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Digital Photography in the Orthodontic Practice

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Digital imaging, one of the hot fields in the computer world, is attracting more and more interest among orthodontists. It is now possible, with a reasonable investment, to digitally acquire, archive, and easily retrieve clinical images of our patients.

The hardware involved includes flatbed scanners, slide scanners, video cameras, and still digital cameras. Digital cameras can be divided into two main groups: compact digital cameras and professional reflex cameras with digital interface. The compact cameras range in price from $300 to $1,500, while reflex cameras start at a minimum of $5,000. In the future, we can expect compact cameras with better performance in the same price range, as well as less expensive reflex cameras.

If your budget allows you to buy a professional reflex camera, it will certainly meet all the requirements for clinical orthodontic photography. The choice of a compact camera can be difficult, due to the wide range of quality and price. Many mistakes can be made in selecting the appropriate system for an orthodontic practice.

This article will discuss the criteria that should be considered before deciding where to invest your money. A subsequent article will review some popular digital cameras.

Optical System Quality for Macrophotography

For intraoral photography, the lens system should allow adequate magnification at a distance of at least 12" from the subject. Shorter distances are of little use to the orthodontist. The optical quality depends on the camera's focal length–the distance (in millimeters) between the image sensor and the optical center of the lens when the lens is focused on infinity.

Manufacturers of digital cameras usually do not indicate the actual focal length, but rather its equivalent on a 35mm camera. For example, a focal length of 5mm on a digital camera is equivalent to 36mm on a 35mm camera. Many compact digital cameras have lens systems with a focal length of 35mm (equivalent to a 35mm camera). This value is inadequate for orthodontic intraoral photography. A 50mm focal length is sufficient, but a 100mm focal length will completely satisfy the requirements for dental photography. A high focal length allows a reasonable distance from the subject, minimizes distortion, increases depth of field, and permits adequate illumination of the subject.

Cameras with a zoom function have a variable focal length, which is expressed as a range. Focal length can be increased with a zoom lens or by the addition of close-up lenses. The best digital cameras have a zoom with a high magnification ratio and the ability to add close-up lenses.

When the zoom is moved toward the maximum enlargement position, or close-up lenses are added, it can become impossible to focus from short distances, and the effectiveness of the autofocus is reduced. Thus, you may see an image in the viewfinder that has a high magnification, but is out of focus. The balance of these factors is what determines the macro capabilities of the system.

We consider the macro quality of a digital camera to be acceptable when it is possible to capture a 70mm horizontal line at full screen, in sharp focus, from a distance of 12". This corresponds roughly to the 1:2 magnification on a conventional 35mm camera (Fig. 1)–one of the most common magnification ratios in orthodontic photography. Many compact digital cameras, however, do not achieve this quality.

Higher macro capabilities can be useful if you prefer a 1:1.7 or 1:1.5 magnification ratio. A very good optical system allows a 35mm line to be captured at full screen, which corresponds to a 1:1 magnification ratio.

Autofocus Speed and Precision

It is important to test the autofocus of a camera, taking into account the magnification ratio, distance from the subject, and illumination. Since the autofocus might not work properly under some orthodontic conditions, the availability of a manual focus is a plus.

A satisfactory autofocus for orthodontic purposes will work properly at a distance of 12" from the subject with a 1:2 magnification ratio.

CCD Resolution and Quality

In digital photography, traditional film is replaced by a Charged Coupled Device. A CCD sensor has thousands of light detectors, called "pixels", on its surface. A high number of pixels ("optical resolution") increases the quality and detail of the image, but also increases the size of the file in which the image will be saved.

File resolution can be increased by a software interpolation, which does not actually improve the image quality. Therefore, when evaluating a camera's optical resolution, the interpolation resolution should not be considered, but only the actual CCD optical resolution.

Some digital cameras allow an image to be captured at two or more different resolutions: the highest is the full CCD resolution, but the lower resolutions use only a portion of the CCD pixels to describe the image. This division can save file space if the CCD has a high optical resolution.

High resolution can only be used to full advantage when nothing extraneous to the required area is captured in the frame. Figure 2 shows an intraoral picture taken at a resolution of 832 X 624–meaning that about 520,000 pixels are used to describe the subject. However, the clinically useful area (shown by the yellow rectangle) is displayed by only 212,000 pixels. If this image has been taken at the maximum possible magnification for the camera, then the latter number represents the "clinically useful resolution" (CUR) for this camera.

The CUR, a key factor in the choice of digital cameras, depends on both the sensor resolution and the quality of the optical lens system. A new generation of compact digital cameras with sensor resolutions of as many as 1,000,000 pixels are now on the market, but they have poor optical systems that diminish their CUR. The CUR also depends on the needs of the user. If you want to photograph dental crown anatomy in detail, you will need a high CCD resolution and/or a powerful lens system.

A CUR of about 400,000 pixels should be adequate for orthodontic use. We recommend selecting a camera with a CCD resolution close to the CUR. Too great a difference will produce unnecessarily large files and thus will require more memory and a longer transfer time to the computer. If the CCD

resolution is much larger than the CUR, it will be necessary to manipulate ("crop") each file on the computer to avoid archiving unwanted information.

The sensor quality of a single pixel in transmitting the luminance (brightness) and chrominance (color hue) of the light signal should be tested by observing the images captured by the digital camera on a properly tuned monitor. Some CCDs show a minor shift in hue toward one of the base colors (red, green, or blue). In our opinion, this problem has a limited impact on image quality, since it can be easily corrected with any imaging software.

Flash Capability

In conventional dental photography, a synchronized ring flash is needed to obtain uniform illumination of the subject in macro mode. External light sources cannot be used, because the lips and chin, the camera, and the operator (who is close to the subject) will create shadows.

Most compact digital cameras have built-in flash units on one side of the lens (Fig. 3)–which will produce uneven light distribution in intraoral photography (Fig. 4)–and have no ports for external synchronized flash units. Even a camera with a connection for a synchronized flash may not allow the use of a ring flash, because it will cover the autofocus sensor. The ability to use a ring flash is therefore an important point in selecting a digital camera.

If your camera does not permit the use of a ring flash, the subject illumination can be improved in two ways:

- 1. Light deflectors (Fig. 5). A mirror system can effectively diffuse the flash light on both sides of the subject (Fig. 6). Light deflectors for some digital camera models are currently on the market.
- 2. Light-activated external flash. It may be possible to mount an external flash on the opposite side of the built-in flash. The two flashes will operate simultaneously, producing good illumination of the subject without shadows.

Viewfinder

An optical reflex viewfinder is ideal, because it provides an almost perfect correspondence between the image seen in the viewfinder and the captured image under all conditions.

An alternative is a Liquid Crystal Display viewfinder. The LCD can be as small as .5", in which case an optical system allows proper magnification with the eye in close contact with the viewfinder, as with most video cameras (Fig. 7). An LCD can also be a small screen, 1.5-2.5" in diameter, in which case the camera must be held away from the eye when shooting (Fig. 8). Most LCDs have a low "refresh rate", meaning that as the camera is moved to frame the best picture, the image in the viewfinder changes jerkily. Other disadvantages are that an LCD is hard to read in bright sunlight, and that a large unit consumes a great deal of battery power.

Digital cameras with Galilean viewfinders are difficult to use, because in macro photography the area framed by the viewfinder will be quite different from the one framed by the lens.

Immediate Review of Recorded Images

This is one of the most important advantages of digital cameras over conventional cameras. You can check the recorded image a few seconds after taking the picture and decide whether it is satisfactory.

If not, you can delete it immediately from the camera memory and take another shot.

Since most compact digital cameras allow replay of recorded images on their LCDs, we recommend avoiding the few that do not.

Tuning of Exposition Parameters

In macro photography, it is important to be able to manually adjust the exposition parameters: the size of the lens opening (aperture), indicated by the f-number, and the shutter speed, measured in fractions of a second. It is often difficult for the automatic mechanism to function properly at close distances, particularly if the flash is used, as is often the case with intraoral photography.

Batteries and AC Connection

Some digital cameras use ordinary alkaline batteries and have a battery life of only 10-15 photographs. Others have rechargeable batteries that can last through more pictures. If your digital camera comes with two rechargeable batteries, you will never experience the "no battery" situation.

An external AC connection can be helpful even if it is not used routinely. The power cord tends to interfere with operator movement, and a socket must be available nearby.

File Format and Software Compression

Once an image has been acquired by the CCD, it is stored in the camera's memory as a file. Image files can be of different formats and, more important, can be compressed. Compression increases the number of images that can be stored in memory, but it also causes a decay of the image quality; the higher the compression, the greater the decay.

A good feature is the ability to choose whether the images are to be saved with or without compression, and at which compression level. This is usually done by selecting the capture mode as "FINE", "NORMAL", or "ECONOMY" (the terms may vary depending on the camera model).

The file storage format is not critical, but it is preferable to use digital cameras that save the acquired images as JPEG or TIFF files, which can be read by virtually any imaging software. Proprietary file formats will require special software.

Number of Images Stored in Memory

There are two types of image storage: built-in (internal) memory and removable memory. Digital cameras with only internal memory should be avoided. Removable memory is like a conventional roll of film that can be used over and over again. Four types of removable memory are currently available for digital cameras:

- Solid State Floppy Disk Card (SSFDC) or "smart card"
- Miniature card
- Compact flash card
- 3.5" floppy disk

SSFDCs can store only as much as 8MB of data, while miniature cards store as much as 24MB.

These two media need a converter that is inserted in a floppy disk or PCMCIA drive.

Compact flash cards can be found in sizes from 2MB to more than 100MB and do not need an adapter for insertion in a PCMCIA drive. Floppy disks are inexpensive and easy to use, but have a storage capacity of only 1.4MB.

The amount of space taken by one image depends on its resolution and on the file compression. An uncompressed image with a resolution of 1,280 X 1,024 takes up 3.75MB, while an 800 X 600 image can be compressed to only 100KB.

A digital camera should have enough memory so that the images do not have to be downloaded to the computer too often. Thirty or forty images are usually sufficient for a whole day of shooting before downloading. Individual practice needs can vary, however.

To determine the amount of removable memory you need to add to your digital camera, count the number of pictures you shoot in an average day and double that number. Calculate the file dimension for each image at the quality you need (this is not always the best possible quality). For example, if you take an average of 20 pictures per day and your digital camera saves the images in 200KB files with acceptable quality, you need an 8MB memory.

Speed of Transfer to Computer

All images stored in the digital camera's memory are eventually transferred to a computer for archiving. The time needed to transfer the images depends on two factors: the size of the image files and the transfer speed (in KB/second). Since the file dimension is determined by the resolution and compression of the image, a reduction in size will have a negative impact on image quality. Therefore, transfer speed is the key variable.

There are two different ways to transfer the images from the camera to the computer:

- 1. Cable connection. Most digital cameras can be connected to a PC or Macintosh computer through a serial or parallel port. This kind of connection is extremely slow, however, and serial transfer is slower than parallel. Some cameras can use a SCSI port, which is much faster, but not available on all PCs.
- 2. Transfer from removable memory through a computer drive. This is probably the most convenient way to transfer the images to the computer.

If the digital camera uses compact flash cards, miniature cards, or SSFDCs, a PCMCIA drive is the method of choice. PCMCIA drives are built into all notebook computers (both PC and Macintosh), but can also be mounted in any desktop PC. We have not found a PCMCIA drive for a Macintosh. File transfer through a PCMCIA drive is extremely fast and easy.

If the camera uses a floppy disk for removable memory, the floppy drive of the computer can be used for file transfer. Floppy disk reading speeds are slow, however, and since each disk can hold only 1.4MB of data, they are used only by digital cameras that store files of limited size.

Conclusion

The ideal features of a compact digital camera can be summarized as follows:

- Lens system with a high focal length and a powerful zoom, allowing intraoral photography with at least a magnification comparable to the 1:2 lens of 35mm cameras.
- Optical resolution of at least 500,000 pixels.
- Clinically useful resolution of at least 400,000 pixels (depending on the two previous criteria).
- Both auto and manual focus.
- Ability to use a ring flash.
- Optical reflex viewfinder, or LCD with a high refresh rate.
- Capability of reviewing the recorded image on the viewfinder screen.
- Ability to manually tune exposition parameters.
- Rechargeable batteries and AC connection.
- External memory that will store an adequate number of images and speed up file transfer to the computer.

Features to avoid include:

- Fixed focal length of 35mm (equivalent to a 35mm camera).
- Low optical resolution (640 X 480 or 300,000 pixels).
- Galilean viewfinder.
- Alkaline batteries.
- Built-in memory only. □

RECOMMENDED READING

- 1. Sawyer, B. and Pronk, A.: *Digital Camera Companion* (book and CD-ROM), Coriolis Group, Scottsdale, AZ, 1997.
- 2. Aitken, P.G.: *Digital Camera Design Guide* (book and CD-ROM), Coriolis Group, Scottsdale, AZ, 1997.
- 3. Kasai, A.; Sparkman, R.; and Hurley, E.: *Essentials of Digital Photography*, New Riders, Indianapolis, 1997.

FIGURES

Fig. 1 1:2 magnification with 35mm camera: 70mm line corresponds to horizontal dimension of film.

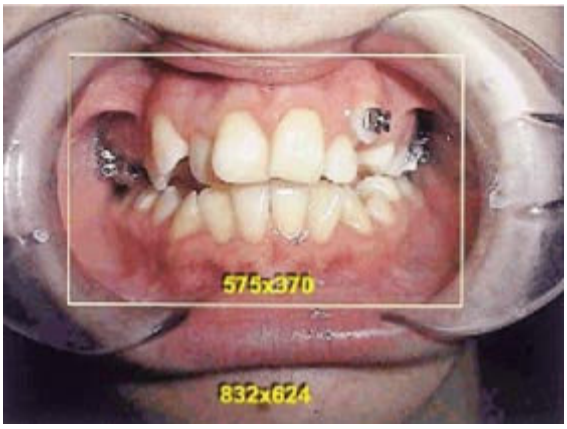

Fig. 2 Clinically useful resolution displayed by only 212,000 pixels (framed) of 520,000 pixels in entire image.

Fig. 3 Built-in flash on side of camera.

Fig. 4 Demonstration of problems with laterally positioned flash unit (on left side of lens). A. In front view, right side is insufficiently illuminated. B. In lateral view, soft tissues project shadow on molar area and central incisors are poorly illuminated.

Fig. 5 Light deflector on digital camera corrects asymmetry of flash unit.

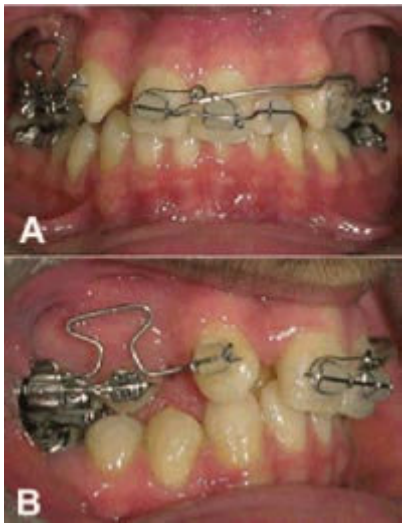

Fig. 6 Photographs taken with camera in Figure 5. A. In front view, light is well distributed. B. In lateral view, no shadows are present.

Fig. 7 LCD viewfinder.

Fig. 8 Image shown in 1.5" LCD screen.