ABSTRACT
Dental Photography is mainly used for documentation and patient education. With development of technology digital photography eliminates the delay between image-capture and review compared to the film based photography in the past. This review article is based on an exploratory study conducted on the medical literature to provide clinicians an overview of the function and basic components of a professional digital single lens reflex (DSLR) camera system, the criteria for evaluating and selecting a digital camera system, clinical applications for dental photography along with the guidelines for obtaining a quality dental image.

Keywords: Camera; Dental; Digital; Photography

Introduction
The field of dentistry has been benefited from the trends and advances in digital photography and a well-designed protocol of dental photography may be a great contribution for the dental practice.¹ The advent of digital imaging is a leap forward for clinical photography because of the elimination of the considerable delay between image capture and review noted with previous film-based photography.² Evolution in photographic techniques has continued to facilitate and enhance the dental practice.³ This review article provides clinicians with an overview of the function and basic components of a professional digital single lens reflex (DSLR) camera system, the criteria for evaluating and selecting a digital camera system, clinical applications for dental photography along with the guidelines for obtaining a quality dental image.

History: The first photographic process was presented at the Paris Academy of Sciences by Louis J. Daguerre in 1839.⁴ Alexander S. Wolcott, in the same year, designed and patented the first camera system that used a concave mirror to form an image on a photographic plate.³ These early photographs called daguerreotype, i.e., an image on a silver coated copper plate.⁵ This photographic phenomenon introduced a new era of objectively reproducing and recording visual images.⁶ The development of dental photography was directly influenced by American dentists who became professional photographers during the 18th and 19th centuries.⁴ Progress in photography continued over the past 150 years, paving the way into the 21st century.⁷ In the past photography utilized silver halide ions in a gelatin emulsion on a strip of celluloid film to capture latent images.³

Digital technology has introduced efficiency to the process.³ The high rate of innovations in the market often confounds dental professionals in the world of digital photography.¹,² Digital images can be viewed and stored instantaneously and economically, without the cost of purchasing and processing film, or the need for other traditional chemical development requirements.³

Camera Systems: The advent of digital technology allowed the popularization of digital cameras that allowed the commercial availability of equipment of different brands, models, features and price.¹⁶ The digital camera systems can be divided into three groups: amateur, semi-professional and professional.¹,³ To improve the image quality, various modifications in these systems have been developed i.e. the use of diffusers, macro lens with integrated ring flash and close-up lenses for improved magnification etc.³ Machado et al. investigated the accuracy of orthodontists in differentiating conventional and digital photographs as well as checking their quality.¹,³,⁸ For that purpose, ten digital and ten conventional photographs of excellent quality were printed on photographic paper with a resolution of 400 dots per inch (DPI) in a professional digital lab.¹ The examiners indicated if the images had been obtained by conventional or digital cameras and judged the quality of digital photography was well acceptable for application in dentistry.¹

The conventional 35mm camera system creates an image by using light to activate the film, through a chemical reaction.³ Light sensitive molecules in the film emulsion are electrically charged in proportion to the amount of light that strikes each area of the film.³,¹¹ Later, during the film development process, each charged molecule is enlarged and stained to become a grain, the basic visible unit of film image detail. Together, the grains combine to collectively compose the photographic image.³,¹²,¹³

The digital 35mm camera system uses light to activate a solid-state sensor through an electrical reaction.³ A charged coupled device (CCD) or a complementary metal oxide semiconductor (CMOS) stores an electric charge in proportion to the amount of light that strikes each portion of the sensor.³ The image is initially converted into dots of digital color information that combine to create the final image. Each dot of color data represents a picture element or “pixel”, the basic visible unit of digital image detail.³ The greater the number of CCD or CMOS, the better the surface detail and image quality recorded.³,¹¹ During the digital image capture process, the sensor elements detect and convert light stimulation into an electrical analog signal. The analog signal is then analyzed and converted into digitized binary code that is computer readable.³,¹¹ The better the resolution of the analog-digital converter, the greater the number of distinguishable luminance levels.³
The light sensing electrodes of the digital sensor (CCD/CMOS) are able to measure brightness levels but cannot measure wavelength (hue) differences. The sensor elements achieve color discernment by placing an ordered mosaic of red, green and blue filters over the entire sensor. Each filter only allows its specific wavelength of color to pass through while blocking the complimentary colors. The color level for a given pixel with a color depth of 8 bits has 256 possible values for each of its three color components. The combination of these three components in varying degrees of intensity provides 16.7 million (256 X 256 X 256) different color combination possibilities. The solid-state sensor determines the quality of the image at the heart of the digital 35mm camera system.

**Components of the digital camera system:** Knowledge about the artistic arrangement and correct framing in extra-oral photographs is fundamental, so that the image may actually reflect what the photographer aims to capture. The basic components include the camera body, lens and the flash system. The lens focuses the light within the camera, supplemented by the flash for intraoral purposes. The film based SLR or DSLR camera system utilizes one lens for both, image composition and image capture. This design allows direct viewing and focusing without parallax error, ideal for dental photography. The camera body coordinates the functions of the image capture. Many errors can occur when taking photographs, including camera positioning, wrong focusing, under and over-exposure of the field of view and positioning errors as the patient height in relation to the photographer, wrong Frankfurt plane, head positioning, hair covering the ears, eyes closed or soft tissues in incorrect position. Other possible errors include excess saliva, fogged mirror, dark buccal corridor, tongue not sufficiently retracted, non-observation of the distal margin of the first molar or photographic retractors obscuring the field of view. The evaluation of the basic components will provide necessary objective information for selection and application for clinical photography.

**Lens Systems:** Dental photography requires magnified views of teeth, gingiva and surrounding structures. While many lenses can magnify the subject matter, macro-lenses are able to capture an enlarged image of a subject while focusing at a close range. Macro lenses with a fixed focal length designation of 100-105mm provide the ideal combination of magnification ability and working distance convenience for dental purposes. For close-up dental imaging, consideration must be given to two interrelated measurements- magnification and magnification ratio.

In photography, magnifying an image requires extending the lens forward, away from the sensor/film plate. The magnification ratio is the ratio of the size of the image projected on the sensor compared to the actual size of the object. To create images with magnification ratios that exceed 1:1, additional attachments can be added to the lens. A tele-converter is a cylinder, with light focusing lens elements that can be placed between the lens and camera body, to multiply the effective focal length of the lens. This effect provides greater magnification for the image at the same working distance. Teleconverter can also cause some degradation in the sharpness of the image. An extension tube is also a cylinder that is mounted between the lens and camera that functions to move the lens farther away from the focal plane. Extension tubes are often used to allow the photographer to gain a larger image by moving closer to the subject, and also do provide some increase in magnification without a change in working distance. Thus, extension tubes cause less light loss than Teleconverter, with no degradation in the crispiness of the final image.

**Flash Systems:** The natural light is inadequate to illuminate most of the dark shadows in intraoral photographs; therefore the most practical light source comes from a supplemental electronic flash source. An electronic flash can provide light with neutral color, short duration and relatively high light output. These allow adequate exposure with low heat generation, for patient comfort. Most digital cameras have the flash connected laterally or above the objective (point flash), which produces an uneven distribution of light in the intraoral photography, creating unwanted shadows, which may be noticed as a shadow in the buccal corridor of the patient. There are various types of electronic flash system configurations, available for dental photography.

**Ring Flash light source system** is considered as the universal flash system for general macro photography and furnishes either a single ring flash tube or individual sector flash tubes that surround the lens. Advantage of this flash system is that objects in the oral cavity can be evenly illuminated without shadows. The disadvantage in the reduction of shadows is that the image may appear to ‘flatten-out’ with reduced discernable contours.

**Point Flash light source system** provides a single strobe light source, mounted to one side of the lens. The isolated light can be moved to different positions around the lens to provide a directional light from different angles. Control of the light direction allows shadows to be cast by the 3D topography of the objects in the scene. The appearance of the shadows improves the visual definition of contour and texture, to emphasize the apparent depth within the image. McKeown et al suggested focusing as distant from the mouth as possible, providing more light and reducing the shadows. In this situation, the area of interest represents only 20% of the area captured by the camera. Therefore, the picture must be trimmed saving only the area of interest, either lateral or occlusal. For that purpose, the camera resolution should be as large as possible to produce a good image after trimming, since 80% of the photograph will be discarded. This design is able to record surface texture details and contour but requires considerable experience and additional set-up time to maneuver the flash position before each exposure.

**Twin Flash light source system** consists of two flash units mounted next to the lens in either of the below mentioned designs. The first has two fixed strobes that are mounted in stationary positions on either side of the lens. The second de-
sign uses two movable flash strobes that are mounted further from the lens on movable arms that can be placed in variable custom positions around a circular mounting bracket. This twin flash design system thus may offer, the best combination of soft, uniform illumination as it simultaneously reveals surface detail, color transitions, translucency variations and crack lines, etc.  

**Camera Body Systems:** A digital camera body possesses several knobs, switches and dials to select settings and control performance. In addition, each possesses indicators to inform the operator about current conditions and potential problems. The features of different camera bodies vary in sophistication. The durability of the materials used in the construction of internal components, extremely rapid auto-focusing systems, fast multi-exposure options and increased size of the sensor are examples of high end features that increase the cost of production and the price of the camera.

In prioritizing equipment purchase decisions, the best dental images would result not from acquiring the most expensive camera body, but from investing in high quality lens and flash components. The most fundamental and critical role of a camera body is that of exposure control. The objective in regulating the exposure is to create an image in which there is discernable detail in all the tones - both light and dark tones. 

In digital dental photography the amount of light falling on the sensor is determined by three factors namely, the aperture diameter of the lens, the duration of the exposure and the relative sensitivity setting of the camera. The aperture is the size of the hole through which the light enters the camera. The specific size of the aperture is called ‘f-spot’ and is calculated as the ratio of the diameter of the lens opening to the lens focal length. The aperture also affects the amount of the scene that appears to be in focus. The amount of the scene that appears to be in focus is called the depth of the field. For dental photography applications, the clinician should maximize the depth of the field by utilizing the minimum aperture diameter possible. To complete the proper exposure, the aperture must be coupled with the proper exposure time and camera sensitivity.

**Reflective Exposure Metering:** In photography, through-the-lens (TTL) metering is a feature of cameras whereby light levels are measured through the lens that captures the picture, as opposed to a separate metering window. TTL metering, being a reflective technology, the amount of light entering the camera is determined by the amount of light that reflects off the subject. Most digital cameras offer a choice of three geometric configurations for TTL metering: spot, center-weighted or matrix. With each of these systems, the camera measures the amount of light reflecting off the subject in trying to determine the proper exposure for that scene.

**Spot metering** measures a small area of the scene i.e., usually 2% or less of the entire image area.

**Center-weighted metering** evaluates the light reflected from the entire scene, but gives priority to a defined area in the center of the frame.

**Matrix metering** measures the entire frame by dividing it into segments. Each segment is evaluated and then compared against a proprietary database library of anticipated image algorithms to yield the final averaged reading.

The photographer thus, should select a metering configuration that evaluates the portion of the scene that represents average luminance while, ignoring areas of extreme highlights and shadows.

**Exposure Compensation:** If the camera monitors an area of the image that is highly reflective, it will mistakenly perceive that a darker exposure is required so, inadvertently recommend the settings for an underexposure. Conversely, if the metering system reads an area of the scene that is low in reflectivity, it will mistakenly discern that a lighter exposure is appropriate and so inadvertently recommend the settings for an overexposure. The high contrast between the dark and light areas of intraoral images presents a genuine problem in exposure determination. For example, with spot metering, the camera would have to be set to modify the calculated exposure to adjust for the bright luminance and high reflectivity of teeth. The camera feature that allows an intentional modification in exposure metering is called exposure compensation. It allows the exposure recommendation made by the camera to be adjusted up or down to accommodate the light or dark subject matter, respectively.

Many camera bodies have an additional feature capability called bracketing. This setting helps the operator take a series of photographs - each with slightly raised and lowered exposure values (relative to the metered exposure) with the exception that one of them will be correct. The number of exposures in the series and the amount of exposure value variation in each interval is predetermined and set by the photographer. Bracketing can overcome the possible error in estimating the exposure compensation required for a particular scene by automatically producing several images of the same view, with each view having a slightly different exposure.

**Exposure Modes:** Once the light for an image has been measured, the camera must be set for those lightening conditions to create the proper exposure. Most camera systems allow the operator to choose whether the exposure will be performed automatically by the camera or manually by the operator. With either method, the diameter of the aperture must be matched with the appropriate exposure time in order to achieve an acceptable result. The key is to find the best combination for application in creating diagnostic dental images.

Taking images of the plain film radiographs can be difficult. The film is placed on an X-ray viewer box and the image is then taken. In most cases, there will be a grayish green cast to the image. This is due to the fluorescent light in the X-ray viewer that produces flicker at the mains frequency. Essentially, when an image is taken, the fluorescent light may be flickering on or off, thereby affecting the color of the image. The image can be manipulated to produce a black and white image using bought software such as Adobe Photoshop (www.ado-
be.com) or using open-source software such as GIMP (www.gimp.org). The second technique and the easiest are to set the digital camera to capture images in black and white.\(^2\)\(^1\)

To resolve this issue, contemporary cameras typically offer a selection among three automated exposure assignment alternatives.\(^3\)\(^,\)\(^2\)\(^1\) In the Program Mode (P), the camera selects both the aperture and exposure time for the photographer. In the Shutter Priority Mode (S), the photographer selects the desired exposure time while the camera selects the matching aperture.\(^3\)\(^,\)\(^2\)\(^2\)\(^0\)

For dental photography, the priority is to create the largest depth of field to maximize the amount of the scene that appears to be in focus. Since the aperture of the lens controls this outcome, the Aperture Priority Mode (A) is the best automated exposure strategy for intraoral photographic applications. In flash assisted intraoral photography, the exposure time is a function of the length of the flash burst, not the duration of the shutter speed.\(^3\)\(^1\)\(^)\) Thus to utilize automated aperture-priority metering, the flash unit must be compatible with TTL technology.\(^3\)

**Incident Exposure Metering:** Sophisticated camera systems often offer a Manual Exposure Mode (M), to benefit from incident light metering as; the photographer sets both the aperture and the exposure time.\(^3\) The ideal method for determining the correct exposure setting for a specific dental scene is to utilize an incident light meter which measures the light falling on a subject and can establish the proper exposure setting from a desired magnification distance.\(^3\)

**Filmless Imaging:** In the past, film based photography required film selection, film and processing costs and waiting for the roll to end. Film development typically was out of hands of the photographer. A consistent and trustworthy processing lab was required to collaborate in the production of the images. Filmless imaging currently presents a new set of variables.\(^3\)

Digital imaging requires the understanding and application of a new set of skills. Beyond mastering the camera, the photographer now also must ‘process’ the images. Color management of the camera, monitor and printer all affect the color of the final image. Workflow decisions regarding color space, image size, formatting and editing are now the photographer’s responsibility.\(^3\)\(^,\)\(^2\)\(^2\)\(^)\(\) Dental practitioners must remember that the ultimate goal of producing an excellent photograph should not be to enhance or disguise the clinical reality, but to accurately capture and share what their eyes see so they can learn from and improve it.\(^3\)\(^,\)\(^2\)\(^3\)

**Clinical applications of Dental Photography:** There are numerous applications for digital photography in dentistry, some of which are: Diagnosis and treatment planning,\(^2\)\(^4\)\(^,\)\(^2\)\(^2\)\(^)\(\) Legal documentation,\(^3\)\(^,\)\(^2\)\(^0\) Unreliable memories,\(^2\)\(^7\)\(^,\)\(^2\)\(^8\)\(\) Forensic documentation,\(^3\)\(^,\)\(^2\)\(^9\) Functional esthetics,\(^3\) Patient education and communication,\(^3\)\(^,\)\(^3\)\(^0\) Laboratory communication,\(^3\)\(^,\)\(^3\)\(^1\) Professional instructions,\(^3\)\(^2\) Insurance verification,\(^1\)\(^3\)\(^3\) and Patient motivation.

**Excerpts for Choosing and Implementation of a digital camera system:** The order of importance and priority in selecting digital camera system components should be: lens, flash and then body, to maximize the image quality.\(^3\) Select a macro lens with a fixed focal length of about 100mm manual focus capability and magnification ratio markings.\(^3\) Set the lens to manual focus mode. If you use autofocus then the magnification ratio will change constantly and therefore there will be no consistency with your photographs. It is best to dial in the required magnification ratio on the barrel of the lens and then focus manually.\(^3\)\(^4\)\(\) Select a flash with neutral color temperature that mimics daylight. A twin tube design is recommended to give the best combination for light accessibility and simultaneous detail illumination. ISO measures the sensitivity of the digital sensor. The lower the number then the less sensitive the sensor is light and the less “noise” created. However if you are using a less powerful flash unit then ISO 200 or 400 will give more than good enough results.

**Select the preferred strategy to be utilized for controlling image exposure:** A camera body with aperture priority, spot metering, exposure compensation and possibly exposure bracketing capabilities. Manual exposure requires more initial learning but requires no experimentation and achieves very consistent results. So, select a camera body with manual exposure capability. When using a digital camera with a sensor that is smaller than a full frame, the final image will reveal an increased magnification ratio as a function of the cropping factor.\(^3\)\(^5\)

Technological developments in the photographic process have continued to change and improve the practice of dentistry.\(^3\)\(^6\) Clinicians must now integrate existing photographic principles with today’s contemporary camera systems and computer software technology. This evolution to a contemporary photographic process in revolutionizing the way clinicians diagnose, treat and communicate with patients and colleagues. In this technologically advancing profession, the clinician should consider using an objective strategy for the selection and application of any camera system.\(^3\)

**Conclusion**

In conclusion, It is important to be aware that dental photography is an essential part of dentistry used not only to document, but also to illustrate and educate.

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References


5. Newhall B. The history of photography from 1839 to the present day.; Book. 1964.


