree of monomer conversion is considered to be a reliable method. There is a strong correlation between the conversion method and the micro-hardness assessment (Hubbezoglu *et al.*, 2007). New bulk-fill resin composites improve the depth of cure by allowing placement of single increments 4-5mm (Yaman *et al.*, 2011).

The bulk-fill composites can be categorized into two different groups: base and full body composites. The base groups of bulk-fill composites have low viscosity (flowable) which facilitate placement in small, narrow and less accessible cavities where coverage with conventional composite is required. This type has lower filler content which reduces the wear resistance and is known as a flowable bulk-fill composite (Van Ende *et al.*, 2017). The full body bulk-fill is considered to be the true bulk filling, in which the complete 4-5mm restoration can be placed without coverage. The full body bulk-fill has a higher filler amount and increases the wear resistance. It is also known as paste-like, full body bulk-fill and examples of these materials are SonicFill 2, Filtek Bulk Fill Posterior and Tetric N Ceram which were used in this study (Van Ende *et al.*, 2017). SonicFill 2 differs from the other two materials as it is applied by an air driven hand-piece with sonic vibration (Van Ende *et al.*, 2017). Most bulk-fill composite materials are purely light-cured. Companies have tried to increase the depth of cure by using different methods including; reducing the filler content, increasing filler particle size, and use of other photoinitiators (Ilie *et al.*, 2013).

Increasing the filler size and decreasing the filler content, decreases the quantity of scatter of the light at the filler crossing point and increases the amount of absorbed light that can activate the photo-initiator (Ilie *et al.*, 2013). Tetric Evo Ceram (European trade name of Tetric N Ceram)

Bulk-fill increases the depth of cure by using different photo-initiators like Ivocerin that allow polymerization of composite filling in larger increments (Vivadent, 2016). Some companies recommend light-curing based on high intensity LED light-curing units, while others mention a minimum curing light intensity which may be higher than many current units (Ilie *et al.*, 2013).

The physico-mechanical properties of composites are strongly influenced by the degree of conversion which is defined as the number of double carbon links (C=C) present in the monomers, which are converted into single links (C-C) to form the polymer chains during the polymerization process referred to as the degree of conversion. Top and bottom micro-hardness depend on the degree of conversion of the resin composite (Alshali *et al.*, 2013).

6.1.2 Evaluation of micro-hardness

In the current study the micro-hardness test, using the Vickers hardness machine, indicated that the microhardness of the top surface of bulk-fill composite samples was higher compared to the bottom surface in all types of bulk-fill composites. This can be due to the smaller quantity of light that can reach the base of the material, or due to scatter light through the filler particles (Halvorson *et al.*, 2003). Thome *et al.*, (2007) stated that higher micro-hardness values were achieved when the tip of the light cure was placed in direct contact with the composite surface. In this *in-vitro* laboratory study the light tip was placed in direct contact with the specimen surface. The optimal distance between the tip of the light cure and the specimen's surface is 0 mm (Caldas *et al.*, 2003). The translucency of the composite resin has an effect on the transmission of the curing light across the thickness of the composite restoration (Moore *et al.*, 2008). The A2 shade Bulk-fill composite was used in this study for SonicFill 2, Filtek bulk-fill and Tetric N Ceram. This shade was selected to reduce the effects of colour on the polymerization of the light. Alrahlah *et al.*, (2014) specified that

after curing, the polymerization process of composites continues at a slow rate and may reach an end point at approximately 24 hours. Flury *et al.*, (2012) found that surface hardness increased up to one month after light curing.

Top surface analyses of micro-hardness of SonicFill 2 followed by Filtek Bulk Fill showed significantly higher micro-hardness values than Tetric N Ceram which showed the lowest top surface micro-hardness. This variation of micro-hardness values was expected as SonicFill 2 composite contains a high load of filler particles (83.5%) as shown in table 3.

Resin composite curing efficiency and micro-hardness cannot be determined by evaluating the top surface of the material only. The micro-hardness of the bottom surface is affected by light intensity which affects the curing (Hubbezoglu *et al.*, 2007). The bottom surface showed lower microhardness values than the top surfaces for all materials in this study. Sonic Fill2 showed the highest bottom micro-hardness values followed by Filtek Bulk-Fill and Tetric N Ceram which showed the lowest bottom micro-hardness.

Flury *et al.*, (2012) found that after measuring the Vickers hardness (VH) for different composite materials, the lowest was Tetric Bulk-fill composite. Leprince *et al.*, (2014) concluded that some of the bulk-fill resin composites like Filtek bulk-fill showed very low Vickers micro-hardness values. Sonic fill showed high micro-hardness (Vickers hardness /VHN) when compared to Tetric EvoCeram (Trade name of European Tetric N Ceram) and Filtek Bulk-fill composite (Alrahlah *et al.*, 2014).

The study by Shalan & Thiab (2017) found the following: LED showed the highest micro-hardness (VHN) value for all tested material; composite resin material with a small filler particles size (0.193.3µm) showed the highest values of light transmission for all filler contents; composites with

a large filler size (0.04-10) μm showed low light transmission for all filler contents; and Sonic Fill had the smallest size filler particles which showed higher micro-hardness among all materials.

These findings were confirmed in the current study.

6.1.3 Evaluation of the depth of cure

Depth of cure can be defined as the thickness of a resin based composite that is adequately cured or the depth where hardness equals the surface value multiplied by an arbitrary ratio, usually 0.8 (Ilie *et al.*, 2013). Watts *et al.*, (1984) concluded that an adequate depth of cure was attained if the bottom surface hardness resembles at least 80% of the top surface hardness. Leprince *et al.*, (2013) described the depth of cure as the depth at which the composite resin matrix changes from a glassy to an elastic rubbery form.

Measurement of depth of cure can be by surface hardness in which the ISO 4049 standard recommends a scraping technique to remove insufficiently cured material with subsequent measurement of the sample height divided by two, also known as the micro-hardness value in which the bottom/top ratio percentage of the maximum hardness is measured (Moore *et al.*, 2008). Depth of cure can also be measured directly based on the degree of conversion with either microRaman or Fourier convert infrared spectroscopy (Li X *et al.*, 2015). Sobrinho *et al.*, (2000) specified that a decrease in surface hardness was found with increased depth of the composite resin. Tsai *et al.*, (2004) study concluded that a decrease in surface hardness of the composite was found with increasing depth of the composite resin.

However, the degree of conversion which plays a major role in depth of cure, is usually evaluated by the amount of aliphatic C=C double bond concentrations in the cured composite, compared to the total number of C=C bonds in the uncured resin composite. Degree of conversion was stated

to be mainly influenced by the curing light and the composite material (Ozturk *et al.*, 2013). The light cure source includes type, power density, wave length, radiation time, radiation distance, and the activation process. The degree of conversion of C=C double bonds for resin composite generally ranges from 55% to 65% (Miletic & Santini, 2008). Sideridou *et al.*, (2002) studied the effect of chemical structure on degree of conversion in light cured dimethacrylate-based dental resins and found that the degree of conversion increased in the order Bis-GMA, Bis-EMA, UDMA and TEGDMA. UDMA had lower viscosity and higher molecular flexibility than BisGMA. The degree of conversion of bulk-fill composites ranged between 54.5%-71.9%. The degree of conversion has been shown to decrease in accordance with the increase in filler and can be attributed to the light cure scattering at the resin filler interfaces. The filler amount, filler form, size, and shape can also influence the effectiveness of light cure scattering (Al-Ahdal *et al.*, 2015).

The manufacturers of the materials used in this study claim that the depth of cure for Filtek Bulk Fill and SonicFill 2 is 5mm and 4 mm for Tetric N-Ceram Bulk Fill. The results of the current study showed that there was adequate depth of cure for Filtek bulk-fill (88.8%), SonicFill 2 (82.8%) and inadequate depth of cure for Tetric N Ceram (65.5%), when bulk-fill materials were used at 4mm thickness. SonicFill 2 showed the highest hardness values but showed lower depth of cure values than Filtek bulk-fill.

Garoushi *et al.*, (2013) found that Filtek Bulk fill composite showed higher depth of cure when compared to Sonic Fill and Tetric N Ceram. Filtek Bulk Fill contains aromatic resins which permitted the refractive index to match the filler so that the curing light would not be significantly bent and more light would be passed through the bulk-fill material which gives better depth of cure (Moszner *et al.*, 2008). Tsujimoto *et al.*, (2017) found that by using a quartz-tungsten halogen unit for 20 and 40 seconds respectively, Filtek Bulk Fill showed lower depth of cure than Tetric N

Ceram. However, after 40 seconds both materials had a depth of cure greater than 4mm. Al-Obaidi, (2015) found a significant difference between Filtek Bulk Fill and Tetric N Ceram where Filtek Bulk Fill showed higher depth of cure than Tetric N Ceram.

Li, X *et al.*, (2015) found the highest depth of cure for Filtek Bulk Fill composite (80.0%) compared to Tetric Evo Ceram (70.8%) and other materials, which was similar to Goracci *et al.*, (2014), Alshali *et al.*, (2013) and Finan *et al.*, (2013). Zorzin *et al.*, (2015) found that at a 4mm specimen thickness Filtek Bulk Fill showed a higher curing depth, more than 80% when compared to Tetric N Ceram which showed a lower depth of cure and did not reach the 80% threshold at 4mm thickness. Miletic *et al.*, (2017) found that Filtek Bulk Fill reached the 5mm depth of cure as mentioned by the manufacturer and showed the highest depth of cure when compared to Tetric N Ceram and Sonic Fill2. In this study SonicFill 2 showed lower depth of cure than Tetric N Ceram and the author revealed that Sonic Fill should be cured adequately, at least 20 seconds for a 4-mm thickness which is different from the manufacturer's instruction that recommended 10 seconds. Ilie & Stark (2014) concluded that an exposure time of 20 seconds is recommended for all bulkfill composite materials with 4 mm bulk placement. Pongprueksa *et al.*, (2016) found a sufficient depth of cure with Filtek Bulk Fill, approximately 92% top to bottom ratio. Shalan & Thiab (2017) showed that Sonic Fill, Tetric N Ceram and Filtek Bulk fill composite reached the Top/bottom ratio of 0.8 when cured with LED, while Filtek Bulk fill composite reached the same ratio when cured with QTH or LED, respectively.

Rodriguez *et al.*, (2016) found that Sonic fill reached an adequate depth of cure at 4 mm and had an average depth of cure higher than 80% after 20 seconds of LED light cure exposure when compared to Tetric Evo Ceram (Trade name of Tetric N Ceram) and other material which showed depth of cure lower than 80%, which is similar to the results of this study. Alrahlah *et al.*, (2014)

found that greatest depth of cure was shown by Sonic Fill 5.03mm and Tetric N Ceram Bulk Fill 4.47 mm.

Tetric N Ceram bulk-fill composite contains translucent filler, matrix and new photo-initiator Ivocerin which increase the absorption of the light, considered to be high between 400- 450 (Jang *et al.*, 2015). Tetric N Ceram showed the lowest depth of cure in this study. Jang *et al.*, (2015) found that Tetric N Ceram did not reach an adequate depth of cure which is 80% bottom to top ratio. Also Tetric N Ceram Bulk Fill and Sonic Fill showed micro-hardness below 80% at 4mm depth (Tarle *et al.*, 2015).

Flury *et al.*, (2012) concluded that all bulk-fill materials met the ISO 4049 standard except Tetric EvoCeram Bulk Fill which did not reach the 80% bottom to top ratio. Another study by Garoushi *et al.*, (2013) found that maximum depth of cure for Tetric Evo Ceram was 2.3mm, which differs from the manufacturer's claim. Benetti *et al.*, (2015) confirmed that Tetric Evo Ceram did not achieve sufficient depth of cure when compared to other Bulk-fill composites. Yap *et al.*, (2016) found that depth of cure of Tetric EvoCeram Bulk Fill was below 4mm. Menees *et al.*, (2015) used a slightly different mould than the standard ISO 4049 and an acceptable depth of cure was found for Tetric EvoCeram Bulk Fill at 4mm and 3.5 mm for Filtek Bulk Fill. Tsujimoto *et al.*, (2016) found an acceptable depth of cure at a depth of 4 mm for Tetric N Ceram by extended curing time to 30 seconds. However, AlQahtani *et al.*, (2015) stated that the 80% bottom to top ratio could only be achieved when Tetric N Ceram was over-exposed to light for 40 seconds, while Garoushi *et al.*, (2013) stated the opposite result. Son *et al.*, (2017) also stated that 40 seconds of light exposure was not sufficient to achieve a depth of cure of 4mm and a higher than 80% ratio for all bulk-fill composites.

The probability of inadequate curing of these materials to more than 4mm thickness was confirmed by the micro-hardness scraping test (ISO 4049) for Filtek bulk-fill in a study by Zorzin *et al.*, (2015) and Tetric N Ceram in a study done by Ilie *et al.*, (2013).

Differences in the depth of cure between bulk-fill composite materials can be due to curing light scattering at particle crossing points and light absorption by photo-initiators and pigments. These factors decrease the light penetration and the degree of conversion of matrix monomers determined by the light irradiance at depth (Garcia *et al.*, 2014). The degree of conversion is associated with the mechanical properties, biocompatibility and colour stability and plays a role in the clinical success of the restoration in terms of increased polymerization, cross-linking and hardness (Lombardini *et al.*, 2012). Depth of cure is enhanced due to the improvement in light transmission as a result of the interaction between the refractive index, the resin matrix and filler. A decrease in refractive index between the resin matrix and filler enhanced the degree of conversion and increased depth of cure (Fujita *et al.*, 2005). The bulk-fill composites acted differently under the light curing settings. An increase in depth of cure with increased energy density was detected with all materials, while extended curing times at the same energy density can improve the mechanical properties (Van Ende *et al.*, 2017).

However, according to the manufacturer, Filtek Bulk Fill showed that the highest depth of cure may be due to the close match in the refractive index between the aromatic dimethacrylate (AUDMA) resin and the filler. This prevents bending of light and therefore allows the light to be transmitted through the material which increases the depth of cure. Additionally, the large filler size allows more light to be transmitted through the material.

The majority of research results showed the highest depth of cure for the Filtek Bulk Fill flowable type which may be related to the low viscosity of the material. The resin of the flowable type had

a refractive index lower than that on the Filtek Bulk Fill Posterior which resulted in greater depth of cure for the Filtek Bulk Fill Posterior (Moszner *et al.*, 2008). Sonic Fill showed high translucency, large filler size, good depth of cure and decreased viscosity (up to 87%). Tetric N Ceram showed the lowest depth of cure and micro-hardness among the tested materials, which can be ascribed to the filler content and the light curing type. Sabatini's (2013) results confirmed significantly greater hardness values when polymerized with QTH for Tetric N Ceram than with a LED curing light. The LED curing may not be compatible with certain dental composites and the photo-initiator systems need to be adjusted to the spectra of the curing light.



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6.1.4 Evaluation of flexural strength

Flexural strength is used to assess the strength of the material by measuring the amount of alteration expected under bending stress (Anusavice, *et al.*, 2013). Condon and Ferracane (1997) stated that when they compared heavily filled composite materials with composites that contain lower filler, composites with higher filler showed better wear resistance, strength and fracture toughness. Willems *et al.*, (1992) concluded that the filler amount should not exceed 70%, due to mechanical problems and reduced physical characteristics. Several studies showed that the filler content of the resin composites plays a major role in the physio-mechanical properties. Increasing the filler load results in a decrease in the volume of the resin matrix for polymerization, which increases the strength and hardness (Leprince *et al.*, 2014). Marchan *et al.*, (2009) stated that the volume and weight of the composite fillers was directly related to the strength of the material. Heintze *et al.*,

(2015) stated that flexural strength can be used as an indicator of the stability of the filling material under masticatory force.

The numerous properties of materials are assessed by using standardized laboratory tests. Teeth and restorative filling materials are exposed to two types of forces, flexural and compressive and therefore investigations to define and assess the flexural and compressive strengths of the materials are very important (Gömeç *et al.*, 2005). Suitable and acceptable restorative material should meet the ISO standards. The minimum flexural strength value set by ISO is (80 MPa), to withstand the occlusal force (ISO, 2000). Therefore, the test results in this study showed that the materials can be used for restorations. The highest flexural strength was shown by Sonic Fill2 with a value of 126.6 MPa followed by Filtek Bulk Fill, 118.3 MPa, and the least flexural strength was shown by Tetric N-Ceram bulk-fill 85.3 MPa.

El-Damanhoury *et al.*, (2013), Garoush *et al.*, (2013), Ilie *et al.*, (2013), Leprince *et al.*, (2014), Tsujimoto *et al.*, (2016) all found low flexural strength for Tetric N Ceram Bulk Fill when compared to other bulk-fill composites. Didem *et al.*, (2014) found that Sonic Fill showed higher flexural strength when compared to Tetric N Ceram and other materials. Ilie *et al.*, (2013) found that Sonic Fill showed higher flexural strength than Filtek Bulk Fill and other materials. Abouelleil *et al.*, (2015) found that the Sonic Fill composite system showed the highest flexural strength followed by Filtek Bulk Fill when compared with Tetric N Ceram which showed the lowest value.

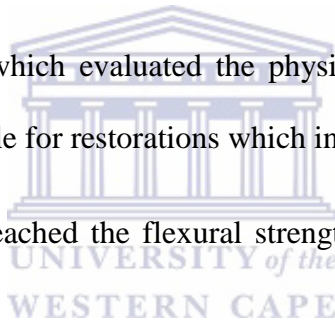
Kim *et al.*, (2002) specified that increasing the filler load of composites, increases the flexural strength. Salerno *et al.*, (2011) also found that the flexural strength of resin composites are directly associated with the filler loading. Flexural strength ensures resistance of bulk-fill composite materials to compressive and tensile forces created by intraoral functions and parafunctions (Jayanthi & Vinod, 2013). Another flexural strength study showed that Filtek Bulk Fill had the

lowest and Sonic Fill had the highest flexural strength value, but the difference is not statistically significant at $p < 0.05$ (Ajaj, 2015), which was confirmed by the results of the current study. Ibarra, (2015) found that the physical properties of Sonic Fill composite compared to other bulk-fill composite materials showed significantly higher flexural strength values. Goracci *et al.*, (2014) compared the flexural strength of bulk fill composites and found that Sonic Fill showed significantly higher flexural strength values compared to other composites.

In the current study Sonic fill showed the highest flexural strength, followed by Filtek Bulk Fill and the lowest was Tetric N Ceram. Sonic fill contained the highest filler (83.5% by weight), Filtek Bulk Fill (76.5% by weight) and Tetric N Ceram had a filler loading of 75% by weight (Table 3).

The results of the current study which evaluated the physical properties, showed that all the investigated materials are acceptable for restorations which involve the occlusal surfaces.

However, none of the materials reached the flexural strength mentioned by the manufacturers (Refer to Table 3).



6.1.5 Evaluation of microleakage

The most important clinical problem of composite materials is their marginal microleakage which occurs as a result of polymerization shrinkage and thermal changes in the oral cavity. Marginal microleakage was reported to be more at the gingival margins than occlusal margins (Basavanna & Kapur, 2012).

According to Radhika *et al.*, (2010) microleakage is due to the clinically undetectable track of bacteria, fluids, molecules and ions between the cavity wall and the restorative material and is one of the main factors that affect the longevity of the restorations. Microleakage is one of the most common problems of composite restorations occurring mainly at the gingival margin of posterior

composite fillings. The addition of fibres to composites can decrease the polymerization shrinkage (Radhika *et al.*, 2010). Other studies concluded that use of different types of bonding systems may reduce the marginal leakage. The mechanism of bonding in the etch-and-rinse scheme is diffusion based. Resin penetrates the collagen fibrils and forms a hybrid layer through micromechanical bonding. The bonding mechanism in a self-etch system is based on the dissolution of the smear layer and infiltration of acidic monomers in dentine, which leads to the hybrid layer formation. In case of mild self-etching adhesive systems, some hydroxyapatite remains around the collagen fibrils which is caused by low acidity of monomers and may have a chemical reaction with functional monomers in addition to micromechanical retention which can reduce marginal microleakage (Kasraei *et al.*, 2011).

Within the limitations of this *in-vitro* study, none of the tested bulk-fill composites completely eliminated microleakage and dye penetration in enamel and dentine.

Patel *et al.*, (2016) found that bulk-fill composites guaranteed suitable marginal adaptation on the tooth enamel, but not on dentin and cementum. This was confirmed by the current study where all the bulk-fill materials showed occurrence of leakage on dentin more than on enamel. ElDamanhoury and Platt, (2013) found that all bulk-fill composite materials showed a smaller amount of polymerization shrinkage than the conventional composite.

Munoz & Campillo, (2012) found that Sonic Fill had the best overall microleakage score at both the occlusal and cervical margins when compared to other material and stated that due to the advantage of the sonic activation, no voids were present in the Sonic Fill bulk fill composite. Another study by Poggio *et al.*, (2013) found that Sonic Fill showed the lowest microleakage when compared to other resin composite materials. Orłowski *et al.*, (2015) compared Sonic Fill, Filtek Bulk Fill and Tertric N Ceram and found that the lowest microleakage score was achieved by the

Sonic Fill system, followed by Filtek Bulk Fill and Tetric N Ceram Bulk Fill which showed the highest microleakage score. This is similar to the current study where the Sonic Fill showed the lowest microleakage score. However there was no significant difference between Sonic Fill and Filtek Bulk Fill in both enamel and dentine. They also stated that sonic-activated composite restorations have better marginal sealing compared to other bulk-fill composites. Gamarra *et al.*, (2017) found that Sonic Fill composite showed gap formation and microleakage, mainly in the dentine at the cervical margin, which is in accord with the current study which showed higher scores in dentine than enamel.

Agarwal *et al.*, (2015) stated that bulk-fill materials with high viscosity showed low percentages of gap formation and the internal adaptation to dentine was better with flowable-like bulk-fill composites (Sonic Fill) than paste-like bulk-fill composites. Kalmowicz *et al.*, (2015) found no difference when using bulk-fill materials like Sonic Fill or 2-mm increments of conventional composite in marginal microleakage in dentine. Al-Harbi *et al.*, (2016) found that bulk-fill restoration of Class II cavities up to 4 mm with Sonic Fill flowable-like bulk-fill composite lead to greater bond strengths than conventional composites and incremental methods.

Sonic fill 2 showed a lower score for microleakage that can be due to the oscillation energy which temporarily increases flowability of the material to achieve accurate filling. The modifier causes a drop in the viscosity to 87%, increasing the flowability of the material and allowing fast placement through a single increment up to 5 mm which leads to a decrease in polymerization shrinkage with reduction in both the marginal gap and leakage. Filtek Bulk Fill also showed no significant difference compared to Sonic Fill2. Filtek Bulk Fill contains two new methacrylate monomers that in combination lead to reduced polymerization shrinkage and gap formation that decreases the microleakage. The first monomer is high in molecular weight and aromatic dimethacrylate

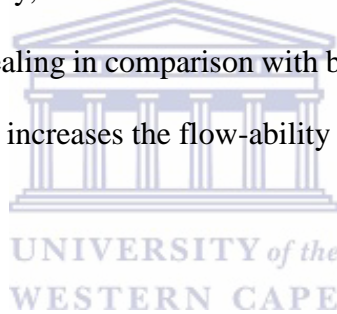
(AUDMA) reduces the number of reactive groups in the resin which helps to moderate the volumetric shrinkage. During polymerization Addition Fragmentation Monomers (AFM) react to the developing polymer as with any methacrylate, in the formation of cross-links between adjacent polymer chains. AFM comprises a third reactive site that cuts through a fragmentation process during polymerization. This process provides a mechanism for the relaxation of the developing network resulting in stress relief and less shrinkage stress (Campodonico *et al.*, 2011) (3M data). Tetric N Ceram showed the lowest adaptation which may be due to inadequate adaptation to internal areas and cavosurface margins at the cervical joint (Agarwal *et al.*, 2015).

However, many *in-vitro* studies confirmed that the marginal integrity of a class II composite filling was higher when a single increment was used and lower with the restoration layering method (Orłowski *et al.*, 2015). Van Ende *et al.*, (2013) presented interesting results of a comparison study of three composites (conventional, liquid, and bulk-fill) placed in the posterior teeth cavities of different cavity configurations. Their hypothesis was that the adaptation of the material to the cavity walls is not affected by the C-factor, type of composite and its application technique. From this hypothesis they concluded that the most suitable bonds with the tooth were found when placing layered restorations in cavities with a low C-factor, regardless of the composite type. Furthermore, bulk-fill materials may have different types of photo-initiators and therefore require curing lights that activate them sufficiently (Par *et al.*, 2014). In the current study the best results were found when the application of the composite took place using an activating sonic hand-piece, which is in agreement with Ben-Amar *et al.*'s, (2007) study conducted on the effect of the composite application and condensation on marginal seal.

Results of the current study showed a difference in the microleakage. The enamel wall showed less microleakage than the cervical wall in all three composites which can be due to morphological, histological, and compositional differences between the enamel and dentine. Enamel is more mineralized than dentine, having an inorganic content of 96% by weight, while the inorganic content of dentine is approximately 70% by weight, 18% organic material and 12% water.

Bonding to dentine is a challenge due to the higher water and organic content. Cementum's organic phase consists of coarser collagen fibres than dentin, therefore a weaker bonding can be expected (Joseph *et al.*, 2013).

Within the limits of this *in vitro* study, it can be concluded that bulk-fill sonic-activated composite restorations have better marginal sealing in comparison with bulk-fill paste-like composites due to a viscosity drop (up to 87%) which increases the flow-ability of the material.



CHAPTER 7

Limitations and recommendations

7.1 Limitations of the study:

- The curing light was in direct contact with the bulk-fill materials. More clinical studies may be required to support the results of this study.
- The current study was done under ideal laboratory conditions, as the clinical functions and characteristics of composite materials are difficult to evaluate under *in-vivo* conditions, and clinical trials cannot estimate physical properties of restored teeth. *Invitro* evaluation provides an opportunity to evaluate the physical properties of restored teeth and is considered a predictor of the possible clinical performance of the restorative material. Clinically other factors, such as moisture control, can affect the results of the current study.
- The storage conditions of the specimens in the current study may vary from the clinical situation.

7.2 Recommendations:

Numerous bulk-fill composite materials are being indicated as restorative materials by single increment placement up to 5mm. The physical properties of these materials might render them inadequate for use as single increments. However, when selecting a bulk-fill restorative material it is important to know the composition of the material as well as the adhesive systems, the light cure type and time recommended by the manufacturer

CHAPTER 8

Conclusion

This *in vitro* study investigated the depth of cure, flexural strength and microleakage of bulk-fill composites. Based on the results, the null hypothesis was rejected.

Within the limitation of this study it can be concluded that:

1. Filtek Bulk Fill composite showed the highest depth of cure among the materials tested.
2. Sonic Fill2 showed the highest flexural strength, good adaptation to enamel and dentin and less microleakage among the materials tested.
3. No significant differences were found between Filtek Bulk Fill & Sonic fill2 in all the test results.
4. Filtek Bulk Fill & Sonic fill2 showed acceptable physical properties.
5. Tetric N Ceram showed the lowest result among all the materials tested.
6. Tetric N Ceram showed acceptable flexural strength but overall low physical properties.



Chapter 9

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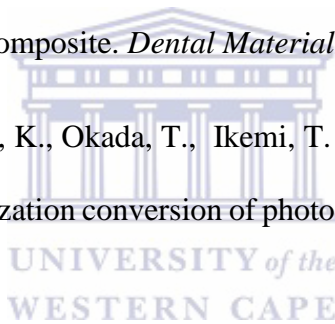
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Chapter 10

Appendix

Appendix 1: Patient Information Sheet

Oral & Dental Research Institute
Faculty of Dentistry and WHO Oral Health Collaborating Centre
University of the Western Cape
Cape Town

Consent form

I, Mr/Mrs/Miss.....

Date of Birth: File no. /Hosp. Sticker.....

I am willing to donate my premolar teeth in the study as described to me in the patient information letter by Dr A. Eltayeb. I understand that donating my teeth is voluntary.

The study is approved by the Ethical and Research Committee of the University of the Western Cape. I have been adequately informed about the objectives of the study. My rights will be protected and all my details will be kept confidential. No personal information will be published.

I hereby consent to donate my wisdom teeth for the research/study.

Patient's/patient's parent or guardian's name:.....

Patient's/patient's parent or guardian's signature:.....

Witness's name:.....

Witness's signature:.....

Researcher's signature:.....

Dr. Aziz Eltayeb


Date:.....



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An *in-vitro* evaluation of the physical properties of a new bulk-fill composite

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Aziz Eltayeb

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