MASTER OF DENTAL SCIENCE

The Identification of Composite Resin Restorations within Natural Teeth

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DECLARATION

I certify that

I am the author of the thesis.

Unless otherwise stated, all references cited have been consulted by me.

The work of which the thesis is a record has been done by me.

This work has not been previously accepted for a higher degree.

ABSTRACT

Composite resin has become a very widely-used restorative material due to excellent physical and aesthetic properties. Unfortunately this makes visual detection more difficult. Restorations form a unique feature of an individual dentition. Therefore it is important to identify composite in conservative dentistry to avoid charting errors and reduce cavity enlargement during restoration replacement. Furthermore it is of great importance in forensic dentistry to be able to identify the presence of all restorations. A number of techniques have been used to identify composite restorations, including dyes, acid-etching, ultra-violet light (UVL), and Quantitave Laser Fluorescence (QLF). As enamel, dentine and composite resin all have different fluorescent properties, ultra-violet light (UVL) has been of particular interest as a method of detecting the presence of composite resin in teeth. The aim of this study was to assess the accuracy of normal vision, magnification loupes and UVL for identifying composite resin restorations. Forty one composite resin restorations were placed in 113 natural teeth mounted in four sets of models. These four sets were examined by 20 dental volunteers using the three methods. The data showed that optical diagnostic accuracy range from 31.6% for visual examination, 25% for magnification to 92% for ultraviolet light. The specificity range from 85% for visual examination and 89.7% for magnification to 99% for ultraviolet light. The results indicated that UVL is the most efficient method of those tested to detect composite resin restorations within the different surfaces of the tooth. It is recommended that UVL is used adjunctively to the ordinary clinical examination, and should be considered in forensic examinations where identification is paramonts.

Chapter 1

1 Introduction

With the increasing use of the tooth coloured dental restorative materials, along with the improved properties, including shade and translucency of these materials, their identification during a clinical examination is becoming more difficult and challenging to clinicians. Failure to identify tooth coloured restorations may have consequences such as cavity enlargement when replacing the restoration due to failure to identify the restoration margins and incomplete removal of luting agents of veneers and resin retained bridges prior to re-bonding. Dental charting errors are another problem that may occur due to failure in recognising a tooth coloured restoration. These may cause misidentification of disaster victims if the dental records are used for identification. Therefore, the correct identification of tooth coloured restorative materials is of significant importance in both clinical and forensic dentistry.

Various studies have been done to investigate the diagnostic efficiency of ultraviolet light (UVL) with different types of composite resin, either in vitro or in forensic dentistry. All of these studies have demonstrated the efficiency of UVL in composite resin detection (Hermanson et al., 2008, Bush et al., 2010, Guzy and Clayton, 2013). Furthermore, other studies have proven that composite resin can fluorescence in sunlight due to the UVL components of sunlight. These studies showed colour changes in composite resin under the sunlight, and this change is influenced by the amount of UV light, the brand and fluorescent particles in the composite resin 2007 (Lu et al., 2006, lee et al., 2007).

Aims

In view of the importance of correctly identifying composite resin within natural teeth, the practical value of different diagnostic methods requires investigation. The aims of this dissertation are to

1) Assess the accuracy of clinicians in identifying composite resin restorations within natural teeth mounted in a simulated mouth using un-aided vision

2) Assess the accuracy of clinicians in identifying composite resin restorations within natural teeth mounted in a simulated mouth using 2.6x magnification loupes

3) Assess the accuracy of clinicians in identifying composite resin restorations within natural teeth mounted in a simulated mouth using an ultraviolet light (UVL)

4) Compare the three methods with the objective of determining the most efficient method for composite resin identification.

These methods have been selected for this study due to their availability and applicability into routine dental practice.

Chapter 2

2 Literature review

2.1 Composite resin

With the increased demand for aesthetic restorative materials in dentistry, manufacturers have increasing developed and the variety of composite resin restorative materials. In addition, in posterior teeth composite resin has become a viable alternative to dental amalgam, it has gained further popularity as a result of better aesthetics and chemical adhesion to tooth structure (Correa et al., 2012). The excellent appearance of composite resin makes it difficult to discriminate from the natural teeth (Tani et al., 2003).

2.1.1 Composite resin development

Silicate filling material was the only tooth coloured direct filling material available before the development of acrylic resin. However, due to its short clinical longevity time (around 4 to 5 years) and solubility in the oral environment, other aesthetic direct filling materials were sought (Bowen, 1956, Bowen, 1982).

The development of composite resin began in 1843 when the German chemist Redtenbacher discovered acrylic acid. This was followed by the development of methyl methacrylate (MMA) and subsequently polymerised to form poly-methyl methacrylate (PMMA) (Peutzfeldt, 1997).

In 1936 poly-methyl methacrylate (PMMA) was introduced into dentistry for denture base fabrication (Chan et al., 2010), and four years later acrylic was used for indirect filling materials (inlays) and fixed prosthesis. The use of direct acrylic resin as a filling material was introduced in Germany during World War II (Rueggeberg, 2002).

It soon became clear that acrylic resin had significant disadvantages such as increase risk of secondary caries, discoloration, high polymerisation shrinkage, and a high coefficient of thermal expansion (Peutzfeldt, 1997).

In 1940 epoxy resin was developed but it had a slow setting time. In 1959 Bowen developed bisphenol A glycidyl methacrylate (Bis_GMA) resin by replacing the epoxy group with a methacrylate group (Bowen, 1982, Bowen, 1956). Bis_GMA is prepared from Bisphenol A and Glycidyl Methacrylate (Bowen, 1962, Peutzfeldt, 1997).

This new Bis_GMA monomer resin had low polymerisation shrinkage and was considered an insoluble esthetic direct filling material for anterior teeth (Bowen, 1962). The development of Bis_GMA monomer was the first successful monomer system in the composite era (Rueggeberg, 2002).

The introduction of the Bis-GMA monomer facilitated the commercial development of composite resin. Robert Chang 1969 and Henry Lee 1970 developed the first use of composite in paste/liquid form.

The paste/liquid composite system was not based completely on Bis-GMA monomer as it has high viscosity due the presence of two hydroxyl groups. Therefore, manufacturers diluted the Bis-GMA monomer with a co-monomer called Triethylene glycol dimethacrylate (TEGDMA).

In late 1960s and early 1970s composite resin restorations that could be used with the newly established enamel etching technique using phosphoric acid were introduced.

Since the 1970s, some aspects of composite resin have researches focused on the filler contents and the polymerisation mode. The type and size of fillers affect the composite surface roughness and the restoration strength. Furthermore, the fillers reduce the polymerisation shrinkage of composite resin due to the decrease of the coefficient of thermal expansion.

Early composite resins were difficult to polish due to the large ground quartz particles (8-12µm), which resulted in rough surfaces. Subsequent, microfilled (approximately 0.02µm) composite resin was introduced in Europe. This consisted of silica particles to provide a highly aesthetic polished surface restoration. Unfortunately micro-filled composites exhibit low strength. Consequently, hybrid composite resins with range of particle filler sizes (1 µm) were developed. These resins have the benefits of good strength and being able to be easily polished. The average particle size of hybrid composite is less than 1µm (Rueggeberg, 2002).

2.1.2 Components of composite resin

Dental composite resins contain an organic matrix, inorganic filler particles, and a coupling agent to bond the organic resin to the inorganic fillers (Hermanson et al., 2008).

Bis-GMA is the most common monomer used in the organic matrix with the addition of a polymerisation initiator and stabilisers (Peutzfeldt, 1997).

Inorganic filler materials, including quartz and/or fused silica, are added to the organic matrix to improve the mechanical and physical properties of the composite resin. The fillers reduce the shrinkage of the composites, provide radio-opacity and improve the aesthetics and the handling properties (Hervas-Garcia et al., 2006).

The organosilane coupling agent forms a chemical bond with the fillers at one end, and the methacrylate group with the resin at the other end (Hervas-Garcia et al., 2006).

Composite resin materials are classified in different ways but the most popular classification is the Lutz and Phillips classification. This classification is based on the filler size and divides the composite materials into three groups: macro-filled composite (0.1 to 100 µm), micro-filled composites (0.04 µm) and hybrid composite with a range of fillers size (Lutz et al., 1983). Manufacturers have also added inorganic oxides of rare earth compounds as fluorescent agents into the filler components or the organic matrix to improve the aesthetics and optical properties of the composite (Hermanson et al., 2008, Park et al., 2007).

2.1.3 Bonding of composite resin to enamel and dentine

Enamel consists of 96% prisms of hydroxyapatite, 1% organic materials, and 3% water (Noort, 2002). The bond between the enamel and the composite resin is created by the increase of the enamel wettability and surface energy. Etching the enamel with 20-50% phosphoric acid may remove up to 10µm of enamel surface with porosities reaching a depth of 25-75 µm. This creates a micromechanical bond between the enamel and the resin when the resin penetrates the enamel micro-irregularities (Buonocore, 1955., Noort, 2002).

Relatively dentine is hydrophilic comprising 70% inorganic material, 20% organic material and 10% water with dentinal tubules running from the pulp to the amelo-dentinal junction. Bonding a hydrophobic resin to hydrophilic dentin is difficult. Therefore, it is necessary to create a hybrid layer of hydrophilic monomers (Noort, 2002)

In consequence, conditioning the whole cavity is important either by three, two or one steps enamel dentin-bonding systems. The first step is removing the smear layer and demineralization of the surface of both enamel and dentin by acid etching leaving dentinal tubules uncovered. In the second step, the amphiphilic (bi-functional molecule) monomer primer (e.g. 2-hydroxyethyl methacrylate (HEMA) penetrates the demineralised surface of enamel and dentin with the outer part of dentinal tubules. This amphiphilic layer will create an intermediate layer to make the bond of the hydrophobic composite resin to hydrophilic dentin possible. The third step is the sealer or bonding agent (mixture of Bis-GMA and HEMA), which bonds the hydrophobic part of primer together create hybrid layer to bond the composite resin to dentin (Nakabayashi et al., 1982).

2.1.4 Light curing of composite resin

Stress at the interface between the composite resin and the tooth tissue due to polymerization shrinkage is a major problem with composite resin restorations. Therefore, different types of light cure systems have been introduced. Continuous cure has high intensity curing light (Feilzer et al., 1995). Soft start curing techniques, where curing starts at a low intensity then rises to maximum during the first half of curing cycle or where it stays low for the first half and then rises for the rest of the cycle. The target of this method is to reduce polymerisation stress by raise the composite flow in the gel state during the first application. Nevertheless, the reduction in shrinkage is minimal and the lower intensity light produce lower level of energy results in less composite polymerization (Yazici et al, 2008)

Pulse curing technique; the most occlusal increment of composite resin activated by short pulse light with low intensity of 100-300 mW/cm2 for 3 seconds, then a pause for 3 to 5 min during which polishing of a restoration can be made, followed by the second pulse start with high intensity of 500-600 mW/cm2 for 30 seconds, The slower polymerization during the first pulse improve the formation of extended polymer chains and hence cross-linking (Kanca and Suh, 1999).

On the other hand, there are a number of other factors that affect the degree of curing such as the distance between the composite resin restoration and the light cure, filler size and number, curing unit, exposure time and composite shade (Rueggeberg et al., 1993).

2.1.5 Identification of composite restorations

The identification of composite resin restorations and their margins is important in restorative dentistry. There is a significant increase in cavity size following the removal of tooth colored restorations, either with or without the use of magnification (Forgie et al., 2001). Furthermore, teeth become weaker and may predispose to fracture in some cases due to cavity enlargement during restoration replacement (Tyas, 2005). Therefore, to prevent cavity enlargement during filling replacement and to preserve sound tooth tissues, correct identification of composite restorations is required.

To address this problem, many studies have used different methods to identify composite restorations, such as ultraviolet light, quantitative light induced fluorescence (QLF), etching, CT imaging, radiographs, chemical softening agents and dyes.

The efficiency of UVL in composite resin detection has been reported in different studies in both forensic and in vitro studies (Hermanson et al., 2008, Bush et al., 2010, Guzy and Clayton, 2013).

Other studies have demonstrated that the amount of change in the composite resin color when exposed to UVL, is affected by the amount of the UVL, and the fluorescence emission of the composite resin is affected by the composite brand and shade (Lu et al., 2006, Lee et al., 2007, Lim and Lee, 2007).

2.1.6 Composite resin – clinical techniques

2.1.6.1 Direct placement

The most common way of placing composite restorations is directly with the material being placed in a prepared cavity and then cured. There are a number of technical challenges that need to be overcome including moisture control, setting contraction and re-establishing anatomical form. Composite restorations need to be placed in a dry environment to enable good bonding to the tooth tissue. Many authorities advocate the use of rubber dam at all times when placing posterior composites. In larger cavities where the depth exceeds the depth of cure or in proximal boxes a layering technique is required to prevent stress on the tooth and to ensure a good marginal seal. In Black's Class II, III and IV cavities establishment of an anatomical contact point is essential to eliminate food trapping and to prevent tooth movement. Careful use of a matrix band along with incremental layering where the contact point is established first help to develop a good contact point (Buonocore, 1955., Chan et al., 2010)

2.1.6.2 Indirect restorations

Composite indirect inlays and onlays were developed in the 1980's to try to eliminate some of the disadvantages of direct composite placement: moisture control, polymerisation shrinkage and difficulty in developing contact points. A higher percentage of filler can be used which reduces the shrinkage and as there are no issues with moisture control or access the technician can construct the inlay/onlay in optimal conditions.(Nandini, 2010)

Composite veneers are a thin layer of composite resin placed on labial or palatal surfaces of teeth. Composite veneers are made to correct developmental abnormalities, aesthetics issues or discolorations and may be either direct or indirect.

Direct composite veneers are applied directly to the tooth at the chairside. This technique has low cost when compared to indirect composite procedures or the alternative porcelain veneers. Repair and polishing can be done intraorally, with better marginal adaptation than indirect composite veneers. However, the disadvantages of this technique are the low resistance to wear, discoloration over a short period of time and fractures (Korkut et al., 2013).

Indirect composite veneers have higher resistance than directly placed veneers to wear, fractures and discolouration due to the optimal exposure to light for maximum polymerization that is possible in a laboratory setting. Considered as higher costs and the need for use of an adhesive cement are the main disadvantages of this technique (Korkut et al., 2013). With the higher filler content acid etching is less predictable and so debonding may occur under load at the veneer/cement interface.

2.2 Other restorative materials

2.2.1 Dental Amalgam

In most of the twentieth century dental amalgam was the pre-eminent material for direct restorations in posterior teeth. Dental amalgam is a mixture of alloy with mercury. Amalgam alloy is composed of silver 40-70%, tin 12-30% and copper 12-24%. It may include indium 0-4% to reduce creep and increase strength in high copper amalgam. Amalgam containing up to 10% indium requires less mercury and lowers the emission of mercury due to the formation of indium oxide and a tin oxide film. The tin oxide film reduces mercury release. Palladium 0-5% is added to reduce tarnish and corrosion, and zinc up to 1% to prevent corrosion and metal oxidation (Bharti et al., 2010). Dental amalgam has been the restorative material of choice for many years in posterior teeth due to its low cost, longevity, low clinical technique sensitivity, ease of manipulation and high strength. However, despite all these advantages, dental amalgam has some limitations such as aesthetics and the fact that it requires mechanical retention within to tooth tissue which may lead to excessive removal of sound tooth structures (Correa et al., 2012). In addition, the signing of the Minnemata convention has placed a legal obligation on signatory countries to reduce the use of amalgam thereby reducing the risks associated with mercury.

2.2.2 Glass Ionomers

Glass ionomer cement is composed of calcium fluoroaluminosilicate glass powder and an aqueous solution of homo or copolymer acrylic acid. Glass ionomer cement has several desirable properties such as adhesion to moist tooth structure and base metals, an anti-cariogenic effect due to fluoride release, a low coefficient of thermal expansion similar to that of tooth structure, bio-compatibility and low cytotoxicity (Xie et al.,2000).

Conversely, glass ionomer has the disadvantages of low mechanical strength and poor wear resistance, therefore it is not suitable for high stress sites. In order to avoid the poor mechanical properties of the conventional glass ionomer cement, resin modified glass ionomer (RMGI) which contains hydrophilic monomer and polymers has been introduced. Resin modified glass ionomers have superior mechanical properties compared to conventional glass ionomer (Xie et al., 2000).

2.2.3 Sealants

A sealant may be either glass ionomer cement, or an autopolymerising or light cured resin used in preventive dentistry to seal the fissures and pits of erupted permanent teeth to prevent caries. Sealants should be placed as soon as possible after tooth eruption and up to four years after eruption depending on susceptibility to caries. However, fissure sealants are very technique sensitive and require good moisture control (Locker et al., 2003).

An autopolymerising resin sealant is used in caries susceptible teeth. Light cured resin sealant is used in teeth with incipient caries and up to 4 years after tooth eruption. Glass ionomer cement should not be used in teeth with incipient caries or after 4 years of teeth eruption (Locker et al., 2003).

2.3 Forensic dentistry

Forensic dentistry/odontology is the branch of dentistry that supports the legal profession and relates to matters of law. In the United Kingdom it is limited to criminal law work but in many other countries forensic dentists also undertake the civil law casework. There are four main aspects to forensic dentistry:

identification, disaster victim identification (DVI), bite mark analysis and age estimation. Only identification and DVI are of relevance to this thesis.

2.3.1 Importance of forensic dentistry

Forensic odontology is considered to be one of the most useful and reliable methods for victim identification in mass disasters and it is one of the three primary techniques that can stand alone to identify the victims with the others being DNA and friction ridge analysis (fingerprints) (Bush et al., 2007). Victim identification through fingerprints is not possible if the victim is decomposed, disarticulated or incinerated (Bush et al., 2007). Friction ridge analysis relies on a fresh body without much decomposition whilst DNA can be time consuming, relies on expensive advanced technology and equipment. In contrast dentistry can be undertaken on fully decomposed bodies, is quick and relatively cheap. Dental records and the combination of tooth size and proportion, decayed, missing and filled teeth are considered unique for each individual.

There have been many examples over the years of the value of dental records in the identification of the victims of violence or mass disasters. In Sweden, Borrman et al. (1993) found that 207 cases (76%) of the 281 deceased bodies that were identified over a 27 year period were identified using dental records. The remaining 74 cases were identified by another method or remain unidentified due to insufficient or an absence of ante-mortem dental records. In 1996 in Spain after a bus accident involving 57 passengers where 28 victims were burned 57% of the victims were identified by their dentitions (Martin-de las Heras et al., 1999, Valenzuela et al., 2000). Pretty and Sweet (2001) reported a case of a 16 year old female body found encased in a waterbed frame after being reported missing for over a year. The body had become mummified and the face features were completely disfigured due to the dry and cool conditions under the bed but the dentition remained in perfect condition. There were sufficient unique features that coincided in the ante-mortem of post-mortem radiographs to identify the victim.

Accurate ante-mortem and post-mortem dental records are essential to enable forensic odontologists to identify victims. The identification of composite resin restorations is of significant importance for correct dental records for forensic odontology. High quality tooth coloured dental restorations, maybe overlooked even by expert dentists (Bux et al., 2006). In 2002, 18 victims were killed after an airplane crash in Nepal. The first autopsy was done in Kathmandu, and the second autopsy of the 14 European victims was held in the Center of Legal Medicine, Frankfort, Germany. The re-examination showed that nine composite fillings, seven root canal fillings and one parapulpal pin were not discovered at the first autopsy (Bux et al., 2006). Linda Agostini was reported missing for several weeks in 1934. She was found partly burned in Albury, Australia. In this case the dentist failed to identify two tooth-colored restorations from her 8 dental restorations that didn't coincide with her dental records. That error was overlooked for 10 years (Brown, 1982).

In December 2004, more than 200,000 victims lost their lives in a tsunami disaster in more than 10 countries in and around the Indian Ocean. In this mass disaster the ante-mortem dental records were an excellent aid to identify the victims in addition to fingerprints and DNA (De Valck, 2006). Nearly 3000 bodies were identified from 3750 victims, 45% by dental records, 35% by finger prints and the remaining 20% by DNA (http://www.interpol.int/News-and-media/News/2005/N20051214)

2.3.2 Forensic dental identification

Forensic dentistry has a significant role in the identification of the deceased after events such as violent crimes, fires, road accidents, airplane crashes, drowning, wars and weather disasters. Dental identification is undertaken for personal and societal reasons (Table 2.1).

The forensic dentist can be involved in the identification process of deceased persons in two ways. Firstly and most frequently when the identity of the deceased is suspected or in a mass disaster when the names of the victims are known the post-mortem (after death) and the ante-mortem records (before death) of the deceased individual are compared. Secondly, in the absence of ante-mortem records or when there are no clues to identity the post-mortem records completed by the forensic dentist can suggest the characteristics of the individual to narrow the search to a specific population pool (Pretty and Sweet, 2001)

Criminal	Typically an investigation to a criminal death cannot begin until the victim has been positively identified
Marriage	Individuals from many religious backgrounds cannot re-marry unless their partners are confirmed deceased
Monetary	The payment of pensions, life assurance and other benefits relies upon positive confirmation of death.
Burial	Many religions require that a positive identification be made prior to burial in geographical sites.
Social	Society's duty to preserve human rights and dignity beyond life begins with the basic premise of any identity
Closure	The identification of individuals missing for prolonged period can bring sorrowful relief to family members.

Table 2-1 Reasons for identification of found human remains (Pretty and Sweet, 2001)

2.3.3 Comparative dental identification techniques

Comparison of ante-mortem and post-mortem records would at first consideration appear to be simple. However, it is a complex process that requires the expertise of forensic dentists or in the case of mass disasters a team of forensic dentists (Hill et al., 2011).

The tentative identification of the missing person is often found on their person e.g. in a wallet or on a keyring. This will ease the collection of the ante-mortem records. However, in other situations the ante-mortem records are obtained from the database of missing persons in the geographical location where the individual was found or other areas where physical characteristics and circumstantial evidence point to a different region (Pretty and Sweet, 2001). Ante-mortem records are collected from different dental surgeries that the victim attended and are amalgamated to create one master ante-mortem dental chart. This master chart is then compared to the post mortem dental chart prepared by the forensic dentist. Other sources of dental information such as radiographs (Figure 2.1), study casts (Figure 2.2), clinical photographs and more recently selfies (Miranda et al., 2016) provide suitable evidence for dental matching. It is good practice to undertake the post-mortem dental examination prior to construction of the ante-mortem master record which should be constructed carefully prior to the comparison with the post-mortem records (Hill et al., 2011). In DVI situations it is common to have a team of dentists compiling the ante-mortem dental charts, a second team preparing the post-mortem chart and a third team undertaking the matching/comparison.

2.3.3.1 Post-mortem profiling

Post-mortem profiling is used when the ante-mortem dental records are not available and the other methods of identification are not possible. Post-mortem dental examination can provide information about the age, ancestry background, sex, socio-economic status, occupation, dietary and behavior habits, dental and systemic diseases. Therefore, it can help the legal authorities by narrowing the missing persons search to a specific population pool (Pretty and Sweet, 2001).

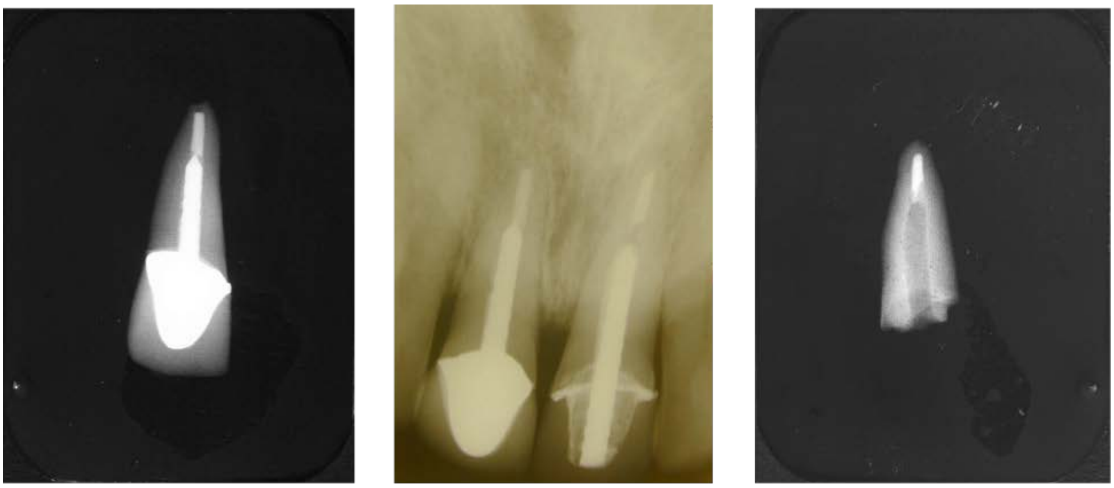

Figure 2.1 Post-mortem radiographs (black backgrounds) taken to display same features as the ante-mortem radiograph (grey background) enabling identification.

Figure 2.2 ante-mortem study cast with the same tooth orientation and spacing as recovered mandible enabling identification. N..B socket in tooth 47 region in mandible suggesting loss of this tooth after death

2.3.3.2 Denture marking

Denture marking is another technique for victim identification (Figure 2.3). Law in Sweden and Iceland requires this. In the United States denture marking is mandatory in 21 states (Borrman et al., 1999). The last recommendation by Swedish National Board of Health and Welfare states that "the patients shall always be offered denture marking and be informed about the benefit there of. Denture marking is not permitted if the patient refuses" (Mohan et al., 2012).

2.3.3.2.1 Importance of denture marking system

Kareker et al (2014) stated the importance of denture marking system as fololows

1. Identification of the dead or deceased when all other means have failed.
2. Identification of individuals for forensic, social and legal reasons.
3. Victim identification in case of mass disasters.
4. Identification of mutilated and decomposed bodies when all other parameters like scars, tattoos, and facial features have failed.
5. Without valid entity to solve the ensuing problems of death certificate, disposal of diseased property, claiming of accrued money or insurance policies, claim for compensation (in case of traffic accidents) denture marking will definitely help in positive identification of victims.

In Sweden the denture should be marked with the patient's date of birth, S for Sweden and a unique number by incorporating a stainless steel metal band into the acrylic (Borrman et al., 1999). The American Dental Association criteria for denture marking are (Mohan et al., 2012).

1. The identification should be specific.
2. The technique should be simple.
3. The mark should be fire and solvent resistant.
4. The denture should not be weakened.
5. The mark should be cosmetically acceptable.

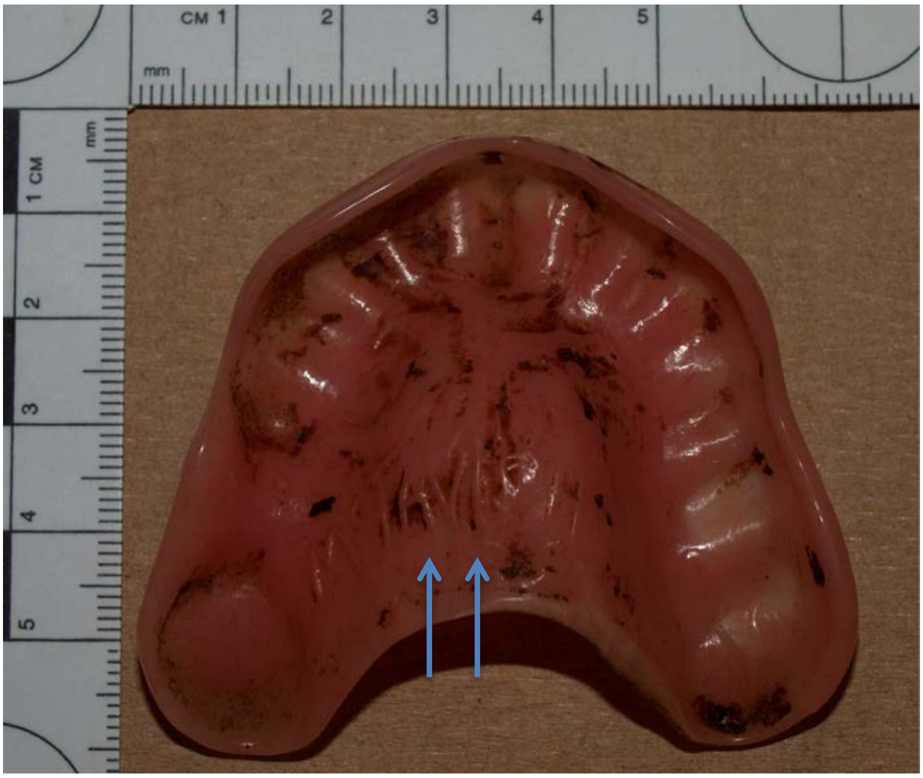

Figure 2.3 A denture with identifying marking

2.4 DNA in forensic dentistry

Teeth are highly resistant to decomposition and high temperatures. Therefore, DNA from teeth can be used in victim identification when the other traditional identification methods are not possible. Teeth DNA can be provided by a technique based on PCR (Polymerase Chain Reaction). Polymerase Chain Reaction is an enzymatic amplification of a specific DNA sequence. This gene analysis technique is a simple method with high reliability (Pramod et al., 2012).

2.4.1 Tooth selection for DNA identification

Tooth DNA identification based on the presence of pulp cells. Therefore, tooth with larger pulp provides best source of DNA. Consequently, multirooted teeth with larger pulp provide more pulp cells than incisors that make them the best candidate for DNA identification (Higgins and Austin, 2013).

2.5 Vision

2.5.1 The eye

The eye lies within the orbit, and eye movement is controlled by six small skeletal muscles called the extrinsic ocular muscles. The extrinsic ocular muscles are innervated by cranial nerve III (oculomotor), IV (trochlear) and VI (abducens).

Vision depends on photosensitive receptor cells and nerves within the retina. The visual system relies on illumination and the ability to determine detail. Photoreceptors consist of rods and cones. Cones are exited only by high illumination and responsible for color vision, whereas rods are responsible for night vision without any color discrimination and low visual acuity (Borrman et al., 1993).

2.5.2 Anatomy of the retina

The retina is a yellow disc with a central area called the macula lutea. The macula lutea is 5 to 6mm in diameter. The fovea is a depression located in the center of the macula lutea (Parr, 1989) and this measures about 1.5 mm in diameter (Holmes, 1993).

The fovea is highly concentrated with cones and few rods. The central region of fovea is a rod free zone. Therefore, the central area of the retina is responsible for clear vision and color vision, whereas the peripheral retina is more responsible for vision at night and dark (Parr, 1989)

2.5.3 Visual acuity

Visual acuity is defined as the ability of the eye to distinguish the finest detail of an object. However, there is a limit of the finest detail that the eye can see ((Parr, 1989)

Visual acuity increases as the distance between the two points of light gets smaller (Holmes, 1993), and with higher luminance. Furthermore, there is higher acuity present in the center of the fovea than the rest of the retina (Parr, 1989)

At a very low level of light, a few groups are formed from many rods and these act as light detectors. On the other hand, when the illumination increases the number of rods decrease in each group (Parr, 1989).

2.5.4 Color vision

In humans, the cones are responsible for color vision. The photoreceptors within the cones form three groups and each group is sensitive to one color. One group is sensitive to green, one to blue, and one to red. The individual with normal vision can see a mixture of these three colors in different amounts (Holmes, 1993).

2.6 Magnification

Magnification is defined as the process of enlarging the size of an object through a lens (Keeney et al., 1995). There are four magnification systems used in dentistry: simple magnifying glasses in spectacle frames, hinged magnifiers that can be attached to either spectacle frames or worn attached to a headband, multiple lens systems commonly referred to as loupes or surgical telescopes and the operating microscope (Forgie et al., 1999).

Simple magnification systems create up to ×2 magnification with normal eyes but the working distance is short and the operator needs to move close to the object. However, getting closer to the object may cause back and neck disorders due to the poor posture, and there are also problems with blurred and distorted images as these systems often have poor quality lenses (Christensen, 2003).

Compound magnification uses more than one lens to view the object and this system allow adjustment to the working length, power and depth of magnification. However, in all types of magnification the depth of focus and the field of view decrease as the level of magnification increases (Forgie et al., 1999).

2.6.1 Magnification and posture

The positive effect of the use of magnification on a clinician's posture has been shown in several studies (Maillet et al., 2008, Branson et al., 2010, Branson et al., 2004). Branson et al. (2010) stated that the use of magnification loupes improved the posture of dental hygiene students and reduced musculoskeletal disorders.

Furthermore, Maillet et al. (2008) found that magnification loupes improved the posture of dental hygiene students and he recommends that all the dental hygiene students should be provided with magnification loupes at the start of their program.

2.6.2 Magnification and visual acuity

Magnification efficiency has been examined in different clinical investigations and treatment in both *in vivo* and *in vitro* studies (Castellucci, 2003, van As, 2003, Forgie et al., 2002, Buhrley et al., 2002, Smadi and Khraisat, 2007). It has been claimed that magnification and illumination improves visual acuity (van As, 2003). Magnification has been show to improve the accuracy of caries detection when compared to unaided vision (Forgie et al., 2002). In endodontics, Buhrley et al. (2002) found that the detection rate of second mesio-buccal (MB2) was approximately three times more with magnification than unaided vision. This result was confirmed by Smadi and Khraisat (2007) who also found that magnification improved the ability to detect MB2 canals. Therefore, magnification and illumination enhance the tooth prognosis and increase the success rate of both surgical and nonsurgical cases. Furthermore, difficult cases can be treated with more confidence and a higher chance of success (Castellucci, 2003)

2.6.3 Magnification in dental practice

In 1999 magnification was used by only a few dentists who had been qualified for less than 20 years, but by over a quarter of dentists who had been qualified for more than 30 years (Forgie et al., 1999). This may be because of the effect of magnification on posture and vision, and the increased need for magnification with age. In a more recent American study 75% of general dentists use loupes routinely for endodontics (Savani et al., 2014). A survey of dental hygienists Jennifer and Thomas (2007) showed that there was wide agreement regarding the benefits of the use of magnification loupes. In addition, dental hygienists believed that the use of loupes should be introduced into dental hygiene educational programs. Other studies have also supported the use of magnification loupes and shown an improvement in clinical skills as a result (Congdon et al., 2012, Maggio et al., 2011). Maggio et al. (2011) investigated the effect of magnification loupes on the skills obtained during a preclinical operative dentistry course. They found that the performance of the students was significantly enhanced while they were using the dental magnification loupes, and they concluded that loupes are an effective adjunct during dental education.

However, in a questionnaire study done among staff and students in accredited dental hygiene programs, Congdon et al. (2012) found that most of the questionnaire respondents claimed magnification loupes had no clinical indications for their use. Furthermore educational programs seem to be slow to adopt and require the use of loupes. Therefore, current clinical policies should involve the use of the magnification loupes, to ensure that the graduates experience the benefits of the magnification loupes in the clinical practice during their education (Congdon et al., 2012).

2.7 Ultraviolet light

Ultraviolet light is emitted in the wavelength range from 100 – 400 nm. In other words, ultraviolet light is that part of the electromagnetic spectrum situated between x-rays and visible light. Ultraviolet light is divided according to their wavelength into vacuum UV, far UV, UV-C, UV-B and UV-A (see Fig 2.4). UV radiation has shorter wavelengths with higher frequencies than visible light, but longer wavelengths with lower frequencies than X-rays (Panov and Borisova-Papancheva, 2015).

2.7.1 Ultra-violet light sources

Johann Ritter discovered ultraviolet light in 1800s, whilst the first commercial ultraviolet light was invented in 1900s (Purgo Enviro Tech, 2011). Sunlight is a natural source of ultraviolet radiation. Sunlight consists of UV-C, which is the most dangerous form of UV rays, it is absorbed in the ozone layer of the atmosphere and therefore the UV-C from the sun doesn’t affect people. Other UV sources include UV nail curing lamps, dental polymerizing equipment, welding equipment, currency detector, tanning booths, bactericidal lamps, black lights, halogen lights, mercury vapor lamps, fluorescent and incandescent equipment and printing ink polymerizing equipment "OSH Answers Fact Sheets”.

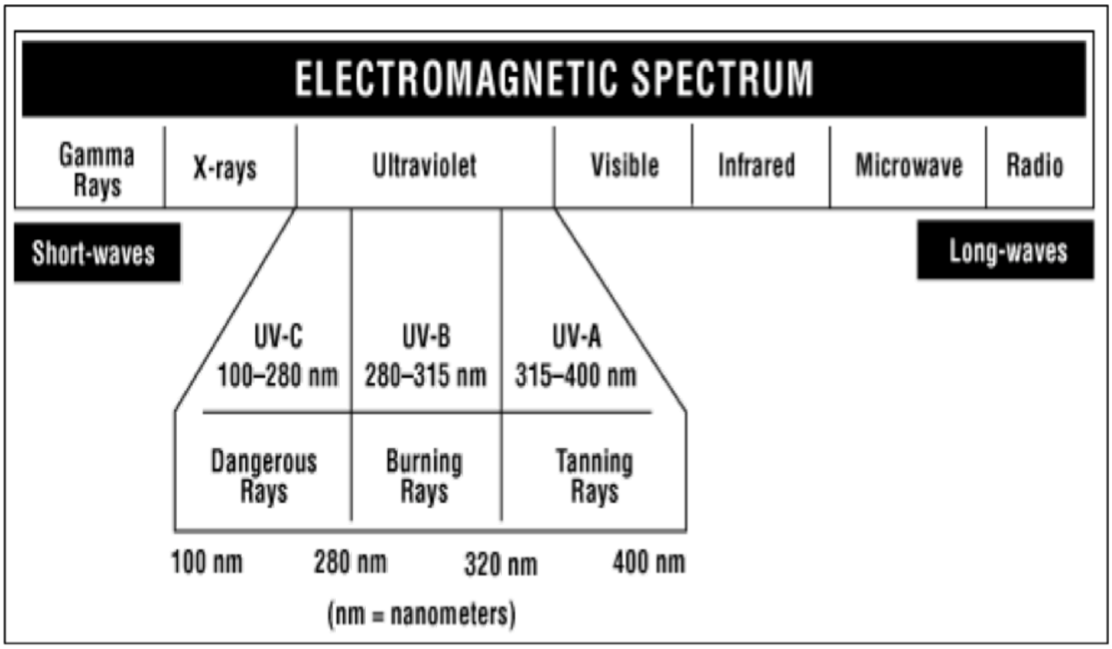

Figure 2.4 Electromagnetic spectrum (CCOHS, 2015)

2.7.2 Beneficial effects of UV radiation

UV-B radiation is responsible for stimulating vitamin D production in the body, 7-dehydrocholesterol in the skin absorbs UV-B to stimulate the formation of pre vitamin D3, that is later converted to vitamin D3. Subsequently vitamin D3 is metabolized in the liver to 25-hydroxyvitamin D3, and then in the kidney to the active form of vitamin D (Holick, 2004). However, the risks of UV radiation outweigh the benefits, as discussed below.

2.7.3 Deleterious effects of UV radiation

UV radiation affects the human immune system and reduces the body's defense against skin cancer. UV radiation induces the keratinocytes to increase the production of cytokines that are responsible for the production of IL 1, IL 3, IL 6, tumor necrosis factor and granulocyte/macrophage-CSF by epidermal cells. These cytokines causes local immunologic and inflammatory reactions following UV irradiation. In addition, UV increases the production of the immunosuppressive factors (T-lymphocytes and antigen-presenting cells) by the erythema (skin redness), tanning (skin darkening). Delayed and prolonged exposure increases the risk of skin cancer (basal cell carcinoma, melanoma, squamous cell carcinoma) and skin ageing (Panov and Borisova-Papancheva, 2015). 95% of the UV radiation that reaches the earth is long wave UV (UV-A). UV-A is less intense than UV-B but more extensive, therefore UV-A is able to penetrate into the deep skin layers to affect the connective tissues and the blood vessels to cause premature aging (Vermont, 2015).

The eyes are very sensitive to UV radiation, such that even a short exposure may cause photokeratitis and photoconjunctivitis. Photokeratitis is defined as an inflammation of the cornea. Conjunctivitis is defined as inflammation of the conjunctiva. Although photokeratitis and photoconjunctivitis are reversible and wouldn't cause any permanent damage to the eyes or the vision, they can be very painful and are associated with watery discharge, blurred vision and discomfort. However, UV-A and UV-B radiation can result in irreversible damage to the eyes such as cataract that may lead to blindness (CCOHS, 2015). The eyes are very sensitive to UV radiation from 210 nm to 320 nm (UV-C and UV-B). The maximum cornea absorption keratinocytes that block contact hypersensitivity reaction and IL1 activity (Schwarz and Luger, 1989). The medium UV wave (UV-B) causes skin burns, occurs at 280 nm (CCOHS, 2015). Table 2.2 highlights the acute health effects of UV light.

Type	**Wavelength**	**Acute Health Effects**
UV-A	315-400 nm	darkening of the skin
UV-B	280-315 nm	reddening of the skin, blistering of the skin, first or second degree burns, darkening of the skin Photokeritisis (welders flash) is inflammation of the cornea: symptoms include watery eyes and blurry vision, itchiness and pain photoconjunctivitis is inflammation of the membrane on the outside of the eye: symptoms include watery discharge and discomfort
UV-C	100-280 nm	In humans, UVC is absorbed in the outer dead layers of the epidermis. Photokeritisis (welders flash) UVC injuries may clear within a day or two, but can be extremely painful

Table 2-2 Acute health effects of UV radiation (Vermont, 2015)

2.7.4 UV safety glasses and face shield

Safety glasses and a reusable face shield should be worn during the application of UV light. Nevertheless, not all safety glasses or re-usable face shield are designed to protect against UV radiation, therefore UV safety glasses and face shields should be marked with the standard basic requirement mark (Z87) or with the standard high impact requirement mark (+Z87). New safety glasses and face shield are marked with U and a number range from 2-6. The higher number the greater the protection (WHO, 2015)

2.7.5 UV applications in medicine

In medicine UV lamps are used to treat some diseases, such as rickets, psoriasis, eczema and jaundice in neonates. However, therapeutic use should be under medical supervision to avoid the side effect of UV radiation (Organization, 2015).

Wave length	**Applications**
230-400 nm	Optical sensors, various instrumentation
240-280 nm	Disinfection, decontamination of surfaces and water (DNA absorption has a peak at 260 nm
200-400 nm	Forensic analysis, drug detection
270-360 nm	Protein analysis, DNA sequencing, drug discovery
280-400 nm	Medical imaging of cells
300-320 nm	Light therapy in medicine, effective long-term treatment for many skin conditions like psoriasis, vitiligo, eczema
300-365 nm	Curing of polymers

Table 2-3 applications in medicine (Panov and Borisova-Papancheva, 2015)

2.7.6 UV light in dentistry

Historically, ultra-violet lights have been large and difficult to use in clinical inspection and required jaw resection if used in forensic dentistry. Modern ultra-violet emitting LED flashlights are small and cheap. This makes their use practical in both forensic and clinical dentistry (Hermanson et al., 2008).

However, ultra-violet light is harmful and requires protective eyewear (Tani et al., 2003, Pretty et al., 2002) as discussed earlier in this chapter.

To mimic the fluorescent properties of natural teeth, dental composite has fluorescent properties as a result of the inclusion of fluorescent agents into the filler components or the organic resin (Hermanson et al., 2008) (Figure 2.5). Guzy and Clayton (2013) stated that the fluorescence from composite resin appears brighter than the surrounding tooth structure when exposed to ultraviolet light. If little or no fluorescing agent is added, the composite will appear darker than the surrounding tooth structure when exposed to the ultraviolet light.

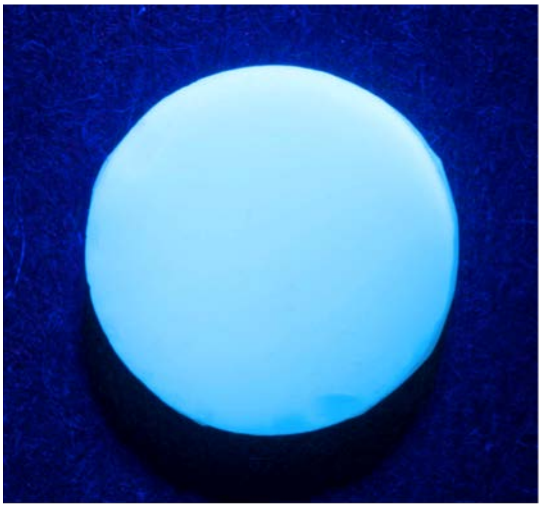

Figure 2.5 Fluorescence in a composite disc with UV light applied

Composite resin fluorescence emission is affected by the brand and the shade of the composite resin, and it is shifted to blue color and an increase in lightness when exposed to illumination, including UV (Lim and Lee, 2007). Studies have been undertaken to examine the effect of UVL on composite resin (Hermanson et al., 2008, Guzy and Clayton, 2013). Hermanson et al. (2008) found that the UVL excitation range between 360-380 nm can be used in forensic dental inspection. They also found that composite and porcelain appear different when exposed to UVL. Guzy and Clayton (2013) examined the use of UVL in two forensic dental cases and showed that it is a very useful tool when used in dental examinations, especially as an adjunct to radiographic examination. Bush et al. (2010), in an in-vitro, study examined the fluorescence excitation and emission of 14 brands of composite resin, each brand being assessed after it has been placed in an extracted tooth. Subsequently, the composite resin was removed and the extracted tooth was assessed with UVL for any composite resin residues. The result indicated that the ideal excitation wavelength was 385-395 nm, and there are 3 types of composite resin according to their fluorescence excitation: highly fluorescent, moderately fluorescent and weakly fluorescent. After the composite was removed the UVL examination revealed the presence of composite resin residues in each tooth, even though the investigators believed that all the composite resin had been removed. The authors of this study concluded that UVL should be used when removing composite resin. Other studies have examined the influence of the different amount of UV components in daylight (sunlight) on composite resin (Lee et al., 2007, Lu et al., 2006)

Lee et al. (2007) stated that “The percentage of the UV component of the daylight simulator influenced the color of composite resins”. Moreover, a study by (Lu et al., 2006) revealed that the colour of composite resin was affected by the amount of the UV components.

2.8 Quantitative light induced fluorescent (QLF)

Quantitative light induced fluorescent (QLF) is a non-invasive method used to detect incipient carious lesions by identifying and quantifying the mineral change in tooth enamel, based on the natural auto-fluorescence property of teeth (Angmar-Mansson and ten Bosch, 2001). The QLF device consists of hardware (handpiece and controlbox) and software. This device consists of a high intensity blue light applied to the teeth surface that emits green light (Inspector Research Systems, BV, The Netherlands, www.inspector.nl). A study by Pretty et al. (2002) indicated that QLF is an accurate method to detect composite resin fillings in natural teeth. QLF is not a practical technique in clinical situation due to size, cost and availability, therefore it was excluded from this study.

2.9 Statistic consideration

Sensitivity is a measure of the proportion of positive findings that are correctly identified.

Specificity is a measure of the proportion of negative findings that are correctly identified. Both are independent on the prevalence of the variable being measured

Diagnostic value or the diagnostic accuracy measures the veracity of a diagnostic test. It is the proportion of true results either true positive or true negative and gives accuracy as one score (Petrie et al., 2002). It is dependent on the prevalence of the variable being measured.

Sensitivity = TP/(TP+FN)

Specificity = TN/(TN+FP)

Diagnostic value = (TP+TN)/(TP+TN+FN+FP)

TP = true positive

TN = true negative

FP = false positive

FN = false negative

Chapter 3

3 Materials and Methods

3.1 Mouth model construction

Eight dental arches of all teeth excluding the third molars were fabricated producing four mouth models. Figures 3.1 and 3.2 are examples of upper and lower arches. The teeth for this *in-vitro* study were selected from the historical collection of teeth at the University of Dundee. One hundred and twelve un-restored permanent teeth were selected and stored in water with chlorhexidine to prevent dehydration. The teeth were cleaned with pumice and a rubber-cup in a slow speed handpiece. Various designs of cavities were prepared in 41 selected teeth and restored with composite resin restorations (Spectrum® TPH®3 DENSPLY). The restorations varied in size from very small to large and well colour-matched to poorly matching restorations. This number and variation of restorations was chosen to reflect a moderately restored dentition in an adult. The teeth were placed in the dental arch moulds, and poured in dental stone then allowed to set. The models were removed from the moulds and the teeth were cleaned manually using a dental scaler to remove the residual dental stone.

Figure 3.1 An example of an upper model

Figure 3.2 An example of a lower model

The pattern of restorations for each mouth model was as follows

Table 3-1 mouth model 1 restorations

	Restoration	Surface(s) restore
17	Yes	D O
16	No	
15	No	
14	No	
13	Yes	B
12	Yes	M D B P I
11	No	
21	No	
22	No	
23	No	
24	No	
25	Yes	O
26	Yes	O
27	No	
37	Yes	O
36	No	
35	No	
34	Yes	O
33	No	
32	No	
31	No	
41	No	
42	No	
43	Yes	B I
44	Yes	O L
45	Yes	O
46	No	
47	No	

Table 3-2 mouth model 2 restorations

Tooth	Restoration	Surface(s) restored
17	Yes	O
16	Yes	O
15	No	
14	No	
13	No	
12	No	
11	No	
21	Yes	M
22	Yes	B
23	Yes	D
24	Yes	P
25	No	
26	No	
27	No	
37	Yes	L
36	No	
35	No	
34	No	
33	Yes	B
32	No	
31	No	
41	No	
42	No	
43	Yes	D L
44	No	
45	No	
46	Yes	O
47	Yes	O

Table 3-3 mouth model 3 restorations

Tooth	Restoration	Surface(s) restored
17	No	
16	Yes	O P
15	No	
14	Yes	O
13	No	
12	No	
11	No	
21	Yes	B I
22	No	
23	No	
24	No	
25	Yes	O
26	No	
27	Yes	O
37	No	
36	Yes	M O
35	No	
34	Yes	O
33	No	
32	No	
31	No	
41	No	
42	No	
43	No	
44	No	
45	Yes	M O
46	Yes	B
47	Yes	O

Table 3-4 mouth model 4 restorations

Tooth	Restoration	Surface(s) restored
17	Yes	O
16	Yes	O
15	Yes	O
14	No	
13	No	
12	No	
11	No	
21	No	
22	Yes	P
23	No	
24	No	
25	No	
26	Yes	O P
27	No	
37	No	
36	Yes	M O
35	No	
34	Yes	B
33	No	
32	No	
31	Yes	L
41	No	
42	No	
43	No	
44	No	
45	No	
46	Yes	O B
47	yes	M O

3.2 Volunteer selection

A convenience sample of subjects from within the dental school was selected. They were given the study protocol and advised that they could withdraw from the study at any time. A consent form was signed (Appendix A). The volunteers were postgraduate students and dental school staff with different experience levels in both clinical and academic sectors.

3.3 Data collection

A binary scoring system was used with each surface being considered filled or not filled. A simple data collection form was constructed (Appendix B).

The time taken for each examination was also recorded. However, participants were advised that there was no time limit and this data was being collected for completeness rather than to rate each examiner.

The accuracy scores were calculated at 4 different levels

All surfaces: Combining the results from every surface on an individual basis

Occlusal surfaces: results from all the occlusal or incisal surfaces

Proximal surfaces: results from all the proximal surfaces

Smooth surfaces: results from all the buccal, labial, palatal and lingual surfaces.

In addition, for visual examination only, the scoring was also applied at the tooth level. In the same manner as the DMF scores can be considered at the tooth level in addition to the surface level. There is a school of thought in forensic dentistry that charting the status of the tooth provides as good evidence as considering surfaces separately. Including this scoring method will allow this reasoning to be tested.

Tooth level: Is there a filling on any surface of the tooth – yes/no i.e a single binary score was given for each tooth regardless of the number of surfaces involved.

3.4 Examination

Examinations were undertaken in a manner that accurately simulated the clinical situation. The mouth models were mounted in a phantom head (Nissin Dental products, Kyoto, Japan) with a distance of 45 mm from the upper first premolar buccal cusp tip to the lower first premolar buccal cusp tip (Figure 3.3). The examiner sat on a height adjustable chair and a portable dental light (Daray, Leighton Buzzard, UK) was used for illumination, using dental mirror with periodontal prob. An air syringe from a portable compressor was available for drying the teeth during clinical examination.

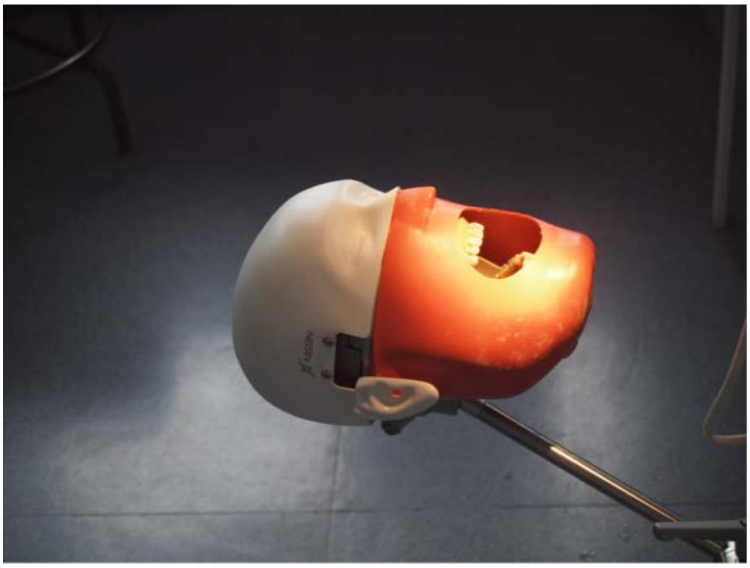

Figure 3.3 The teeth mounted in the phantom head and illuminated

Each participant examined the 4 mouth models on three occasions at least one week apart. The order of examination was normal vision then magnified vision and finally UV assisted examination. Visual examination was undertaken using normal vision including any prescription spectacles normally worn during clinical work. Magnification was achieved using flip down x2.6 Gallilean magnification loupes as shown in Figure 3.4 (Orascoptic, England).

Figure 3.4 Galilean loupes

Ultra-violet assisted examination involved the use of an ultra-violet light (UltraFire WF-501B G60) without the aid of the magnification loupes with the dental inspection light available.

Figure 3.5 Ultra violet torch

3.5 Data handling and analysis

The data were input into Word for Mac and exported to an Excel spreadsheet for data analysis. Statistical calculations were carried out manually. Each surface was classified as either True Positive (data score 0), False Positive (data score 1), True Negative (data score 2) and False Negative (data score 3). Using the decision matrix below.

		true state	
		sound	**filling**
test result	**sound**	**TN**	**FN**
	filling	**FP**	**TP**

Sensitivity, specificity and diagnostic value were calculated for each examination technique, combining all surfaces, for occlusal/incisal surfaces only, for proximal surfaces only and for smooth surfaces only.

Paired t-tests were then applied to the three sets of data (i.e. the three methods used to examine the teeth) for Diagnostic Value to determine whether there were any significant differences.

Chapter 4

4 Results

4.1 Study subjects

Twenty subjects were recruited. 18 postgraduate dental students and 2 senior academic staff.

4.2 Unaided Visual inspection

All surfaces combined

11,200 surfaces were examined. Of the restored surfaces 632 were correctly identified (TP), whilst 548 surfaces with restorations were missed (FN). Of the 10,020 unrestored surfaces 9,464 were correctly identified (TN) with 556 incorrectly considered restored (FP).

The sensitivity was 0.54, specificity 0.94 and diagnostic value 0.90.

Occlusal surfaces only

2,240 surfaces were examined. Of the 600 restored surfaces 447 were correctly identified (TP), whilst 153 surfaces with restorations were missed (FN). Of the 1,640 unrestored surfaces 1512 were correctly identified (TN) with 128 incorrectly considered restored (FP).

The sensitivity was 0.74, specificity 0.92 and diagnostic value 0.87.

Proximal surfaces

4,480 surfaces were examined. Of the 220 restored surfaces 76 were correctly identified (TP), whilst 144 surfaces with restorations were missed (FN). Of the 4,260 unrestored surfaces 3,983 were correctly identified (TN) with 277 incorrectly considered restored (FP).

The sensitivity was 0.35, specificity 0.93 and diagnostic value 0.91.

Smooth surfaces

4,480 surfaces were examined. Of the 360 restored surfaces 112 were correctly identified (TP), whilst 248 surfaces with restorations were missed (FN). Of the 4,120 unrestored surfaces 3,967 were correctly identified (TN) with 153 incorrectly considered restored (FP).

The sensitivity was 0.31, specificity 0.96 and diagnostic value 0.91.

Tooth level

2,240 teeth were examined. Of the 820 restored teeth 527 were correctly identified (TP), whilst 293 teeth with restorations were missed (FN). Of the 1,420 unrestored teeth 1,212 were correctly identified (TN) with 208 incorrectly considered restored (FP).

The sensitivity was 0.64, specificity 0.85 and diagnostic value 0.78.

Table 4.1 shows the visual examination results adjacent to each other to allow a quick comparison.

	Sensitivity	**Specificity**	**Diagnostic value**
Tooth level	64%	85%	78%
All surfaces	54%	94%	90%
Occlusal surfaces	74%	92%	87%
Proximal surfaces	35%	93%	91%
Smooth surfaces	31%	96%	91%

Table 4-1 Unaided visual inspection Sensitivity, specificity and diagnostic value

4.3 Inspection with Magnification loupes

All surfaces combined

11,200 surfaces were examined. Of the 1,180 restored surfaces 616 were correctly identified (TP), whilst 564 surfaces with restorations were missed (FN). Of the unrestored surfaces 9592 were correctly identified (TN) with 437 incorrectly considered restored (FP).

The sensitivity was 0.52, specificity 0.96 and diagnostic value 0.91.

Occlusal surfaces only

2240 surfaces were examined. Of the 600 restored surfaces 447 were correctly identified (TP), whilst 153 surfaces with restorations were missed (FN). Of the 1640 unrestored surfaces 1545 were correctly identified (TN) with 95 incorrectly considered restored (FP).

The sensitivity was 0.74, specificity 0.94 and diagnostic value 0.89.

Proximal surfaces

4,480 surfaces were examined. Of the 220 restored surfaces 55 were correctly identified (TP), whilst 165 surfaces with restorations were missed (FN). Of the 4,260 unrestored surfaces 4,018 were correctly identified (TN) with 242 incorrectly considered restored (FP).

The sensitivity was 0.25, specificity 0.94 and diagnostic value 0.91.

Smooth surfaces

4,480 surfaces were examined. Of the 360 restored surfaces 114 were correctly identified (TP), whilst 246 surfaces with restorations were missed (FN). Of the 4,120 unrestored surfaces 4,012 were correctly identified (TN) with 108 incorrectly considered restored (FP).

The sensitivity was 0.32, specificity 0.97 and diagnostic value 0.92.

Table 4.2 shows the x2.6 magnification examination results adjacent to each other to allow a quick comparison.

	Sensitivity	Specificity	Diagnostic value
All surfaces	52%	96%	91%
Occlusal surfaces	74%	94%	89%
Proximal surfaces	25%	94%	91%
Smooth surfaces	32%	97%	92%

Table 4-2 Inspection with magnification l Sensitivity, specificity, and diagnostic value

4.4 Inspection using ultra violet light

All surfaces combined

11,200 surfaces were examined. Of the 1,180 restored surfaces 976 were correctly identified (TP), whilst 204 surfaces with restorations were missed (FN). Of the 10,020 unrestored surfaces 9,896 were correctly identified (TN) with 124 incorrectly considered restored (FP).

The sensitivity was 0.83, specificity 0.99 and diagnostic value 0.97.

Occlusal surfaces

2240 surfaces were examined. Of the 600 restored surfaces 557 were correctly identified (TP), whilst 43 surfaces with restorations were missed (FN). Of the 1640 unrestored surfaces 1626 were correctly identified (TN) with 14 incorrectly considered restored (FP).

The sensitivity was 0.93, specificity 0.99 and diagnostic value 0.97.

Proximal surfaces

4,480 surfaces were examined. Of the 220 restored surfaces 155 were correctly identified (TP), whilst 65 surfaces with restorations were missed (FN). Of the 4,260 unrestored surfaces 4,200 were correctly identified (TN) with 60 incorrectly considered restored (FP).

The sensitivity was 0.70, specificity 0.99 and diagnostic value 0.97.

Smooth surfaces

4,480 surfaces were examined. Of the 360 restored surfaces 264 were correctly identified (TP), whilst 96 surfaces with restorations were missed (FN). Of the 4,120 unrestored surfaces 4,070 were correctly identified (TN) with 50 incorrectly considered restored (FP).

The sensitivity was 0.73, specificity 0.99 and diagnostic value 0.97.

Table 4.3 shows the UV light examination results adjacent to each other to allow a quick comparison and Figure 4.1 demonstrates the fluorescence of teeth in a mouth model

	Sensitivity	**Specificity**	**Diagnostic value**
All surfaces	83%	99%	97%
Occlusal surfaces	93%	99%	97%
Proximal surfaces	70%	99%	97%
Smooth surfaces	73%	99%	97%

Table 4-3 UVL Sensitivity, specificity and diagnostic value

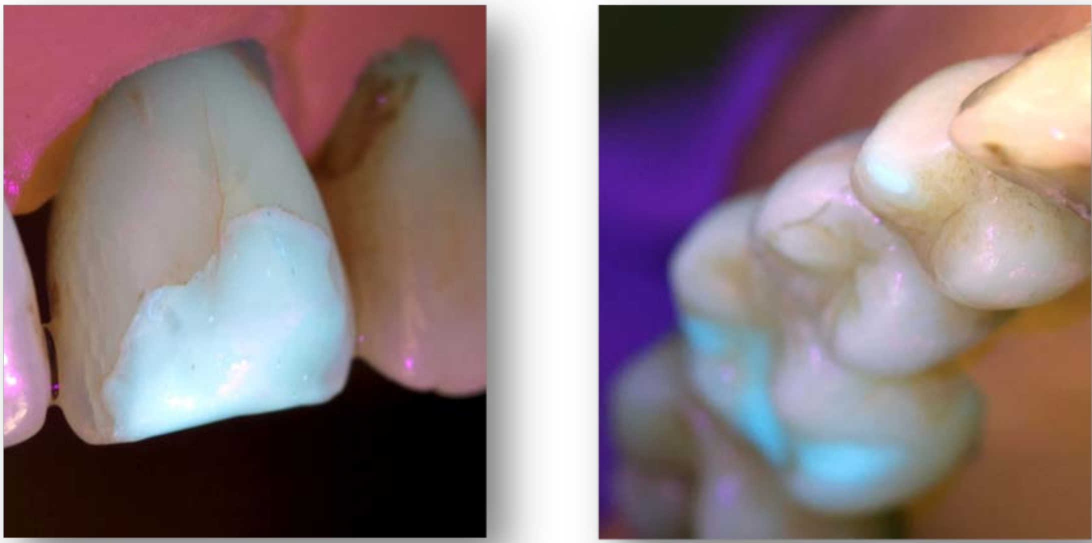

Figure 4.1 Fluorescence in teeth 21, 14, and 16

4.5 Comparison of examination techniques

When paired t-tests were applied to the Diagnostic Values for the three sets of data, it was found that there was no significant difference ($p = 0.215$) between visual examination and x2.6 magnification examination. However, there was a highly significant difference ($p = 0.005$) between x2.6 magnification examination and UVL examination.

	Sensitivity	Specificity	Diagnostic value
Visual inspection	54%	94%	90%
Magnification loupes	51%	95%	90%
UVL inspection	83%	98%	97%

Table 4-4 Comparison between three methods (visual, loupes and UVL inspection)

Chapter 5

5 Discussion

5.1 Context and study design

Different studies have been done in identification of tooth coloured dental restorations (Bush et al., 2006, Hermanson et al., 2008, Benthaus et al., 1998, Pretty et al., 2002). However, this study has determined the accuracy of a variety of techniques to identify composite restorations and will discuss the results later in this chapter. However, it is important to justify the study design and the requirements of a composite identification technique.

This study design closely replicates the clinical situation by using natural teeth, mounting them into anatomically correct arches and placing them in a "phantom head". The teeth were kept moist to ensure true life optical characteristics of the teeth. Similar models have been used extensively in caries diagnosis research throughout the world. The examinations were undertaken at least a week apart to reduce the possibility of memory bias. One major weakness of the present study is the lack of reproducibility data. However, previous studies in caries diagnosis have shown this study design to have acceptable reproducibility. Less research has been undertaken in the forensic field but studies looking at ultraviolet light have also shown good reproducibility. The average adult in the U.K. has 7 fillings (http://www.nationalsmilemonth.org/facts-figures/). Our population had 10 restorations that are higher, but as sensitivity and specificity are independent of prevalence it was felt appropriate. In addition, the most regular attenders in clinical practice are middle aged and are likely to have above average numbers of restorations.

An ideal diagnostic technique is one with high sensitivity and specificity. However as a general rule as one increase the other decreases. What has not been considered yet is whether it is more important to have a high sensitivity with a reduced specificity or vice versa. This decision comes down to deciding whether a false positive (incorrectly identifying a composite) or a false negative (missing the presence of a composite) is more serious.

In clinical situations the consequence of not identifying composite is incomplete removal of an old restoration or luting cement. The modern approach to cavity design is much more conservative than previously and with bonding of restorations even if caries is left below the unidentified composite it is likely that bacterial death will occur and the carious lesion will not progress. If luting cement is not identified the bond of the new veneer/resin retained bridge may be compromised. If tooth tissue is mistaken for composite removal of healthy tooth structure will occur. This is less ideal and may even lead to pulpal exposure. Therefore, for clinical work a composite identifying technique with a high specificity is desirable even if that is at the expense of sensitivity.

In dental identification the forensic dentist has to consider if any discrepancies between ante-mortem and post-mortem records are possible. It is possible for there to be a restoration on the post-mortem chart which is not on the ante-mortem chart; the victim may have subsequently been to a different dentist. However, it is not possible for a tooth classified as restored in the ante-mortem record to be sound in the post-mortem one; teeth cannot self- repair. Therefore, for forensic work a composite identifying technique with a high sensitivity is desirable even if that is at the expense of specificity.

5.2 Examination techniques

5.2.1 Unaided vision

The sensitivity of unaided vision ranged from 31% to 74%. Somewhat surprisingly, it was lowest on the smooth surfaces (31%) and highest on occlusal surfaces (74%). It might have been expected that the restorations on proximal surfaces would have been more difficult to identify but they had the second lowest value at 35%. This may be due to the fact that restorations on smooth surfaces are easier to polish to match the tooth and that carving techniques are not required on these surfaces. Equally surprising was that the restoration missed the most was a whole crown build-up of the upper right lateral incisor in mouth model 1; only 5 subjects correctly identified the tooth as fully restored, 10 subjects missed the restoration completely and 5 partially identifying the restoration.

Specificity ranged from 92-96% with smooth surfaces having a specificity of 96%. This indicates that subjects were unlikely to say that an unrestored surface was restored.

Diagnostic values ranged from 87% (occlusal surfaces) to 91% (proximal and smooth surfaces).

In conclusion, this study indicates that unaided visual identification of composite resin is not very satisfactory for routine clinical work but it could be appropriate for forensic dentistry work in association with radiographic examination.

5.2.2 x2.6 magnification

The sensitivity of x2.6 magnification ranged from 25% to 74%. The lowest score being found on the proximal surfaces being an unsurprising result. Again, the smooth surfaces showed a low level of sensitivity (32%) which is very similar to that found with unaided vision. This indicates that, overall, magnification was a hindrance to identification on proximal surface compared to unaided vision. The volunteers who were used to examining or working with magnification loupes found that the restorations were easier to detect. On the other hand, the volunteers who were using loupes for the first time found difficulties such as:

1. Blurred vision after a while from using the magnification loupes.
2. Dizziness during and temporarily after using the magnification loupes.
3. Difficulties in magnification loupes visual adjustment.
4. Difficulty to adjust their posture setting.
5. Some weight on the face.

It is likely that the blurred vision and dizziness are related to the difficulty in adjusting the loupes. On reflection it would have been better for the researcher to have more experience at fitting loupes to subjects. The limitation of movement is also disconcerting until acclimatized to loupes. The loupes had a metal frame and more modern versions use lightweight sports frames. Weight can be reduced even more if through the lens loupes are used but they are clinician specific and cannot be adjusted to fit more than one person making them impractical for this study. All these difficulties will have had an effect on the examination results as some volunteers attempted to expedite the examination to get rid of the magnification loupes, or took more time trying to concentrate. Specificity for the x2.6 magnification method ranged from 94-97% and is therefore marginally higher than unaided vision emphasizing the suitability of magnification for clinical work. The diagnostic values of x2.6 magnification are almost identical to those of unaided vision with the slightly lower sensitivity being compensated by the slightly higher specificity.

In another study done to compare identification of composite resin by using aided and unaided visual examination by removing the composite resin found that there are no significant different between the two techniques (Forgie et al., 2001).

In conclusion, the results show that unaided visual identification of composite resin is satisfactory for routine clinical work but that it does not offer any advantages for identifying composites in forensic dentistry work over normal vision.

5.2.3 Ultraviolet light examination

The sensitivity of ultraviolet light examination ranged from 70% on proximal surfaces to 93% on occlusal surfaces. Again, somewhat surprisingly, the smooth surfaces sensitivity (73%) was lower than that found on the occlusal surfaces (93%). This is hard to explain, as it would be expected that the ultraviolet light might not reach the deep fissures on the occlusal surfaces. However, when the lingual/palatal surfaces are looked at individually the sensitivity drops to 48%. The reason for this is that the lamp was difficult to orientate in the mouth to reach the lingual aspects; and that was without a tongue being present.

Specificity was universally high at 99%. The diagnostic values were all 97%.

The volunteers found that when using the ultraviolet light the composite restorations were very clear, even the small ones that were never detected in the other examination methods (Figure 4.1, tooth number 14). Despite none of the subjects having any experience in the use of the ultraviolet light it was deemed to take the least effort of all the techniques. Nevertheless, Hermanson et al. (2008) have been proved the same result in his study.

It is unusual for a diagnostic technique to have higher sensitivity and specificity scores. Therefore, it is possible to state from this experiment that compared to unaided vision and x2.6 magnification the use of an ultraviolet light significantly improves the detection of composite restorations. The very high specificity levels make it very appropriate for clinical use although safe working practices would need to be adopted to prevent any damage to either patients or staff (WHO, 2015). From a forensic perspective the higher sensitivity scores are a significant advantage but they still do not reach near 100% making it possible that composite restorations may still be missed. Most forensic dentists use radiographs to ensure that no restorations are missed. However, in most use mortuaries intra-oral radiography equipment is not present due to the expense and complex health and safety guidelines required. In such circumstances the use of an ultraviolet light would be of benefit when identifying composite restorations.

5.3 Time taken for examinations

Unaided visual examination took the longest time 45 minutes for the 4 mouth models. Magnification showed significant variation in time taken for the examination (30-45 minutes) possibly due to the diligence of some subjects and the wish to get the magnification examination completed by others. Interestingly both inexperienced and experienced magnification had a large range of times. The time taken for examination using the ultraviolet light was less than for the other techniques ranging from 20 to 30 minutes.

5.4 Consideration of whole tooth scoring

The sensitivity of unaided vision when whole tooth scoring method was used (one score per tooth) 64% is significantly higher than when a score was allocated to each surface (54%). There is a concomitant drop in sensitivity 94% to 85%. From a forensic perspective this trade-off is acceptable as the consequences of missing a composite restoration are more severe than falsely identifying one: a restored tooth becoming unrestored is an impossible transformation for dental identification and a reason for exclusion. However, the sensitivity is still not ideal and with the excellent sensitivity and specificity of ultraviolet assisted identification and the benefits of using radiographs where available the use of whole tooth scores has little benefit.

5.5 Future work

Hemasathya and Balagopal (2013) study indicate that the unique shape of composite resin restoration can be used for forensic identification. Therefore, one of the biggest questions coming out of the work in this thesis is how much does the quality of the composite restoration in terms of appearance alter the accuracy of composite identification? It would be interesting to evaluate the restorations before placing them into the mouth models and then relating quality of restoration to identification accuracy. Common sense would suggest that for unaided vision and magnification appearance quality would have a large effect and for ultraviolet light it would be less marked.

Two of the weaknesses of this thesis the lack of reproducibility data and the lack of training in the use of magnification could easily be addressed in future research projects.

From the forensic perspective it would be good to compare the accuracy of radiography to that of the ultraviolet torch. This would be possible with the current mouth models. This would enable the forensic community to make informed judgment on the need for expensive intra-oral radiographic equipment in every mortuary.

Chapter 6

6 Conclusion

This thesis has met its aims of assessing the accuracy of clinicians in identifying composite resin restorations within natural teeth mounted in a simulated mouth using un-aided vision, x2.6 magnification loupes and an ultraviolet light.

There was a significant increase in the sensitivity of the detection of composite restorations when using ultraviolet light compared to clinical visual examination, with or without the use of magnification loupes. This increased sensitivity applied to all tooth surfaces and unusually for diagnostic testing did not result in a decrease in specificity. In addition, examination using the ultraviolet light was quicker than the other methods and was able to identify even the smallest composite restorations in hidden surfaces and cusp tips.

The answer to the objective of determining the most efficient method for composite resin identification is unquestionably ultraviolet light examination. Despite the need for eye protection this thesis recommends that UVL is used adjunctively to an ordinary clinical examination when identification of composite is of clinical importance. From the forensic perspective it has quantified the benefit associated with the use of the ultraviolet light for composite restoration identification.

7 References

ANGMAR-MANSSON, B. & TEN BOSCH, J. J. 2001. Quantitative light-induced fluorescence (QLF): a method for assessment of incipient caries lesions. *Dentomaxillofac Radiol,* 30**,** 298-307.

BENTHAUS, S., DUCHESNE, A. & BRINKMANN, B. 1998. A new technique for the postmortem detection of tooth-coloured dental restorations. *Int J Legal Med,* 111**,** 157-9.

BHARTI, R., WADHWANI, K. K., TIKKU, A. P. & CHANDRA, A. 2010. Dental amalgam: An update. *J Conserv Dent,* 13**,** 204-8.

BORRMAN, H., TAHERI, M. & WOXBERG, B. 1993. 27 years of forensic odontology in Goteborg, Sweden. *Swed Dent J,* 17**,** 249-53.

BORRMAN, H. I., DIZINNO, J. A., WASEN, J. & RENE, N. 1999. On denture marking. *J Forensic Odontostomatol,* 17**,** 20-6.

BOWEN, R. L. 1956. Use of epoxy resins in restorative materials. *J Dent Res,* 35**,** 360-9.

BOWEN, R. L. 1962. Dental filling material comprising vinyl silane treated fused silica and a binder consisting of the reaction product of bis phenol and glycidyl acrylate. Google Patents.

BOWEN, R. L. 1982. Composite and sealant resins--past, present, and future. *Pediatr Dent,* 4**,** 10-5.

BRANSON, B. G., BLACK, M. A. & SIMMER-BECK, M. 2010. Changes in posture: a case study of a dental hygienist's use of magnification loupes. *Work,* 35**,** 467-76.

BRANSON, B. G., BRAY, K. K., GADBURY-AMYOT, C., HOLT, L. A., KESELYAK, N. T., MITCHELL, T. V. & WILLIAMS, K. B. 2004. Effect of magnification lenses on student operator posture. *J Dent Educ,* 68**,** 384-9.

BROWN, K. A. 1982. The identification of Linda Agostini. The significance of dental evidence in the Albury 'pyjama girl' case. A case report. *Forensic Sci Int,* 20**,** 81-6.

BUHRLEY, L. J., BARROWS, M. J., BEGOLE, E. A. & WENCKUS, C. S. 2002. Effect of magnification on locating the MB2 canal in maxillary molars. *J Endod,* 28**,** 324-7.

BUONOCORE, M. G. 1955. A simple method of increasing the adhesion of acrylic filling materials to enamel surfaces. *J Dent Res,* 34**,** 849-53.

BUSH, M. A., BUSH, P. J. & MILLER, R. G. 2006. Detection and classification of composite resins in incinerated teeth for forensic purposes. *J Forensic Sci,* 51**,** 636-42.

BUSH, M. A., HERMANSON, A. S., YETTO, R. J. & WIECZKOWSKI, G., JR. 2010. The use of ultraviolet LED illumination for composite resin removal: an in vitro study. *Gen Dent,* 58**,** e214-8.

BUSH, M. A., MILLER, R. G., PRUTSMAN-PFEIFFER, J. & BUSH, P. J. 2007. Identification through X-ray fluorescence analysis of dental restorative resin materials: a comprehensive study of noncremated, cremated, and processed-cremated individuals. *J Forensic Sci,* 52**,** 157-65.

BUX, R., HEIDEMANN, D., ENDERS, M. & BRATZKE, H. 2006. The value of examination aids in victim identification: a retrospective study of an airplane crash in Nepal in 2002. *Forensic Sci Int,* 164**,** 155-8.

CASTELLUCCI, A. 2003. Magnification in endodontics: the use of the operating microscope. *Pract Proced Aesthet Dent,* 15**,** 377-84; quiz 386.

CHAN, K. H., MAI, Y., KIM, H., TONG, K. C., NG, D. & HSIAO, J. C. 2010. Review: Resin Composite Filling. *Materials,* 3**,** 1228-1243.

CHRISTENSEN, G. J. 2003. Magnification in dentistry: useful tool or another gimmick? *J Am Dent Assoc,* 134**,** 1647-50.

CONGDON, L. M., TOLLE, S. L. & DARBY, M. 2012. Magnification loupes in U.S. entry-level dental hygiene programs--occupational health and safety. *J Dent Hyg,* 86**,** 215-22.

CORREA, M. B., PERES, M. A., PERES, K. G., HORTA, B. L., BARROS, A. D. & DEMARCO, F. F. 2012. Amalgam or composite resin? Factors influencing the choice of restorative material. *J Dent,* 40**,** 703-10.

DE VALCK, E. 2006. Major incident response: collecting ante-mortem data. *Forensic Sci Int,* 159 Suppl 1**,** S15-9.

FEILZER, A. J., DOOREN, L. H., DE GEE, A. J. & DAVIDSON, C. L. 1995. Influence of light intensity on polymerization shrinkage and integrity of restoration-cavity interface. *Eur J Oral Sci,* 103**,** 322-6.

FORGIE, A. H., PINE, C. M., LONGBOTTOM, C. & PITTS, N. B. 1999. The use of magnification in general dental practice in Scotland--a survey report. *J Dent,* 27**,** 497-502.

FORGIE, A. H., PINE, C. M. & PITTS, N. B. 2001. Restoration removal with and without the aid of magnification. *J Oral Rehabil,* 28**,** 309-13.

FORGIE, A. H., PINE, C. M. & PITTS, N. B. 2002. The use of magnification in a preventive approach to caries detection. *Quintessence Int,* 33**,** 13-6.

GUZY, G. & CLAYTON, M. A. 2013. Detection of composite resin restorations using an ultraviolet light-emitting diode flashlight during forensic dental identification. *Am J Forensic Med Pathol,* 34**,** 86-9.

HEMASATHYA, B. A. & BALAGOPAL, S. 2013. A study of composite restorations as a tool in forensic identification. *J Forensic Dent Sci,* 5**,** 35-41.

HERMANSON, A. S., BUSH, M. A., MILLER, R. G. & BUSH, P. J. 2008. Ultraviolet illumination as an adjunctive aid in dental inspection. *J Forensic Sci,* 53**,** 408-11.

HERVAS-GARCIA, A., MARTINEZ-LOZANO, M. A., CABANES-VILA, J., BARJAU-ESCRIBANO, A. & FOS-GALVE, P. 2006. Composite resins. A review of the materials and clinical indications. *Med Oral Patol Oral Cir Bucal,* 11**,** E215-20.

HIGGI, D. & AUSTIN, J.J. 2013. Teeth as a source of DNAfor forensic identification of human remains: A review. Science and Justice, htt://dx.doi.org/10.1016/j.scijus.2013.06.001

HILL, A. J., HEWSON, I. & LAIN, R. 2011. The role of the forensic odontologist in disaster victim identification: lessons for management. *Forensic Sci Int,* 205**,** 44-7.

HOLICK, M. F. 2004. Sunlight and vitamin D for bone health and prevention of autoimmune diseases, cancers, and cardiovascular disease. *Am J Clin Nutr,* 80**,** 1678S-88S.

HOLMES, O. 1993. *Human Neurophysiology A student text,* London, Chapman and Hall.

HTTP://WWW.INTERPOL.INT/NEWS-AND-MEDIA/NEWS/2005/N20051214. *INTERPOL support to continue as tsunami victim identification centre relocates* [Online].

JENNIFER, R. & THOMAS, F. D. 2007. Dental hygienists' opinions about loupes in education. *J Dent Hyg,* 81**,** 82.

KANCA, J., 3RD & SUH, B. I. 1999. Pulse activation: reducing resin-based composite contraction stresses at the enamel cavosurface margins. *Am J Dent,* 12**,** 107-12.

KAREKER, N., ARAS, M. & CHITRE, V. 2014. A review in denture marking systems: A mark in forensic dentistry. *J Indian Prosthodont Soc 14 (suppl 1), 4* -13.

KEENEY, A. H., HAGMAN, R. E. & FRATELLO, C. J. 1995. *Dictionary of ophthalmic optics* Butterworth-Heinemann.

KORKUT, B., YANIKOGLU, F. & GUNDAY, M. 2013. Direct composite laminate veneers: three case reports. *J Dent Res Dent Clin Dent Prospects,* 7**,** 105-11.

LEE, Y. K., KIM, J. H. & AHN, J. S. 2007. Influence of the changes in the UV component of illumination on the color of composite resins. *J Prosthet Dent,* 97**,** 375-80.

LIM, Y. K. & LEE, Y. K. 2007. Fluorescent emission of varied shades of resin composites. *Dent Mater,* 23**,** 1262-8.

LOCKER, D., JOKOVIC, A. & KAY, E. J. 2003. Prevention. Part 8: The use of pit and fissure sealants in preventing caries in the permanent dentition of children. *Br Dent J,* 195**,** 375-8.

PURGO. ENVIRO TECH. 2011. *Ultraviole (UV) Light* [Online]. Available: http://www.spectralinnovations.com/reference/ultraviolet_light.htm.

LU, H., LEE, Y. K., VILLALTA, P., POWERS, J. M. & GARCIA-GODOY, F. 2006. Influence of the amount of UV component in daylight simulator on the color of dental composite resins. *J Prosthet Dent,* 96**,** 322-7.

LUTZ, F., PHILLIPS, R. W., ROULET, J. F. & IMFELD, T. 1983. [Composites--classification and assessment]. *SSO Schweiz Monatsschr Zahnheilkd,* 93**,** 914-29.

MAGGIO, M. P., VILLEGAS, H. & BLATZ, M. B. 2011. The effect of magnification loupes on the performance of preclinical dental students. *Quintessence Int,* 42**,** 45-55.

MAILLET, J. P., MILLAR, A. M., BURKE, J. M., MAILLET, M. A., MAILLET, W. A. & NEISH, N. R. 2008. Effect of magnification loupes on dental hygiene student posture. *J Dent Educ,* 72**,** 33-44.

MARTIN-DE LAS HERAS, S., VALENZUELA, A., VILLANUEVA, E., MARQUES, T., EXPOSITO, N. & BOHOYO, J. M. 1999. Methods for identification of 28 burn victims following a 1996 bus accident in Spain. *J Forensic Sci,* 44**,** 428-31.

MIRANDA, G. E., FREITAS, S. G., MAIA, L. V. & MELANI, R. F. 2016. An unusual method of forensic human identification: use of selfie photographs. *Forensic Sci Int,* 263**,** e14-7.

MOHAN, J., KUMAR, C. D. & SIMON, P. 2012. "Denture marking" as an aid to forensic identification. *J Indian Prosthodont Soc,* 12**,** 131-6.

NAKABAYASHI, N., KOJIMA, K. & MASUHARA, E. 1982. The promotion of adhesion by the infiltration of monomers into tooth substrates. *J Biomed Mater Res,* 16**,** 265-73.

NANDINI, S. 2010. Indirect resin composites. *J Conserv Dent,* 13**,** 184-94.

NOORT, V. 2002. *introduction to dental materials*, Elsvier science ltd.

PANOV, V. & BORISOVA-PAPANCHEVA, T. 2015. Application of ultraviolet light (UV) in dental medicine. *Medinform***,** 194-200.

PARK, M. Y., LEE, Y. K. & LIM, B. S. 2007. Influence of fluorescent whitening agent on the fluorescent emission of resin composites. *Dent Mater,* 23**,** 731-5.

PARR, J. 1989. *Introduction to Ophthalmology,* Oxford medical publication.

PETRIE, A., BULMAN, J. S. & OSBORN, J. F. 2002. Further statistics in dentistry, Part 5: Diagnostic tests for oral conditions. *Br Dent J,* 193**,** 621-5.

PEUTZFELDT, A. 1997. Resin composites in dentistry: the monomer systems. *Eur J Oral Sci,* 105**,** 97-116.

PRAMOD, J. B., MARYA, A. & SHARMA, V. 2012. Role of forensic odontologist in post mortem person identification. *Dent Res J (Isfahan),* 9**,** 522-30.

PRETTY, I. A., SMITH, P. W., EDGAR, W. M. & HIGHAM, S. M. 2002. The use of quantitative light-induced fluorescence (QLF) to identify composite restorations in forensic examinations. *J Forensic Sci,* 47**,** 831-6.

PRETTY, I. A. & SWEET, D. 2001. A look at forensic dentistry--Part 1: The role of teeth in the determination of human identity. *Br Dent J,* 190**,** 359-66.

RUEGGEBERG, F. A. 2002. From vulcanite to vinyl, a history of resins in restorative dentistry. *J Prosthet Dent,* 87**,** 364-79.

RUEGGEBERG, F. A., CAUGHMAN, W. F., CURTIS, J. W., JR. & DAVIS, H. C. 1993. Factors affecting cure at depths within light-activated resin composites. *Am J Dent,* 6**,** 91-5.

CCOHS. 2015. *Ultraviolet radiation* [Online]. Available: http://www.ccohs.ca/oshanswers/phys_agents/ultravioletradiation.html 2015].

SAVANI, G. M., SABBAH, W., SEDGLEY, C. M. & WHITTEN, B. 2014. Current trends in endodontic treatment by general dental practitioners: report of a United States national survey. *J Endod,* 40**,** 618-24.

SCHWARZ, T. & LUGER, T. A. 1989. Effect of UV irradiation on epidermal cell cytokine production. *J Photochem Photobiol B,* 4**,** 1-13.

SMADI, L. & KHRAISAT, A. 2007. Detection of a second mesiobuccal canal in the mesiobuccal roots of maxillary first molar teeth. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod,* 103**,** e77-81.

TANI, K., WATARI, F., UO, M. & MORITA, M. 2003. Discrimination between composite resin and teeth using fluorescence properties. *Dent Mater J,* 22**,** 569-80.

TYAS, M. J. 2005. Placement and replacement of restorations by selected practitioners. *Aust Dent J,* 50**,** 81-9; quiz 127.

VALENZUELA, A., MARTIN-DE LAS HERAS, S., MARQUES, T., EXPOSITO, N. & BOHOYO, J. M. 2000. The application of dental methods of identification to human burn victims in a mass disaster. *Int J Legal Med,* 113**,** 236-9.

VAN AS, G. A. 2003. The use of extreme magnification in fixed prosthodontics. *Dent Today,* 22**,** 93-9.

VERMONT, T. U. O. 2015. *Hazards of Ultraviolet Radiation* [Online]. Available: http://www.uvm.edu/safety/lab/hazards-of-ultraviolet-radiation 2015].

WHO. 2015. *Ultraviolet radiation and the INTERSUN Programme* [Online]. Available: http://www.who.int/uv/faq/uvhealtfac/en/index1.html.

XIE, D., BRANTLEY, W. A., CULBERTSON, B. M. & WANG, G. 2000. Mechanical properties and microstructures of glass-ionomer cements. *Dent Mater,* 16**,** 129-38.

YAZICI, A. R., CELIK, C., DAYANGAC, B., & OZGUNALTAY, G. 2008. Effects of Different Light Curing Units/Modes on the Microleakage of Flowable Composite Resins. *Eur J Dent*, *2*, 240–246.

8 Appendix A – consent form

Identifying white fillings study

Background

As dentists it is important that we can identify white fillings; this is true for clinical and forensic reasons. Identifying white fillings is a challenging task and our initial research has found that dentists miss many white fillings.

Aim

We are interested to see how good non-dentists are at identifying white fillings

Request

We are asking you to look at the imitation head and try to identify any white fillings. They can be on any surface of any tooth. One of our researchers will help you with recording what you find. It will take about 5 minutes but you can take as long as you like. We will not ask for any personal details other than adult or child. There are no consequences if you do or don't take part. We have to ask for consent from any participant during any research project

Questions

You can ask any of the researchers any questions you may have about this study to help you decide whether you want to take part.

Consent

I have had the study explained to me and am willing to take part in the study identifying white fillings.

9 Appendix B – data collection form

Model number

Candidate name

Technique

Tooth	Filling yes/no	Surface(s) filled
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10 Appendix C - abstract

Presented at the Intersocietal Symposium of the International Association of Legal Medicine, Venice: June 2016

Manal Aljadi and Andrew Forgie

The Identification of Composite Resin Restorations within Natural Teeth

Background and Aims

Dental comparison is used for single victim identification and for victim identification in mass disasters. Composite resin which has excellent aesthetic properties is increasingly used as a filling material. Composite fillings are, therefore, difficult to identify during post mortem dental examinations especially when radiographic facilities are not available or when examination conditions are less than ideal. Errors in detecting them could compromise the accuracy of dental identification.

The aim of this study was to assess the accuracy of normal vision, magnification loupes and an ultra-violet light source for identifying composite resin restorations.

Materials and Methods

40 composite restorations were placed in previously unrestored extracted teeth. A further 72 unrestored teeth were selected and the 112 teeth were mounted into 4 anatomically correct mouth models. 20 dentists examined each mouth in a manner that simulated the clinical situation: the mouth models were mounted in a phantom head, the examiner sat on a height adjustable chair, a dental operating light was used and air was used to dry the teeth during examination. At least one week later the same volunteers examined the same 4 mouth models with the aid of x2.6 magnification loupes. After another week the same volunteers carried out an examination with the aid of a ultra-violet light but not magnification. Each tooth surface was classified as either filled or unfilled by the examiners. Each decision was classified as a true positive, true negative, false positive or false negative.

Sensitivity, specificity and diagnostic values were then calculated for each technique.

Results

Normal examination had a sensitivity of 54%, a specificity of 94% and a diagnostic value of 90%. Magnification examination had a sensitivity of 51%, a specificity of 95% and a diagnostic value of 90%. Ultra-violet examination had a sensitivity of 83%, a specificity of 98% and a diagnostic value of 97%. There was no statistical difference between the normal and magnification techniques ($P>0.05$ paired t-test) but a highly significant difference between the Ultraviolet technique and the other two methods ($P<0.005$ paired t-test).

Conclusion

The use of an ultra-violet light significantly improves the accuracy of identifying composite restorations and will allow more accurate post mortem dental charts to be constructed.