5 Dental Photography as a Key to Clinical Success

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Much of dental treatment success relies on efficient communication between professionals and patients, among members of the professional team, along with the laboratory prosthesis technician involved in the treatment. Dental photography allows us to capture details and share certain aspects of a clinical case, such as tooth shape, texture, color, and perceived translucency [1, 2]. Furthermore, it enriches the communication between work team and patient since they enable us to capture smile harmony, the exposure of the incisal edge with resting lips, gingival exposure, and oral corridor. Photographs have become an essential tool in dentistry, as they have improved the way we communicate and relate to people. Besides documenting cases and assisting in planning treatments, dental photography also offers the possibility of reviewing the treatment performed to enhance and evolve our skills. DSLR (digital single-lens reflex) cameras are currently the gold standard in dentistry for providing high-quality results, on top of the ease of sharing the images and videos obtained. However, with technological development, more straightforward digital cameras such as smartphones and compact cameras have become a viable entry level option for the world of dental photography. Understanding how a digital camera works and knowing the differences between the various cameras and accessories available is imperative. As is acquiring knowledge on their advantages and limitations, knowing how to adjust the settings of your equipment, and mastering the concepts and fundamentals of photography. Grasping these core aspects will help you obtain even better images.

5.1 Digital Cameras

There are currently several types of digital cameras available for use in dentistry from different manufacturers. They each bear its own characteristics, indications, and limitations, and can be classified into five distinct groups as presented in the image below (Fig. 5.1).

5.1.1 Smartphones

Smartphone cameras have evolved significantly in the recent years, as have devices and their processors in general. Instead of using lenses with optical zoom—which would compromise the thickness of phones—most manufacturers have incorporated multiple lenses. High-end smartphones have three lenses (ultra-wide, wide, and

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Fig. 5.1 Classification of digital cameras

telephoto lens) that can be easily selected according to each specific situation. However, even with the versatility of using multiple lenses, the image capture sensors in these devices are still small. They tend to obtain more pixelated images when greatly enlarged or in low light environments. Some devices feature a pro mode or manual mode, which allows for the adjustment of settings. When this function is not present, there are specific downloadable apps for this purpose. Even though they do not have a dedicated macro-lens, their portability and accessibility make them excellent entry option to start capturing dental photographs, despite their limitations.

Recommendation: if you opt to use a smartphone for dental photography, since they do not include a dedicated macro-lens, we suggest opting for a model with multiple lenses (Fig. 5.2). Remember to check that one of the lenses is a telephoto lens. If your smartphone does not offer a telephoto lens option, you can use the digital zoom of your device, mindful that this will lower the resolution of image. The use of telephoto lens or digital zoom causes less image distortion since wide and ultra-wide lenses tend to change the photographed object's proportion, known as the barrel distortion. Another critical point for capturing good quality dental photographs is the use of an external continuous light source, such as LED panels or an LED ring light. This allows brighter images to be obtained and avoids high noise in the image by the camera's ISO (sensitivity) compensation.

5.1.2 Compact Cameras

Developed to be portable and user-friendly, these were the first digital equipment accessible to the general public, that associated the digital technology of the time with affordability. Also known as point-and-shoot cameras, they had added features to facilitate usage. These properties included automatic mode, autofocus, retractable zoom lenses, built-in flash, and video recording, making them very popular since the beginning of the year 2000. Nowadays, some compact cameras even feature a manual mode for configuring camera settings and, along with smartphones, they are an excellent entry level choice for the world of dental photography.

Recommendations: if present, we recommend using the camera in manual mode, with the macro-function activated, employing the optical

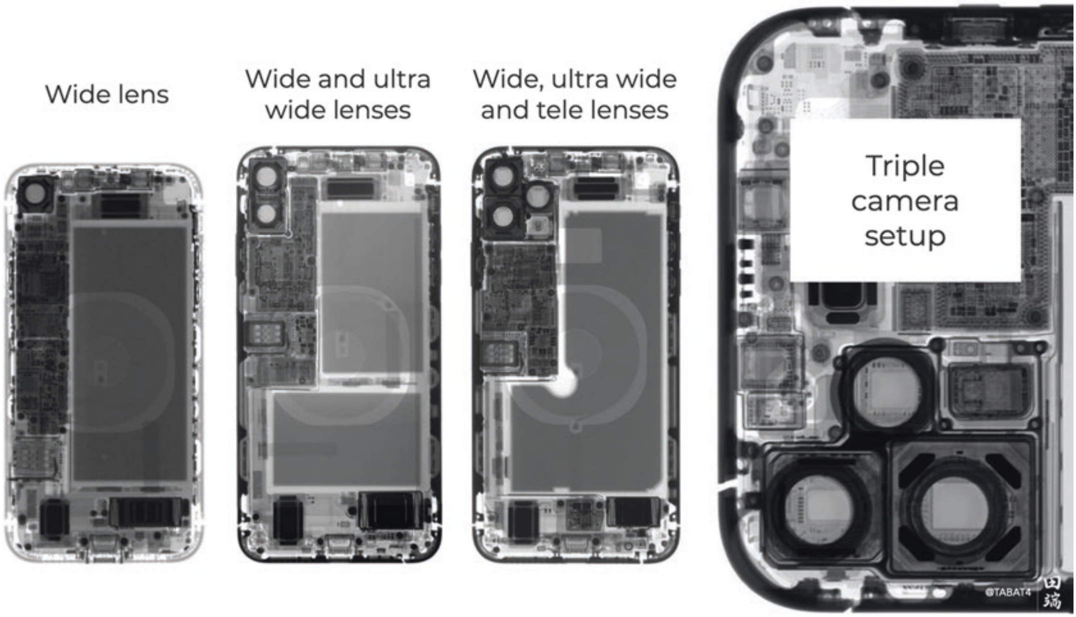

Fig. 5.2 X-ray of smartphones showing the digital camera components. (Adapted from https://www.creativeelectron.com/)

zoom lens to reduce image distortion. It is recommended to combine it with an LED illuminator or an external flash to synchronize with camera's shutter, whenever available.

This feature grants users the ability to adapt to different situations. We recommend using a dedicated macro-lens from 100 to 105 mm and a circular or twin macro-flash.

5.1.3 DSLR (Single-Lens Digital Reflection)

DSLR cameras are characterized by using a pentaprism (reflex mirror) to visualize the object before the photographic record occurs. These are often considered professional or semi-professional cameras, which employ full-frame or APS-C type sensors to capture images with excellent resolution and high quality. Another key feature is the possibility of adjusting the equipment's settings to manual mode. This optimizes the capture of images and grants the operator total control over the photograph to be obtained. The use of an interchangeable lens (Fig. 5.3) and an external flash as an auxiliary source of illumination, makes this equipment the gold standard for dental photography, especially when the goal is to attain high-quality images.

5.1.4 Mirrorless Cameras

Considered an evolution of DSLRs and cameras, they present the same possibility of using interchangeable lenses and external flashes. The main difference is the absence of the pentaprism (reflex mirror) inside the camera body, which allows this equipment to be smaller and lighter than the DSLRs. Instead of the optical viewfinder, these cameras enable digital previewing of the image on a built-in rear LCD screen or an electronic viewfinder (EVF). A disadvantage of mirrorless cameras when compared to a typical DSLR is its shorter battery life, due to the power consumption of the viewfinder. However, an in-camera setting on some models can mitigate this issue. With more technology involved, they still have higher cost, which should become more accessible over time.

Fig. 5.3 Schematic illustration of a DSLR equipment. (https://www.dpreview.com/articles/6579860130/canoneos500d)

We recommend using a dedicated macro-lens from 100 to 105 mm and a circular or twin macro-flash.

5.1.5 Specific Cameras for Dentistry

There is also on the market a digital dental camera designed exclusively for dentistry (EyeSpecial C-IV, SHOFU, JAPAN), which incorporates the advantages of DSLR cameras with the simplicity of compact cameras. It features software with a user-friendly interface, touchscreen and the menu offers pre-configured modes. Among its advantages is the body. Its lightweight unibody construction in polymer is resistant to moisture and disinfection protocols, favoring biosafety within the office space. It features a dual twin flash integrated into the camera body, which is selected according to the pre-configured modes. There is also a 28–300 mm lens with the option of adding a close-up lens for macro-photography, and an adapter for cross-polarized photography for photos of color selection.

We advise using the pre-configured modes recommended by the manufacturer, since the equipment is specific for dentistry.

5.2 Knowing the Photographic Equipment and Accessories for Dental Photography

5.2.1 Sensor

Sensors are responsible for capturing the light reflected by an object, which will later be processed to acquire the desired photographed image. There are two main types of image sensors for digital cameras and camcorders: CMOS and CCD. Both are made of silicon and work in similar way. They depend on the photoelectric effect, the interaction between photons (particles of light) and the silicon, to move the electrons in the sensor to capture the image. All these sensors are charge-coupled devices and their basic functions are to capture images and transform them into electrons (electromagnetic signals) and bits and bytes by a microprocessor in an analog-digital process that generates the image. The main difference among equipment resides in the type and size of sensor used (Fig. 5.4). Professional DSLR cameras use full-frame sensors, while intermediate and entry level DSLRs use APS-C sensors (1.5–1.6x smaller than the full-frame sensor). Compact cameras use 1″

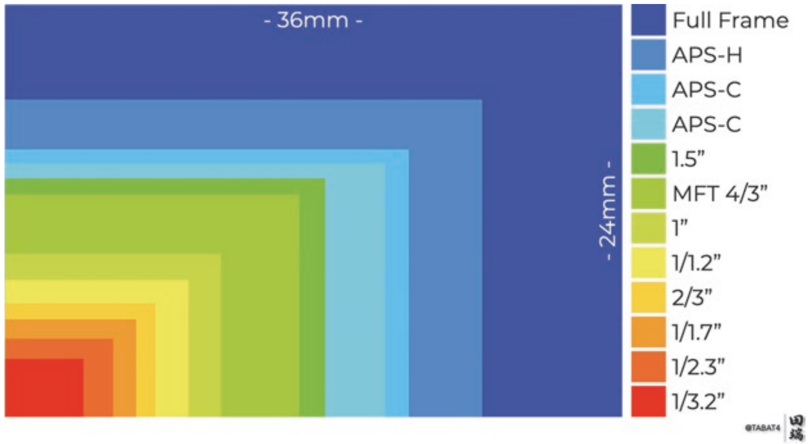

Fig. 5.4 Comparison of the size of the digital sensors used in photographic equipment. (Adapted from https://newatlas.com/camera-sensor-size-guide/26684/)

sensors, while smartphones use 1/3″ sensors, almost 50 times smaller than the full-frame sensor.

5.2.1.1 How Important Is the Size of the Sensor?

A digital camera's resolution is often limited by the image sensor that turns light into discrete signals. Depending on the sensor's physical structure, a color filter array may be used, which requires demosaicing to recreate a full-color image. The brighter the image at a given point on the sensor, the higher the value read for that pixel. The number of pixels in the sensor determines the camera's "pixel count." In a typical sensor, the pixel count is the product of the number of rows and the number of columns. For example, a 1000 by 1000 pixel sensor would have 1000,000 pixels or 1 megapixel. In practice, while smaller sensors tend to produce more pixelated and noisier images, larger sensors capture more defined images. These present superior color contrast and performance in a low light situation, lower noise at high ISOs, and lower crosstalk.

5.2.2 Camera Body

The framework is responsible for maintaining and protecting the sensor and processor, along with supplemental electronic equipment, that together allow the camera to function. The body's size may vary between equipment based on the amount and size of electronic components. Larger bodies provide space for larger sensors and enable better handling and grip. In DSLR or mirrorless cameras, it is possible to connect a single lens and flashes to the equipment's body. Not all compact cameras include these options, and it is not possible to exchange lenses. Only a few models offer the possibility to connect an external flash to the camera body. In smartphones, the camera body is integrated with the mobile itself, which, like compact cameras, offers little possibility of adapting direct lenses and synchronizing flashes as DLSRs and mirrorless do.

5.2.3 Lens

A lens is composed of several optical elements, which can be made of plastic or glass. Optical glass elements generally provide a clearer, higher-quality lens result. Each element has a specific function in focusing the light towards the sensor, either generally shaping the light to fit the sensor's size, correcting problems, or providing the final point of focus. An interesting feature of these lenses is the automatic focus. In this case, a motor's aid allows for the final optical element or collection of some elements to be moved closer or farther from the sensor. This enables different areas of an image to appear in focus and is one of the main aspects of a practical camera system. The lens can be considered the most important element of a camera. Aspects such as number, size, and configuration of optical elements, material quality, number of blades in the diaphragm, and electronic components, determine its characteristics. These characteristics have direct impact on clarity, maximum aperture, fixed or variable focal length, whether wide, macro, or telephoto, and manual or autofocus.

5.2.3.1 Which Lens Should I Use for Dental Photography?

In everyday clinical practice, we need a versatile lens that allows us to perform portrait and intraoral close-ups with minimal distortion (Fig. 5.5). For this purpose, dedicated macro-lenses for DSLR or mirrorless cameras have been the gold standard in dentistry. It is important for the focal length to be between 100 and 105 mm, depending on the manufacturer, to allow for a 1:1 magnification. For devices that do not offer the possibility of using interchangeable lenses, such as compact cameras and smartphones, we suggest using the camera's optical zoom, whenever possible, or the telephoto lens on a smartphone (Fig. 5.6). Otherwise, digital zoom can be used, with the understanding that this will decrease the resolution of the image.

5.2.4 Memory

Some smartphones and most digital cameras store image data on flash memory cards or other removable media. Most stand-alone cameras use SD format, while a few use CompactFlash cards, and some brands opt to use their specific memory cards. Knowing how files are stored inside your device is extremely important, as it allows you to better organize. We recommend that photos be downloaded or uploaded to cloud storage services more often on smartphones that rely solely on the device's internal memory. It is important to note that adopting a file organization protocol is crucial to keep track of your cases. Whenever necessary, consider using an external hard drive to backup your digital files.

5.2.4.1 Which File Format Should I Use?

The Joint Photography Experts Group (JPEG) standard is the most common file format for storing image data. Other file possibilities include Tagged Image File Format (TIFF) and several RAW image formats. Raw image is the unprocessed set of pixel data directly from the camera sensor, often saved in a proprietary format. Many

Fig. 5.5 Display of barrel distortion. Barrel distortion is usually present in most lenses, especially at wide angles. The distortion amount can vary, depending on the distance between camera and object, especially over short distances

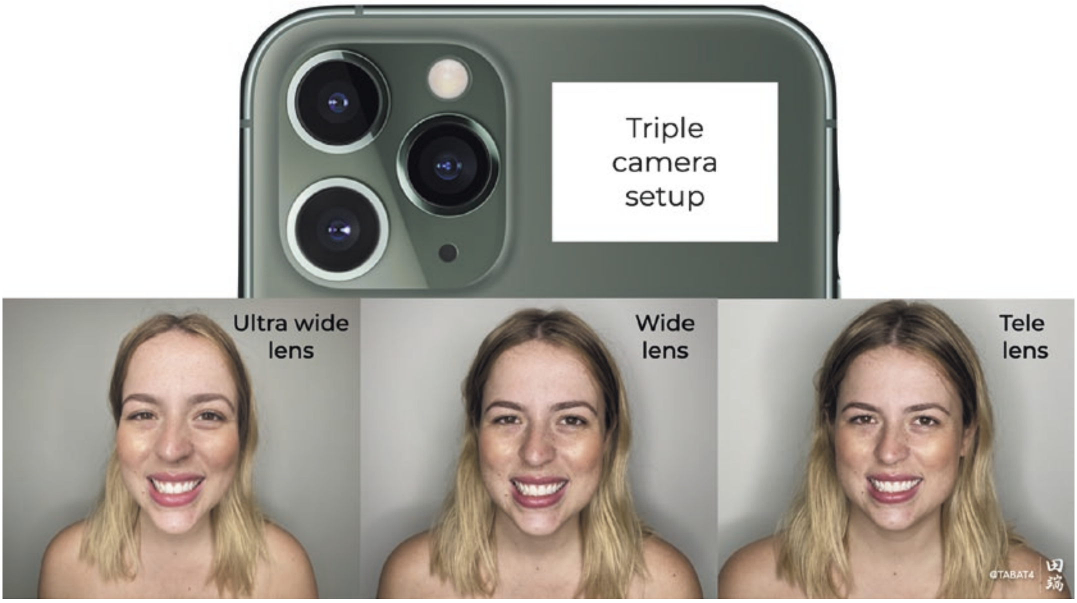

Fig. 5.6 Display of barrel distortion present in smartphones

cameras, especially high-end ones, support a RAW image format. At first, RAW files had to be processed in specialized image editing programs but, over time, many conventional editing programs, such as Google's Picasa, added support for RAW images. Rendering to standard images from RAW sensor data grants more flexibility when making major adjustments without losing image quality or retaking pictures. In general, it is relevant to consider that the RAW format will be necessary when you intend to enlarge a picture for printing, or even in cases where it is necessary to prove copyright. Another instance when this might be needed is to confirm the absence of image editing, as well as in cases of communication of shade selection with a laboratory technician. For this purpose, we recommend the use of a gray card associated with a cross-polarizing filter which will be later explained in this chapter. When sharing patient's image in clinical routine, JPEG format will suffice.

5.2.5 Lighting Equipment for Dental Photography

Light is the main ingredient for photography and are classified as natural or artificial. In this chapter, we will cover those of interest to dentistry, which are artificial lights. There are four common types of artificial light sources used in photography: incandescent, fluorescent, LED, and flash. For dentistry purposes, we will deal with the latter two (Fig. 5.7). In dental photography, we work with artificial light from lighting equipment classified as continuous light equipment or flash-type equipment. While both options illuminate and provide better results in filming and photographing, they present some technical differences, such as the "time" in which the light is available. Continuous light is an option that promotes continuous lighting over timer, while with flash, lighting occurs punctually. Other factors such as color temperature and light intensity

Fig. 5.7 Artificial lighting equipment available for use in dental photography

should also be considered when choosing between these options.

5.2.5.1 Continuous Light Equipment

LED means light-emitting diodes. The light source in such devices is generated by a series of light-emitting diodes present in each lamp. These illuminators are classified as continuous light equipment because the light remains on the entire time and does not flash like a strobe light. Most LED equipment offers brightness adjustment for the emitted light, as well as color temperature adjustment option, which ranges from 3300 (yellowish light) to 6600 K (white light), for example. Since LEDs are not as bright as the light emitted from a flash light, they are not recommended for taking photographs with DSLR or mirrorless cameras. However, it is possible if you use a high ISO setting (800+) or position them very close to your subject.

Despite that, LED illuminators are effective with smartphone cameras and compact cameras (Fig. 5.8) since the camera's shot cannot be synchronized with the flash device in this case. Another interesting possibility of using LED equipment is while filming. Whether with DSLR, mirrorless, compact, or smartphone cameras, a continuous light source is always needed.

5.2.5.2 Flash Equipment

Photographic flash, sometimes referred to as a strobe or simply a flash, is a device used in photography to allow pictures of dark areas to be taken by producing an extremely bright light. This illumination is not continuous and, in a small fraction of a second, it bursts outward in large amounts. Most photographic equipment includes built-in flash, but external flashes will be needed for dentistry purposes since they enhance the lighting system. A critical factor when using this light source is the need to synchronize the firing of the photographic flash with the digital camera's shutter opening, to enable light to be captured by the electronic image sensor. In DSLRs and mirrorless cameras, the mechanism is usually a programmable electronic timing circuit, which can, in some equipment, receive input from a mechanical shutter contact or work wirelessly.

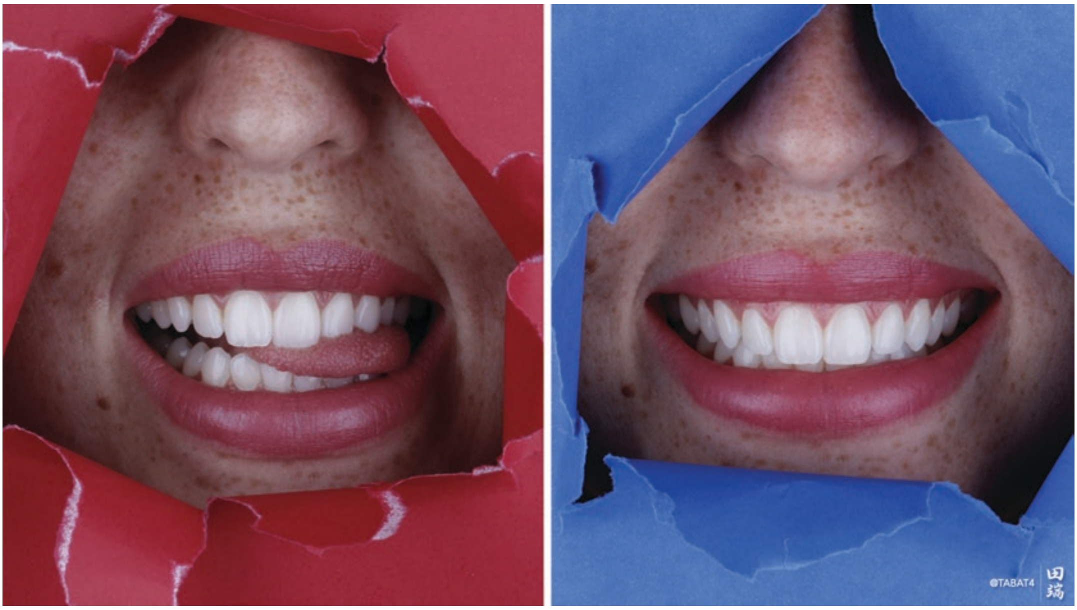

Fig. 5.8 Artistic photography was obtained using studio flash and a DSLR camera equipped with a 100 mm macro-lens

5.2.5.3 Macro-Flash for DSLRs and Mirrorless

For dental photographs, based on equipment configuration adjustments (which will be later discussed in this chapter), and due to the need to capture close-up photographs of subjects, built-in flashes are not recommended as they create shadows in the image. Instead, macro-flashes, like ring light and twin flashes, should be your first option for such situations. The advantage of these flashes is the ability to position the light source at the same plane as the lens, which provides better lighting for dental photos. An alternative to macro-flashes is the use of a pair of conventional external flashes, mounted on a bracket or on tripods, that are activated in remote mode to function as a twin flash or a studio flash. A critical factor when using these sources is the need to correctly set the light's intensity. This can be controlled automatically or in manual mode by the operator, providing greater control over the final result of the image.

5.2.5.4 Studio Flash

Another option that has become very attractive to clinicians is the use of studio flash equipment within the dental office. There are currently different models on the market, which can be mounted on tripods or attached to the dental office's ceiling. These models have greater power than macro-flashes and work plugged in, allowing for a faster firing cycle and less variety of light intensity since they do not depend on batteries. Studio flashes are generally combined with softboxes or umbrellas, which help diffuse the light from the flash, and provide softer shadows in the images, with a more artistic appeal (Fig. 5.8).

5.2.6 Light Modifying Accessories

The main objective of modifying the light of a photographic flash is to soften shadows. Since the photographic flash is a small, high-intensity light source, it usually produces harsh, unattractive shadows. Hard light directly affects the photographed object, by causing a well-marked and sharp shadow. Unlike with hard lights, the shadows generated by soft lights are absent of sharp edges, making it impossible to determine exactly where the shadow begins or ends (Fig. 5.9).

Fig. 5.9 Light modification accessories

5.2.6.1 Softboxes and Bouncers

There are two ways to "soften" the light from flashes: filtering or bouncing it, by using diffusers and reflectors, respectively, that work as light distribution devices. Flash diffusers soften shadows by refracting the light through a translucent material. When the light is refracted through a translucent material, this material becomes the new and the largest light source, as in the softboxes used in studio flashes. A simple and cheap solution is to attach a sheet of white paper over the twin flash with tape. In the case of reflectors, the light from the flash is directed to the reflectors' surface, which then reflects the light on its surface, and provides softer shadows. In practice, it is possible to soften shadows by using a light modifier that amplifies the light as a larger light source. This strategy produces a more gradual transition between deep shadow and full illumination. The most common misconception is that spreading the light over a wider area will soften the shadows. This is not the case. You must enlarge the light source to soften the shadows.

5.2.6.2 Brackets Mount

Another way to modify the light is to change the position of the light-emitting source or flash. For this, there are devices called brackets available, with option for fixed or articulated arms. These allow the twin flashes to be adjusted in different positions to increase distance or approximation of the light source concerning the subject and the camera lens. By modifying the flashes' positioning, indirect or oblique light are obtained enabling better visualization of the tooth's buccal surface texture. Since it provides more detailed information for laboratory procedures, this feature becomes very interesting when communicating with the laboratory technician. This bracket system can be used with conventional external flashes, along with remote mode and macro-twin flashes.

5.2.7 Accessories for Dental Photography

To perform good dental photographs, especially intraoral photographs, it is necessary to keep the lips, cheeks, and tongue out of the image The market has a variety of accessory models available that can be chosen from according to the photographic registration needs. Here we will address some possibilities and their practical applications (Fig. 5.10).

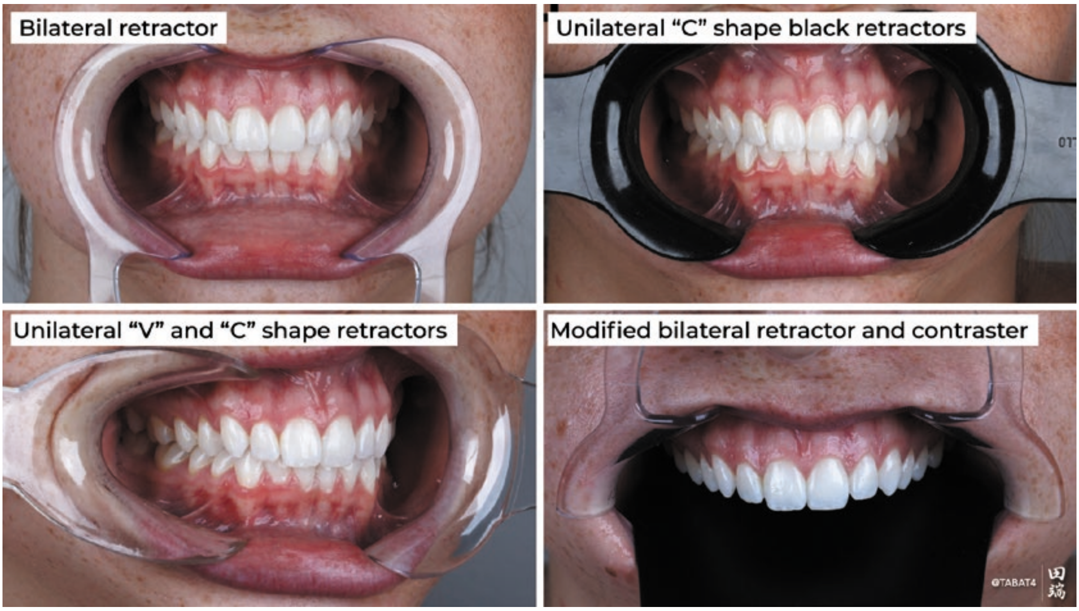

Fig. 5.10 For front photos, we recommend the use of a bilateral retractor, also known as self-retracting or unilateral retractors. For side shots, we suggest the use of an associated "V" shaped retractor (for the side to be photographed) and "C" shaped retractor (for the contralateral side). For occlusal photos, we recommend using a modified bilateral retractor with a mirror or an anterior photo with a black background

5.2.7.1 Mouth Retractors

Mouth retractors keep lips and cheeks out of the image. There are several mouth retractors available, which can be unilateral or bilateral, with C or V shape, transparent or colored. If necessary, we can modify retractors, mainly to optimize use when employing mirrors and black backgrounds.

5.2.7.2 Mirrors

A wide variety of mirrors are available for many intraoral situations, differing in size, shape, and the presence or not of a handle. These are essential for occlusal photos and can be associated with modified bilateral retractors for better results. Mirrors with handles help to ensure no fingers appear in the image. To prevent the mirror from fogging up due to the patient's breathing, we recommended the use air spray or preheating the mirror prior to performing the photoshoot.

5.2.7.3 Black Background

Black backgrounds or contrasters are used to isolate the anterior teeth, especially the upper teeth. When positioned behind the anterior teeth, the light from the flash is absorbed instead of reflected, enabling nuances of the tooth enamel to be observed, especially of the incisal edges and in the transition areas. This is very effective in communicating with the laboratory technician.

5.3 Fundamentals of Dental Photography: The Exposure Square

Dental photography is available to everyone. However, some basic principles about the dynamics of the equipment and the light's behavior are necessary and will be addressed in this section. After all, the etymology of the word photography does say it all: the art of drawing with light. From the Greek "phosgraphein"—"phos" or photo, which means "light," and "graphein," which means "to mark," "to draw" or "to register." The term "exposure" appears as a synonym for "making a photograph," and, from a technical point of view, it represents the amount of light that can reach the image recording medium [3].

5.3.1 Exposure

In photographs, exposure is responsible for capturing the amount of light that can reach the sensor of a camera. That is, it defines how light or dark photos will be. For instance, if the result of the image captured is very bright, it is because the image was overexposed, indicating "too much light." If it is too dark, it was underexposed, indicative of "low light."

Depending on the effect you are looking for, this may or may not be a good strategy. If the sensor receives a significant amount of light, the photo will be overexposed, with large white areas and the lack of details. In contrast, if the image sensor does not receive enough light, the photo will be underexposed, with black areas, yet also devoid of details. The ideal strategy to avoid missing details is to find balance.

In classic photography literature, three basic settings allow you to deal with the exposure of your photos: Shutter Speed, Aperture, and Image Sensor Sensitivity. These three configurations form what we call the Exposure Triangle. In Dental Photography, because we are dealing with the registration of a dark cavity that is not efficiently lit by ambient light, the use of flash is necessary and mandatory. Hence, when the Exposure Triangle of classical photography literature gains an additional pillar in Dentistry, it turns into an Exposure Square: the flash configuration (Fig. 5.11). All basic settings are interdependent, and each has a remarkable creative impact on the image.

5.3.1.1 Shutter Speed

Shutter Speed or exposure time translates into the time that the machine's shutter (the part that isolates the light sensor) remains open, letting the photographic film or the digital sensor absorb light and form an image. The longer the exposure time, the greater the absorption of light by the sensor, therefore the more exposed the image will be. Exposure time is usually given in $1/x$ format, where X represents a fraction of time in seconds. This component of the exposure triangle varies between 1/8000 of a second (very short time, higher speed) and several seconds (very long time, lower speed). Specifically, we can distinguish the short times (less than 1/60) from the long times (more than 1/60).

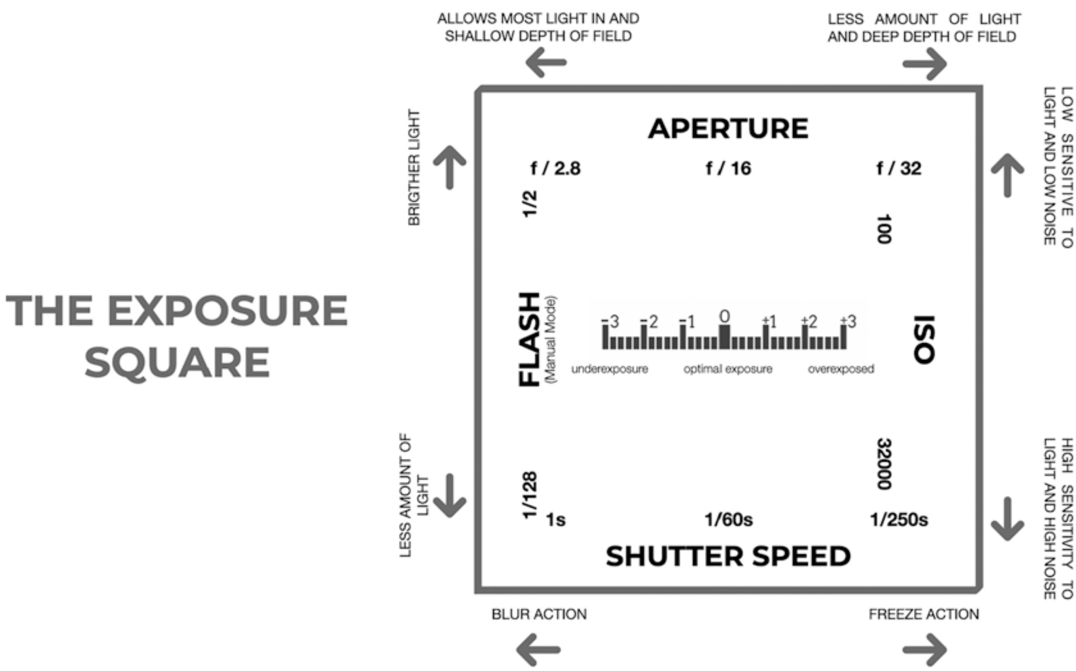

Fig. 5.11 The exposure square

Although very popular in the photographic field, the term speed is not correct. The shutter, as we have seen, works with exposure times, in general fractions of seconds, which does not relate to the speed of operation or exposure [4].

5.3.1.2 Impact of Shutter Speed on Image Blur

Shutter speed controls the effects of movement on your photos. This can occur deliberately, from the camera's movement by the photographer while recording an image, or from movements from your subject within your composition. Although fast shutter speeds freeze the action, slow shutters can register the action as a blur.

In Fig. 5.12, we can see three photos of the same pinwheel, taken of the object in motion, though with different exposure times. In conclusion, just remember, short exposure time causes a freezing effect of the motion of the subject to be photographed, while long exposure time causes motion blur or background.

5.3.1.3 Aperture

The camera lens contains a diaphragm, a type of membrane formed by a set of metal sheets, which can be closed more, or less, to allow greater or fewer light to pass through (Fig. 5.13). The wider the aperture, the more the image will be exposed.

Aperture is expressed by a number. The smaller the number, the greater the aperture. It is an inversely proportional relationship. For all lenses, the smallest aperture number (or f-stop)—1.4, 2, 2.8, or 4, depending on the lens—represents the largest aperture. The minimum aperture is often 22 at minimum focal lengths and can reach 38 or more.

5.3.1.4 Impact of Diaphragm Opening on Depth of Field

We call Depth of Field (DoF—Depth of Field) the area of the image that will be sharp, while the rest will be blurred. This Depth of Field depends on several factors:

1. *The opening of the diaphragm*: the more open the diaphragm, the smaller the depth of field.
2. *The long focal length*: long focal lengths (telephoto) tend to decrease the depth of field.
3. *The focus distance*: the closer the subject is, the smaller the depth of field.

For portraits, for example, a reduced depth of field is preferred so that the subject is sharp, but the background completely blurred. To do this, you need a lens with a large aperture (ex: f/1.8). We can also use zoom to take close-ups of the object so that it looks closer. It is a photographic

Fig. 5.12 Impact of the Shutter Speed on motion blur. (Adapted from https://digitalwarehouseblog.wordpress.com/2016/01/26/when-the-lights-go-down-low-light/)

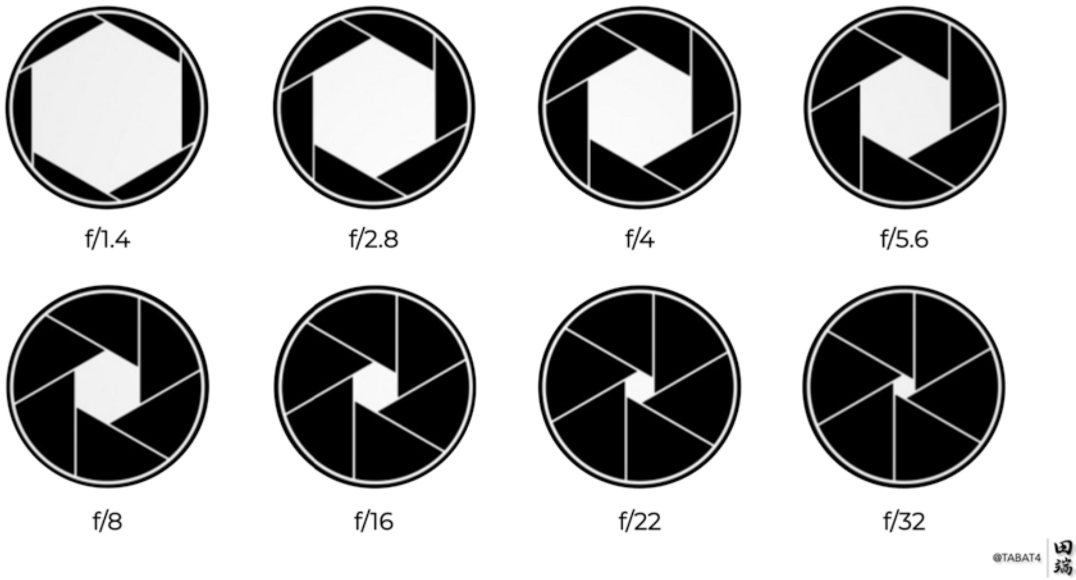

Fig. 5.13 Diaphragm and set of blades

Fig. 5.14 Reduced depth of field, showing in focus every tooth until the canine

technique widely used when it comes to highlighting the subject in the foreground.

In short, a large aperture (small number) produces a reduced depth of field (small area of sharpness). A small aperture (large number) leads to a greater depth of field (area of deep sharpness). See Fig. 5.14.

5.3.1.5 Sensitivity (ISO)

The sensitivity of the image sensor (expressed in ISO—International Organization for Standardization) is the standard that describes the absolute sensitivity of the digital sensor to light, and it varies between 50 and 128,000. The higher the ISO, the lesser amount of light is needed to obtain a correct exposure since the sensitivity of the digital sensor to capture light will be grater.

The sensitivity of today's cameras reaches 128,000 ISO, and noise is almost invisible up to 3200 ISO. Noise can be defined as a kind of interference in the image that manifests itself in the form of pixels of very different colors from reality, usually in dark scenes [5] (Fig. 5.15).

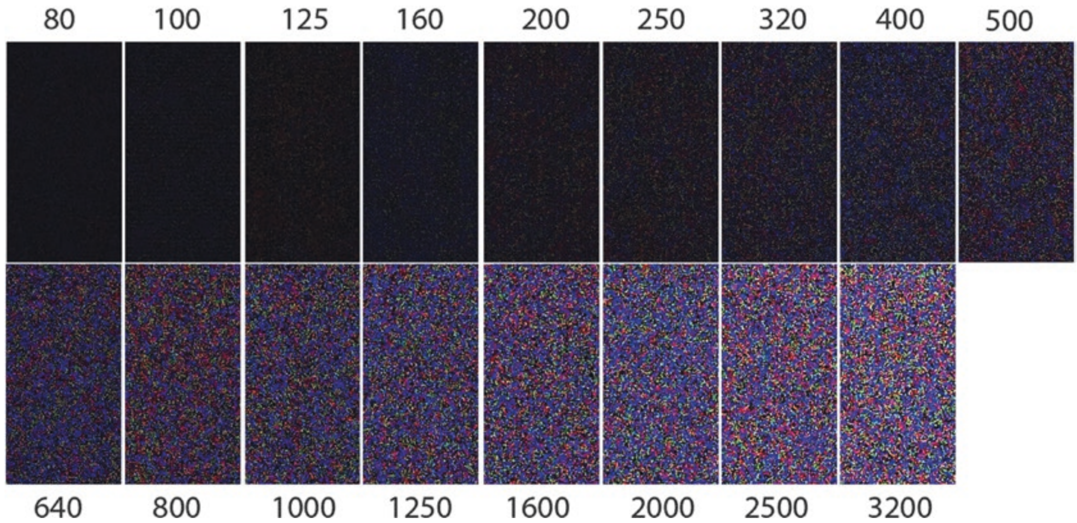

Fig. 5.15 ISO and noise production in the image

However, it is best to keep the ISO as low as possible: 100 ISO for sunny days, 200 ISO for cloudy days, and up to 400 ISO indoors. Nevertheless, if the scene demands it, do not hesitate to raise the ISO.

5.3.1.6 Impact of Sensitivity on Image Noise

As previously mentioned, increasing the ISO sensitivity can make photos lighter, however, it decreases the sharpness because it produces undesirable noise in the images due to the greater sensitivity to capture light.

It is recommended to maintain minimum sensitivity in Dental Photography. The ideal is to work with the ISO as low as possible, preferably in a range of 100–200, aiming to obtain images with the lowest possible level of noise and greater clarity. Any dark or shady area in the oral cavity can have its lighting issue resolved by using an integrated flash system specifically for this purpose.

5.3.2 Master the Exposure of Your Equipment

As we have seen, the correct adjustment of your equipment can favor obtaining better images. These settings adjustments may vary from equipment to equipment, depending on the type, model, and manufacturer. Below you will find a summary of general equipment configurations, though it is crucial that you carry out some tests with your equipment and adjust it according to your needs (Table 5.1 and Fig. 5.16).

5.4 Dental Photography with Gray Card

Gray cards are designed to help you adjust your exposure and white balance settings consistently, providing a reference point. This reference point will define a white balance or color balance point for a given image and all images subsequently captured. The reference point will ask your camera to compensate for any illuminating color in the space you plan to shoot, adjusting the white balance and the color profile (Fig. 5.17). With a gray card, it becomes possible to correct the values of color differences of dental elements to visually imperceptible values. This achieves one of the major advances in the standardization of photography for color registration. To measure your reference point, place the gray card in the area or scene where you intend to capture, with the gray side facing the camera. For most accu-

Table 5.1 Compilation of your equipment configuration recommendations

DSLR and Mirrorless	Compact Cameras	Smartphone Cameras
CAMERA MANUAL MODE • **F22** for better depth of field • **1/125** to avoid blur image • **ISO 100** for low noise • **WB** flash or use grey card for color correction FLASH MANUAL MODE • **1/2** to **1/4** MACRO LENS **100** or **105**mm • Autofocus or manual	• Use an external **LED light source** or flash equipment is possible to synchronise the shot. • Use optical **zoom** to decrease barrel distortion. • Select **macro** function. • **Adjust setup** on manual mode if possible.	• Use an external **LED light source**. • **Enable HDR** on your smartphone. • Use smartphone's **tele lens** or **digital zoom** to decrease barrel distortion. • Adjust setup manually on pro mode or using an app, or **adjust exposure** on your mobile screen. • To avoid shaky photos, use **timer** function.

Fig. 5.16 Image results from smartphone plus LED (top left). Compact camera plus LED (top right). DSLR camera with a macro-lens and ring flash (bottom left). DSLR camera with a macro-lens and twin flash (bottom right)

rate results, place the card close to the patient's mouth so that it reflects the light from the flash. Then, adjust the white balance settings on the camera to ensure optimal exposure and focus. Shoot normally, remembering that you must repeat a new photo with the gray card whenever you change the lighting settings.

Another possibility is the post-processing procedure of white balance correction in software like Photoshop or Lightroom. To do so, merely

Fig. 5.17 The photograph was taken with a gray card (left side) and WB adjustment made in photoshop (right side)

open the test image that contains your gray card in Photoshop and create a Level Adjustment Layer. You will find three droppers stacked next to the Levels histogram. Select the middle dropper and click on the gray card. Photoshop will automatically adjust the color levels of the image for you. If you need to apply these settings to other images taken in the same lighting conditions, click on the drop-down menu in the upper right-hand corner of the Levels column and select "save preset levels." Name and save the preset, then open your other files for editing. For each image, find "load level preset" in the Levels column drop-down menu and select the saved preset file to apply it. To do this in Lightroom, simply select the White Balance dropper tool from the Developing Module Basic menu and click on the gray card. Then, highlight all the images you want to color and click on the "synchronize" button in the screen's lower right-hand corner. Check the "White balance" and click "synchronize."

5.5 Cross-Polarization in Dental Photography

For years, there were uncertainties regarding the ability of photographic captures to effectively register color shades of dental elements. These concerns related to the possibility of lighting affecting color, and to the potential of variations happening between the various sources of illumination. This was greatly attributed to possible variations and discrepancies occurring because of different photographic processes and the brand of the equipment. Some of the probable variances include intensities, degrees of angulation, distance, the use of modifiers, as well as the configuration of the camera and the differences between operators (dental surgeons, dental technicians, and dental assistants).

The human eye does not have the ability to distinguish between randomly oriented light and polarized light, and polarized flat light can only be seen through an effect of intensity or color. For example, by the reduced brightness when wearing polarized sunglasses. In fact, humans cannot differentiate real high contrast images seen in a polarized light microscope from identical images of the same specimen captured digitally (or on film) and then projected onto a screen with light that is not polarized.

The basic concept of polarized light is illustrated in Fig. 5.18 for a non-polarized light beam incident on two linear polarizers. Electric field vectors are represented in the incident light beam as sine waves that vibrate in all directions (360°; although only six waves, spaced at 60° intervals, are represented in Fig. 5.18). In reality, the electric field vectors of incident light are vibrating perpendicular to the direction of propagation, with an equal distribution in all planes before encountering the first polarizer [6].

The polarizers illustrated in Fig. 5.18 are filters containing long-chain polymer molecules oriented in a single direction. Only incident light vibrating in the same plane as the oriented polymer molecules are absorbed, while light that vibrates perpendicularly to the polymer plane passes through the polarizer. The polarization direction of the first polarizer is oriented vertically towards the incident beam so that only waves with vertical electric field vectors will pass through the first polarizer. The second polarizer, subsequently, blocks the wave that passes through the first polarizer because this polarizer is oriented horizontally concerning the electric field vector in the light wave. The concept of using two polarizers oriented at right angles to each other is commonly called Cross-Polarization and can be used with transmitted light (Transmitted Cross-Polarization—TCP) and reflected light

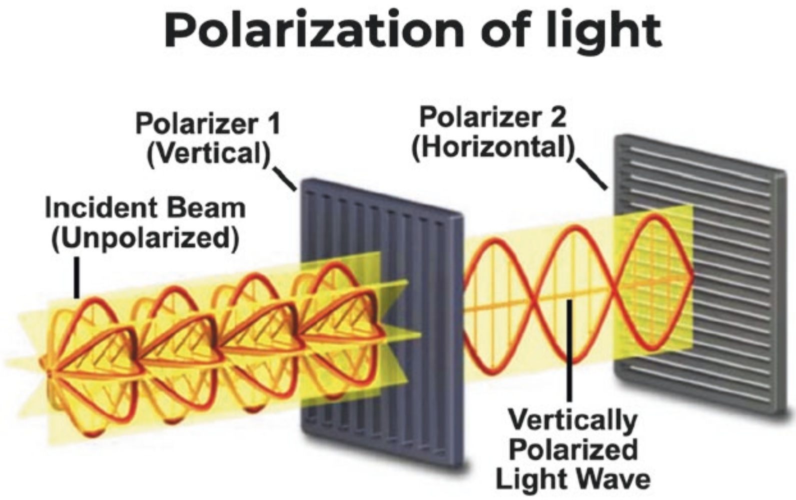

Fig. 5.18 Polarized light concept. (Source: https://www.microscopyu.com [7])

Fig. 5.19 Photo with color scale for communication with the laboratory. Note that the reflection of the flash interferes with the correct color analysis

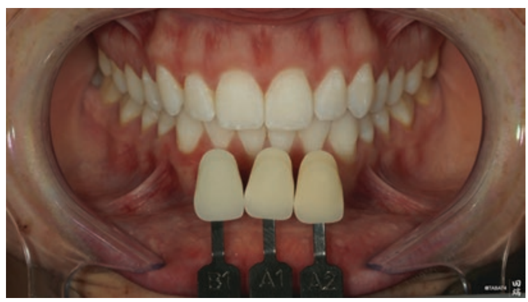

Fig. 5.20 Photo with the color scale using the reflected cross-polarization. By removing the flash light reflection, a better color evaluation of the patient's smile is possible

(Reflected Cross-Polarization—RCP). In photographs using the Transmitted Cross-Polarization, the light passes through the object to be studied and reaches the objective. In photographs using Reflected Cross-Polarization, the light falls on the object's surface to be studied and is then reflected towards the lens (Figs. 5.19 and 5.20).

5.6 Communication with the Laboratory

Color selection in dentistry is considered a subjective process, dependent on three factors: light source, object (tooth), and observer (dentist/patient/laboratory technician) [8]. Some studies [9–13] have been developed to try to standardize these factors using reflected polarized lighting and an absolute gray reference card, also called a white balance card.

The use of cross-polarized filters for dental photography allows the elimination of unwanted stray light and specular reflection from the dental structure from the buccal surface. These filters are incorporated into the flash and are located perpendicular to another polarizing filter located simultaneously on the front of the lens. This results in a high contrast image or a supersaturated image, allowing detailed chromatic mapping of the dental element (Figs. 5.21 and 5.22).

As demonstrated, the use of polarizing filters associated with digital photography is a simple and direct method used to better understand the color of the natural anterior dentition, improving communication with laboratory technicians, which makes the rehabilitation much more predictable (Fig. 5.23).

Sampaio et al. [10], compared the performance of different digital equipment and accessories for color selection. Among them were a smartphone, a DSLR camera with circular flash, a DSLR camera with twin flash, a DSLR camera with twin flash and light modifiers, and a DSLR camera with twin flash with polar eyes system, associated with the use of a gray card. They concluded that the use of gray cards favored results, optimizing the usage of digital equipment for color selection. The employment of reflected cross-polarization with the polar eyes system showed the best results and, according to this study, the smartphone was the least accurate.

Fig. 5.21 Polar-eyes® cross-polarization filters. (Adapted from https://www.youtube.com/watch?v=uZwNKHnQyPw)

Fig. 5.23 Result achieved, harmonizing the element with a darkened substrate to the rest of the dental elements

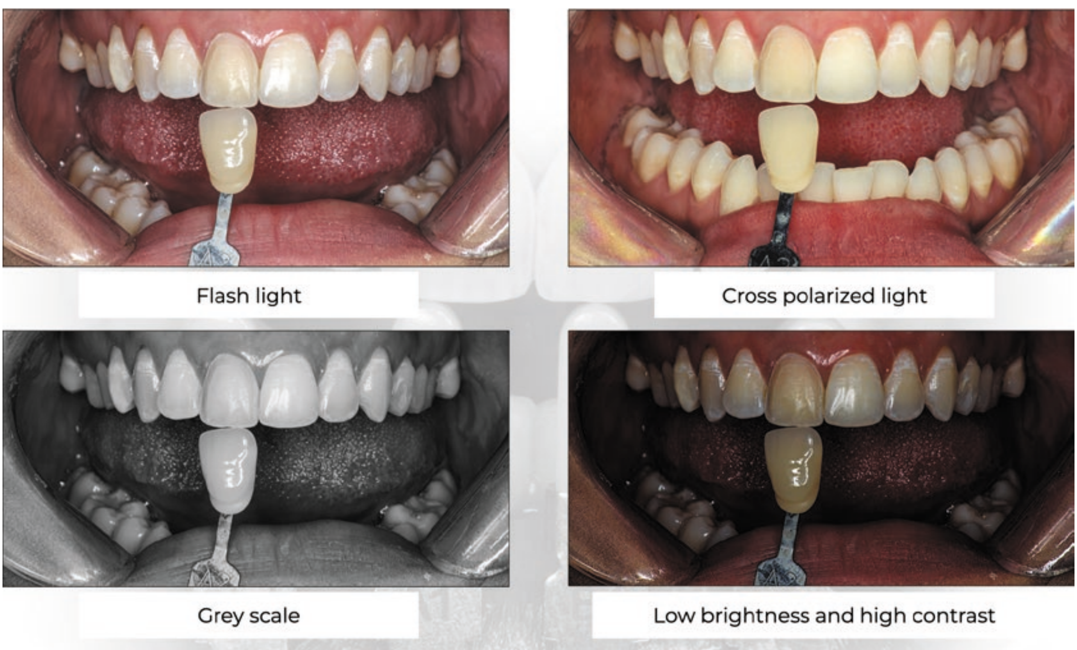

Fig. 5.22 The color taking of the substrate of the dental element, with the aid of reflected polarized light, for esthetic rehabilitation

As we mentioned at the beginning of this chapter, smartphones and compact cameras are still a long away from offering the same photographic quality achieved with DSLRs and mirrorless equipment. Nevertheless, these devices work for the entry level path in the world of dental photography and can be used until a better equipment can be acquired. Although they present some limitations (regarding sensor size and absence of a dedicated macro-lens), good results may be achieved with proper lighting and configuration setup. And indeed, a simpler picture of a clinical case performed with straightforward devices are better than no photo at all.

5.7 Photography in the Daily Practice of Dentistry

In the last decades, the evolution of digital cameras and accessories, its user-friendliness, larger accessibility, and lower costs, have exponentially increased the role of images in the dental practice quotidian.

Nowadays, it is possible to affirm that there is always a feasible way, regardless of budget, of recording dental treatment steps. Either by using an always present smartphone or a high-end camera with plenty of accessories, capturing relevant visual information opens a myriad of uses for the images. Quality will certainly vary according to the used equipment and the photographer's training and experience. Adjusting the needed equipment for one's routine is an exercise that, if well performed, will result in finding the best cost-benefit for each particular case.

The first reason to include photography in the dental practice routine to record patients' baseline and post-treatment images with the intent of documentation. It is also important for legal protection and for long-term follow-ups. As commonly said, an image is worth a thousand words. Nowadays with the availability of electronic files for patients, digital images can be easily attached and stored to records, enriching the documentation of treatment stages, and enhancing the level of recorded details.

In our experience, patients enjoy and value seeing on a screen (or even on the camera's LCD) what is being performed during treatment. A clinical picture can be a valuable instrument to increase patients' understanding of why certain procedures are needed, for educating patients on required behavioral changes, and for treatment planning. A well-known concept that uses standardized clinical pictures (and videos) for planning a dental treatment is the Digital Smile Design (DSD). It also allows digitally simulating possible treatment results and to visually explain (show) to the patient what may be achieved. This tool certainly aids esthetic treatment plan acceptance.

Post-treatment pictures, with or without an "artistic touch," are also very useful. And not only for documentation, or to allow long-term follow-ups comparisons, but to reinforce patients' perception of the dentists' work quality, which increases patients' fidelity.

Before and after photographs may also be used for marketing purposes. Be sure to always respect local regulations in terms of patients' privacy and all mandatory legal authorizations.

Well performed dental pictures greatly enhance the communication between dental professionals when discussing treatment plans and are valuable assets for educational and scientific purposes. Presenting clinical cases with images rich with relevant information, together with a solid scientific content, is the cornerstone of many of the best lectures at the main dental congresses of the world.

For those involved in prosthodontics, enabling the dental technician to see, in detail, the clinical case for which an indirect restoration will be produced is truly a must. Tooth color, shape, texture, and the singularities of each patient's tooth can be easily shared. Digital photography and, in present days, the commonly digital flux of restorative dentistry have surely increased the quality of exchanged information and reduced distances in the dentist/dental technician relationship. The use of standardized reference shade tabs, gray cards, calibrated monitors, and a good understanding of some of the dental photography concepts presented in this chapter on both the clinical and the laboratory ends of the process strengthen the level of communication [11].

On the topic of color, standardized digital photography—particularly those using concepts of exposure adjustment with a gray card and reflected cross-polarization—can be used not only to shade selection in prosthodontics [11, 12], but also for the quantification of color in clinical research [14].

5.8 Final Remarks

Dental photography is an inseparable part of modern Dentistry. In every dental specialty, predominantly those involved in esthetics, the use of images has increasingly gained relevance over the past years. Knowledge of the basics of the subject, such as required equipment, fundamentals of photography, and some practical training on achieving useful images, should be part of a contemporary dental curriculum.

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