RELIABILITY OF DIGITAL IMAGING SYSTEMS IN ORTHODONTICS

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Imaging is an important tool in orthodontics. We use it to record and measure the size and form of the craniofacial structures, as these elements are essential in diagnosing and treatment planning our cases. Today we can run a practice almost paper free by using electronic patient records instead of paper records. Along with the advantages of digital technology, however, there are downsides, and orthodontists must be aware of them before jumping into the world of digital imaging.

Digital imaging is widely employed in medicine. In the field of orthodontics, digital imaging is involved in:

- digital photography
- digital radiographs (with/without software on-screen digitizing)
- treatment prediction software
- 3D study models
- turning existing paper records into digital records

While digital imaging has many advantages, it also has complex issues such as picture quality, color balance and contrast, sharpness and file size that are problematic. Despite the growing use of digital images, there have been few attempts to standardize digital photography.

Previous research has shown the importance of color when digital images are used for diagnosis and treatment planning. In some areas of medicine, *e.g.* dermatology, plastic surgery and forensics, a number of critical medical decisions are based on morphological evidence observed in various color images. Accurate recording and reproduction of colors is essential; color inconsistencies may lead to erroneous diagnoses. In orthodontics, poor color reproduction of digitized images does not really affect diagnosis or treatment planning, but color consistency of digital photographs still should be a priority in the protocol for orthodontic records (Fig. 1).

Another area that is inadequately standardized is how digital photos are obtained. Incorrect positioning of the camera in terms of distance and height of the camera can lead to severe distortions. Classification of certain orthodontic problems can be altered by a photograph taken from a different angle. The intraoral photographs in Figure 2 are of the same patient. The patient's deep bite can be increased or decreased depending on the angulation of the photo. Figure 3 demonstrates that altering the parallax of the camera can make the patient's left buccal segment appear more Class I.

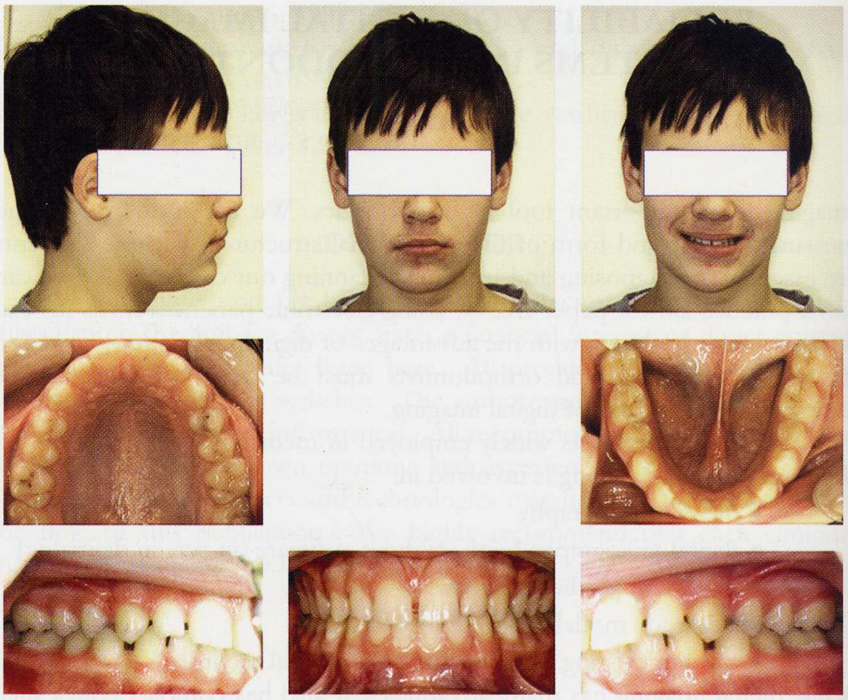

Figure 1. Color inconsistencies are often seen in composites of digital pictures.

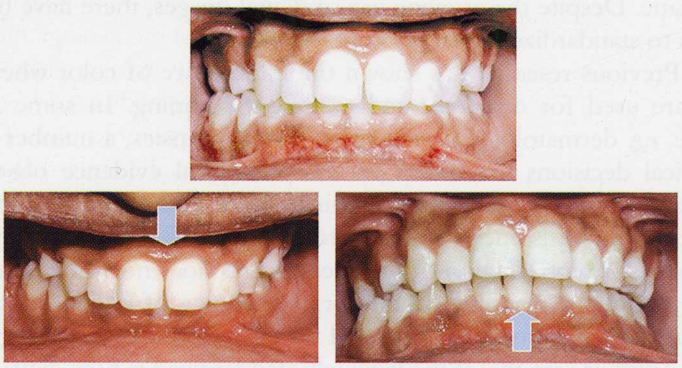

Figure 2. Altering the angulation of the camera changes the depth of the patient's bite.

Digital images are more efficient and inexpensive to store than conventional photographs, but most software applications limit the file size. Therefore, in order for us to store digital images, we must decrease the file size. It is important to consider the problems associated with small file size, because compression may result in distortion of the images.

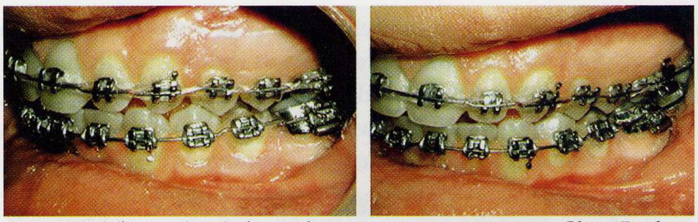

Figure 3. The patient's buccal segment appears more Class I when the camera is positioned more anteriorly.

The first step in obtaining good digital images is selecting a good digital camera. The camera chosen for clinical purposes should have at least two megapixels and produce a minimum of 300 dpi printing resolution for 4"x 5" prints. The original pictures will be in either a "TIFF" or "bmp" format, but subsequently are stored in a JPEG format. Every time a file is compressed from a TIFF format into a JPEG format, some loss of information occurs. The question then is how much compression is possible without altering the quality of the pictures? As Wallace (1991) pointed out, if compression of a file to 0.75 bits/per pixel is maintained, the image will be similar to the original image. Consequently, a file of 200 KB will be an acceptable image.

Another area relevant to orthodontics is digital radiology. Digital radiographs use pixels or small light sensitive elements. These elements detect and convert the x-rays to an electrical charge by an x-ray sensor that is connected to the computer which ultimately provides the digital images (Brennan, 2002).

As with photography, some of the problems of digital radiology are related to the number of pixels, loss of color and contrast information, and incomplete calibration. Despite all of the improvements that digital radiology brings with it, some of the problems of conventional radiology remain such as errors due to 2D representation of 3D structures, the assumption that there is a perfect superimposition of the right and left structures, and radiographic projection error or so-called operator error, *e.g.*, errors due to patient positioning (Quintero *et al.*, 1999; Fig. 4).

While digital radiographs and cephalograms in particular are flawed, they still are the only method that permits the evaluation of key cranial and dental structures. Evaluation involves identifying landmarks on cephalograms, joining them to define lines or angles and then measuring them. There are different ways of tracing or so-called digitizing digital cephalograms: digitizing a tracing, direct digitations with a tablet or digitizing on screen. Some studies have compared hand tracing conventional radiographs with digitized radiographs. Forsyth and colleagues (1996) looked at the differences between hand tracing conventional radiographs and screen digitizing. Landmark identification was performed on a total of 30 radiographs using a conventional digitizer on the original film and using a mouse that controlled a cursor on the displayed digital image. The results showed that the error associated with angular/linear measurements and landmark identification is greater when performing digital imaging.

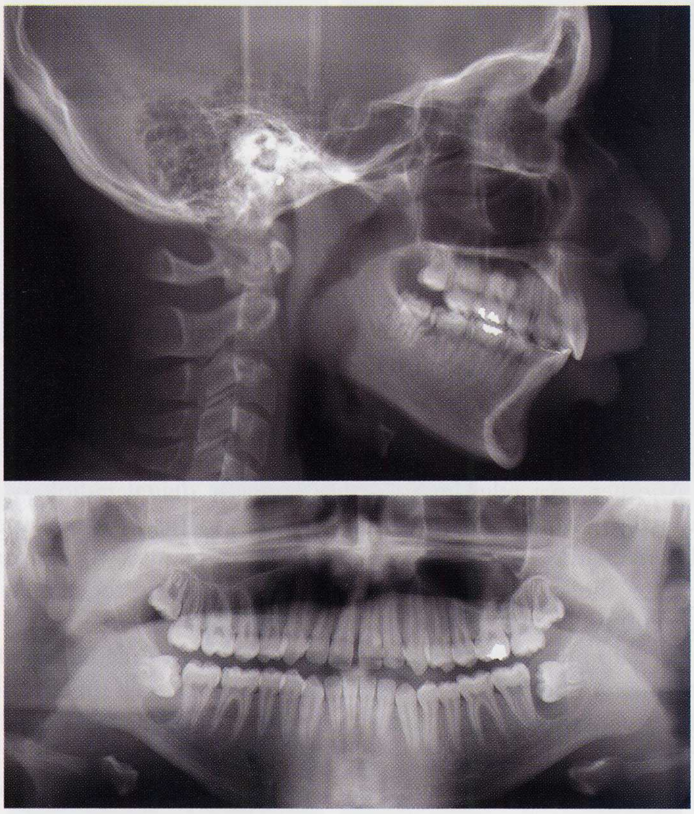

Figure 4. Patient positioning error. Cephalometric radiograph: improper head position. Panoramic radiograph: the apices of the maxillary teeth are not clear.

Geelen and colleagues (1998) looked at the reproducibility of cephalometric landmarks on conventional radiographic films, digital hardcopy and monitor-displayed images obtained from storage phosphor radiography. Six observers located 21 landmarks on each of 19 randomly chosen cephalometric films that were hand traced, digitized using a digitizing tablet, and digitized on monitor-displayed images. The reproducibility of cephalometric landmarks was significantly different on the film, hardcopy, and monitor-display images for 11 of the 21 landmarks. Overall reproducibility was lower (on average 3 mm greater variation over 21 landmarks) for the monitor-displayed image than for either the film or hardcopy, but there were no differences between conventional film and digital hardcopy. Lower reproducibility was explained by eye fatigue while concentrating on the monitor. Lower reproducibility for the monitor-displayed images was not considered clinically significant.

Chen and colleagues (2000) assessed the reliability of cephalometric landmark identification on digital images compared to those on the original radiographs. Nineteen landmarks were identified on each of ten cephalograms. The study found that the reliability of landmark identification in digital images was comparable to that on the original radiographs except for 4 of the 19 landmarks identified. The four landmarks were Po (porion), Ar (articulare), ANS (anterior nasal spine) and UM (mesiobuccal cusp of the upper first molar).

In Naini's study (2001), 30 cephalograms were used to compare the accuracy of manual tracing, digital tablet tracing and on-screen digitizing with a computer mouse. Inter-examiner reproducibility showed digitizing on a tablet to be the most accurate method and manual tracing to be the least accurate method. The on-screen digitizing also had the advantages of taking less time to gather or enter the data, the ability to enhance and enlarge portions of the image and ease of producing customized analyses.

To summarize, there seems to be some error introduced in screen digitizing; however it occurs only for specific landmarks, and it is not clinically significant. The benefits seem to outweigh the disadvantages of tracing errors which could be attributed to phenomena such as eye fatigue.

Another benefit of digital radiographs is the ability to combine the tracings with soft tissue facial images to obtain what we term prediction imaging programs (PIPS). PIPS allow clinicians to manipulate pretreatment digital images to produce a treatment simulation. Morphing software packages have become particularly important in combined surgical-orthodontic cases as a visual aid to obtaining an informed consent for orthognathic surgery. At present there are several software programs available that allow manipulation of the hard and soft tissue.

Reliability and accuracy of PIPS have been evaluated in several studies (Sinclair *et al.*, 1995; Kolokitha *et al.*, 1996; Grau, 2001). According to these studies, predictions of AP movements are more predictable than vertical movements. With regard to individual structures, the most predictable structures are the nose and chin, followed by the upper lip. The least accurate area is the lower lip. In addition, the greater the surgical movement the less accurate is the prediction (Sinclair *et al.*, 1995; Kolokitha *et al.*, 1996; Grau, 2001). The importance of a very detailed informed consent agreement clearly informing the patient of the limitations of a prediction cannot be underestimated.

Plaster casts are very important in orthodontic practice, but using them has disadvantages. Casts require lab processing and considerable storage space. Digital study models provide the same benefits as plaster casts but not the burdens. Digital study models are 3D, but how reliable are they?

Santoro and colleagues (2003) evaluated the reliability of ORTHOCAD™ (Cadent, Inc, Carlstadt, NJ), one of many computer model systems available, by comparing the measurements performed on plaster models and the digital analog. Two independent examiners compared tooth size, overbite and overjet on digital and plaster models. The results showed significant differences in tooth width and overbite measurements; the digital measurements were smaller than the plaster model measurements. No differences were found in overjet measurements, and the magnitude of the differences was not found to be clinically significant.

Zilberman and colleagues (2003) tested the accuracy of measuring plaster casts with the aid of digital calipers versus using the ORTHOCAD system. Mesiodistal tooth width and intermolar and intercanine dimensions were measured on 20 plaster and digital models. The results showed that both methods were acceptable, although using digital calipers resulted in greater accuracy and reproducibility than ORTHOCAD. According to the authors, ORTHOCAD is acceptable for clinical use, whereas digital calipers are more appropriate for scientific purposes.

TURNING PAPER RECORDS INTO DIGITAL RECORDS

In paper patient charts, photographs are available either as slides or paper pictures. To convert them into digital photographs, they must be scanned with at least a 300 dpi scanning resolution. If there are any inconsistencies in color, all imaging software allow adjustments for brightness or contrast. In addition, the internet has multiple, very simple software programs that help match the hue and color. The image then must be saved as a JPEG file.

All these steps also apply to scanning radiographs, but during scanning a transparent adapter is used. For cephalometrics, however, it is important that during the conversion of film radiographs into digital files, no information is lost that might affect the cephalometric measurements. Is there a better way than just scanning the film and screen digitizing? What will happen to the measurements?

Kusnoto (2002) compared different tracings of the same cephalometric radiograph obtained by different methods. These comparisons included: scanned without tracing versus photographed with tracing, scanned without tracing versus scanned with tracing, scanned tracing versus photographed tracing, scanned tracing versus on screen digitizing from scanned radiograph with tracing, on screen digitizing from photographed radiograph versus photographed tracing and on screen digitizing from scanned radiograph versus on screen digitizing from a scanned tracing. Overall, the most accurate option was to scan the cephalogram with its tracing and then screen digitize it (Fig. 5). For scanning resolution, according to Ongkosuwito and colleagues (2002), scanning cephalometric x-rays at a resolution of 300 dpi is sufficient for clinical purposes and comparable to the paper analog.

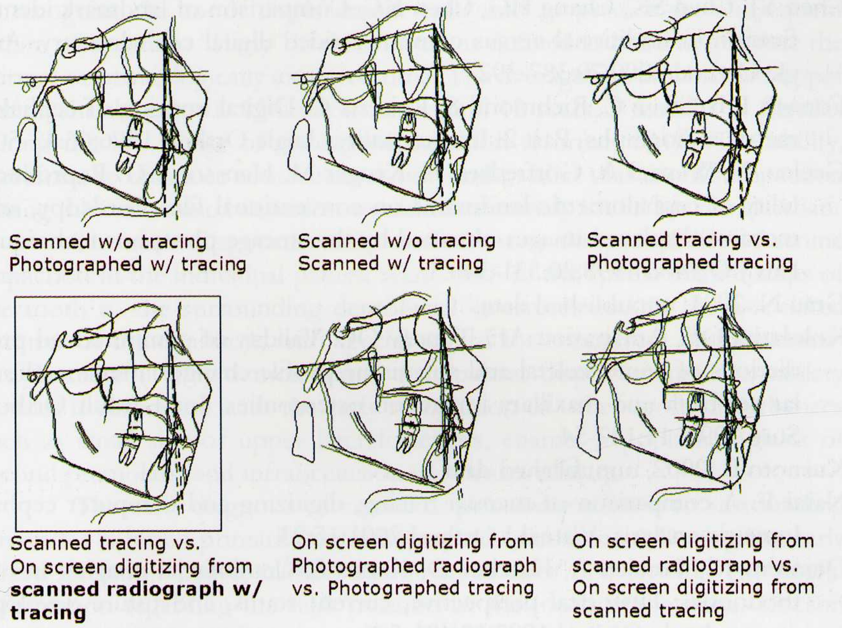

Figure 5. Comparison of methods used to turn cephalometric radiographs into digital files without affecting cephalometric measurements. The best choice is indicated with a box (Kusnoto, 2002).

SUMMARY

To summarize, it is important to evaluate the reliability of digital records, because it is important to know the pros and cons of anything new before embracing it. Despite minor flaws, digital records are the best alternative. Using them is important, not only for their convenience, but also for the messages that using them sends to patients. It follows by implication that an office using state-of-the-art technology for patient records also uses state-of-the-art treatment modalities. The technology is available; not using it denies change and improvement in orthodontics. It need not happen all at once; digital photographs are a good start, followed by radiographs and finally, digital models. One should not wait too long, because today's procedures soon will become obsolete. The future comes in 3D!

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