

Literature Reviews

Simplified digital infra red photography: an alternative tool in Bite mark forensic investigation

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ABSTRACT

Background: Decades ago, documentation of forensics evidences such as bitemarks, bloodstains and others which required sophisticated photographic techniques and equipments such as infrared (IR) and ultraviolet (UV) photography, became a problem since they only use film that must be developed. Therefore, direct evaluation of the photographic result could not be directly visualized. The equipments prices were relatively high. Moreover, most of the equipments were still not available and relatively expensive; and converted IR digital camera could not use for regular photography. Recently, digital camera made image documentation and editing easier. **Purpose:** This review was aimed to explore the different characteristics and benefits of regular digital camera in IR forensic photography as well as to simplify the equipments needed. **Reviews:** IR photography becomes easier since certain digital cameras could capture the IR image by using IR filters or to be switched to IR camera. The regular non-SLR digital camera had certain advantages compared to SLRs, such in focusing. However, since not every digital camera has the ability to capture IR light, laser pointer or TV remote could be used as a tester. **Conclusion:** Knowledge about IR Bite mark photography, characteristics of regular digital camera and its accesories could reduce the budget for an ideal standard forensic photographic equipments by modifications.

Key words: Digital photography, infrared, Bite mark, forensic

ABSTRAK

Latar belakang: Puluhan tahun silam, dokumentasi bukti forensik seperti teraan gigit, bercak darah dan sebagainya yang memerlukan teknik dan peralatan yang canggih seperti fotografi infra merah (IR) dan ultraviolet (UV) merupakan masalah karena memakai film yang harus diproses terlebih dahulu untuk mengetahui hasilnya. Akibatnya, hasil pemotretan tidak bisa langsung dievaluasi, selain itu harganya relatif mahal, kamera digital yang diubah menjadi kamera IR tidak bisa untuk pemotretan biasa. Saat ini kamera digital dan program komputer mempermudah dokumentasi dan penyuntingan. **Tujuan:** Tujuan dari tulisan ini adalah untuk menjabarkan sifat dan keuntungan kamera digital dalam fotografi IR forensik dan menyederhanakan peralatan yang dibutuhkan. **Tinjauan pustaka:** Fotografi IR dipermudah karena kamera digital tertentu dapat menangkap gambar IR dengan menggunakan filter IR atau diubah menjadi kamera digital IR. Kamera biasa non-SLR mempunyai beberapa keuntungan dibandingkan SLR antara lain dalam memfokuskan obyek. Walaupun demikian, karena tidak semua kamera digital biasa dapat menangkap sinar IR, dapat dilakukan pengujian dengan penunjuk laser atau pengatur jarak jauh televisi. **Kesimpulan:** Pengetahuan tentang fotografi IR, kamera digital biasa dan peralatan tambahannya dapat mengurangi biaya peralatan fotografi IR standar forensik dengan cara modifikasi.

Kata kunci: Fotografi digital, infra merah, teraan gigit, forensik

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INTRODUCTION

Photography often represents the best method to collect and preserve evidence in forensic cases. This is especially true in forensic odontology with cases involving dental identification, human abuse and, perhaps most significantly, bitemark cases. Basic visible light photography is adequate in most dental identification cases; however, full spectrum digital photography is best utilized to collect all available evidence in cases of human abuse and Bite marks. It captures the forensic injuries using special techniques recording the injuries in each of the four resultant events that occur when light strikes skin.¹ However, decades ago when developed acetate film were used, direct visualization of the image was impossible, thus “trial and error” photography such as bracketing exposures to get the best image. Therefore, a lot of films were needed as well as difficulties in film developing.^{1,2}

In most forensic odontology cases, evidence collection and preservation using photography is a crucial aspect in the management of cases as they move forward to become part of a future legal proceeding.³⁻⁵ Full spectrum (infra red, visible light and ultra violet) forensic photography is very important in cases involving dental identification, human abuse and Bite marks. By understanding the individual techniques associated with full spectrum digital photography, complete evidence collection becomes routine when a forensic dentist is faced with the collection and preservation of the evidence.^{3,5-8}

In dental identification, it may be necessary to take ultraviolet (UV) photographs of loose teeth found⁵ indicating a non-natural avulsion. Similarly, in human abuse or bitemark cases it may be advantageous to use alternate light imaging (ALI) photography to document injuries to the skin that are not visible to the naked eye. Infrared (IR) photographs can be useful to locate and document bleeding below the surface of the skin or to enhance detail of tattoos in decomposing or mummified skin.^{3,7} In all cases, the investigator should take typical visible light photographs, as well as employ special non-visible spectrum photographic techniques, so that the images are captured using the full spectrum of light.^{1,9} Nevertheless, these techniques needed relatively expensive equipments such as special camera, filters as well as special light source.

This review was aimed to explore the different characteristics and benefits of regular digital camera in infra red forensic photography as well as to simplify the equipments needed.

Standard photographic technique

Ensuring accuracy during the process of photographing evidence such as Bite mark injuries requires a thorough understanding of the basic principles of image capture, including a familiarization with the camera’s features, limitations, and other equipment necessary for the task. Attempting to achieve success without first comprehending the fundamentals of photography is just like playing golf

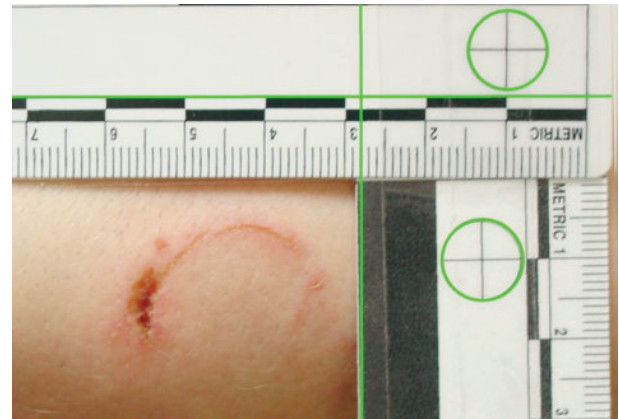


Figure 1. Bite marks on victim body with ABFO #2 scale.¹

in the dark.¹ Familiarization with the essentials should occur long before the photographer ever finds him/herself employed in a real-time situation so that he/she knows exactly what camera settings, filters, and light sources are appropriate for each different protocol. A standard technique for crime scene photo-documentation includes proper orientation shots, close-up (macro) photography, correct angulation of the lens of the camera to the plane of injury, and inclusion of a scale with identifiers for each case.⁵

Orientation photos

Orientation shots are for the purpose of showing the location of the Bite mark. These are usually captured from three to five feet from the subject and include enough information in the frame to see exactly where on the body the bite occurred (Figure 1).^{1,8} Inclusion of a scale is not mandatory; however, it is a good idea to acquire a few images with a scale in place from this distance for data reference which can be included on a label attached to the scale. One recommended scale that is readily accepted by the forensic scientific community is the American Board of Forensic Odontologist (ABFO) #2 scale available from Lightning Powder Corporation.¹

ABFO #2 scale is an L-shaped scale with two arms perpendicular to each other. It includes millimeter indices, neutral grey color blocks, and perfect circles placed at the ends and intersection of each arm. The inclusion of the scale allows the user to determine photographic distortion if any, the ability to correct it later with imaging software such as Adobe Photoshop, and facilitates enlargement of the injury to life-sized proportion. The protocol for image handling could be read in Digital Analysis of Bite mark Evidence published in 2002.⁹

Electromagnetic radiation and skin

The full spectrum of electromagnetic radiation ranges from extremely short wave lengths (200–375 nm), which is ultraviolet light, through the visible spectrum (400–700 nm) to the longer infrared wavelengths of 700–900 nm (Figure 2). Regular camera is incapable of seeing outside

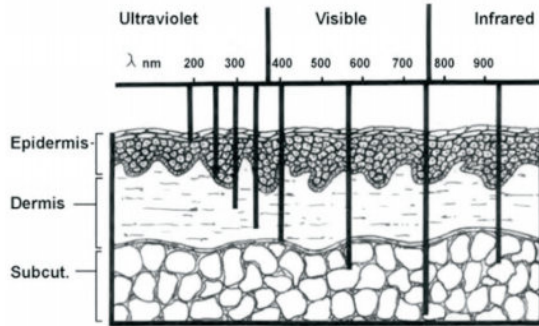


Figure 2. Penetration of different wavelengths of electromagnetic radiation to the skin.⁵

the visible light spectrum; therefore, special photographic techniques are utilized to create images in the non-visible zones of electromagnetic radiation such that they can be seen with the human eye.^{5,10}

When light strikes skin, there are four simultaneous events that occur: reflection; absorption, fluorescence, and scattering of the light within the skin (also known as diffusion). Reflection occurs as the shorter wavelengths of light strike the surface of the skin. Depending on the racial characteristics of an individual, the incident angle, and concentration of radiation, up to 50% of shortwave lengths do not penetrate the surface of the skin and are reflected back. Conversely, the longer wavelengths of light (700–900 nm) can penetrate the skin up to 3mm. Other wavelengths of light strike the skin and diffuse throughout the layers of the skin such that they dissipate without being absorbed or reflected.^{1,5,10}

One final event that occurs when light strikes skin is a molecular-level excitation within the skin that increases the resting state energy of the molecules within the skin, which is known as biofluorescence. Almost anything can be made to fluoresce.⁷ However, the laws of physics require objects to maintain a resting state (neutral) energy level or risk being destroyed. Therefore, when light energy is applied to skin, the molecules must get rid of the extra energy. The skin removes the energy of the molecular excitation by re-emitting the energy at a lower wave fluorescent level glow that lasts only 10^{-9} s. Skin reaches peak fluorescence at 450 nm incident light, but it is such a lower energy event that lasts such a short time, it cannot be seen without employing special photographic techniques such as ALI illumination.^{2,11,12}

The role of dentists in forensic dentistry

Forensic odontology involves the management, examination, evaluation and presentation of dental evidence in criminal or civil proceedings, all in the interest of justice. The forensic odontologist assists legal authorities by examining dental evidence in different situations. The subject can be divided roughly into 3 major fields of activity: civil or noncriminal, criminal and research.^{4,13-15}

Eventhough general dentists do not involved directly to forensic dentistry, each practitioner has a responsibility

to understand the forensic implications associated with the practice of his or her profession. Appreciation of the forensic field should give the dental clinician another reason to maintain legible and legally acceptable records, and assist legal authorities in the identification of victims and suspects.^{16,17} The dental record is a legal document owned by the dentist, and contains subjective and objective information about the patient. Results of the physical examination of the dentition and supporting oral and surrounding structures must be recorded. In addition, the results of clinical laboratory tests, study casts, photographs and radiographs become components of the record, and should be kept for 7 to 10 years.^{18,19}

All entries should be signed or initialled by recording personnel. Changes in the record should not be erased, but corrected with a single line drawn through the incorrect material. This method permits the original entry to remain readable and removes any questions about fraudulent intent to alter recorded information. Recently, computer-generated dental records are becoming more common for dental records. The obvious advantage of the electronic record is that it can be easily networked and transferred for routine professional consultation or forensic cases requiring dental records for identification.^{4,14,16}

Bite mark

A Bite mark can be generally defined as a pattern made by teeth in a substrate. Since the teeth can be of human or animal origin and the substrate can be skin, food, or a firm but compressible substance, more specific definitions are needed. Most Bite marks of forensic interest involve the contact between human teeth and skin.²⁰⁻²² The American Board of Forensic Odontology defines the human cutaneous bitemark as follows: “An injury in skin caused by contacting teeth (with or without the lips or tongue) which shows the representational pattern of the oral structures”. The definition excludes other nonpatterned injuries made by teeth contacting skin such as might be encountered by a fist to the mouth. It also excludes the closing action of jaws during intended biting if a recognizable pattern is not produced.^{20,23-26} These other tooth-to-skin interactions are still important even if not distinguished by the term “Bite mark” because they can be responsible for infection, tissue destruction, or transmissible diseases, and they can transfer DNA in saliva.¹¹ However, by convention, the term “Bite mark” signifies to the forensic odontologist an injury that, by its pattern, helps establish its origin from teeth.^{11, 26-27}

Therefore, not all of these marks should be called Bite marks. Those marks that occur as a result of objects or surfaces striking the teeth are more accurately called teeth marks. Bitemarks are created by the dynamic actions of the mouth and jaw complex of a person or animal. In human interactions, biting is known to occur in situations ranging from play to lovemaking and, more malevolently, in violent interchanges, such as fights and frays, and criminal activities from assaults to homicides.^{20,24,25}

In a pathologist perspective, a patterned injury such as a Bite mark is made visible not by a transfer of material and

not often by indentations, but rather by a vital response of the bitten tissue. It may include the superficial scraping of epithelium by the contacting teeth (abrasion), the bleeding within skin by the pressure of the teeth (contusion), or the tearing of skin by teeth (laceration) that renders the Bite mark visible.²⁰ Bleeding or scraping of skin under assault is not obliged to conform precisely to the anatomy of the object that produced it. The bleeding can extend beyond the tooth marks. Conversely, bitten skin may not have been sufficiently damaged to react at all.^{20,25} The Bite mark is not an imprint or impression, but rather a reactive response generated by injured skin that is invariably less precise than a direct recording.^{20,26,27}

Since Bite mark will fade or changes its color with time, standardized forensic photography should be done as soon as possible. The use of UV and/or IR photographic equipments are able to enhance the captured image of “old” Bite mark. Decades ago, conventional camera which used films, special filters and lighting were the main tools.^{1,27}

Conventional vs. digital camera for UV and IR photography

Prior to the introduction of UVIR digital cameras, all images were film based. Special IR film is still available for purchase, however there are specific handling, developing, and focusing requirements that must be employed for successful image capture. Unfortunately most digital cameras are designed for capturing images using visible light only.¹ Their manufacturing process includes software designed for only the visible part of the light spectrum and a special filter in front of the electronic sensor that blocks the UV and IR ends of the spectrum.^{1,27, 28}

Therefore, in order to acquire IR images with a digital camera, one must either have a camera that has been produced specifically for UV and IR capture, or modified to accomplish the task. Fujifilm of North America was the first company to produce a digital camera with these capabilities. Nevertheless, these cameras are no longer being produced. Many a fine art photographer has modified an older, retired digital camera and resurrected it for use specifically for IR imaging.²⁹ The same modification allows the forensic photographer to shoot images in IR and UV.^{1,5} Since UV photography needs more sophisticated equipments, this article limits only on infrared photography.

Infrared (IR) photography

Digital infrared photography can be tricky when it comes to record Bite mark in that one must adjust for a focal shift due to the longer wavelength of light reflecting back to the sensor. Focal shift changes can be eliminated with a quartz lens, a subject that will be discussed in the UV section of this paper. An IR filter must also be placed over the lens so that only the IR part of the spectrum is transmitted through the lens to the sensor. There are several types of IR filters to choose from, however a #87 glass or gelatin filter will suffice for this application.¹ Lighting for IR is generally not an issue, as most ambient or room light will be adequate for exposures. Infrared photography also

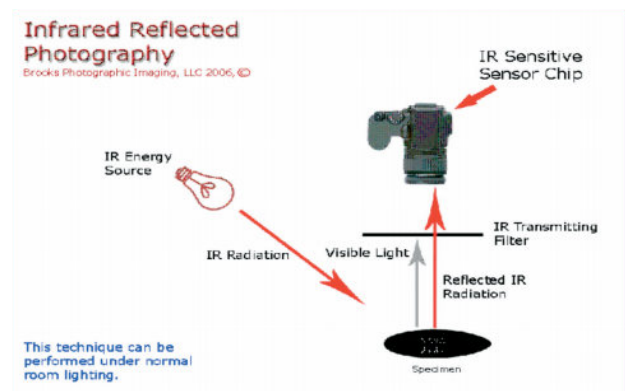


Figure 3. Infrared reflected photography setup.⁶

requires the use of a full spectrum or modified IR digital camera and lens. Additional armamentarium necessary includes an IR band pass filter.^{1,5,27}

In Bite mark photography, the IR range of the spectrum shows the viewer the deepest part of the bruise pattern, well into the dermis and underlying vascular tissue. Results are often mixed, with IR photos showing less detail than ALI and visible techniques.²⁸⁻³⁰ However, one very useful area where IR application outperforms visible light techniques is in tattoo documentation when the original tattoo is either occluded or has faded considerably. IR also has the ability to see through blood.^{10,27,28} With practice, the forensic photographer should be able to repeatedly get good results using the IR technique.

Finally, there must be an IR light source illuminating the patterned injury. There are several types of IR light sources on the market, ranging from typical flash units modified to emit IR light to specialized IR LED light sources. One of the simplest way in lighting setup for IR photography is using overhead fluorescent and tungsten room lights which create adequate illumination under normal room lighting (Figure 3).⁶

Single lens reflex (SLR) vs non-SLR in IR digital photography

For newcomers in digital IR photography it should be a prime question why an expert said that the digital SLR camera was not the best choice for IR, that is for two main reasons. First, the light metering in digital SLRs is not done by the image sensor itself (like in non-SLR models), but by a separate set of sensors, which may have a different response to IR. One cannot rely on camera's autoexposure, although it may be able to correct a given camera/filter combination. Second, many cameras in lower type of SLR camera do not offer real-time electronic preview, because the light from the lens reaches the sensor only during the actual exposure.^{12,29} This means that you have to put the camera on a tripod, compose the picture without the IR filter, then put it on and shoot blind; most camera makers offer now models with the Live View. This is why it may be easier to do IR photography using an advanced non-SLR model, or an electronic-finder camera.^{1,7,12}

Simplified digital infrared (IR) photography

Eventhough the best digital IR photography is a "true" IR camera followed by IR conversion camera, there are several ways to make regular digital camera to produce IR imaging, such as using IR filter, creates simple IR light source from IR or regular flashlight covered with thin plastics; and IR computer software such Adobe Photoshop and special IR conversion softwares. These simple steps could be done to regular digital camera to capture IR images; a better way than digital IR conversion cameras which cannot make regular pictures.^{1, 5, 12}

Infrared photography with regular digital camera

Regular digital camera is able to catch infrared spectrum by attaching infrared filter and replacing the IR blocking filter with a visible light blocking filter. However, this kind of camera needs long exposure if using infrared filter. Therefore, the second choice is more practical, because unconverted cameras need long exposures, thus tripod use was mandatory; or strong infrared light source that sometimes not easily found. Replacing IR blocking filter can be done by experts in this techniques. Simple test to reveal that a digital camera is sensitive to infrared spectrum is just by pointing TV remote control towards camera lens and see in the LCD panel.^{1, 5}

Simple infrared light source

The "True" IR light source in Figure 4 is relatively expensive. Other IR light source is SureFire™ illuminator that is around USD 160.³⁰ A brilliant idea by creating simple IR source using regular LED flashlight or IR LEDs is cheaper. The more or the bigger LED's will give more illumination; however, the simple IR light source bt using black plastic disk from 3.5" computer disk on the front of LED flashlight was considered adequate to illuminate limited area of skin (Figure 4). Nevertheless, the darker the environment light may help enhancing the illumination. Other light source such as halogen bulb or light white bulb could be used, but these thin disk may not withstand the heat produced by these light sources. Therefore, making LED light source from special LED's which emit infrared light is a better idea.³¹

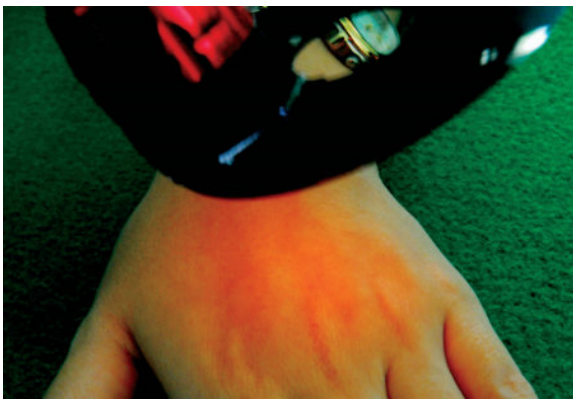


Figure 4. IR illumination with LED flashlight covered with floppy disk.

To the human eye, the 950 nm IR LEDs looked completely black, even when held up to a bright light source, but when viewed by a video camera, appear perfectly clear, even when not powered. The reason the camera can see right through the LEDs is because the plastic is made up of materials that only pass infrared light, creating a band pass filter that blocks most of the light that is not within the specified wavelength. So, if this LED emits light between 800 and 1000 nms, the band pass filter may help cut all unwanted light except for the output close to 950 nms as specified in the datasheet. Other LEDs are perfectly clear, or have slightly blue tinted plastic bodies.³¹

Other difficulty in IR photography with non-converted IR camera, that is by attaching IR filter is in focusing. Firstly because autofocus will not work well in attached IR filter, because of IR filter is very dark. Secondly, if the photographic object is not well illuminated, some digital camera that doesn't have preflash illuminator and through the lens (TTL) flash metering may not have a problem in autofocusing. Nevertheless, it could be solved by fixing the camera on the tripod use manual focus and attach the filter after sharp focus is accomplished. If you have a ring flash, just attaches it on the flash unit screw in and bring it tightly closed to the lens after focusing, but it must be sure that no visible light enters.^{6, 32}

DISCUSSION

Difficulties in infrared film photography, according to Schneider,¹² who quote Chuck McKern, an experienced IR expert, "It's difficult getting the film, difficult shooting with it, and difficult processing it." Infrared film must be handled and processed in total darkness, is susceptible to static markings in low humidity, and requires a series of tests using heavy filtration such as a no. 87, 87C, or 89B filter that blocks all UV radiation and visible light to determine the best exposure.

In forensic photography, photographing evidence using full spectrum digital camera was still complicated, mostly because the UV/IR camera and special lens such as Nikon UV 105 mm were discontinued. Additionally, it was quite expensive for newcomers, approximately USD 2000-3000 used.¹ Therefore, some modifications or "simple inventions" should be found to fulfill the requirements.

In this article, the discussion is limited to simplified IR bitemark photography using mostly available digital camera and simple IR light source. It is interesting that on the contrary with UV light source, which could be found as fake money detector, finding simple "true" infrared light source is more challenging. "True" infra red light source such as produced for the military, Surefire™ is the best choice but it is also expensive.³⁰ Capturing Bite marks and teeth marks in considered "new" or "old" ones was different. A new Bite mark, which happened within hours is best captured with UV because it produced sharper images;

nevertheless, Bite mark up to two weeks is best captured with IR since it could reach deeper tissue^{6,9}

Concerning the difference of SLR and non-SLR regular digital cameras for IR photography, several characteristics, even though the non-SLR cameras seems smaller than SLR, are superior than SLRs such as in easier autofocusing for IR photography. Autofocus (AF) is performed in the image sensor plane, by contrast detection. This means the circuitry will properly detect when the image is in focus, regardless of the light type. There may be a problem with the amount of light available for the job, especially if IR filter is used, but not with its kind; the AF action may be slower and less reliable, but there will be no systematic shift. If your camera is capable of autofocusing in low light down to exposure compensation 0 (EVO) or not much above, you'll be just fine.^{12,32}

Other inferiority of digital SLRs in IR photography in autofocusing is because the AF is done by dedicated sensors behind a system of mirrors. These sensors are at the same effective distance from the lens as the imager. This should, in principle, functional, as both the AF sensors and the imager are getting IR light only. There may be, however, some inaccuracy caused by the fact that both sensors are receiving somewhat different kind of IR, so both focus planes will be shifted with respect to each other: what the AF sensor will see as in focus, the imager may see somewhat out-of-focus. Nevertheless, it does not mean that non-SLR digital camera always more superior, because the lens quality as well as the camera type, which should not a "point and shoot", or the very basic non-SLR digital camera that has poor image quality.^{12,30-3}

For the concluding remarks, knowledge about IR Bite mark photography, characteristics of regular digital camera and its accessories could reduce the budget for an ideal standard forensic photographic equipments by modifications.

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