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TECHNICAL NOTE

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Ultraviolet Illumination as an Adjunctive Aid in Dental Inspection*

ABSTRACT: Tooth-colored resin fillings have become increasingly popular as restorative materials. Their presence in the dentition presents a challenge to the clinician and the forensic odontologist, as detection of the fillings can be difficult both visually and radiographically. As they necessarily form part of the unique dentition of an individual, recognition of the resins is important for forensic identification. Alternative light sources have been used with success in various fields of forensic science. In recent years small LED flashlights emitting at specific wavelengths in the ultraviolet light (UV) range have been developed. Their low cost, small size, and ready availability makes their use practical in both forensic dental inspection and clinical settings. UV inspection is of interest because enamel, dentin and dental materials all have differing fluorescent properties when illuminated by UV light. It was one goal of this research to quantitatively assess the fluorescence properties of modern restorative resins in order to predict their behavior during inspection using UV illumination. The second goal was to demonstrate practical use of UV in dental inspection with examples of how different materials fluoresce. Quantitative measurements were obtained for optical emission wavelength and intensity for 15 modern resins using a spectrophotometer. Results indicated that resin brands fluoresce at different wavelengths and with varying intensities. Practical use and comparison of the flashlights revealed that the most useful excitation wavelengths for resin detection were in the UVA range (365 and 380 nm). Porcelain restorations and composite resin fillings exhibited different responses to these two wavelengths and thus use of both is recommended for forensic dental inspection.

KEYWORDS: forensic science, forensic odontology, restorative composite resins, fluorescence spectroscopy, ultraviolet light

The clinician is presented with a wide array of composite restorative resins from which to choose. The popularity of these materials is reflected in the fact that there are over 60 brands currently available (1). Their increasing use in dentistry presents a challenge to the clinician and forensic odontologist alike. In general, the manufacturers have achieved their esthetic goals, with the result that the resins have shade and translucency that can be visually indistinguishable from tooth structure. Furthermore, some brands of resin can be radiographically similar to tooth structure, making recognition of a resin difficult (2). Indeed, a study by Chesne et al. concluded that up to 40% of tooth-colored restorations could not be detected radiographically with sufficient sensitivity (3).

As placement of resins has become more common (and as amalgams are replaced), the ability to recognize their existence and to chart their presence becomes more important, especially in forensic situations. Resins form part of the uniqueness of human dentition, along with the combination of filled, unfilled, missing, and decayed teeth. The presence of a resin on a given tooth surface may be a significant concordant point in victim identification.

With these issues in mind, investigations have been performed in the use of applied dyes, and in recognition of dental materials using various light wavelengths (4–6). The use of UV illumination was recommended in the case of victim identification in a 2002 airplane crash (7). In this study, a retrospective examination was made of the victims 6 months after the initial autopsy examination. A number of composite resins were discovered that were missed initially. Composite resins may have fluorescent properties that differ from tooth structure when illuminated with UV light.

Fluorescence can be simply described as the emission of a longer wavelength of light when a shorter wavelength is used as an illuminant. Natural tooth structure exhibits fluorescence when exposed to UV light. This fact has led a number of manufacturers to incorporate fluorescing compounds in their products to simulate the natural properties of enamel and dentin. Some manufacturers, however, have ignored this issue, resulting in dental materials with a wide range of response to UV illumination. It is this contrast, or difference in either color or brightness between individual materials and tooth structure, that makes fluorescence a property of immediate interest to the forensic community.

Historically, UV inspection lights of the tube or lamp type have been large and difficult to use for dental inspection. Jaw resection would be a necessary condition for use of these lamps. The advent of UV-emitting LED flashlights, therefore, has made possible rapid inspection without the need for jaw resection. A number of small flashlights are available with 3–6 LEDs, which produce adequate intensity and maneuverability for intra-oral inspection. This is particularly of importance in situations where a large number of victims must be inspected, such as in a mass disaster. Inspection with a flashlight is a very fast procedure and can reveal features that would otherwise be very difficult to observe.

Composite resins consist of two principal components; a mixture of organic resins which form the matrix, and inorganic filler particles. In addition, there may be a silane coupling agent, polymerization inhibitors, and organic dyes to produce shade variation. It has been shown that there is a surprising variation in filler particle size, loading, and elemental composition between resin brands (8). Particle size may range from nanometer scale to over 20 microns, and the filler particles may contain elements such as Ba, Sr, Zr, and

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TABLE 1—*Resin brands and manufacturers used in this study.*

Brand	Manufacturer
Prisma APH	Dentsply Caulk, Milford, DE
Filtek Supreme	3M ESPE, St. Paul MN
Z100	3M ESPE
Amelogen	Ultradent, South Jordan, UT
Esthetx Flow	Denstply Caulk
Vit-l-escence	Ultradent
Venus	Heraeus Kulzer, Armonk, NY
Esthetx	Dentsply Caulk
Quixx	Dentsply Caulk
Gradia	GC America, Alsip, IL
Tetric Ceram	Ivoclar, Amherst, NY
Heliomolar	Ivoclar
4 Seasons	Ivoclar
TPH3	Dentsply Caulk
Surefil	Dentsply Caulk

Yb, added to increase radiopacity. In the case of resins, however, it is an organic compound that causes the fluorescence.

Porcelain materials, including inlays, onlays, veneers, PFMs, and all-porcelain crowns also possess varying fluorescent properties. In this case it is an inorganic component that fluoresces, which may be a rare earth or transition element oxide. Although porcelain restorations are usually more readily distinguished radiographically, there are situations, such as in skillfully fabricated veneers, in which they may be difficult to visualize. It is a fortunate fact for the forensic odontologist that both resins and porcelains exhibit unique fluorescence properties.

Alternative light sources have been used with success in various fields of forensic science. It was one goal of this research to quantitatively assess the fluorescence properties of modern restorative resins in order to predict their behavior during inspection. The second goal was to evaluate LED flashlights in order to recommend to the forensic community practical aspects of their application.

Materials and Methods

Fifteen discs of restorative resin were prepared by polymerization between two glass slides. The brands used in this study are listed in Table 1. Control samples of enamel and dentin were prepared from a freshly extracted human premolar. A plane slice was taken from the buccal surface using a slow-speed diamond saw. The surface to be analyzed was polished using a series of silicon carbide papers of decreasing grit size down to 1200 grit. The purpose of this preparation was to produce a surface comparable to the smooth surfaces of the resins so as to reduce refraction and absorption by a rough surface.

Quantitative fluorescence spectroscopy was performed using a UV-visible light spectrophotometer. The maximum fluorescence intensity for each resin was recorded and also the wavelength at which the maximum fluorescence occurred for each excitation wavelength. The purpose of this was to understand the basic fluorescence properties of the resin materials with respect to tooth structure.

LED flashlights were obtained from several suppliers (Table 2). For this study, a variety of flashlights were compared, ranging from single LED penlights to 40 LED D-Cell powered lights. The wavelengths of the LED emitters are listed in Table 2.

In addition to the cured discs of resin and slice of enamel/dentin, composite resin restorations of different brands were placed in extracted teeth to determine the optimal illumination wavelengths to produce contrast between tooth structure and resin. To further gain experience with the flashlights, 26 cadaver dentitions were inspected using the LED lights. This provided practical experience of inspection, simulating morgue conditions.

TABLE 2—*LED flashlights evaluated in this study. The 40 LED model had LEDs of four selectable wavelengths.*

Model	No. of LEDs	Wavelength (nm)	Source
Inova X5 Tactical	5	380	AdvancedMart.com
AM1403UV	14	380	AdavncedMart.com
XeLED 4UV 375	4	375	TheLedLight.com
XeLED 6UV 365	6	365	TheLedLight.com
XeLED-40-UV-FE	40	465/395/380/360	Xenopus Electronix

It should be noted that UV light can be damaging to the human eye. Operators should never look directly at the LED emitters. UV-absorbing protective eyewear should be utilized during all inspection procedures.

Results

All of the composites fluoresced. The composites could be organized into three categories: highly fluorescent, moderately fluorescent, and weakly fluorescent, based on the intensity of light emission. Figure 1 shows the emission intensities of the resins

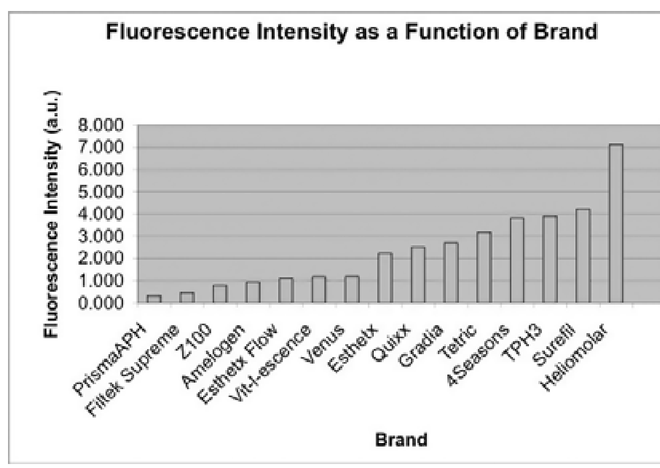

FIG. 1—*Fluorescence intensity (brightness) of fifteen brands of resin.*

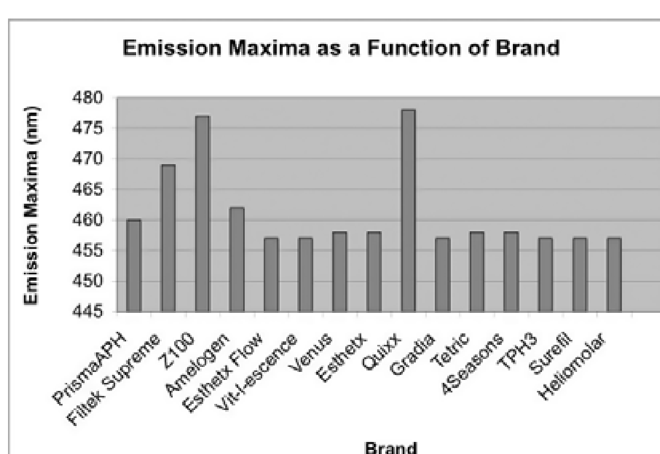

FIG. 2—*Emission maxima, showing the wavelength of brightest emission for fifteen resins.*

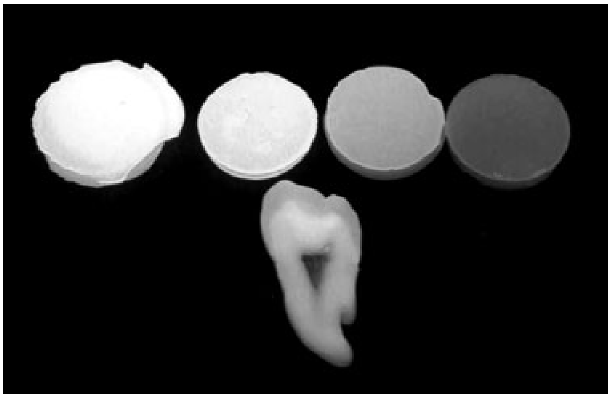

FIG. 3—*Four discs of different resin brands and a section of tooth, illuminated with 365 nm UV light, illustrating the difference in fluorescence properties between enamel, dentin, and the resins.*

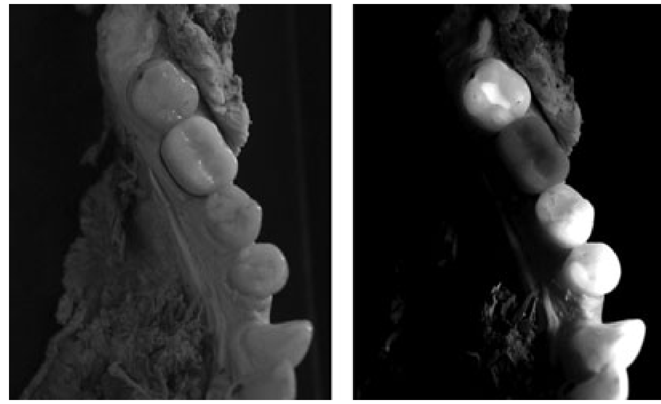

FIG. 5—*Mandible illuminated with white light and a 40 LED 365 nm UV flashlight (right). The porcelain crown shows dark and an occlusal restoration is evident in tooth no. 18.*

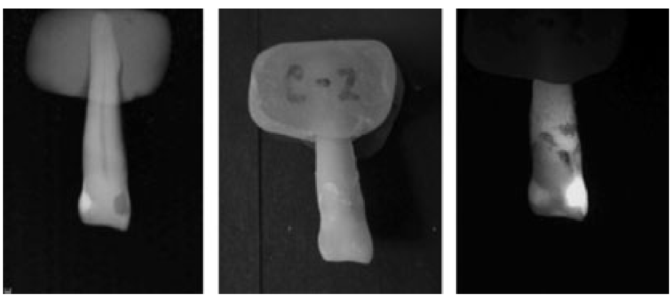

FIG. 4—*Radiograph of extracted tooth restored with two brands of resin, left. Center, tooth illuminated with white light. Right, tooth illuminated with a 14 LED 380 nm UV flashlight.*

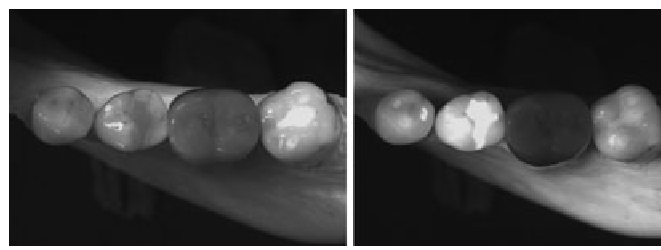

FIG. 6—*Mandible illuminated with 365 and 380 nm UV flashlights. Under 380 nm the restorations in teeth no. 20 and 21 are now readily visible.*

studied in arbitrary units, as measured with a UV-visible light spectrometer. The emission intensity indicates relative brightness of fluorescence under UV illumination. Figure 2 shows the emission maxima of the resins, which indicates the differences in observed color of the emitted light. Enamel and dentin also fluoresced. Dentin fluoresced more strongly than enamel. It was found that some resins fluoresced more intensely than tooth structure, while some were less intense. In both cases, inspection would reveal contrast between the resin and tooth. Some of the resins exhibited fluorescence properties very similar to tooth under illumination with a specific wavelength.

Figures 3–7 are reproduced in black and white. There are, however, very significant differences in color (emission wavelength) between the materials shown. Visual contrast between tooth structure and restorative materials is dependent not only on brightness differences that translate as gray scale differences in black and white images, but also on color. The images shown in this study were obtained with digital cameras. The response of the camera optical sensors and the human eye to both the exciting and fluorescent wavelengths differs. The human eye has a greater dynamic range and small differences in color and contrast may be detected that are not visible in a digital image.

Figure 3 shows cured discs of four different brands of composite resin illuminated with a 40 LED 365 nm UV flashlight. A longitudinal section of a tooth is included for comparison. The dentin can be seen to be brighter than enamel, while the resins may be brighter or darker than tooth structure.

In Fig. 4, an extracted tooth is shown. Two brands of restorative resin were placed to illustrate differences in both radiographic contrast and that produced by illumination with 380 nm UV light.

Figure 5 shows a resected mandible in white light and illuminated with a 40 LED 365 nm UV light. There is an obvious contrast difference in tooth no. 19 due to the presence of a porcelain crown. A bright region on the occlusal surface of no. 18 reveals the presence of a composite resin restoration. In Fig. 6, the same mandible is shown after maceration. The mandible is illuminated with a 40 LED 365 nm and a 14 LED 380 nm UV flashlight, respectively. The contrast between the porcelain and teeth is even stronger under 380 nm, and now a large restoration is revealed in tooth no. 20 and two smaller ones in no. 21. What is not shown in the black and white illustration is the fact that the restoration in tooth no. 18 fluoresces bright yellow, while those in no. 20 and 21 fluoresce bright blue, indicating that a different type of material was used for these restorations. Figure 7 shows a resected maxilla illuminated with white light, 365 and 380 nm UV. Under 365 nm the different porcelain materials have varying contrast, again indicating the use of different materials. Under 365 nm a yellow occlusal preparation in no. 2 is noted. Close examination of tooth no. 8 shows a mesial incisal lingual restoration and a small distal lingual restoration. The contrast of the former reverses with a change of wavelength, while the latter shows bright in both conditions. When 380 nm was used, the occlusal preparations in no. 15 were obvious.

When an obvious resin restoration did not fluoresce using one wavelength, it was found that the small shift in wavelength between 365 nm and 380 nm produced a change in contrast

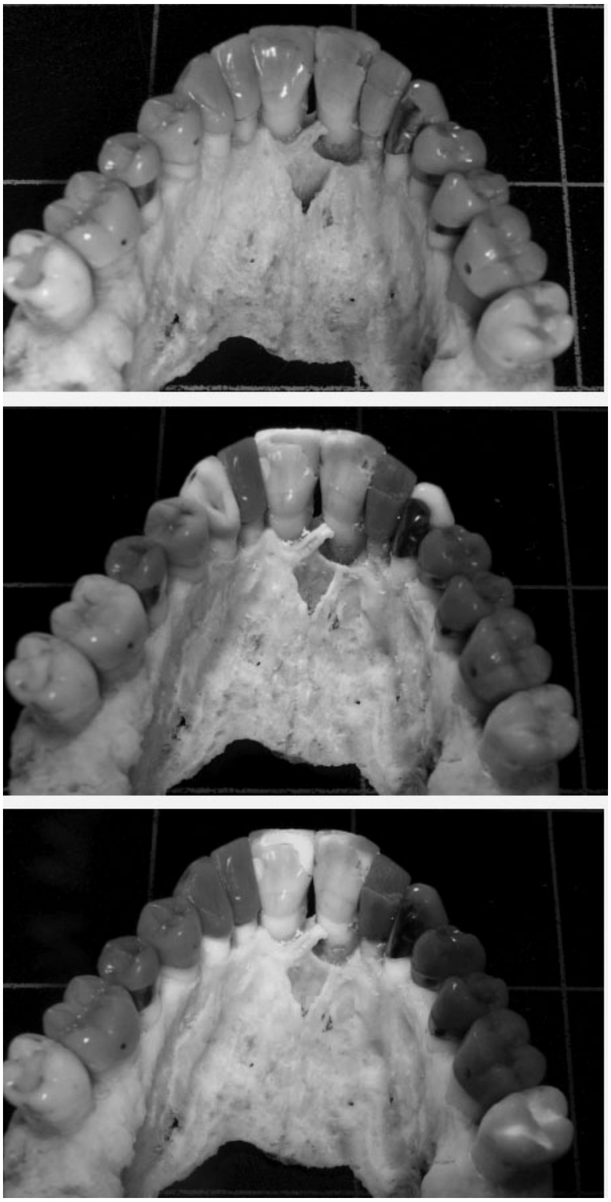

FIG. 7—*Maxilla illuminated with white light, 365 and 380 nm UV. The contrast between the porcelain materials and the restorations in teeth no. 2 and 8 present differently under each condition.*

sufficient to reveal the resin. This is the basis for our strong recommendation to inspect with two distinct wavelengths. It was also found that porcelain-containing restorations varied considerably in fluorescence properties, from very dark to very bright. Veneers were detected by this method that were difficult to recognize visually or radiographically.

Discussion

Quantitative fluorescence spectrophotometry revealed the intensity and fluorescence wavelengths of 15 resins when illuminated by wavelengths in the ultraviolet region. The resins exhibited different fluorescent intensities and maxima (brightness and color). Even though some resins did not fluoresce significantly, the use of ultraviolet radiation provided enough contrast to determine that there was a foreign material present on the tooth surface.

Difficulties were encountered when the fluorescent intensity of the resin matched that of the tooth surface under illumination by a single wavelength. Re-inspection using a second wavelength, however, always resolved the issue of the presence of a certain material.

Use of ultraviolet illumination as an inspection tool is strongly recommended, because in the majority of cases, sufficient contrast (whether in color, darkness or lightness) was noted between the resin and tooth structure to positively distinguish the materials. The speed of inspection with a light source warrants use of this technique as an adjunctive means of inspection, as the majority of these restorative materials will be made visible. This is especially appropriate in situations where many dentitions are to be screened.

This study not only results in a recommendation for the clinical and forensic community for inspection protocol for resins, but also reveals the dramatic differences in resin fluorescence characteristics. The forensic odontologist should be aware of the qualities of the materials used, and the fact that nonuniform fluorescence characteristics should be anticipated during inspection for resins.

The greater likelihood of encountering resins in modern dentitions demands that we anticipate their presence. Any means of gaining additional levels of certainty in victim identification should be utilized. Thus recognition of resins by ultraviolet inspection and further analysis of resin composition by elemental analysis techniques may add certainty to identification through distinction of resin brand (8). This study once again shows the critical need for careful dental charting and accurate record keeping as the complexity and variety of restorative materials broadens.

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