

Viewing your digital radiographs: which monitor is best?

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VERIFIABLE CPD PAPER

IN BRIEF

- Explains specifications relating to monitors for clinical practice.
- Looks at the differences in medical grade and commercial monitors.
- Suggests image quality checks for a monitor.

Many dental practitioners use flat panel monitors in their practices on a daily basis, and for those practitioners who have made the move to digital imaging, the use of this device often extends to viewing digital radiographs. Monitors that present good quality images should be used and the image quality should be checked. This article provides practitioners with some of the key areas they should consider when selecting or buying a flat panel monitor for dental radiology purposes.

INTRODUCTION

As with many film-based modalities, dental radiography is making the switch from conventional film to digital. It should be remembered that dental film that has been properly exposed and developed, and viewed on an adequately maintained illuminator under reduced ambient light will still produce a quality image that is permanent. A dentist who is considering the move from film-based to digital imaging would need to consider radiation dose, infection control, the type of image receptor, digital image manipulation, image storage and mode of display.

Computer monitors, and even handheld devices such as personal digital assistants (PDAs), smartphones, and tablet devices can be used to view a variety of images (Fig. 1). However, until further research is carried out on the use of these handheld devices for image display in dental radiology and appropriate guidelines from professional bodies are developed, it may be prudent to view these images on the type of monitors one would normally encounter in the dental practice, which are usually positioned to facilitate the ergonomics for the dentist in question. The greyscale values that are displayed by the monitor help the dentist to evaluate the type of tissues being examined,

to assist in determining the origin of lesions and to look for density changes within the displayed structures, especially bone, so it is important that the monitor provides a good overall presentation of greyscale. The use of colour in dental imaging has also increased significantly in the past few years, and both extra-oral and intra-oral photography is now an increasing part of dental record-keeping and so accurate colour display is also important. Soft copy dental images may also be shared among practitioners as part of the patient's care pathway in a number of disciplines and particularly in the area of implant planning and treatment, so there is a need to select monitors that are appropriate for viewing these images and an increasing expectation that quality assurance is undertaken on these display devices.¹

MONITOR SPECIFICATIONS

Brightness is a subjective quality, a perception that humans express in terms of 'dark', 'dim', 'bright' or something intermediate. Flat panel monitors are usually liquid crystal display (LCD) or light emitting diodes (LED). LCDs use cold cathode fluorescent lamps (CCFLs) to provide backlighting, whereas LED monitors use an array of smaller usually more efficient light emitting diodes to illuminate the screen so that one can perceive the level of brightness. Whatever the type of flat panel monitor, the fundamental function is to emit a quanta of light (luminance) which is detected by the retina and processed by the visual cortex (Table 1). Luminance can be measured with a photometer and can be expressed in absolute numbers such as candela per metre squared (cd/m^2).

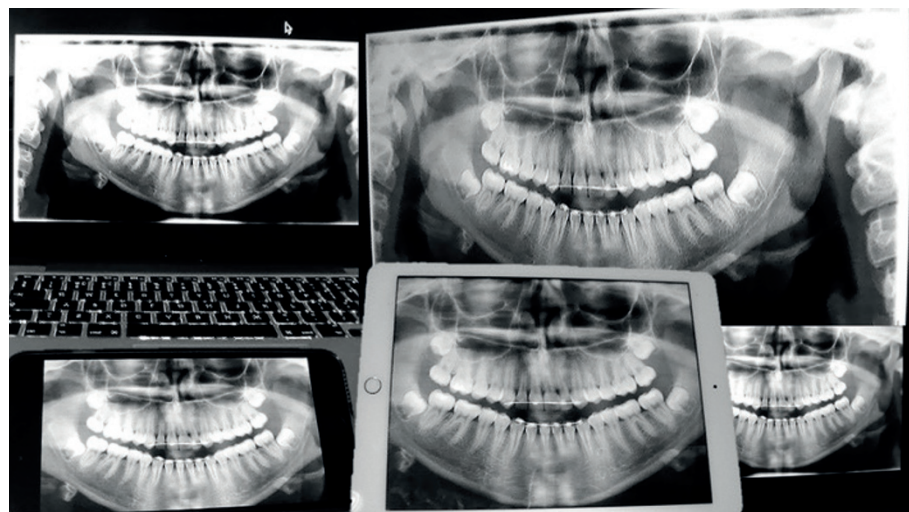


Fig. 1 Dental practitioners need to consider the type of device on which they are viewing and interpreting digital dental radiographs

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When one sees a maximum luminance of the order of 250-300 cd/m² quoted in the list of specifications for a particular monitor, this value would produce an acceptable brightness for assessing and interpreting dental radiographs. The contrast ratio is the ratio between the brightest white and the darkest black with all the greys in between that a monitor can produce. A contrast ratio of 1,000:1 stated in the list of specifications would tell us that the minimum luminance for this particular monitor is around 0.3 cd/m². Resolution, which usually refers to the total number of pixels that a monitor can display, is often misconstrued as the most important specification when selecting a monitor, and while high resolutions are vitally important for many life-saving medical radiology applications, resolutions of 1 and 2 megapixels and screen sizes from 18 to 24 inches seem adequate for dental radiology at the present time, especially when the viewing software often allows image manipulation features such as panning and magnification for the end-user.² These specifications contribute to the aspect ratio of the monitor which make up the actual active video area of the screen. A monitor stating a native resolution of 1,920 by 1,080 in the specifications has a pixel density of 2 megapixels (MP), and it is important to remember that spatial resolution is both a function of the size and luminance of the pixels displaying the image.

Practically all flat panel monitors used routinely in dentistry are colour monitors and are connected to a display controller (graphics card, video card) which is a piece of electronic circuitry inside the computer that creates the picture on a monitor.

It is recommended for viewing and manipulating Cone Beam Computed Tomography (CBCT) images that the monitor is connected to a dedicated graphics card. Flat panel monitors transmit light, and the brightness levels of the red (R), green (G) and blue (B) subpixel components of the monitor screen is what determines the colour and appearance of a presented image. However, for a greyscale image these subpixels transmit light at brightness levels $R = G = B = 0$ (black) and $R = G = B = 255$ (white), meaning that a colour monitor will display a radiographic image in 256 shades of grey. In the list of specifications it would state that these monitors can display over 16 million colours often referred to as true colour or 32 bit colour, which translates into 256 shades of grey or 8 bit greyscale when displaying dental radiographs. The response time for the monitor is the time it takes for a pixel to change colours or from black to white, or to transition from one shade of

Table 1 The main specifications to consider when selecting a monitor for dental radiology

Specification	Comment
Screen size	Measured diagonally in inches for example, 20 inches
Screen panel	LCD or LED
Maximum brightness	Maximum luminance for example, 300 cd/m ²
Contrast ratio	Ratio of maximum luminance to minimum luminance, for example, 1000:1
Native resolution	Horizontal pixels x vertical pixels for example, 1920 x 1080 is 2 megapixels (2 MP)
Displayable colours	32 bit colour or 256 shades of grey
Aspect ratio	Ratio of the width of the screen to the height, for example, 16:10 for most modern flat panel monitors
Response rate	Time taken for the transition from one shade of grey to another for example, 8 ms

grey to another when viewing radiographs. It is most relevant when displaying video, a response time in and around 8 milliseconds (ms) shown in the specifications would be quite adequate for still images. Almost all flat panel monitors have a refresh rate of 60 Hz (a refresh rate is the number of times per second that the monitor can redraw the entire screen). There is no issue with flicker for these monitors because the backlight is always on. The detectable changes in grey level are produced over the luminance range for the monitor and can be controlled to some extent by the brightness and contrast controls of the monitor. This characteristic is known as the 'gamma' and it should be appreciated that every monitor has a unique and variable way of producing these changes in luminance such that a grey level can be perceived.³

To overcome any variability in image presentation from different monitors it is recommended in medical radiology that monitors are calibrated to the Digital Imaging and Communications in Medicine Greyscale Display Function (DICOM GSDF),⁴ and recent research in dentistry has found that monitors calibrated to this function can improve the presentation of dental images for the observer.⁵ The benefits of this calibration process are threefold.

- It optimises brightness changes within the monitor in such a way that the grey levels are readily perceived by the visual system of the observer
- The maximum number of perceived grey levels that the monitor can produce are identifiable to the human visual system.
- There will now be a consistent presentation of displayed images from different calibrated monitors, and on the same monitor at different times.

Finally ambient light or diffuse light can come from many directions in the dental surgery as indirect light sources, it will add

to the minimum luminance that the monitor can display and the contribution from this bright surrounding light could effectively wash out the display of some structures in the dark area of a displayed image, therefore it is good practice to view the displayed image on the monitor in subdued lighting.

MEDICAL GRADE OR COMMERCIAL-OFF-THE-SHELF (COTS) MONITOR

The type of the monitors that are used in dental surgeries are for the most part commercial-off-the-shelf (COTS). A few of the companies that manufacture and distribute the high-end medical grade monitors have now turned their attention to the production of monitors specifically for dentistry. There are differing opinions as to whether medical grade monitors (Fig. 2) offer any superior diagnostic properties for observers over COTS in medical radiology,^{6,7} and the same question is now being asked regarding their use in dental practice.^{2,8,9}

While it is clear that with the continuing advances in COTS monitor technology to meet consumer demands, dental practitioners will be able to select COTS monitors that have a high luminance profile and if calibrated to the DICOM GSDF by software packages which are readily available to achieve this transformation, then these monitors (Fig. 3) should be able to display optimal and consistent images for diagnostic purposes. Nevertheless, the contribution to the quality of care and the safety of the patient should always be the defining outcome when selecting display devices for clinical practice.

Brettle¹⁰ describes a five tier banding scheme for monitors used for viewing soft copy images in the hospital environment, with the top two categories for high level reporting, a middle category for interpretation that would feedback immediately to clinical activity and would correspond to the situation one usually encounters in dental practice,



Fig. 2 A high-end DICOM GSDF calibrated medical grade monitor that would be found in the reporting room of a medical radiology department. Image used with permission from Barco

and two lower bands that are strictly reviewed and used for non-diagnostic purposes. A soft copy display used for interpretation, and in the treatment of the patient would be considered a medical device, and this type of monitor should be able to meet the requirements that have been stipulated by various guideline documents that are currently available.^{1,11} Therefore, one important and defining technical factor for monitor selection that must be taken into account is the difference in luminance stabilisation between a medical grade monitor and COTS monitor. Even with a high luminance COTS monitor, when the monitor is first turned on, luminance output tends to be lower until the backlight warms up. They slowly increase to maximum luminance over the first 30 to 60 minutes of run time and dental research in this area has shown that COTS monitors are more prone to a gradual deterioration in luminance level over time.¹² Medical grade monitors typically have a backlight capable of producing much more luminance than required when the monitor is new ($>350 \text{ cd/m}^2$), these monitors also have a luminance stabilisation circuit which allows them to maintain a constant brightness over a much longer time period than COTS monitors.

Unlike COTS that have to be calibrated to the DICOM GSDF using a software package, these medical grade monitors are pre-calibrated to this function, and the manufacturers of these monitors will provide the purchaser with software and assistance to undertake quality assurance testing on their brand of monitors. These high brightness medical grade monitors are much more suitable for the bright surroundings of the dental surgery and recalibration to

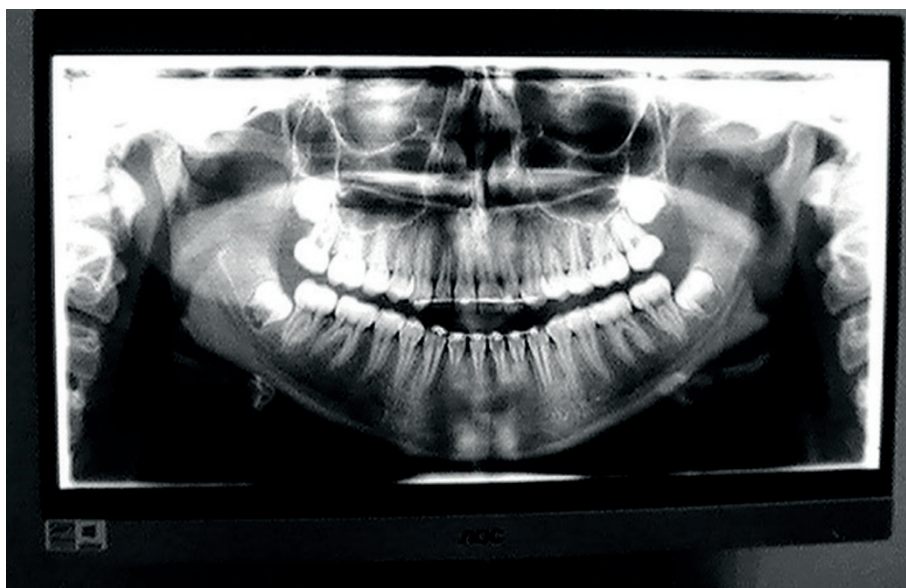


Fig. 3 A commercial-off-the-shelf (COTS) monitor that is usually found in most dental practices, and could be calibrated to DICOM GSDF using a specific software package



Fig. 4 Dedicated medical grade monitors for dental applications have a stabilized brightness at all times, are pre-calibrated to DICOM GSDF, will follow a manufacturer's quality assurance (QA) protocol, and are designed to facilitate decontamination. Image used with permission from Barco

the DICOM GSDF does not need to be performed as often as would be required for a COTS monitor. Furthermore, medical grade monitor manufacturers are also developing their technology in other important areas, and Brettle's banding scheme offers credibility to these endeavours. The monitors that would be placed on the upper end of the banding scheme would be devices that are safe to be positioned in the patient environment with added grounding and reduced current leakage and other electrical safety features that would conform to International Electrochemical Commission (IEC) electrical safety guidelines.¹³ Manufacturers of medical grade monitors are developing monitors with a fully cleanable design so that they

are sealed completely to prevent moisture and liquid from getting to the inside of the device. This design is reflected in the monitor's IP rating where the first digit indicates the level of protection from solid objects, and the second digit indicates the level of protection from liquids. Some technically advanced monitors may have an IP rating which indicates that the whole unit is sealed front, back and sides to the ingress of any cleaning agents or disinfectants that are applied. A general dental practice therefore might need one monitor dedicated to the evaluation of radiographs in the confines of the clinical practice area (Fig. 4), and a different monitor situated more remotely for all other types of work.

MONITOR IMAGE QUALITY

Softcopy display of digital images is the last component in the imaging chain and optimisation of image quality is a requirement when using medical ionising radiation, therefore it is important that the monitor displaying the digital dental radiographs is checked. The optimal and consistent display of image quality for a monitor is one area that can be checked by qualitative and quantitative methods using an appropriate test pattern such as the Society of Motion Picture and Television Engineers (SMPTE) (Fig. 5). The pattern should be displayed in full screen and daily checks can then be carried out in the dental surgery (Table 2).

- The screen of the monitor should be kept clean from dust, finger prints and anything that could obscure parts of the image. A slightly dampened cleaning cloth followed by a drying cloth can be used or the manufacturer’s method for cleaning should be followed
- The pattern should be in the active area of the display monitor, the border around the pattern should be straight. The vertical and horizontal grid lines throughout the pattern should also be straight and not misaligned
- The alphanumeric characters at the bottom of the pattern should be clear and in focus
- The change in grey level increments in the 0% to 100% squares in the middle of the test pattern should be observed
- The horizontal and vertical high contrast line – pairs should be distinguished at the centre and corners of the test pattern to check the resolution of the monitor
- Adequate brightness and contrast is determined by detecting the square within a square for the squares that are labelled 0/5% and 95/100%.

More quantitative type measurements (Table 3) that would require the use of a photometer and medical physics support should be carried out on an annual basis.

- The minimum and maximum luminance of the monitor can be recorded by taking a reading for the 0% and 100% squares respectively, this will allow an estimate of the contrast ratio
- The uniformity of the luminance output over the whole screen can be determined by taking luminance readings of the grey squares from different areas of the screen
- A quantitative value of conformance of the monitor to the DICOM GSDF can be obtained by recording luminance values for each of the 0% to 100% squares at the centre of the pattern (Fig. 6)

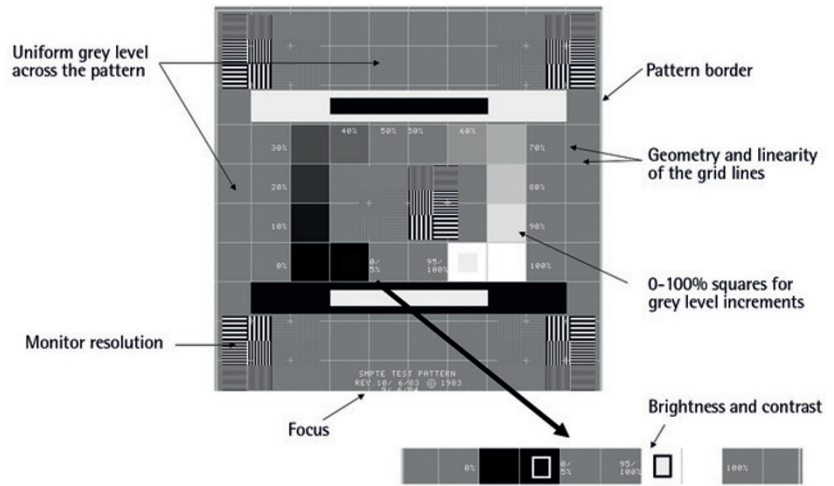


Fig. 5 The SMPTE test card can be used to carry out quick monitor quality checks in the dental surgery as well as quantitative tests

Table 2 Daily checks on monitor quality that can be carried out by dental staff within the dental surgery

Check	Procedure
Monitor screen cleanliness.	Clean monitor screen with power off.
Visibility of the grey level steps.	Observe 0% to 100% squares.
Linearity and geometric distortion.	Observe pattern border and grid lines.
Uniformity of the image.	Observe grey squares in different areas of the pattern.
Focus	Observe alphanumeric characters.
Resolution	Distinguish horizontal and vertical line pairs.
Brightness and contrast.	Distinguish 0–5% squares and 95–100% squares

Table 3 Annual checks on monitor quality that would require medical physics input

Check	Procedure
Minimum luminance	Photometer reading of the 0% square
Maximum luminance	Photometer reading of the 100% square
Contrast ratio	Maximum luminance: Minimum luminance
Luminance uniformity	Photometer readings from different grey squares
DICOM GSDF	Calculated from photometer readings of the 0–100% squares
Ambient lighting	Illuminance reading with a lux meter

- A reading of the ambient light level (illuminance) in the dental surgery or in the vicinity of the monitor should also be taken using a lux meter.

An additional useful observer performance method that could be carried out in the dental surgery to check image quality between monitors is a visual grading method.¹⁴ Fulfilment of image criteria (IC) is the simplest visual grading method, in which the task of the observer is to state whether a certain criterion is fulfilled or not in a presented clinical image. An image criteria

score (ICS) is then calculated as the proportion of fulfilled criteria and would allow a quantitative value to be established for the monitor in question.

CONCLUSION

The future will see medical grade monitor manufacturers understanding the imaging needs of the dental profession by providing monitors with screen panels that can offer 12 and 16 bit greyscale precision for the display of dental images. At the present time 10 bit precision is already the norm for the screen panels of most of these medical grade monitors

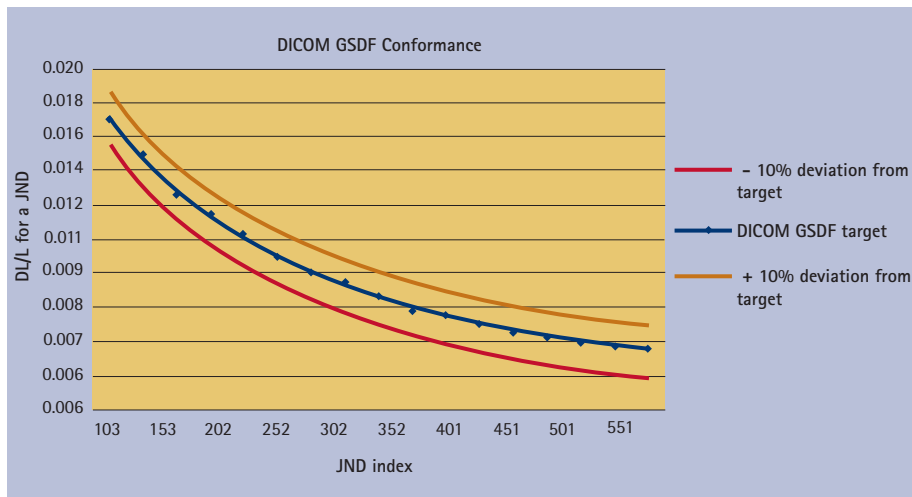


Fig. 6 Extract from quality assurance (QA) software showing the conformance of a tested monitor to the DICOM GSDF target. The change in luminance (DL/L) for a just noticeable difference (JND) is plotted against the JND index for the monitor. The 10% tolerance intervals for a diagnostic monitor are shown

available for dental use. An agreed standard for the high quality visualisation of colour medical images will be established. Dedicated monitors for dental radiology will come with an associated display controller that will allow 10 bit or higher input of data to allow the display of more of the data that has been captured during the acquisition stage and possibly more structures within the image could be visualised. In CBCT imaging these display controllers will integrate with the reconstruction software through their own graphics processor units to allow parallel processing of the captured image data and produce much clearer and sharper segmented aspects of the 3D rendered views resulting in crisper and anatomically accurate dento-alveolar structures. Flat panel monitors

have a space saving design, they are light, consume low levels of electricity and have a low heat production. With regular quality assurance checks by staff within the dental practice, one would expect monitors used for dental radiology to display optimal and consistent images. However, dental practitioners should also consider patient safety and other quality factors along with luminance profile when selecting monitors for clinical practice.

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