Evaluation of 4 Commercial Viewing Devices for Radiographic Perceptibility and Working Length Determination

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Abstract

Introduction: This study compared images displayed on 1 desktop monitor, 1 laptop monitor, and 2 tablets for the detection of contrast and working length interpretation, with a null hypothesis of no differences between the devices. **Methods:** Three aluminum blocks, with milled circles of varying depth, were radiographed at various exposure levels to create 45 images of varying radiographic density. Six observers viewed the images on 4 devices: Lenovo M92z desktop (Lenovo, Beijing, China), Lenovo Z580 laptop (Lenovo), iPad 3 (Apple, Cupertino, CA), and iPad mini (Apple). Observers recorded the number of circles detected for each image, and a perceptibility curve was used to compare the devices. Additionally, 42 extracted teeth were imaged with working length files affixed at various levels (short, flush, and long) relative to the anatomic apex. Observers measured the distance from file tip to tooth apex on each device. The absolute mean measurement error was calculated for each image. Analysis of variance tests compared the devices. Observers repeated their sessions 1 month later to evaluate intraobserver reliability as measured with weighted kappa tests. Interclass correlation coefficients compared interobserver reliability. **Results:** There was no significant difference in perceptibility detection between the Lenovo M92z desktop, iPad 3, and iPad mini. However, on average, all 3 were significantly better than the Lenovo Z580 laptop (P values $\leq$.015). No significant difference in the mean absolute error was noted for working length measurements among the 4 viewing devices (P = .3509). **Conclusions:** Although all 4 viewing devices seemed comparable with regard to working length evaluation, the laptop computer screen had lower overall ability to perceive contrast differences. *(J Endod 2015;41:1120–1124)*

Key Words

Contrast, display, perceptibility curve, perception, working length

Digital radiography has become a staple in modern endodontic treatment (1). Concerns that digital sensors produce inferior images compared with traditional film have been overcome with advancing technology. Many studies have found that digital images are comparable with those acquired on film (2, 3). Digital radiography offers advantages of instantaneous image generation, a potential reduction of radiation dosage, and image manipulation and storage capabilities (4, 5).

Investigations have mostly centered on image acquisition, including X-ray units and sensors. However, interpretation also depends on the image display device and viewing conditions. Display differences include monitor size, pixel number, graphics card pixel depth, and screen luminance (6). Display quality may impact image interpretation.

In the last decade, cathode ray tubes have been replaced by liquid crystal display and light-emitting diode monitors, which offer reduced size and reflection characteristics. (7, 8). Portable devices such as the iPad tablet (Apple, Cupertino, CA) have risen in popularity and hold promise in clinical and academic endodontics. Apple's iPad 3 boasts a "retina display," touted as a high-resolution device with more than 3 million pixels (9). The iPad mini, available with a nonretina display, has a 7.9-inch screen, lending much versatility in various settings (10). Few evaluations of tablet performance in dental radiography exist (11, 12).

The perceptibility curve (PC) test has been used to evaluate the performance of radiographic imaging systems (13). An aluminum block, with several variable-depth milled details, is exposed by a digital radiography system, and observers record the number of image details perceived. This test evaluates a system's contrast resolution (the ability to differentiate between areas of differing radiographic density). This method has also been used to compare different types of image acquisition systems and image enhancement modalities (14–16). Few studies have looked at the effect of the image display device on perceptibility outcomes.

Numerous studies have compared the accuracy of film-based versus digital images regarding working length measurement (17–21). Successful endodontics requires attention to proper working length, allowing canal systems to be adequately cleaned, shaped, and obturated (22). The ability to detect the terminus of a file is critical in establishing and verifying this length (23). Digital sensors capture information, and display monitors allow visualization and interpretation. Portions of the information

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0099-2399/$ - see front matter

http://dx.doi.org/10.1016/j.joen.2015.02.027

captured on digital sensors, especially the file and root ends, may be invisible or misinterpreted if displayed on a low-quality monitor. The 4 tested in this study were selected because they are all widely available and commonly used viewing devices and therefore may be used by endodontists in their offices. The aim of this study was to compare images on 4 display devices to determine differences between them with respect to the perception of detail by means of a perceptibility test and errors in working length measurements. The null hypothesis stated that there were no differences between the display devices.

Materials and Methods

Part 1

Three aluminum perceptibility test blocks (7 mm × 15 mm × 25 mm) were obtained (24). Blocks were divided into 15 squares by 1-mm-deep boundary lines. Ten randomly selected squares contained circular depressions 2 mm in diameter with depths ranging from 0.1–0.9 mm (in 0.1-mm increments) and one at 1.5 mm. Five squares, serving as controls, had no depressions (Fig. 1*A* and *B*).

Test blocks were radiographed with an X-ray unit (Progeny Dental, Lincolnshire, IL) operating at 60 kVp and 70 mA, and images were acquired using a new Schick (Sirona Dental Systems, Long Island City, NY) CDR Elite sensor (size 2). Fifteen different exposure settings were selected from 0.02–0.5 seconds, which gave a wide range of underexposed and overexposed images. The exposures in μC/kg were measured at every setting using a calibrated ionization chamber (Unfors Raysafe, Billdahl, Sweden). The 45 resultant images (15 exposures of each of the 3 blocks) were converted to the Tagged Image File Format (TIFF) to avoid "lossy" compression (Fig. 1).

Six observers (3 endodontic residents and 3 endodontists) evaluated test block images on 4 different display devices: the Lenovo Thinkcenter Desktop M92z (Lenovo, Beijing, China), the Lenovo Ideapad Laptop Z580 (Lenovo), the iPad 3 tablet, and the iPad -mini Tablet. Table 1 shows details for each device. The images were inserted into a PowerPoint 2010 (Microsoft, Redmond, WA) slideshow. Four different viewing orders were created using a random sequence generator (Randomness and Integrity Services Ltd, Dublin, Ireland). Additionally, images were randomly rotated 90°, 180°, and 270° to prevent pattern recognition.

The iPad devices were set at 75% brightness and the Lenovo devices at 100% brightness. These values were subjectively determined by the investigators to produce a similar luminance on both types of devices. Without altering brightness or contrast, observers recorded the number of radiolucent circles that they visually detected (with 100% confidence) for each image. With a minimum 24-hour interval between sessions, observers examined all of the images on each of the 4 devices. Viewing conditions were standardized by stationing the observers under the same clinic lighting conditions and ensuring a consistent black background on the screen around the aluminum block image. A location was selected in the resident room that reflected clinical conditions. No attempt was made to exclude ambient light, only to select a location that reduced reflections from it. Each device was positioned 18 inches from the front of the table, and the center of the display screen was positioned 12 inches in height. A microfiber pad was used to clean each display before each session. Observers repeated the viewing of 15 images (representing all exposure levels) 1 month later to measure intraoperator reliability.

Part 2

Access cavities were prepared in extracted, deidentified, single-rooted human anterior teeth. Orifices were located, and crown-down coronal shaping was completed using Gates Glidden burs (Roydent, Johnson City, TN). K-files (Roydent) were used to negotiate the canals until the tip of a 15 K-file was visualized flush with the major apical foramen using a dental operating microscope (Global Surgical, St Louis, MO) at 8× magnification. Teeth with atypical foramina locations, unnegotiable canals, or aberrant anatomy were excluded.

The file was removed and measured, and the incisal edge of the tooth was reduced until the tooth measured to the nearest whole millimeter confirmed with a digital caliper (Global Industrial, Port Washington, NY). Size 15 K-files were variably placed among 42 samples, from 2 mm short to 0.5 mm beyond the major foramen, and then secured in place using bonded, flowable composite resin (Ultradent, South Jordan, UT; 3M, Saint Paul, MN; and Meta-Biomed, Chungcheongbuk-do, South Korea). Each tooth with its affixed file in place was impressed in a prepared socket of a human mandible using Apex Putty (Acadental, Overland Park, KS), allowing ease of sample interchange and reproducible spatial relationships.

To eliminate image distortion, an apparatus was constructed to guarantee a proper, consistent relationship between the x-ray tube, mandible, and sensor. The source-object distance was fixed at 30 cm, and a 1.5-cm-thick plexiglass plate mimicked the soft tissue effect. Images were acquired at 60 kV and 7 mA at 0.2 seconds (9.3654 μC/kg) using a new Schick CDR Elite size 2 sensor. These exposure settings produced optimal darkness and contrast as determined by consensus of the observers. This resulted in 42 images of extracted teeth with files placed anywhere from 0.5 mm beyond the outer surface of the root to 2.0 mm short of the outer surface of the root.

Each of the 42 working length images was evaluated by the same 6 observers on each of the 4 display devices with a minimum 24-hour interval between sessions using installed Schick software or via a remote desktop connection. Images were arranged randomly. Observers used the software measurement tool to determine the distance from the file tip to the outer surface of the root. A mouse or stylus was used as a pointing device for the desktop and laptop or tablets, respectively. If the file tip extended beyond the outer surface, a positive number was entered. If

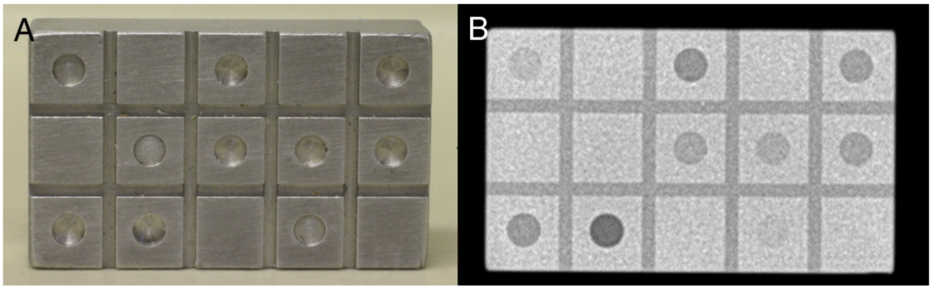

Figure 1. (*A*) The aluminum test block and (*B*) the corresponding radiograph.