1

Photographic Equipment

The most frequently asked questions about dental photography are:

> 'Which equipment do I need?'
> 'What is the cost?'
> 'How long will it take to learn?'

The aim of this opening module is to provide answers to these questions.

Photography should be regarded as an integral part of daily clinical practice (Reddy et al. 2014), and photographic equipment as part of the dental armamentarium, no different to a dental handpiece. However, the common consensus is that a camera is an extraneous apparatus, exclusively reserved for specialists, or clinicians with a penchant for taking pictures. These are erroneous assumptions since photographic documenting is essential for diagnosis, treatment planning, treatment options, educating patients and ancillary staff, communicating with colleagues, recording treatment sequences, assessing and monitoring outcomes, marketing, and serves as irrefutable evidence if litigation ensues. Furthermore, it is important to emphasise that dental photography is not solely for specific treatments such as elective cosmetic procedures, but a requisite for recording pathological conditions of the oral mucosa or even the simplest treatment modalities such as tooth whitening.

The first thing to appreciate is that there are no 'quick fixes' and no 'deals', and fellow colleagues or companies who propagate these myths are misguided and misleading. A number of dental companies exploit photographic ignorance by offering 'quick fixes', with low-end cameras specifically adapted for dental photography, often sold at inflated prices for the gullible and uninitiated. However, most of these cameras are compromises, yielding inferior image quality, which is hopeless for precise diagnosis, treatment planning, follow-up and communication. If the objective is simply to produce bland and boring pictures, similar to passport or 'mug shots', then these devices fit the purpose. However, there is still a learning curve with these modified cameras, and it is questionable whether the toil is worthwhile for disappointing results. Alternately, the same time and effort can be channelled to learning correct techniques with appropriate equipment, which yield excellent and gratifying results.

Similar to learning a particular clinical technique such as crown preparation or implant surgical procedures, there is a learning curve for mastering dental photography that cannot be ignored. However, the time required to learn basic photographic techniques is reduced with proper advice and guidance. Taking pictures is probably easier than restoring a Class I cavity, but does require a degree of patience and perseverance. As mentioned in the Preface, once

Essentials of Dental Photography, First Edition. Irfan Ahmad.

basic techniques are mastered in a few days (preferably combined with hands-on or online training course),[1] a routine photographic session should take no more than 10 minutes of clinical time; a small sacrifice compared to the innumerable benefits if offers.

Cameras

Before choosing a camera and the accompanying accessories, it is crucial to establish the basic requirements of dental photography. Dental photography is essentially divided into two types of picture: portraiture and macrophotography. Portraits are necessary for several disciplines and clinical scenarios such as orthodontics, prosthodontics, aesthetic/cosmetic dentistry, facial enhancement procedures, external traumas to the dentition, or accidents involving soft tissue bruising, lacerations and fractures of the facial skeleton. Macrophotography encompasses both intra-oral pictures of the oral environment consisting of the teeth and surrounding anatomy, and extra-oral pictures of the dento-facial composition and bench images of diagnostic casts or artificial prostheses/restorations. Therefore, it is essential to choose a camera and accessories that fulfil the requirements of both portraiture and macrophotography.

The market is awash with cameras offering countless functions, some superfluous, others essential, and deciphering which are useful or redundant is a challenging and annoying endeavour (Ahmad 2009a). Many camera features that are supposedly added to make life easier often end up as frustrating nuisances, and wading through never-ending cascading menus requires aptitude and endurance. This is probably the biggest turn-off for potential purchasers, who are bombarded with technical jargon, acronyms they do not understand and features they are unable to comprehend. Therefore, it is important to ignore manufacturers' hype and concentrate on salient specifications. The type of camera systems available is a minefield, such as point-and-shoot, compact, CCS (compact camera systems), EVIL (electronic viewfinder interchangeable lens), MILC (mirrorless interchangeable-lens compacts), rangefinders, dSLR (digital single lens reflex) and, of course, not forgetting the smartphone (cellphone) varieties (Figure 1.1).

Nowadays, no discussion on photography would be complete without mentioning smartphone cameras. In recent years the quality of smartphone cameras has increased exponentially, and these devices are capable of delivering images that were once only possible with dedicated digital cameras. In addition, many reputable camera manufacturers such as Leica®, Hasselblad® and Carl Zeiss® are collaborating with phone companies to develop cameras and accessories for mobile hardware. The convenience, expediency and connectivity offered by smartphones and tablets is obviously the driving force for this rapidly evolving industry. Also, there has been a discussion in the dental literature about the suitability of cellphones or tablets for dental photography (Manauta and Salat 2012). The main purpose of smartphone cameras is that they are designed for social photography. Hence, to use these units for medical/dental purposes, the in-built cameras need to be calibrated and modified for macro use, which requires a degree of training. Whilst the disseminating convenience offered by mobile devices is unmatched, to achieve clinically useful images requires perseverance. Smartphones are ideal for random shots showing patients' particular oral problems, or sharing cursory images with dental technicians regarding oral rehabilitation, but to take this a step further, training is essential. Nevertheless, this technology is difficult to vilipend, because in the near future, mobile devices may evolve to be the standard for photodocumentation for many fields, including dentistry.

1 https://www.dentalphotomaster.com/online-training

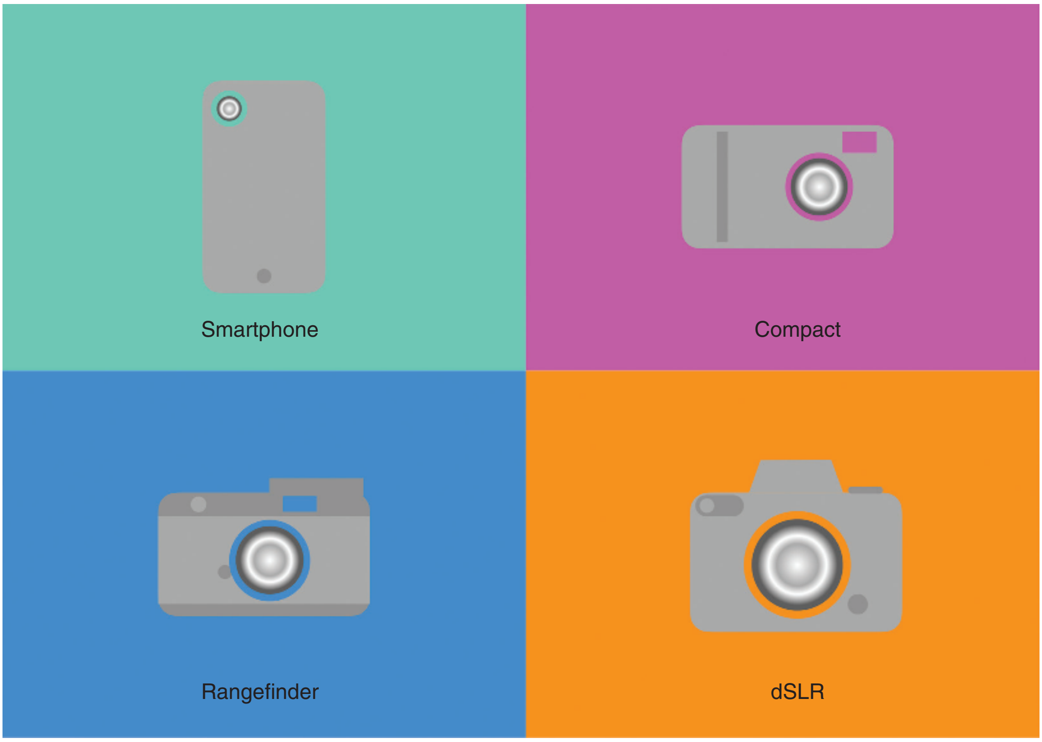

Figure 1.1 Different types of camera systems.

In order to satisfy the requirements of dental photography and produce images rich in detail, vibrancy, nuances of colour, texture, form, conveying emotions, feelings and unparalleled quality, the only choice at present is a dSLR.[2] Whilst other category of cameras can be tailored or adapted for dental use, the task is onerous, and probably not worth the frustration for the small cost saving that is often elusive. Having established that a dSLR is the ideal camera for dental applications, the next question is: which proprietary brand to choose?[3] The advice in this book concentrates on generic photographic equipment, which fulfils basic requirements for dental applications. Also, with technological advances, newer products are perpetually being introduced, which readily become obsolete in a short space of time. Furthermore, mid-range dSLRs from any major brands are almost identical in terms of features and the image quality they offer.

A dSLR consists of a body containing the mechanics and electronics, or brain, of the camera. A camera body usually comes as a kit with a lens and other basic accessories. However, most lens that form a kit are often unsuitable for dental applications, and, if possible, it is advisable to purchase the body alone, or exchange the accompanying lens for one that is more suited for dental use. The primary features to look for in a camera body are the physical size of the sensor, megapixel count, colour depth, numerical white balance input, external flash synchronisation via a hot-shoe with TTL (through-the-lens) metering, switchable manual focusing, sensor speed or ISO (International Standards Organisation) range, remote

2 http://www.dentalphotoapp.com/7.html
3 http://www.photomed.net

shutter release, tripod thread(s) and ease of sensor cleaning. The secondary features include exposure modes and metering, shutter speeds, sequential frames per second, colour space, dust and water spray sealing, anti-fingerprint and anti-scratch coating of the LCD (liquid crystal display) touch screen, RAW file formats, video capability, GPS (global positioning system), WiFi, storage media, interface for data transfer, built-in photo-editing software, build quality, size, weight and, of course, the price. Whilst there is no compromise of the mandatory primary features, the secondary features are desirable, but not necessary. Although the list of primary or secondary specifications may seem endless, there is no need to fret, since most dSLRs have these features as standard. But, like anything in this world, you get what you pay for; the higher the specifications, the higher the price. All major camera brands, such as Canon, Nikon, FujiFilm, Sony, Panasonic (Lumix), Pentax and Olympus, offer mid-range or semi-professional dSLRs suitable for dental requirements for around US$ 500 at current prices. Table 1.1 itemises the specifications for choosing a camera, and for those wishing to understand the relevance and importance of these features, an explanation of the major specifications is given below.

Sensors

The heart of a digital camera is the sensor, a solid-state device composed of tiny photosensitive diodes called pixels, (abbreviation of 'picture elements'). The pixels are stimulated by incoming light through-the-lens to create an electrical charge that is an analogue signal. The electrical signal is then converted by an analogue to digital converter (A–D converter) into a binary digital code, or data, for creating the image. The pixels are colour blind, only capable of registering black and white, or brightness and darkness (Figure 1.2), and require some types of filters to produce colour images using the additive red, green and blue (RGB) colour system. The additive RGB colour system represents the three primary colours RGB, which collectively produce white when mixed together. This is in contrast to the substrative colour system: cyan, magenta, yellow (CMY) – Figure 1.3. The colour filter system used by manufacturers for adding colour is either the mosaic Bayer pattern, or the Fovean X3® colour filters. The former uses a single layer with the imprinted Bayer pattern to add colour, whilst the latter has individual RGB filters stacked on top of each for capturing the corresponding RGB channels. In the Bayer system two green squares are included, representing greater sensitivity of the eyes to the colour green (Figures 1.4–1.8).

There are two types of sensors, CCD (charged couple device) and CMOS (complementary metal oxide semiconductors). CCD was the first type of sensor, offering superior image quality but with higher power consumption. The newer CMOS sensors are more efficient, better in low light conditions and offer high-speed capture. Furthermore, recent technical sophistication means that CMOS sensors are viable contenders to CCDs in terms of image quality. Most contemporary cameras use CMOS as the preferred type of sensor. Sensors are available in various physical sizes, some popular examples include medium format (up to 53.9 mm × 40.4 mm), full-frame (similar to 35 mm film – 36 mm × 24 mm), APS-H (Advanced Photographic System-type H – 28.7 mm × 17 mm), APS-C (Advanced Photographic System-type C – ranging from 23.6 mm × 15.7 mm to 22.2 mm × 14.8 mm), four thirds, micro-four thirds (17.3 mm × 13 mm), 1″ (13.2 mm × 8.8 mm), 1 : 2/3″ (8.6 mm × 6.6 mm), 1 : 1.7″ (7.6 mm × 5.7 mm) and 1 : 2.5″ (5.76 mm × 4.29 mm) – Figure 1.9. To complicate matters further, some sensors sizes are unique (or renamed) to a particular camera brand, e.g. the Nikon DX-format is equivalent to the APS-C format. The key issue is the physical size (or dimensions) of a sensor: the larger the sensor, the better the image quality, irrespective of the pixel count.

Table 1.1 Specifications of a digital single lens reflex (dSLR) camera for dental photography.

Specification	Must have	Wish list
Sensor size	minimum Advanced Photographic System-type-C (APS-C)	full-frame (36 mm × 24 mm), matching the focal length of lens
Pixel count in MP (megapixels)	minimum 18 MP (depending on physical size [dimensions] of sensor)	> 18 MP (depending on physical size [dimensions] of sensor)
No anti-alias filter	Desirable	Mandatory
ISO (International Standards Organisation) range	minimum 100–200: any maximum	
Sensor cleaning	Ease of manual sensor cleaning	Automatic, built-in sensor cleaning mechanism
Colour depth	8 bit/colour (channel)	16 bit/colour (channel)
Dynamic range (human eye = 24 *f*-stops)	minimum 6 *f*-stops	≥ 10 *f*-stops
White balance	Auto, or numerical input [5500 K]	
Focusing	Manual focus capability	
External flash connections	Hot-shoe, x-jack	Wireless/via smartphone
Remote shutter release	Wired hand/foot cable release	Wireless/via smartphone
Tripod screw thread	1/4–20 UNC (Unified National Coarse)	1/4–20 UNC or 3/8–16 UNC and a 1/4–20 UNC adapter
Exposure modes	Aperture priority and manual	
Metering modes	Centre-weighted, multi-zone, spot	
Shutter type	Focal plane	Built-in lens
Shutter drives	Single and multiple	
Shutter flash synchronisation speed	1/125 s or 1/250 s	Any shutter speed possible with built-in lens shutters
Colour space	sRGB, Adobe® RGB	
File format	Proprietary RAW or Adobe DNG (digital negative graphic), JPEG	
Storage	UHS I (30 MB/s writing speed) SD card	UHS II (100 MB/s writing speed) SD card or internal RAM storage
Data transfer	USB 3 or greater, audio in/out jacks, HDMI	WiFi
Video recording capability	HD 1080p (progressive) to 60 fps (frames per second)	> 4 K (similar quality to conventional cine film)
Location		GPS (global positioning system)
LCD (liquid crystal display)	Touch screen	Anti-fingerprint and anti-scratch coating
Camera protection		Dust and water spray sealing
Build quality, weight, size	Portable, light-weight, die-cast aluminium	Milled aluminium

Figure 1.2 Pixels are only capable of registering lightness and darkness, i.e. black and white.

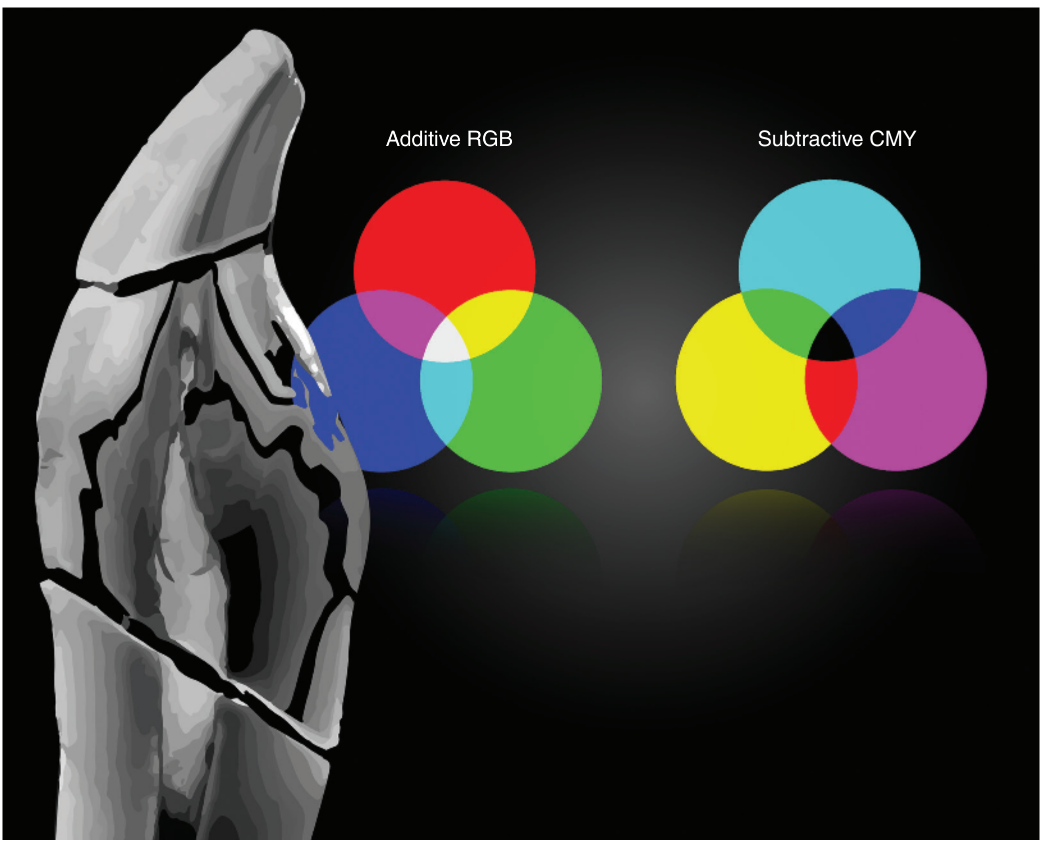

Figure 1.3 The additive red, green and blue (RGB) and subtractive cyan, magenta and yellow (CMY) colour systems.

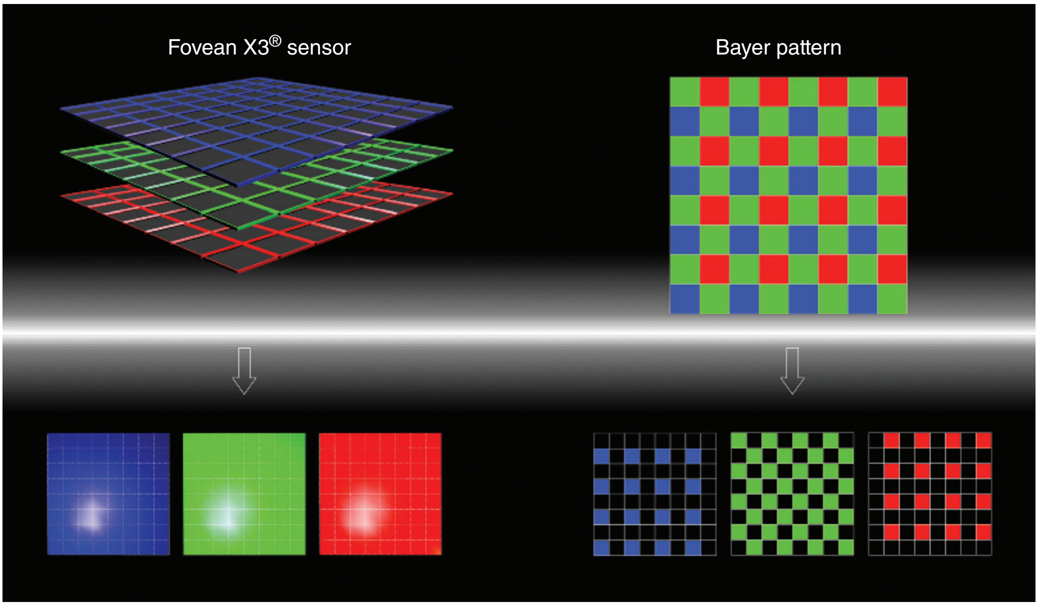

Figure 1.4 A colour image is created by colour filters corresponding to the three channels, red, green and blue, e.g. the Fovean X3 system or the mosaic Bayer pattern.

Figure 1.5 Red channel colouration.

Resolution

The resolution of an image is complex, depending on many variables, including the resolving power of the lens, sensor size, number and size of pixels, bit depth (range of colours), dynamic range (degree of contrast), signal to noise ratio (amount of 'noise' or graininess in an image), method of in-camera analogue to digital conversion, file format, subsequent post-capture editing with computer software, circle of confusion (distant from which an image is viewed) and the display media (monitor, projector, printing).

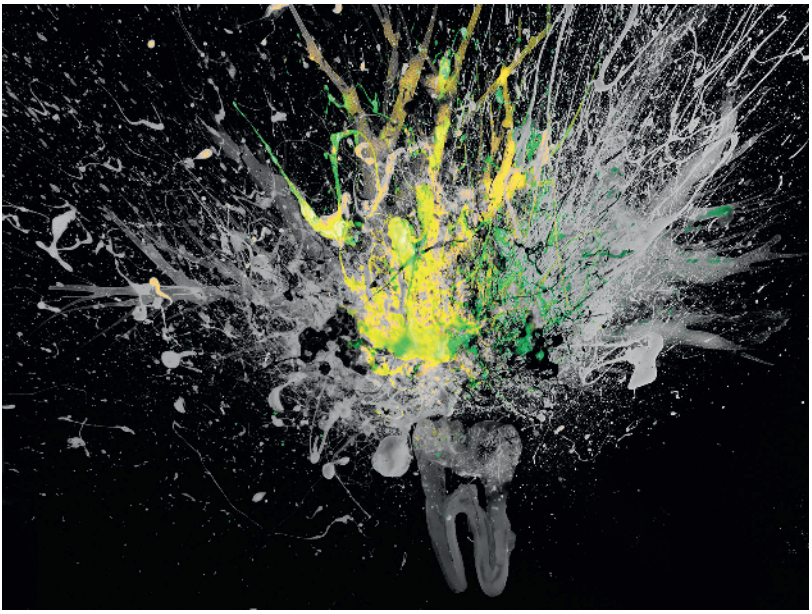

Figure 1.6 Green channel colouration.

Figure 1.7 Blue channel colouration.

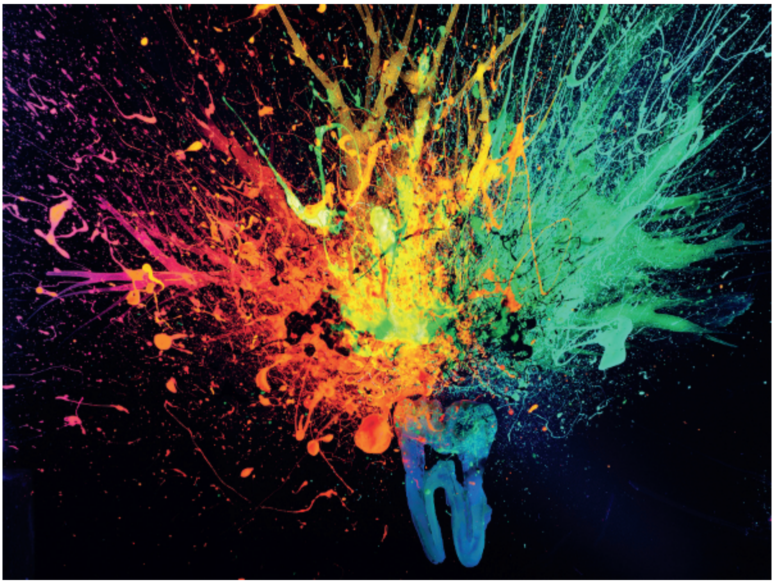

Figure 1.8 The final coloured image combining the three red, green and blue (RGB) channels.

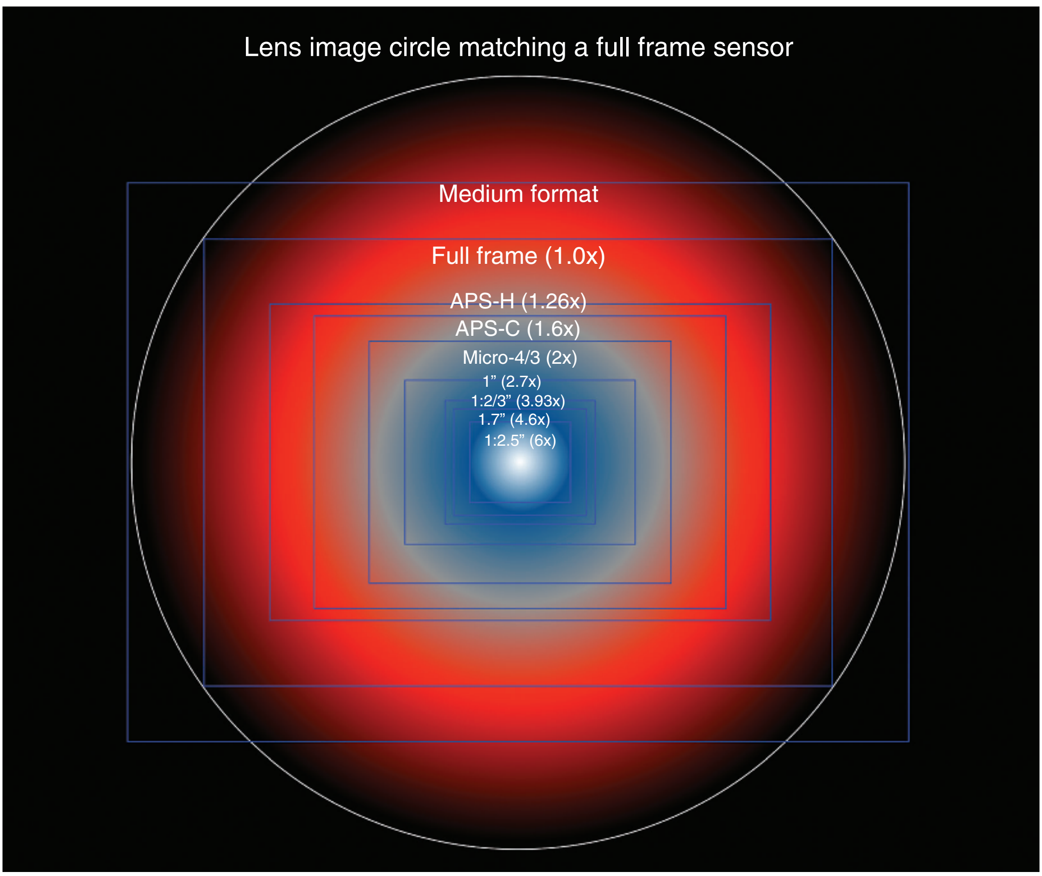

Figure 1.9 Comparison of digital camera sensor sizes, together with the corresponding crop factor in parenthesis.

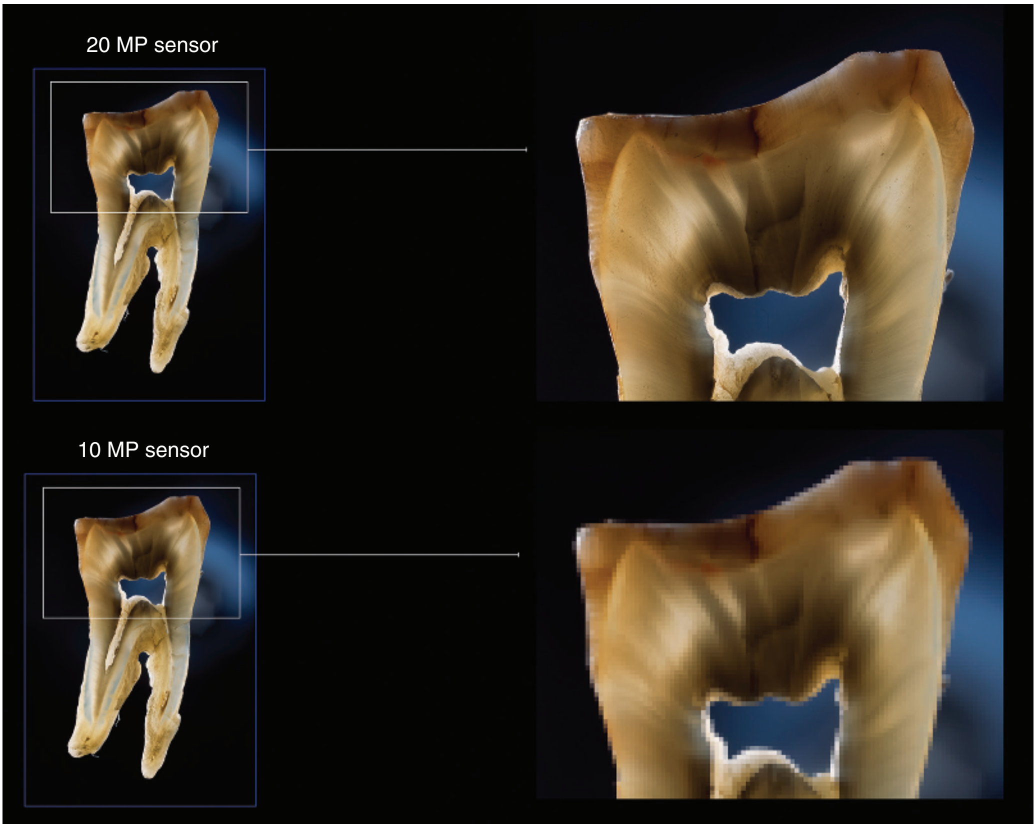

Figure 1.10 A sensor with a smaller megapixel count will result in deterioration in image quality when part of the image is magnified.

The resolution of the human eye varies from 324 megapixels (90° angle of vision) to 576 megapixels (120° angle of vision), which is far beyond any contemporary digital camera sensor.[4] However, one of the major misconceptions is relating pixel count to resolution, i.e. equating the number of pixels to image quality, often misleadingly perpetuated by camera manufacturers. The number of pixels determines the size of an image, not its ultimate resolution. However, a large pixel count is significant if the resolution is not to be compromised when part of an image is magnified or cropped. Hence, the resultant image quality depends on the number of megapixels (MP) and the physical size of the sensor (Figures 1.10 and 1.11). Understanding the significance of physical size of the sensor and its MP count are crucial when purchasing a camera. For example, a full-frame sensor with a pixel count of 20 MP yields a higher resolution than a smaller-sized sensor with the same or greater number of pixels. This is because the larger pixels found on large-sized sensors are capable of gathering more detail than the smaller pixels on small-sized sensors. Therefore, a small sensor with a large pixel count, often found in compact cameras, produces inferior quality images compared to a larger sensor with fewer pixels in a dSLR. Another factor to enquire about is the presence or absence of an anti-alias filter on the sensor. Newer cameras without anti-alias filters offer superior resolution and therefore better image quality. Further information about resolution can be found in Modules 3 and 8.

4 http://www.clarkvision.com/articles/eye-resolution.html

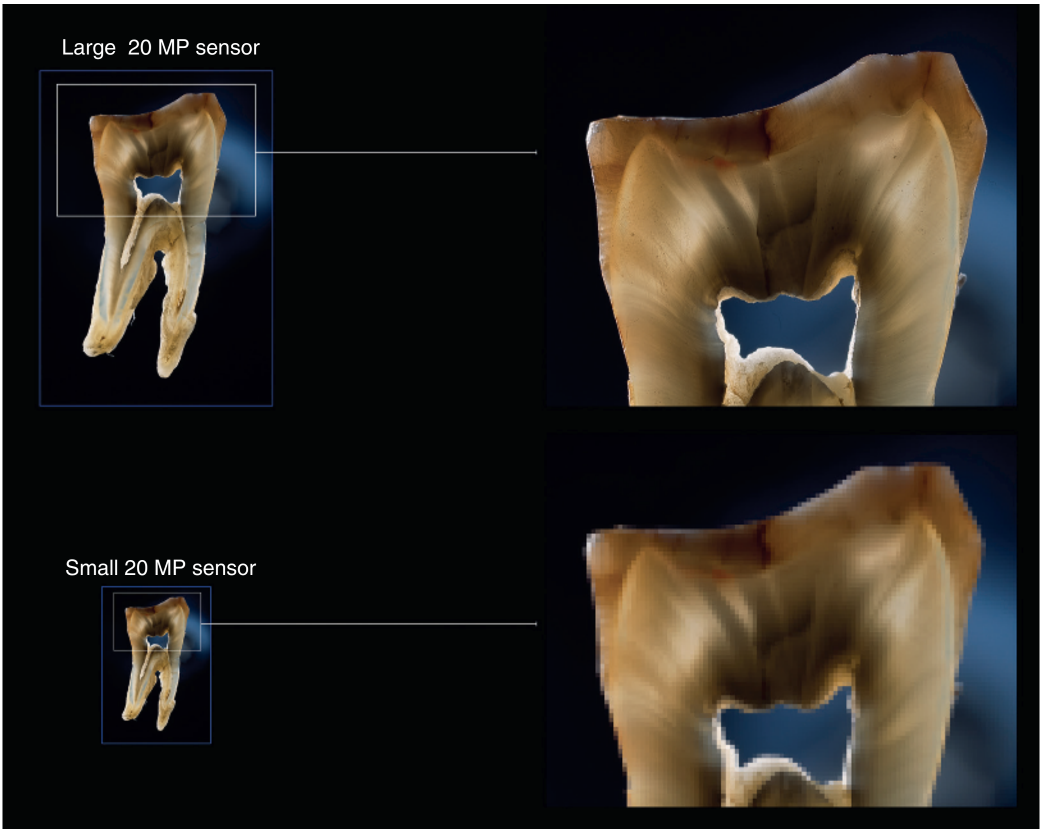

Figure 1.11 A large sensor will retain image quality when part of the image is magnified, compared to a small sensor with the same megapixel count.

Sensor Speed or ISO

The sensitivity of the sensor to light is represented by its ISO number. The ISO scale determines the intensity of light that is necessary for correct exposure; a lower ISO number requires more light, whilst a higher ISO number less light. Although higher ISO values have the benefit of taking pictures in low lighting conditions, the drawback is that the pictures are more grainy (with increased 'noise') and consequently with inferior resolution (Figure 1.12). As a general guide, an ISO value of 50–100 will produce insignificant noise but requires brighter illumination, whilst the ideal for dental use is between ISO 100 and ISO 200, and certainly should not exceed ISO 400.

Sensor Cleaning

Dust particles enter the camera at the junction where the lens is mounted onto the camera body, and also by the movement of the internal mirror (if any) within the camera. This is particularly significant when changing lenses or focusing screens, which should be performed in a dust-free environment, preferably with appropriate vacuum suction. The dust particles are a nuisance, adhering to the sensor surface and appearing as black or white specks on an image, especially noticeable with light backgrounds such as teeth (Figure 1.13). Although these

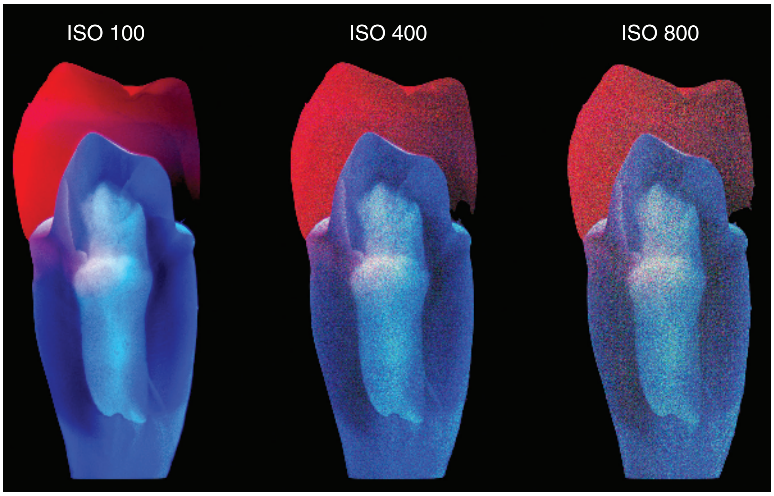

Figure 1.12 Increasing the ISO (International Standards Organisation) value has the advantage of taking pictures in low light, but at the expense of introducing graininess or noise that degrades image quality.

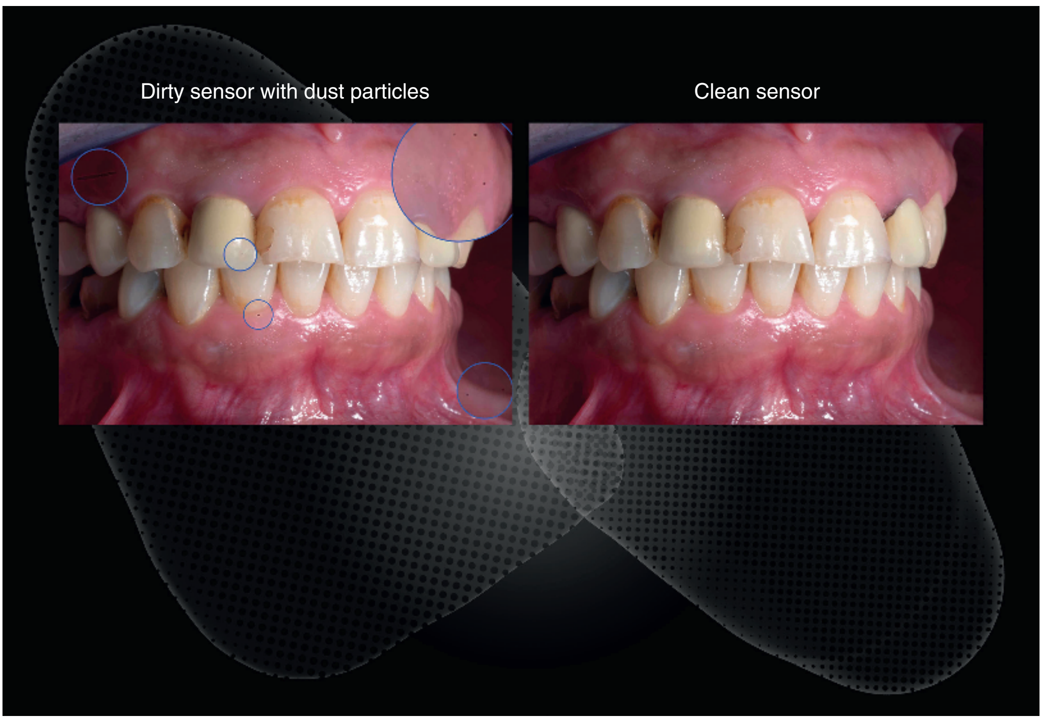

Figure 1.13 Dust particles adhering to the sensor surface are particularly conspicuous against light-coloured backgrounds.

blemishes can be erased with software during the editing stage, the process is tedious, time-consuming and best prevented at the outset. Sensors are difficult to access and clean manually, requiring a degree of dexterity to prevent inadvertent damage to the most delicate and expensive part of the camera body. Many proprietary sensor cleaning kits are available that

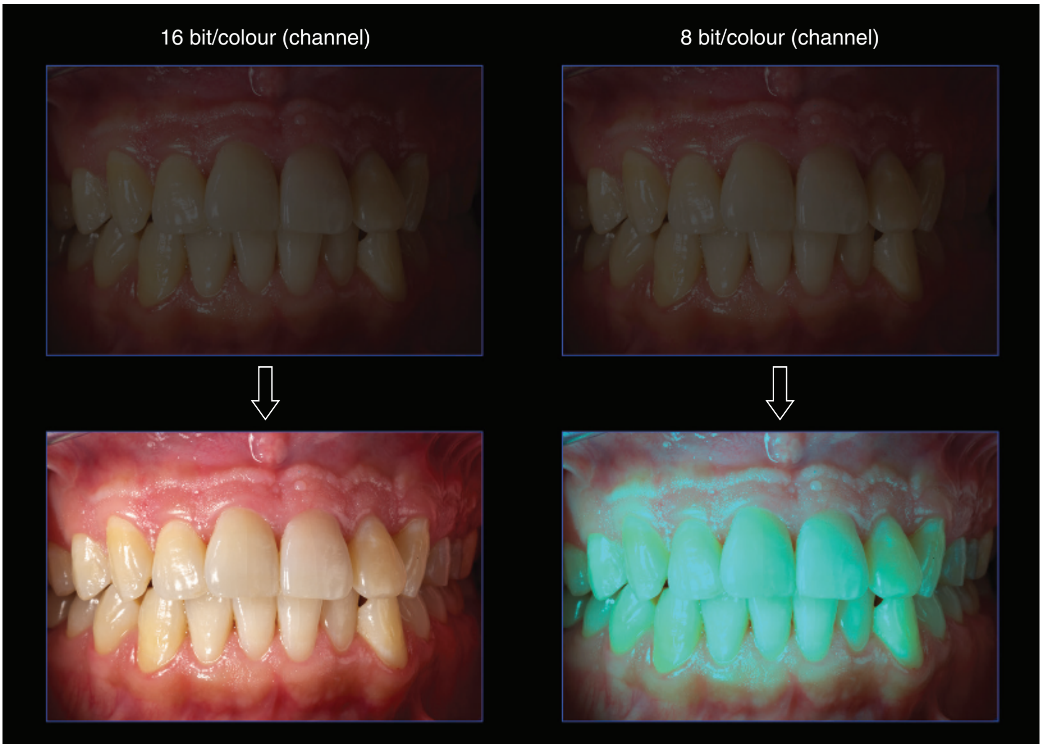

Figure 1.14 Bit/colour (channel) significance: A grossly underexposed 16 bit/colour image is capable of withstanding substantial exposure compensation without losing quality (left images), whereas an 8 bit/colour image is labile to degrade, often with resulting unwanted colour casts (right images, notice greenish colour cast after exposure compensation).

facilitate this process and provide invaluable and detailed instructions for mitigating irreversible damage to the sensors. In addition, many cameras have built-in sensor-cleaning mechanisms that minimise dust accumulation and facilitate its removal. Whichever mechanism a camera employs for sensor cleaning, it is important to enquire about ease of sensor cleaning, or built-in cleaning systems, when purchasing a camera body.

Colour (Bit) Depth

The colour, or bit depth, is a measure of the number of colours that can be captured by a sensor. It is expressed as bits/channel or bits/colour of the three photographic additive primary colours, red, green and blue. A camera with a colour depth of 8 bit/colour (channel) will have a total bit depth of 24, or 2^{24}, and is capable of producing 16.7 million colours, far more than the 10 million colours that the human eye can perceive.[5] High-end cameras have digital sensors with 16 bit/colour (channel) and are capable of discriminating 2^{48}, or 281 trillion colours. The advantage of having a larger bit depth is reducing degradation of image quality that occurs if substantial editing or manipulations are anticipated with post-capture software. Therefore, starting with a large bit depth at the outset compensates for this eventuality (Figure 1.14).

5 http://dmimaging.net/8-bit-vs-16-bit-images

Figure 1.15 White balance: An image showing different colour rendering by altering the white balance setting on the camera (AWB = automatic white balance).

White Balance

Unlike our brains, cameras do not possess colour adaptation, and have to be ‘told’ about the colour temperature of the illumination, a process known as setting or calibrating the white balance. Most cameras have pre-set automatic white balance (AWB) options that signify the quality, or colour temperature of the light, e.g. natural daylight of 6500 K, or indoor tungsten illumination of 3200 K. Photographic daylight is 5500 K because at this colour temperature all the three photographic primary colours (RGB) are present in equal proportions. This is an important issue for dental images because ensuring correct colour rendering is essentially from a dento-legal perspective. Therefore, the colour accuracy needs to be precise, without colour casts, for faithfully reproducing the actual colour of the soft and hard tissues. This allows distinguishing between health and pathological changes, as well as matching the shade of artificial restorations to natural teeth. Most dental photography uses artificial [flash] lighting, and it is important to ensure that the white balance on the camera is either set to AWB, or preferably input manually numerically to 5500 K (Figure 1.15).

Focusing

Almost every camera these days has auto-focus (AF) as standard, which is indispensable for the majority of photographic needs. However, for macrophotography, especially in the restricted confines of the oral cavity, AF often malfunctions. This is due to incessant patient or operator micro-movements, and extreme light thresholds of the highly reflective surfaces of teeth with the dark posterior regions of the mouth, which additively confuses the automatic focusing mechanism. Therefore, the ability to switch to manual focus (MF) is a prerequisite to compensate for the unique conditions of the oral environment. The usual method for ensuring sharply focused dental images is either using a mechanical focusing stage (discussed below), or moving hand-held cameras backwards and forwards until focusing is accomplished. Another advantage of MF is that it allows pre-set magnifications (e.g. 1 : 1 or 1 : 2) for consistent scaling of images that is useful for comparisons, whereas with AF, the magnification perpetually changes according to the distance of the subject from the lens.

External Flash

There are two types of external flash lighting necessary for dental applications: compact flashes and studio flashes or strobes. Compact flashes are mainly used for macrophotography and require a hot-shoe contact, usually found on top of the camera, to access the electronics of the camera for TTL metering for ensuring correct exposure. Once an initial contact with the camera is established via the hot-shoe, additional compact flashes can be triggered by wired or wireless interfaces, whilst the TTL function cuts off, or quenches, the flashes once correct exposure is attained. Studio flashes utilised for portraiture are triggered either by a wired standard x-jack connection on the camera body, or by a wireless radio or infra-red device connected to the hot-shoe, termed slave flash photography. Also, it is possible to control some studio flashes, similar to compact flashes, by the camera electronics using TTL metering. This requires purchasing additional camera brand specific remote controls, which allow the camera to control the flash duration of the strobes for ensuring correct exposure.

Remote Shutter Release

The camera shutter is usually released by pressing a button on the camera body. This is satisfactory for the majority of dental images, but for certain treatment modalities that require photographs from various angles of view such as aesthetic dentistry, or surgical procedures where cross-infection control is paramount, it is necessary to mount the camera onto a tripod and delegate this task to another member of the dental team. In these circumstances, it is helpful to have remote shutter triggering mechanisms that do not compromise or interfere with the clinical procedure. Several options are available, including wireless, foot control and smartphone apps, which are operated by an ancillary not directly involved with the treatment.

Lenses

The technical requirements of a lens for dental photography is that it serves a dual-purpose, first for portraiture and second for close-up or macrophotography. The ideal lens for portraiture is around 100 mm focal length, and for macrophotography is a macro facility for achieving a 1 : 1 or 1 : 2 magnification. A 1 : 1 magnification ratio means that the image recorded on the sensor is the same size as the object, whilst a 1 : 2 magnification means that the captured image is half the size of the object. Macro lenses are either available as fixed focal lengths, called prime lenses, or zooms with variable focal lengths. It is recommended to use prime lenses, rather than zooms, which are usually impractical for dental photography. Furthermore, fixed focal length macro lenses greater or less than 100 mm are unsuitable for the following reasons. To achieve a 1 : 1 magnification with a 50 mm macro lens requires moving the camera extremely close to the subject, which may be intimidating for the patient. In addition, at this close distance, the cheeks and lips block the flash lights illuminating the oral cavity. Another problem with a 50 mm lens is that portraits at close distances result in spherical distortion, making the nose or other prominent parts of facial features appear larger and less flattering. Conversely, macro lenses greater than 100 mm, say 200 mm, require greater distances for obtaining a 1 : 1 magnification. This is also a hinderance since brighter lights are necessary to correctly illuminate the subject that is now further away, plus the physical size and weight of these lens is inconvenient for hand-held cameras. Many contemporary lenses offer image stabilisation for preventing blurred images. However, this feature is superfluous for dental photography since the high flash synchronisation shutter speeds (1/125 seconds or 1/250 seconds), and the fraction of a second flash burst 'freezes' the subject, obviating the need for image stabilisation. It is important to realise that image stabilisation is different to focusing; the former compensates for involuntary micro-movements referred to as 'camera shake' (for hand-held cameras), whilst the latter is concerned with focusing a sharp image onto the sensor depending on the distance of the object from the camera.

Most dSLRs are sold with general-purpose lenses, usually variable zooms, satisfying broad photographic genres such as family shots, portraiture, landscape, sports, wildlife, etc. However, these lenses are a 'jack of all trades and master of none'. They offer acceptable resolving power, but not superlative resolution. As mentioned above, the lens is a crucial factor for determining the image quality, and its resolving power should match or be greater than the size of the pixels, which vary from 5 to 12 μm. An array of lenses is available, either the same brand as the camera, third-party, or from different brands using appropriate adapters. The same brand lenses have the advantage that they seamlessly synchronise or integrate with the camera electronics and can be updated with the latest firmware, but are usually more expensive. The market is inundated with third-party lenses, some inferior, and others offering even better resolution than same brand lenses. Lastly, lenses from old 35 mm film cameras can easily be fitted with relatively inexpensive adapters to almost any camera. These offer excellent optics since they are usually constructed of glass elements but are heavier, whereas newer versions are often made of plastic elements, with reduced acuity, but are much lighter in weight. Some high-end macro lenses have the prefix 'Apo' and 'ASPH', which eliminate apochromatic and aspherical aberrations, respectively. These optically corrected lenses may be the same brand as the camera or third-party lenses, with state-of-the-art optics for exceptional resolution, but come with a hefty price tag, e.g. Carl Zeiss, Schneider-Kreuznach®, Meyer-Optik Gorlitz®, Voigtlander® and Leica to name a few. In addition, a search on e-Bay™ offers many pre-owned high-end lens at a fraction of the new retail price, and with appropriate adapters, e.g. from Fotodiox® or Novoflex®, can be fitted to almost any camera body. The major disadvantage is that some electronic functions of the camera, such as AF or auto-exposure, are disabled, and therefore the lens has to be used in manual mode. Other methods for achieving macro images are using various inexpensive attachments on standard lenses, such as reversal rings, conversion rings, extension tubes, bellows, or Lensbaby™ macro converters. The drawbacks are a slight deterioration in image quality, and the additional weight, which may be off-putting for hand-held photography.

Irrespective of the lens, a wise precaution is to purchase a UV (ultra-violet) filter that screws onto the front of the lens for protection from dust, water or other oral effusions. In addition to offering physical protection, a UV filter eliminates unwanted 'haze', enhancing the colour rendition of the image. Another useful attachment is a lens hood to eliminate flare from intense illumination (e.g. direct sunlight or flashes pointing towards the camera) that causes glare on images.

A further issue to contend with is whether the focal length of the lens matches the size of the sensor. The focal length of lenses is usually quoted according to old 35 mm film cameras. If the camera has a full-frame sensor (36 mm × 24 mm), the image seen in the viewfinder will almost be identical to what is recorded on the sensor (crop factor of 1). However, if the size of the sensor is smaller, say APS-C (22.2 mm × 14.8 mm), the lens image circle is greater than the sensor size, and only the central part of the image is recorded on the sensor. For example, with an APS-C sensor the lens has a crop factor is 1.61 (see Figure 1.9). Also, for smaller sensors found in compact cameras the crop factor becomes even greater, whilst for larger sensors in medium format cameras, the crop factor reduces to less than 1. Therefore, it is desirable to have a full-frame sensor so that the focal length of the lens matches the sensor size, but the additional cost of the camera body may be prohibitive. To summarise, the choice of a lens for dental photography is empirical, dictated by personal preferences and cost, which can vary from US$ 600 to UD$ 1000, or more, if image quality is an absolute priority.

Lighting

There are two types of lights required for dental photography: compact and studio flashes Ahmad (2009b). Many cameras have built-in flashes that pop-up when the lighting conditions are less than optimal. This is satisfactory for general photography but ill-advised for macrophotography. First, the built-in flashes are usually not congruous with the lens axis, and at close distances cast an unwanted shadow which obscures essential parts of the image. Second, on-camera flip-up flashes are relatively weak, with low intensity, and unable to adequately illuminate the entire oral cavity.

The compact flashes are further sub-divided into ring flash (ring-light), compact off-the-camera bilateral (bi-directional or twin-light) flashes, or a single unit consisting of both ring and twin-lights (Figures 1.16 and 1.17). Compact flashes, also known as hot-shoe flashes, connect directly onto the hot-shoe of the camera body and are subsequently controlled by the camera electronics. Their intensities are measured in guide numbers at ISO 100, the higher the guide number, the brighter the light output. Typical compact flashes have a guide number ranging from 20 to 50 (100 ISO metre) or 65 to 165 (100 ISO feet). For dental use, a guide number of ISO 30 (metre) is more than adequate. All electronic flashes serve a dual purpose, first to

Figure 1.16 Ring flash on a digital single lens reflex (dSLR) camera system.

Figure 1.17 Bilateral twin flashes on a digital single lens reflex (dSLR) camera system.

provide sufficient illumination for correct exposure, and second, to 'freeze' the object being photographed due to the fraction of a second burst of light (up to 1/20 000 of a second). In addition, nearly all compact flashes (ring flash and lateral flashes) are compatible with camera brand-specific TTL metering for measuring exposure. Continuous lights sources such as daylight, tungsten lamps, fluorescent tubes and LED (light emitting diode) are capable of delivering adequate illumination but cannot 'freeze' movement. The latter is significant since the patient is unlikely to keep rigidly still during an arduous photographic session, feeling uncomfortable and claustrophobic with cheek retractors, photographic mirrors, dribbling saliva, not to mention the operator contortions with hand-held cameras. Therefore, a dental photographic session should be conducted as quickly and efficiently as possible, which is expedited by the endearing property of flashes because they allow pictures to be taken in rapid succession, simultaneously illuminating and 'freezing' the subject.

Compact ring flashes attach directly onto the front of the lens, emitting uniform (360°) shadowless illumination, which is ideal for hand-held pictures, especially in the darker posterior regions of the mouth where access for light is restricted by the surrounding cheeks and lips. The price for ring flashes ranges from US$ 100 to US$ 500, depending on the type, make and guide number. The major drawback of ring flashes is that the light is harsh, uniform and characterless. Whilst ideal for photographing posterior teeth, for anterior teeth this type of illumination produces images that are bland, boring and lacklustre. For anterior teeth, or for restorations where aesthetics are of paramount concern, ring flashes are not recommended since the uniform burst of light obliterates fine detail, translucency, surface texture, topography and subtle colour transitions and nuances within teeth or artificial restorations.

To overcome the shortcoming of ring flashes, compact bi-directional or bilateral flashes offer lighting that sculpts the object giving it a three-dimensional appearance with highlights and shadows, allowing visibility of enamel characterisations such as mamelons, cracks, staining, translucency, restorative marginal defects. Furthermore, by manipulating the light source reveals colour nuances and depth of the underlying dentine strata, which is essential for mimicking these characteristics in indirect prostheses. The intensity of individual flashes can be muted, or turned off, to enhance highlights or shadows that are ideal for capturing micro and macromorphology.

Figure 1.18 Ring flashes produce lacklustre, bland two-dimensional images.

Three are two varieties of lateral flashes. The first type attaches onto the front of the lens by an adapter and has two projecting flashes, which can be positioned right, left, top, bottom or anywhere in between. Also, since the flashes fire wirelessly, they can be detached, hand-held and positioned as desired. The negative aspect of these flashes is their proximity to the teeth, and depending on the guide number, the flash burst can be harsh, similar to ring flashes that obliterate fine detail. To circumvent this undesirable effect, the second type of lateral flashes are mounted with a bracket, or flash extension arms, beneath the camera and positioned behind the lens. These units are also triggered wirelessly but emit much softer subtle light. In addition, the light can be further attenuated by covering the flash heads with cloth or plastic diffusers to soften the output. Soft lighting adds ambience to an image, and depending on intensity and distance can reveal subtle detail by creating shadows and highlights, as well as emulating natural lighting conditions in which teeth are usually viewed. As an analogy, using ring flashes is identical to taking a picture of a subject head-on in front of car headlights, whereas lateral flashes, dampened with diffusers mimic realistic lighting of natural surroundings such as reflections and shadows from people, buildings, water, foliage, furniture, walls, etc. (Figures 1.18 and 1.19). Both types of lateral flashes, lens or bracket mounted, cost around US$ 500.

Lastly, several unusual light sources and light modification attachments are available for dental photography. For example, ingenious contraptions such as flexible LED fibre-optic 'Medusa-like' cables for directing light into the tiniest recesses of the mouth. Also, relatively inexpensive flash accessories can be purchased to manipulate the emitted light, such as diffusers of various sizes, reflector cards of different colours (matt white, glossy white, grey, silver). Also, elaborate magnifying lenses attached to flashes can focus the light beam to highlight individual teeth or particular areas of interest.

Figure 1.19 Bilateral flashes produce three-dimensional images conveying depth and vitality.

The second type of lighting is for dental portraiture, which may be hot lights, cool lights or flashes. The first two types, hot and cool lights, offer continuous illumination that is suitable for video but unsuitable for still photography. The preferred types of lights for portraits is studio flashes. Two varieties of studio flashes are available, the monolights, which connect directly to the mains, or the pack and head, which require a separate power pack and are indicated for location shooting. For dental applications, monolights are the most convenient, incorporating integral modelling lights to help position and orientate the flashes before taking a picture. A modelling light is a continuous light source that allows the photographer to visualise the lighting effect the flashes will produce, but does not affect the actual exposure (aperture and shutter speed) when the flashes are triggered. These continuous pre-flash, low-intensity lights also keep the pupils dilated, and together with ‘catch lights’ or Obies confer a shining aura to the subject. Catch lights are tiny reflections on the cornea that create a glint or sparkle, attracting the viewer to the eyes of an individual (Figure 1.20).

The flash intensity or output of a flash tube is measured either in watts/second (W/s), or expressed as a guide number (GN), similar to compact flashes, e.g. a 120 W/s flash has a GN of 125 (100 ISO feet) or 38 (100 ISO metre), whilst a 300 W/s has a GN of 190 (100 ISO feet) or 58 (100 ISO metre). If the flashes are intended only for head-shots of a single person, two 120 W/s flashes are sufficient. However, if pictures of small groups, bigger objects in larger spaces, or creative lighting with light-modifying attachments is required, two or more >300 W/s flashes are recommended.

Many light-modifying attachments are available for manipulating light for creative effects, e.g. reflective umbrellas, soft boxes, gels, barn-doors, honeycomb grid diffusers, reflectors, Fresnel lenses, etc. A good starting point is using two soft boxes, and once proficient, experiment with more sophisticated modifiers for conveying ambience and mood. Unlike compact

Figure 1.20 Catch lights glints representing reflections of studio flashes or reflectors that attract the observer to the eyes of the subject.

ring or lateral flashes that use TTL metering for correct exposure, studio flashes usually require manual exposure settings. The exposure can either be assessed experimentally, or precisely calculated using an incident light meter for determining the exact aperture and shutter speed. Since purchasing a light meter is an additional expense, an economical approach is taking a few test shots for determining exposure settings, distances of flashes and reflectors, which are repeatable for a given set-up. Studio flashes can either be triggered with synchronisation (or sync.) cables plugged into the standard x-jack on the camera, a radio or infra-red wireless device fitted onto the hot-shoe, or via apps from a smartphone, tablet or computer. Usually only one flash needs to be connected directly to the camera, whilst the remaining flashes are simultaneously triggered by light receiving sensors on the additional flashes. A starter studio flash kit with two monolights, two reflective umbrella or soft boxes, two air-cushioned stands or tripods and triggering mechanism costs around US$ 300–500, and is an ideal package for starting portraiture photography (Figure 1.21).

Finally, portraiture requires backdrops or backgrounds, which are limited only by the imagination. These can simply be suspended coloured cloths or elaborate stage set-ups; the choice resides with the photographer.

Supports

Most clinician and dental technicians take photographs with hand-held cameras for convenience and expediency. However, there are instances when supports are invaluable for stabilising the camera and allowing hands-free operation for precisely positioning flashes and ancillary equipment. This could be during surgical procedures, a detailed aesthetic or soft tissues analysis, and portraiture. The variety of supports available is perplexing and confusing, including

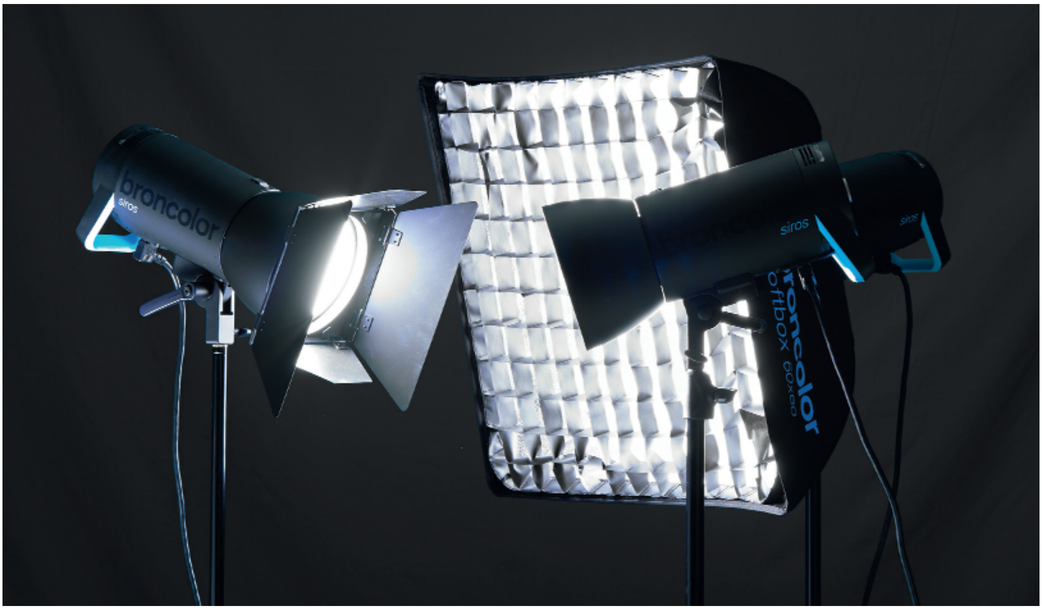

Figure 1.21 Examples of studio flashes for portraiture.

Figure 1.22 Tripod-mounted camera, compact flashes and focusing rail.

monopods, tripods, jibs, cranes, booms, cages, clamps, brackets, steady cams, rails, slides, dollies and suction pads. To simplify matters, for dental photography, a tripod with a dolly (wheels), and a four-way focusing rail (stage) for fine focusing is all that is necessary. The tripod head should have a pan (side to side) and tilt (up and down) movements, and be resilient enough to carry the payload of the camera, lens, flashes and macro focusing rail. The focusing rail is attached underneath the camera, and is indispensable for fine manual focusing at pre-determined magnifications. The cost of a tripod with a dolly, tripod head and macro focusing stage is around US$ 250 (Figure 1.22).

Table 1.2 Budget photographic equipment for dental photography[a]

Item	Cost (US$)
dSLR camera body	500
Marco lens – 100 mm (or equivalent)	600
Compact ring flash	100
Compact lateral (bi-directional) flashes (2)	500
Bracket for lateral flashes	50
Flash accessories (diffusers, reflectors)	50
Studio flash kit for portraits	300
Backdrops and reflectors for portraits	100
Tripod, tripod head, focusing stage	250
Remote shutter release	100
SD, SDHC, SDXC, CF 16 Gb storage cards (2)	30
Data storage card reader	15
Rechargeable batteries with charger for compact flashes	20
Polarising filter (circular)	50
UV bulbs	40
Total:	US$2705

[a] Prices quoted from B&H Photo, Video, Pro Audio (https://www.bhphotovideo.com/c/browse/Digital-Cameras/ci/9811/N/4288586282/1).

Other Photographic Items

Some relatively inexpensive items are also useful for completing the photographic equipment arsenal. These include rechargeable batteries, a multi-card reader for transferring images to a computer, UV bulbs for visualising fluorescence of natural teeth and artificial prostheses, or porosity defects in porcelain restorations. A polarising filter is helpful for analysing shade by eliminating specular reflections (glare) off the enamel surface. Polarising filters are available in two varieties; linear or circular, and in practice, both do the same job. The former, linear, is better suited for manual focusing but more costly, whilst the latter, circular, is cheaper and can be used in both manual and AF modes. Finally, digital photography requires a computer and processing software, and recommendations for the latter are given in Section 3, dealing with editing, exporting and managing images.

Table 1.2 itemises the essential photographic equipment necessary for dental photography. However, in the beginning, it may be prudent to start by purchasing equipment for only intra-oral photography, and eventually progressing to portraiture lighting with other ancillary equipment. On a budget, the cost of purchasing all the requisite items is US$ 2705, but if finances are unlimited, the sky is the limit.

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