Digital dental photography. Part 6: camera settings

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VERIFIABLE CPD PAPER

PRACTICE

IN BRIEF

- Since most camera and equipment set-ups for dental photography are identical, the steps outlined in this article need only be performed once.
- The main camera settings relate to depth of field, exposure and white balance calibration.
- Spending a little time at the beginning making the necessary setting will avoid frustration, and pay dividends in the long-term.

Once the appropriate camera and equipment have been purchased, the next considerations involve setting up and calibrating the equipment. This article provides details regarding depth of field, exposure, colour spaces and white balance calibration, concluding with a synopsis of camera settings for a standard dental set-up.

Having chosen a camera, lens, lighting and accessories, the next step in preparation for taking a photograph is setting up and calibrating the equipment. Since most of dental photography uses similar set-ups, the settings and calibrations need only to be performed once. The main items to consider are depth of field, exposure, colour spaces and white balance calibration.

DEPTH OF FIELD

Depth of field determines which parts of an image are in sharp focus. Unlike the human eye where everything is in focus, cameras do not share this luxury. Depth of field determines the extent of focus in front of and behind the plane of critical focus. The plane of critical focus is the point to which the lens is focused. For portraiture, the depth of field is usually divided into one-third in front and two-thirds behind the point of focus, but for close-up photography the division is equal, ie one-half in front and one-half behind. Furthermore, the depth of field for close-up photography is usually small (a few millimetres) and hence the point of focus is crucial for obtaining sharp images.

Most digital SLRs (DSLRs) have the capability to set auto or manual focusing. For the majority of situations auto-focus works well, but the dental environment of bright teeth surrounded by pink gingivae with a dark oral cavity sometimes causes malfunction of the focusing mechanism. If pictures are constantly out of focus, switching to manual focusing is a solution. Some high-end digital cameras can display a live video image of the subject being photographed, either via a monitor on the back of the camera or on a computer laptop screen via a USB or Firewire cable. The advantage is that focusing, framing, composition and exposure can be checked with a preview shot before the final picture is taken. Furthermore, with magnification, focusing is possible by viewing individual pixels. This facility is ideal for still life photography but of limited use in dental photography. The live image is constantly refreshed to compensate for camera and subject movement and is not a true representation in time of what is being viewed. For example, teeth may appear sharp on the screen, but when the picture is taken the patient may have moved before the camera has updated the live image.

Depth of field varies inversely with the aperture opening. A wide-open lens with an aperture of f4 has little depth of field whereas if stopped down to f22, almost everything from front to back will be sharply focused (Figs 1-2). As close-up dental photography has a small depth of field, it becomes essential to have a small aperture opening, say f22, so that as many teeth as possible or a large area of soft tissue is in focus. In theory, to obtain a

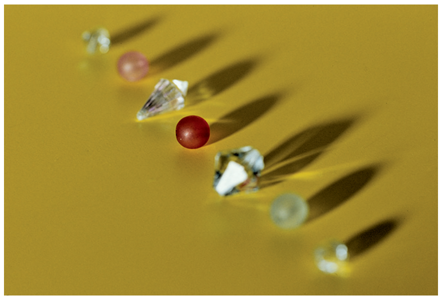

Fig. 1 Small depth of field: a wide aperture opening will result in only a few items being sharply focused, for example the red bead in the centre

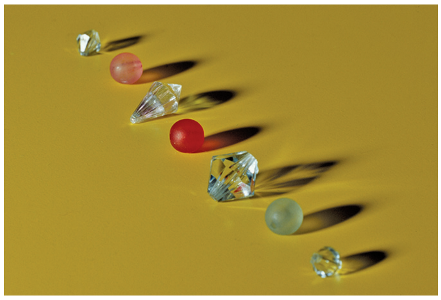

Fig. 2 Large depth of field: a small aperture opening will result in many items being sharply focused (compare with Fig. 1)

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Fig. 3 The aperture on a macro lens should not be set smaller than f22 to prevent diffraction

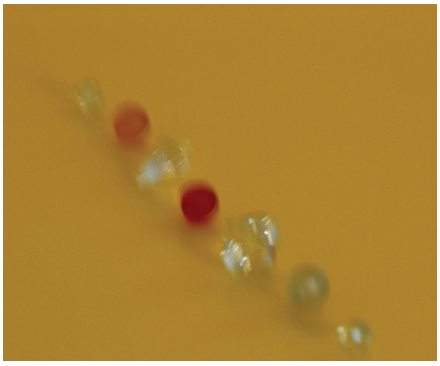


Fig. 4 The shutter speed should be fast enough to prevent blurring

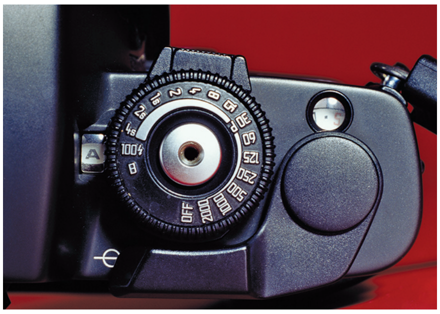


Fig. 5 When using electronic flash, the shutter speed must be set to synchronise with the flash output, represented by a 'lightning' symbol

greater depth of field one could consider using even smaller apertures, say f32 or f64, but this practice deteriorates the image quality due to diffraction. When light rays are bent around edges of objects they produce an iridescent or rainbow-like effect termed diffraction. This is more evident the smaller the aperture diaphragm, resulting in decreased resolution. Therefore, setting the aperture to smaller than f22 will seriously diminish image clarity without a substantial gain in depth of field. This is the reason why most macro lenses are designed with diaphragms that do not close smaller than f22 (Fig. 3).

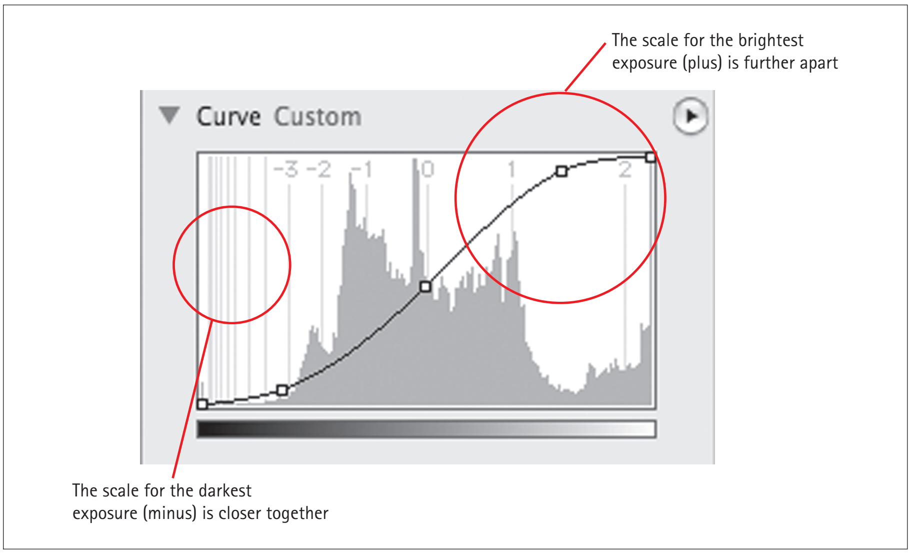


Fig. 6 A histogram with a logarithmic scale from the darkest (minus) to the brightest (plus) exposure

EXPOSURE

Achieving correct exposure is a quintessential requirement of photography, the consequences of which are blatantly obvious. Exposure is a combination of two camera settings, the lens aperture and the shutter speed. Exposure explains how light acts on a photosensitive material, for example a digital sensor. The lens aperture, or opening, controls light intensity, while the duration of light is controlled by the shutter speed. The aperture size is calibrated in f-stop numbers; the larger the number, the smaller the lens opening. The shutter speed is the length of time the shutter remains open when the shutter release is activated, expressed in fractions of seconds, for example, 1/125 s is faster than 1/60 s. Most contemporary cameras have automatic exposure, which calculates the shutter speed once the aperture is set (in aperture priority mode metering).

However, with dental photography two aspects require attention. The first is ensuring an adequate depth of field, which leaves little latitude but to select a small aperture opening, usually f22. The second factor is ensuring that the shutter speed is fast enough to prevent image blurring due to patient movements or camera shake (if not tripod mounted) – see Figure 4. A fast shutter speed (minimum 1/125 s) is necessary to prevent camera shake and freeze patient movements, even if a tripod is used. Blurring is especially a problem with a continuous light output such as LED illumination, halogen or tungsten lamps. In these circumstances, it is vital to use fast shutter speeds to 'freeze' the subject. On the other hand, when electronic flashes are used, blurring is less of a concern. This is because the duration of the flash light output is shorter (usually 1/2,000 s) than the camera shutter speeds, and the subject is 'frozen' by the sudden burst of light rather than the opening of the camera shutter. Most electronic flashes require that the shutter speed be set to synchronise with the flash output and depending on the camera manufacturer and type of lens, this varies from 1/60 s to 1/250 s and is represented by a 'lightning' symbol (Fig. 5).

With analogue photography, automatic exposure with electronic flashes was relatively simple. The TTL (through the lens) metering and OTF (off the film) plane measurement of light striking the film emulsion allowed the camera to control the duration of the flash output, which was cut-off once sufficient light had reached the film for a correct exposure. However, with digital sensors there is no film emulsion for light measurements. The sensors are covered with a protective glass that is highly reflective, making light measurement impossible. Some DSLRs have overcome this problem with sophisticated electronics, but others have yet to reach a practical solution. If this is the case, two options are available to ensure correct exposure. The first is to set the flashes to automatic mode, which calculates the exposure by emitting an infrared beam directed to the subject to gauge lighting conditions. This is satisfactory for photographing distant subjects, but due to the proximity of the lens to the subject in macro-photography, the infrared beam misses the intended subject and the image is often under-exposed. The other option to consider is increasing the exposure factor.

As a lens moves closer to the object, as in close-up photography, the exposure increases exponentially. For example, for a 1:1 magnification, the exposure increase factor is four. Consequently, in order to obtain a correctly exposed image, one or more of the following need adjusting:

1. Increase aperture (wider f-stop)
2. Increase time (longer shutter speed)
3. Increase sensor sensitively (higher ISO number)
4. Increase illumination (brighter lighting).

Increasing the first two factors is impractical for the reasons already cited, ie a wider f-stop would drastically diminish the depth of field and a longer exposure time would introduce blurring. The third factor is increasing the sensor sensitivity, which reduces image quality by introducing noise or grain. The only practical solution is increasing the intensity of the illumination. This is accomplished by using flashes with higher guide numbers, or if possible, increasing the emitted output. A good method for confirming exposure is taking test shots for a given set-up, and once exposure is corrected, these settings can be used repeatedly for all subsequent pictures.

The histogram

A histogram is a graphical representation of the tonal value and exposure of an image. It shows the tonal or value range from the brightest to the darkest parts of a picture. In this respect, it is the digital photography equivalent of a light exposure meter. Histograms are part of the menu that can be displayed on LCD backs of digital cameras or within photo-editing software.

The two main functions of a histogram are ascertaining exposure and dynamic range (DR). Dynamic range is the difference in brightness between the darkest and brightest part of an image. The significance of the dynamic range is that fine detail is only discernible within this range, and is expressed in the number of f, or aperture stops. Subjects outside the DR will either be under- or over-exposed

Fig. 7 Correctly exposed image

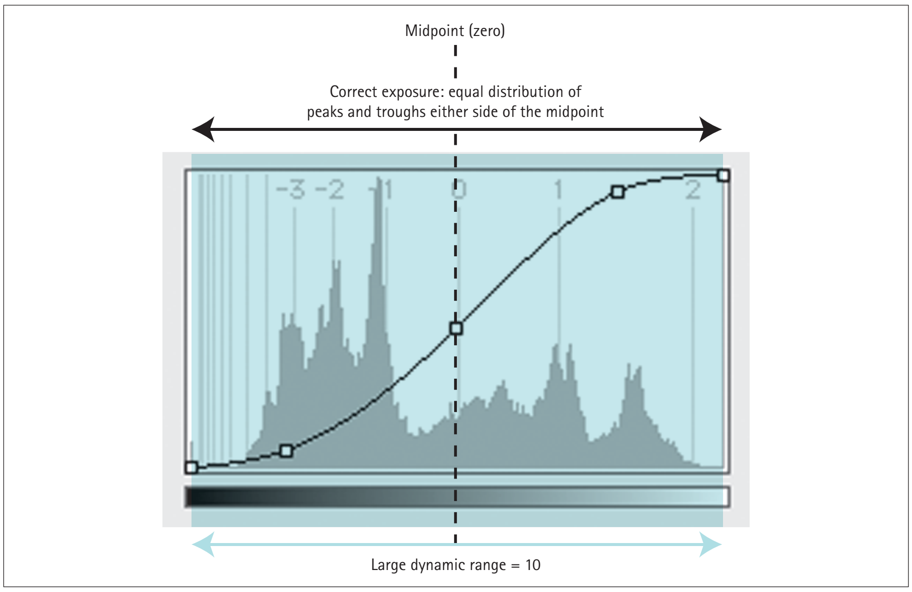


Fig. 8 Histogram of correctly exposured image in Figure 7 showing equal distribution of peaks and troughs from the midpoint, but a large dynamic range

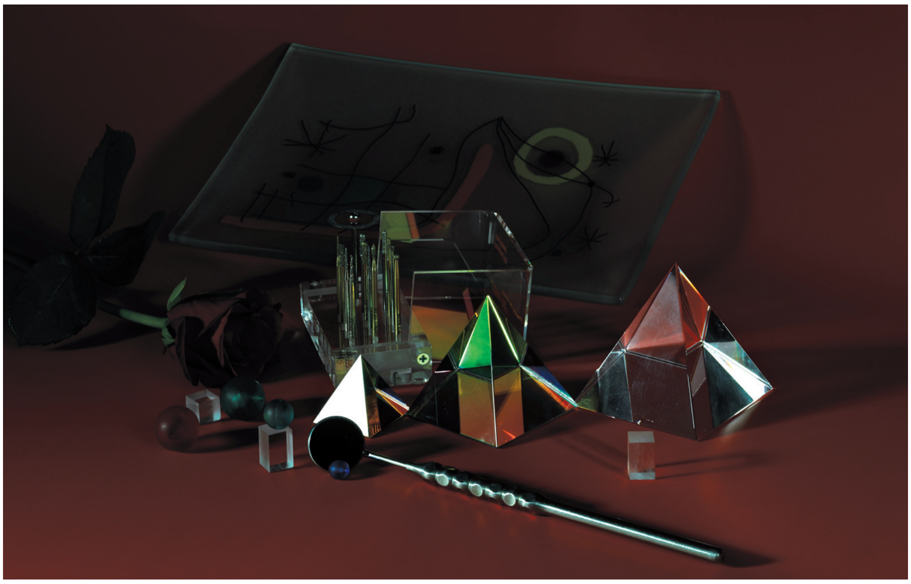


Fig. 9 Under-exposed image

without discernible detail. The human eye has a large DR of 10, a high-end digital camera 11, film transparency or high quality photographic print 6 and the printing press 3 to 5, depending on equipment and the quality of printing paper. What this translates to is that a high-end digital camera can record nearly 4 f-stops more detail than film, and has a DR equal to that of the human eye. The other factor is that the human eye does not perceive DR in a linear manner but in a logarithmic one, ie the difference in the darkest part of an image is less than in the brightest parts. This is depicted in a histogram by exposure stops being closer together in the dark parts and wider apart in the bright parts (Fig. 6). This means that darker areas of an image contain more detail than the brighter ones.

Correct exposure and DR are interlinked, and the goal of obtaining correct exposure and an acceptable DR is achieved as follows. Firstly, to ensure correct exposure, the peaks and troughs should be evenly distributed on either side of the midpoint or fulcrum (Figs 7-8). If the image is underexposed, the distribution of the peaks is confined to the negative zone left of the midpoint, and the opposite is the case for an overexposed image (Figs 9-12). It is obviously very easy, and tempting, to correct the exposure by adjusting the brightness and contrast in a photo editing software. Although minor adjustments have little significance, manipulation should be performed judicially, as gross correction sometimes causes changes in colour rendition leaving unwanted colour casts. Also, over-exposed parts of an image contain little detail and correcting exposure by reducing brightness will not add more detail. A better alternative is considering exposure increase factors discussed above, ie altering the intensity and distance of the illumination.

Secondly, the DR should be created depending on the intended use of the image. If the purpose is to print the image, it is futile to have a DR of 10, since the printing process will degrade the image to a value of 4, and six aperture stops of detail will be lost. However, for projection or viewing, the DR needs to be greater, up to the range of the human eye, ie 10. Images with a large DR have greater detail and are vibrant, while low DR images are bland and dull. Practically, it is advisable to achieve a mid-range DR in an image, say 6, which

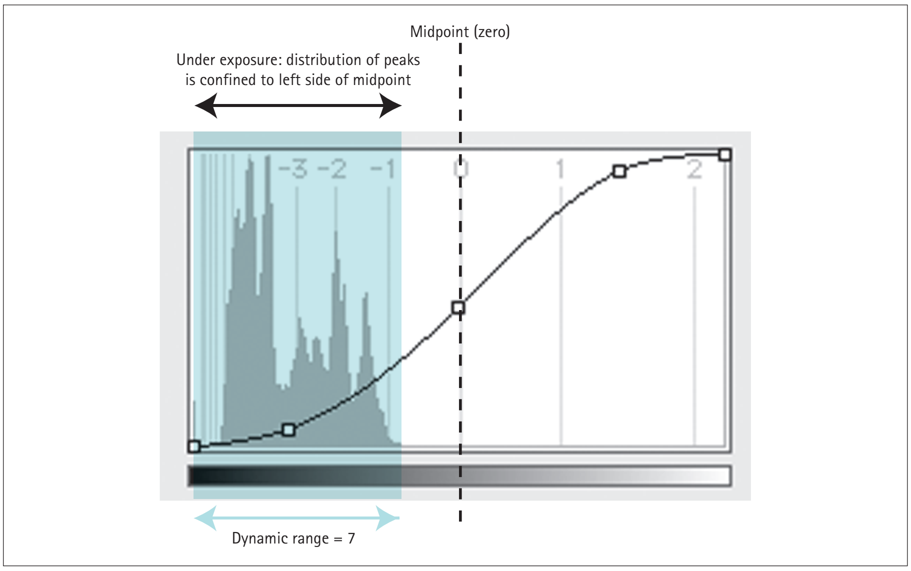


Fig. 10 Histogram of image in Figure 9 showing that the distribution of peaks confined to the left of the midpoint, with a dynamic range of 7

Fig. 11 Over-exposed image

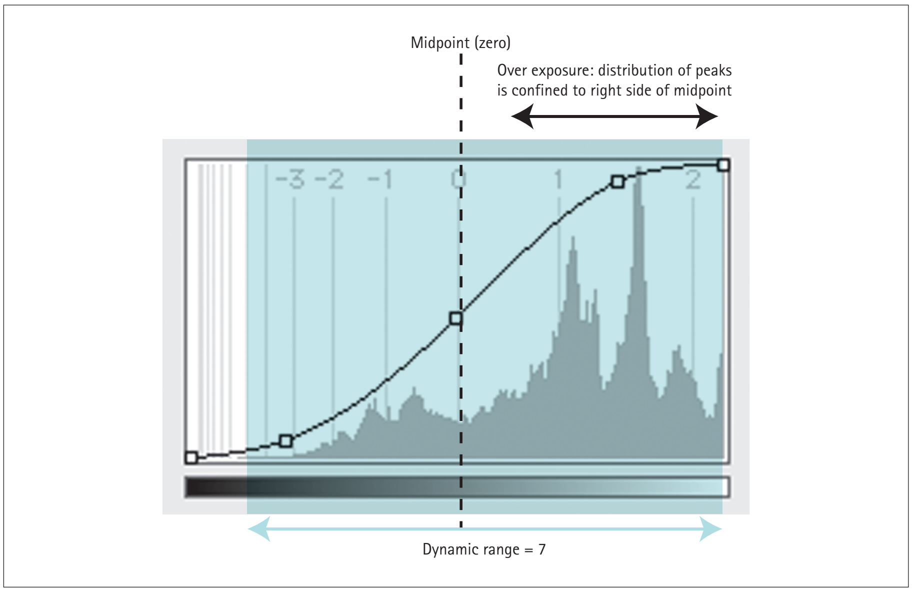


Fig. 12 Histogram of image in Figure 11 showing that the distribution of peaks is confined to the right of the midpoint, with a dynamic range of 7

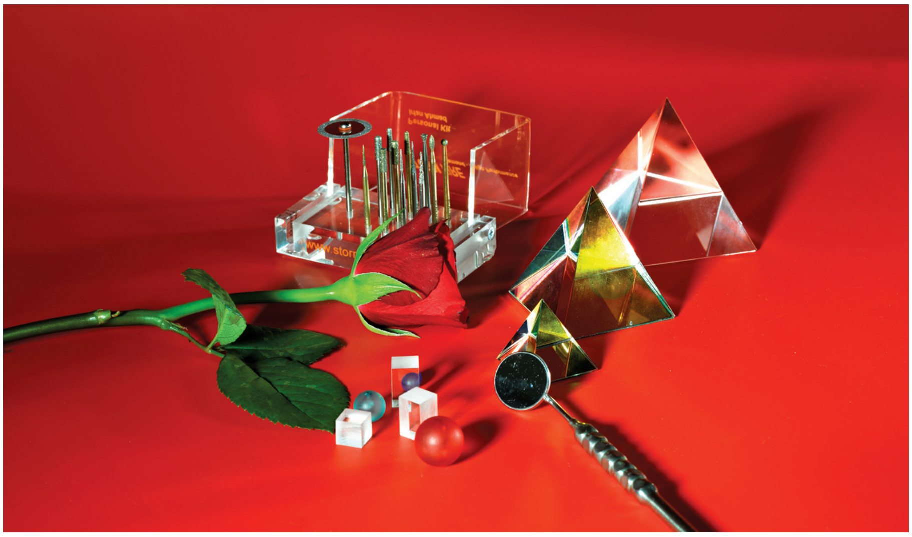


Fig. 13 Image with a dynamic range of 6

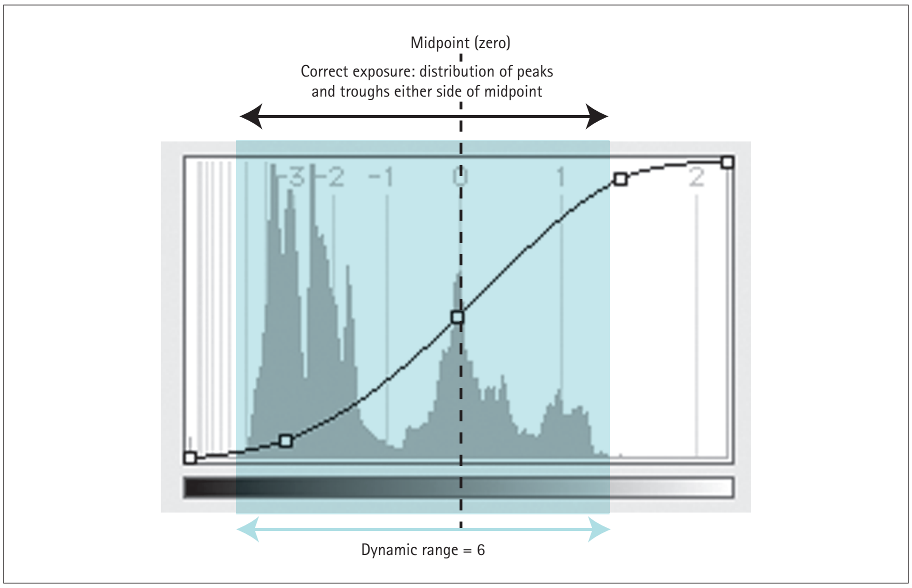


Fig. 14 Histogram of image in Figure 13 showing correct exposure and a dynamic range of 6

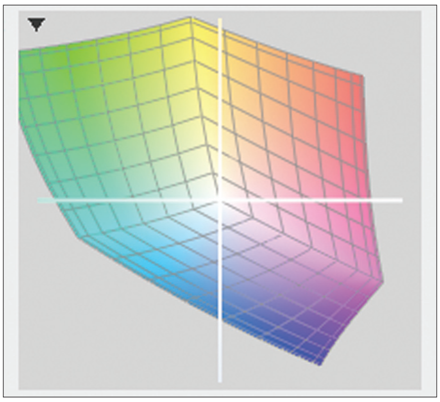


Fig. 15 The Adobe® RGB colour space has a large gamut, with many unprintable colours

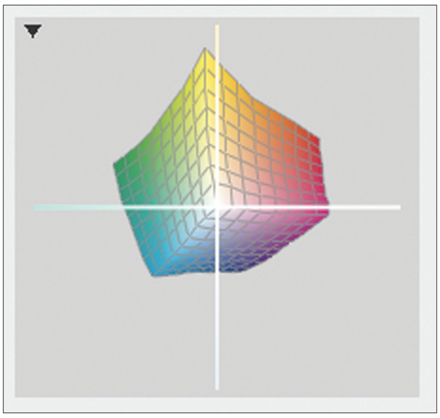


Fig. 16 The CMYK colour space has a smaller gamut than the Adobe® RGB and the sRGB colour spaces

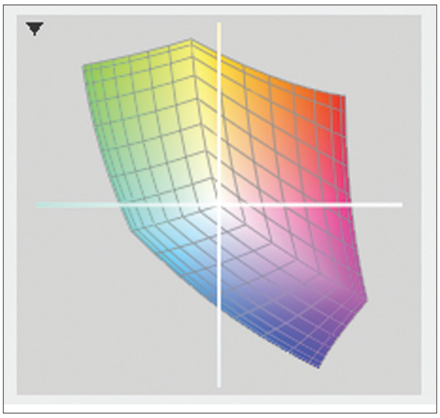


Fig. 17 The sRGB colour space found in many digital cameras corresponds to the average computer monitor

allows acceptable viewing and also reduced detail loss when printed (Figs 13-14).

COLOUR SPACES

Colour spaces are illustrations of colour models and their content is called a gamut, which describes the range of colour that a device can output (for example a printer) or record (for example a camera or scanner). Each space is device specific for a given piece of equipment with little standardisation between output and recording devices. Numerous manufacturers have proposed spaces, ranging from large to small. The most frequently used spaces are the Adobe® RGB, which has a larger gamut than most monitors and contains many unprintable colours since the CMYK printing space is smaller (Figs 15-16). Another colour space, smaller than the Adobe® RGB is the standard RGB (sRGB), which is frequently used in digital cameras and has a gamut corresponding to the average computer monitor (Fig. 17). For dental applications either the Adobe® or sRGB is acceptable. The former has greater latitude, while the latter is ideal for viewing on monitors or for presentations using a projector.

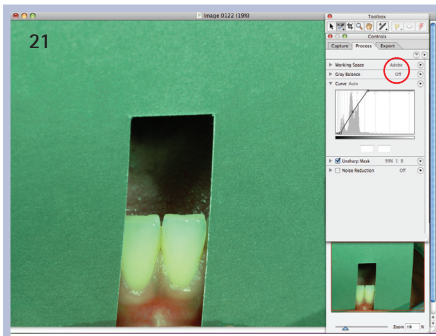
WHITE BALANCE

The next setting to consider is white balance, which is defined as follows. When a piece of white card is viewed outdoor in daylight it appears white. If the same card is viewed with indoor tungsten lights, it still appears white! The reason for this is that even though the colour temperature of the ambient light has changed, the card still appears white due to a phenomenon termed colour adaptation. Colour adaptation is the brain's ability to compensate for different illumination: because short-term memory 'remembers' the card as being white, it therefore appears white irrespective of the lighting source. As discussed in part 5,[1] the quality of light depends on its colour temperature; daylight is 6,500 K, while tungsten is 3,500 K. In the present example, if colour adaptation were absent the white card would appear bluish with daylight

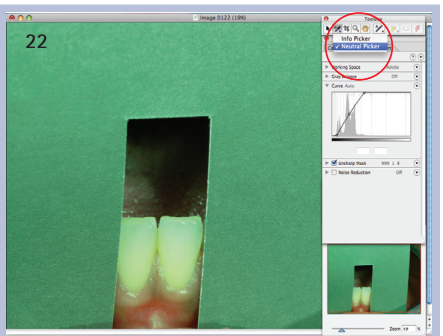
Fig. 18 Incorrect white balance setting at 5,500 K using 3,000 K illumination, the result is that the paper appears yellow instead of white

Fig. 19 Correct white balance setting at 5,500 K using 5,500 K illumination, the paper now appears white (compare with Figure 18)

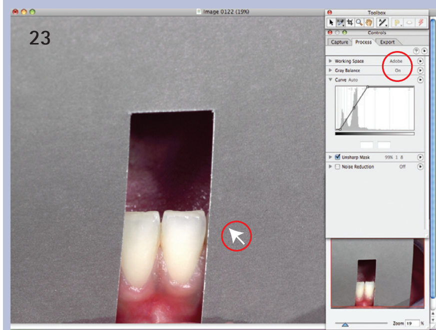
Fig. 20 WB (white balance) setting dial on a digital camera back



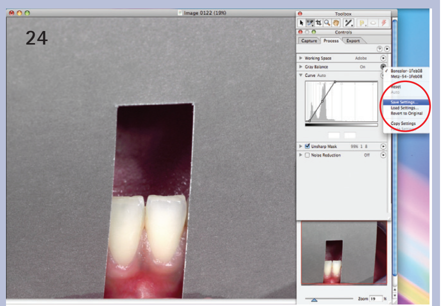
Step 1: Open RAW image with 18% grey card in proprietary software. Note that 'Gray Balance' is turned 'Off'



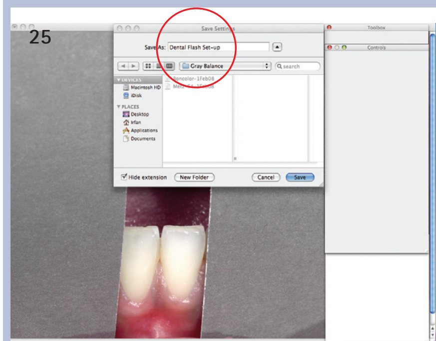
Step 2: Choose 'Neutral Picker' tool from toolbar



Step 3: Click any part on the grey card. Notice that image instantly changes to the correct grey balance and 'Gray Balance' is turned 'On'



Step 4: Save settings of the grey balance for future recall



Step 5: Type name for grey balance setting eg 'Dental Flash Set-up'

Figs 21–25 Steps for grey balance calibration

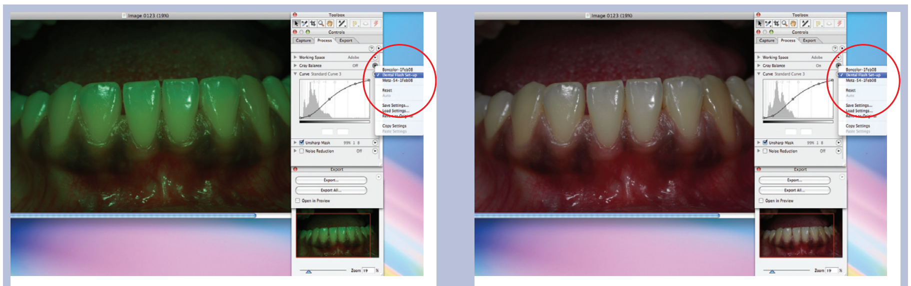
and yellow with a tungsten lamp.

Unlike the brain, cameras do not possess colour adaptation and have to be told about the colour temperature of the illumination (Figs 18-19). This process is termed setting or calibrating the white balance. White balance calibration is set using three methods: automatic, manual, or with an 18% neutral density grey card.

All cameras have an automatic white balance (AWB) setting, where the internal electronics calculate the white balance according to the colour temperature of ambient light. For most situations this setting is adequate and functions accurately. However, certain circumstances, for example daylight entering a window in a room lit with tungsten lights, may confuse the camera's AWB and require the user to make the setting manually. The white balance dial on cameras offers various colour temperature settings to choose from (Fig. 20). These are either represented diagrammatically, for example symbols of a candle, light bulb, clouds or sunshine, or have numerical values. If the latter is the case and electronic flashes are being used, the setting to choose is 5,500 K or photographic daylight.

The most accurate method for setting the white balance is calibration with an 18% grey card. The advantage of this method is that in close-up photography the camera metering system may not function to its full capacity when the distance from the subject to the lens is small. In addition, the oral cavity has a unique range of bright and dark areas, ie white teeth, pink soft tissues and the dark oral cavity background. This variance of value or brightness often confuses the camera's electronics and the white balance may therefore be erratic or incorrect. Of course it is easy to subsequently correct a colour cast in photo editing software, but the greater the manipulations, the greater the deterioration in image quality. Consequently it is crucial that the white balance is set correctly before taking a picture to limit post-capture processing to a minimum.

The procedure for white balance calibration with a grey card is as follows. A piece of 18% neutral density grey card is appropriately cut to size and photographed



Correcting grey balance: open image and recall setting eg 'Dental Flash Set-up'

Correcting grey balance: corrected image

Figs 26–27 Single or multiple images are instantly corrected for grey balance by recalling previous settings

Fig. 28 Final image after grey balance correction and cropping

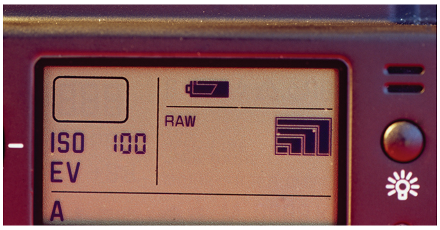


Fig. 29 File format set to 'RAW'

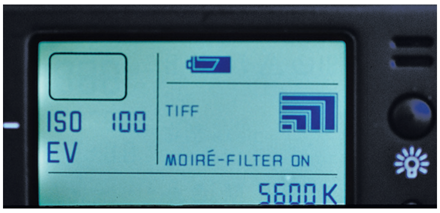


Fig. 30 File format set to 'TIFF'

Fig. 31 File format set to 'JPEG'

alongside the teeth using a given lighting set-up. This image serves as a reference and is opened either in software specific to the camera manufacturer or in Adobe® PhotoShop. Next, the 'Neutral Picker' tool is selected from the toolbar and the mouse cursor is clicked onto the grey card in the picture. The colour rendition instantly changes to the correct white balance. The setting is saved in the Grey Balance menu tab with a unique name, for example, Dental Flash Set-up (Figs 21-25). In order to correct the white balance of subsequent images with the same lighting set-up, the setting is recalled from the Grey Balance menu tab. Furthermore, multiple thumbnails can be selected and all images of a photo session can be simultaneously and instantly corrected with a single click of the mouse (Figs 26-28). As previously mentioned, most dental photographs are taken with identical set-ups. Therefore, the calibration procedure need only be performed once unless different flashes or a different type of illumination is used, for example natural daylight. Of course minor adjustments may be necessary, such as changing flash positions or camera angles, but these alterations have little affect on the white balance. Furthermore, if necessary, minor colour shifts can be tweaked, but gross changes will require the calibration procedure to be repeated.

SYNOPSIS OF CAMERA SETTINGS

The camera settings for a standard dental set-up are summarised below:

1. Focusing: auto-focus. If pictures are blurred, or for greater control for focusing on specific detail, revert to manual focusing, for example to focus on soft tissue lesions instead of the teeth
2. Metering mode: APERTURE PRIORITY
3. Type of metering (if available): matrix or centre weighted
4. Aperture: f22
5. With electronic flashes, the shutter speed is synchronised automatically by the camera (ranging from 1/60 or 1/250 s)
6. With a continuous light source, ensure shutter speed is fast enough to prevent blurring and cameras shake, ie 1/125 s or faster. Alternately, if possible, increase intensity of illumination until a speed of 1/125 s is possible
7. Set ISO to 100 or lower for maximum signal to noise ratio (ie low noise) to avoid grainy pictures
8. Colour spaces (domains): Adobe RGB (larger colour space, ideal for publishing) or sRGB (smaller colour space, ideal for displaying on computer monitor or projector)
9. Other options: brightness, contrast, colour saturation and sharpness to zero (can be adjusted later in photo-editing software)
10. White balance:
    a) Automatic
    b) Manual
    c) Calibration with 18% grey card
11. File format (to be covered in detail in part 10):
    a) RAW – maximum quality, highest bit depth, greater dynamic range, large files, additional processing time, requires experience and training for editing (Fig. 29)
    b) TIFF – good quality, large file, quicker processing than RAW, ideal for archiving and printing (Fig. 30)
    c) JPEG – maximum workflow, small files, quickest processing, reduced quality, ideal for e-mail attachments and printing, unsuitable for archiving (Fig. 31)
12. Moiré filter 'On' to avoid chequered patterns (Figs 30-31).

1. Ahmed I. Digital dental photography. Part 5: lighting. *Br Dent J* 2009; **207:** 13–18.