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A Comparison of Conventional and Digital Radiographic Methods and Cephalometric Analysis Software: I. Hard Tissue

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Various modes of digital cephalometric imaging and cephalometric analysis software are commercially available. This study compared the reliability and dispersion of 10 angular and 5 linear cephalometric parameters (primarily hard tissue) of conventional images, scanned conventional images, and storage phosphor images (DenOptix) measured by using manual tracings and 3 software programs (Dolphin Imaging v. 6.7, Vistadent v. 7.33, and Vistadent v. 8.01). The reliability of each method was considered clinically acceptable. Although there were statistically significant differences in the means of numerous parameters between manual tracing and other modes of images and analyses, the differences did not appear to be clinically meaningful.
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Technological advances in dentistry have greatly impacted the orthodontic profession. Computer software is used to manage patient clinical records, financial information, and scheduling. Digital cameras have become a major form of extraoral and intraoral imaging for many practices and have all but eliminated the need for film and film processing. The same possibility lies in the area of radiology.

Digital radiology has advanced beyond the technology of the 1980s and early 1990s when the landmarks on conventional radiographs were transferred to video monitors using digitizing pads. Some orthodontists currently convert conventional radiographic images to digital files via video film[1] or via flatbed scanners for purposes of measurement and storage. This format offers the advantage of digital enhancement and filtering techniques. Transfer of images between professionals is also easier. The images can be displayed on a monitor or printed. Images can be superimposed to show the effect of treatment or growth[1] and can be modified to predict growth or surgical outcome. However, this approach also requires the film, chemicals, and equipment needed for conventional films in addition to the cost and space of computer hardware and software. Another disadvantage is the increased time to convert images to a digital format as well as the increased number of steps with potential errors associated with each step.

More direct forms of digital radiography are now available as charge-coupled devices (CCDs) and storage phosphor plates. These forms reduce radiation exposure[2-4] and allow all the benefits of the older digital forms of radiology while eliminating the need for film or the associated chemicals necessary for development.

The CCDs work well for periapical and bitewing radiographs, but are thick and rigid resulting in discomfort for some patients. CCD technology is also a costly option for panoramic or cephalometric films.

Storage phosphor imaging has been available since 1987[5] when it was first used for bedside chest radiographs. Since then, numerous articles have been published concerning the use of storage phosphor image acquisition for medical and dental purposes. Its similarities to conventional film and the advances in computer technology make it easy for office personnel to operate. Storage phosphor plates allow image capture while eliminating the cumbersome cords associated with CCDs. The thinner plates and lower cost also make storage phosphor appealing for the orthodontic community. The time needed to capture an image and complete the analysis is less than the time required for conventional cephalometry.[1]

There are limited data that compare cephalometric imag-

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ing techniques including traditional radiography, digitization of conventional films, and digital radiography using the storage phosphor plates. The images appear to be diagnostically acceptable, but the reliability of cephalometric measurements on storage phosphor images using commercially available PC-based software has yet to be determined. To convert to a totally filmless practice, computerized analysis of storage phosphor images must be as accurate and reliable as conventional radiographic measurements. A practitioner's cost and time, as well as patient treatment decisions, require verification of these technologies.

There are several modes by which digital cephalometric images can be captured. The differences could affect the reliability of the identification of cephalomeric landmarks and of measurement of various parameters. For example, Houston[6] determined landmark reliability and other cephalometric parameters by repeatedly entering the landmarks on conventional cephalograms by using a digitizing pad. In some studies,[2,4,7] the printed phosphor image was compared with the conventional cephalogram. Seki and Okano[2] determined that a substantial dose reduction did not have a clinical effect on the reproducibility of landmark identification on prints of phosphor images of four different groups of patients. Lim and Foong[7] compared reliability by digitizing landmarks that were identified on printed phosphor cephalometric images with those on traditional cephalograms. Even though the phosphor images required 30% less radiation than the traditional cephalograms, they reported no statistically significant differences between the groups when the raters and the imaging systems were considered as factorial variables. They used different patients to take each group of cephalograms. Hagemann and coworkers[4] indicated that the reproducibility of cephalometric landmarks was significantly higher on 100 images obtained by using storage phosphor plates compared with 100 conventional cephalometric radiographs of the same patients taken at another appointment, even though they reduced radiation exposure by more than 20% for the phosphor images. However, they compared the reliability of landmark identification of printed storage phosphor image with conventional radiographs and did not use a monitor-displayed image.

Many orthodontic offices identify landmarks on monitor-displayed images. Therefore, a comparison between manual-traced and monitor-displayed images is necessary if phosphor images and scanned conventional cephalograms are analyzed by using current cephalometric software. Geelen and coworkers[8] compared the reproducibility of cephalometric landmarks by using three different images, which included conventional films and two images acquired by storage phosphor technique. The images were acquired simultaneously by placing the storage phosphor screen into the cassette with the traditional film (hybrid cassette technique). The two storage phosphor images were evaluated on hard copy (printed on film) and on monitor-displayed versions. Six individuals recorded 21 landmarks as x–y coordinates on each of the three different images. There were many statistically significant differences when the landmarks were identified by using the monitor-displayed image when compared with the conventional film and with the hard copy, although there were no statistically significant differences between the conventional film and the hard copy printout. In general, reproducibility was poorer for the monitor-displayed landmarks, although this appeared to be related to specific individuals identifying the landmarks. The authors suggested that the lack of reproducibility had little clinical significance.

Although digital cephalometric images are reported to be diagnostically and clinically acceptable for orthodontic treatment planning purposes,[8] there is limited comparison between the various radiographic modes (conventional and digital) of image capture. There is also a need to compare scanned conventional films and the digital radiographic methods of image capture on the basis of monitor-displayed images. The reliability of several commercially available software programs used for cephalometric analysis also must be tested.

The purpose of the present study was to compare the reliability of measurements of cephalometric parameters on storage phosphor digital cephalograms and conventional cephalograms by using traditional hand tracing and commercially available cephalometric analysis software. The second purpose of the study was to determine if there are differences in the dispersion of measurements among the various modes of imaging and cephalometric analysis software.

Materials and Methods

Subjects

Seven male and four female white subjects between 13 and 18 years of age who required cephalometric radiographs at the University of Missouri-Kansas City Orthodontic Postgraduate Clinic were selected. The exclusion criteria were (1) obese subjects whose excess soft tissue could interfere with locating anatomic points; (2) asymmetric subjects whose landmarks could introduce variables involved with halving the differences between the two nonmidline structures; and (3) subjects with known craniofacial defects that would confound landmark identification. The first 11 subjects who met the criteria and agreed to participate in the study were enrolled. Only white patients were selected to limit confounding variables and to minimize the effects of ethnic characteristics on landmark identification.

Preliminary Studies

Preliminary tests were performed varying the position of the storage phosphor screen and the standard cephalometric film in the film cassette. A 21-step wedge was placed on the outside of each cassette before exposure and the density of each cephalogram was read via a densitometer (X-Rite Model 301, 3100 44th Street SW, Grandville, MI). With the conventional film closer to the beam source (in front of the storage phosphor screen), the digital images from the hybrid cassette had density readings (148) equivalent to that of exposing the storage phosphor screen alone (151). Thus, these densiometric readings confirmed other reports that this hybrid method

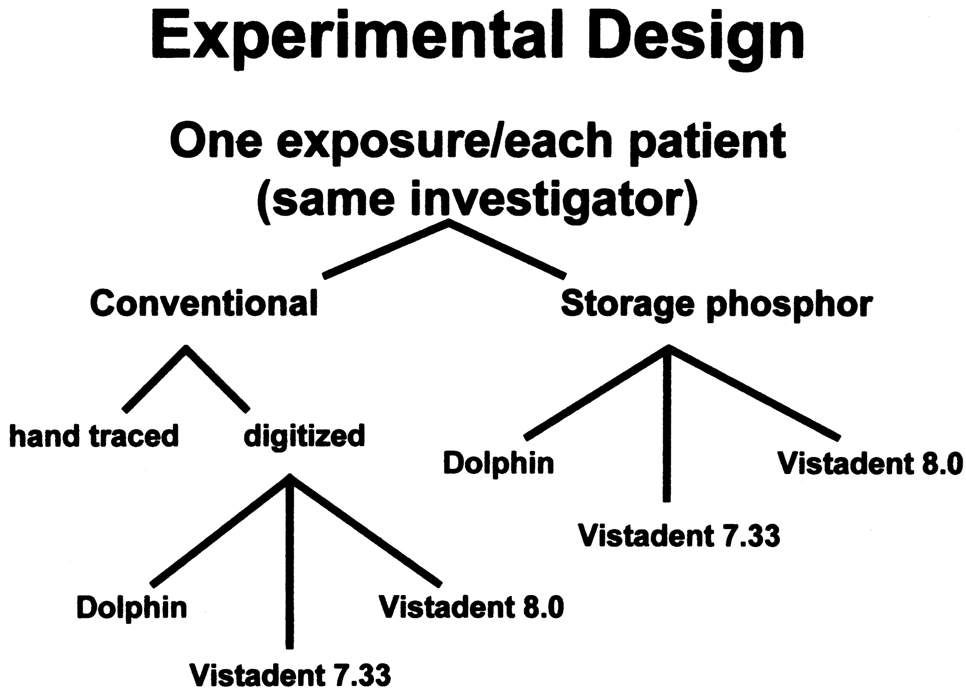

Figure 1 Experimental design.

of image capture (placing the phosphor screen further from the beam source than the conventional film) was a viable means to evaluate dual images.[9-11]

Phase I: Intrarater Reliability

To determine intrarater reliability, two lateral cephalograms (one conventional and one digital) were taken simultaneously of one individual (male subject 0001) using standard radiographic techniques and hygiene [80 KVP, 1/5 sec, and 50 ma using Quint Sectograph (Los Angeles, CA) with a 15-cm distance from film to subject midline and 5-foot source-to-film distance]. Within the cassette, the conventional cephalogram film was placed closest to the patient. The phosphor screen (DenOptix Digital Imaging System, Gendex, Des Plaines, IL) was placed behind the conventional film (hybrid cassette technique) and further from the patient since it needed less radiation for adequate exposure than the conventional film.[7]

The cephalograms were traced and landmarks identified using a 0.5-mm mechanical lead pencil onto 0.003-inch matte acetate tracing paper taped to a conventional cephalogram. This method was considered the reference. All tracings were performed on a view box (SlimLite, Image Marketing Corporation, Mesa, AZ) under dim-lighted conditions. The measurements were made by using a cephalometric protractor for angular measurements and a millimetric ruler for linear measurements to the nearest 0.5 mm (3 mol/L Unitek Tracing Template, ref 701-603, and a 3 mol/L Unitek Cephalometric Protractor, ref 701-402, Unitek, Monrovia, CA).

The conventional cephalogram was also scanned via an Epson Expression 1600 Color Flatbed Scanner (Epson America, Inc, Long Beach, CA) using standardized image settings (Document source: TPU for pos film; Image type: 24-bit color (std); Destination: screen/web; and Resolution: 200) and saved to a zip disk as an uncompressed JPG file. All films were scanned at one sitting to enhance consistency. These images were then imported separately into the three different software programs. The landmarks were identified on a monitor and registered via a mouse (Dolphin registered with a cross-hair cursor while Vistadent used a conventional arrow pointer) using the manufacturers' directions. The landmarks were automatically recorded as x–y coordinates and the angular and linear parameters calculated and displayed by the different programs. The landmarks in each software program were registered by using the same computer (Dell OptiPlex BX110, Dell Computer Corporation, Round Rock, TX) with the monitor setting at True color (24 bit).

The storage phosphor images were immediately converted directly into a JPG file by using a DenOptix Digital Imaging System laser scanner (Gendex) and were entered into each of the software programs. The compression format used to save the images was TIFF JPEG LOSSLESS and is the default for x-ray images (page 13 of the DenOptix VixWin32 software user manual, October 1998). The file size when using this default was approximated by Gendex as 800 kilobytes (KB) per image. The same landmarks on each of the images were identified and the angular and linear parameters calculated and displayed by the different programs.

Thus, there were a total of seven image/measurement groups. The conventional cephalogram was manually traced and then scanned and the image saved to disk (Fig 1). The digitized image of the conventional cephalogram was imported independently into three cephalometric software programs (Dolphin Imaging Software, Dolphin Imaging, Canoga Park, CA; Vistadent Imaging Software Version 7.33 and Vistadent Imaging Software Version 8.01, Dentsply Interna-

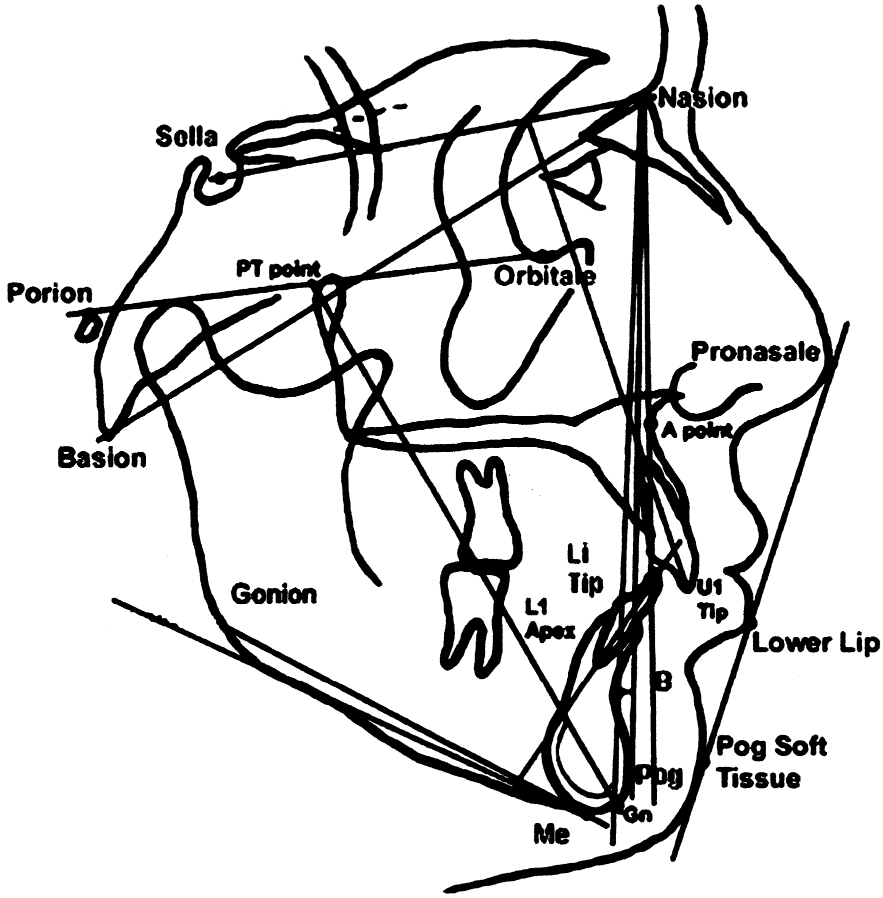

Figure 2 Cephalometric landmarks and parameters.

tional Inc., York, PA). The image from the storage phosphor plate was saved to disk after capture and was entered into the same three cephalometric software programs as stated above (Fig 1). One investigator identified landmarks on all seven images of the single individual (Fig 2). Measurements of 15 linear and angular parameters (Table 1) were taken of each image/measurement group 10 times on separate days to minimize rater bias.

Phase II: Comparative Analysis

In the second phase of the study, 10 additional patients were selected according to the exclusion criteria used for the intrarater reliability study. The same image capture for Phase I was used for Phase II as was the process of importing the images into the different software programs. Each image was manually traced, and both the scanned and digital images were imported from disk into the three software programs. The same 10 angular and 5 linear parameters were measured as in Phase I. Therefore, each research subject had seven sets of measurements. All images were measured on separate days to reduce the possibility of landmark reproduction due to memory.

Table 1 Cephalometric Parameters Measured in Study

Angular Parameters (degrees)	Linear Parameters (mm)
SN-GoMe	U1-NA
FH-GoMe	L1-NB
SNA	PoNB
SNB	L1-APog
ANB	E-line–lower lip
NBa-PTGn	
U1-NA	
L1-NB	
IMPA	
U1-SN	

Data Analysis

To assess the reliability of the 10 measurements made by the same rater in Phase I, means, standard deviations, and coefficients of variation (CVs) were calculated for each parameter and for each imaging modality. Coefficients of variation express variability as the standard deviation divided by the mean, and larger coefficients of variation indicate greater variability in the measurements. The difference in means between the manual tracings (reference) and each of the remaining image modalities was determined for each parameter. Any difference less than 2 mm or 2° was considered to be clinically acceptable.

For the 10 cephalograms measured in Phase II, the data were analyzed by a repeated measure analysis of variation (ANOVA). An alpha level of 0.01 was accepted as statistically

significant. The difference in means between the manual tracings (reference) and each of the remaining image modalities was determined for each parameter. Any difference less than 2 mm or 2° was considered to be clinically acceptable.

Results

The means, standard deviation, and coefficients of variation for the single image measured 10 times (Phase I) are reported in Table 2. For manual tracing, the coefficients of variation (CV) were equal to or less than 0.10, except for PoNB, suggesting a high degree of intrarater reliability. Both the scanned and the digital images generally showed a high degree of intrarater reliability. The L1-APog parameter had high CVs for most of the scanned and digital images; PoNB was also elevated for Vistadent v. 7.33 digital. Differences of more than 2 mm or 2° from hand tracing (Table 2) occurred in NBa-PTGn, IMPA, and U1-SN. The differences occurred in the scanned image and in the digital image depending on the parameter and only in the Vistadent versions.

Statistically significant differences between the imaging modalities (Table 3) were present for the following parameters of the 10 patients: SN-GoMe, FH-GoMe, SNA, SNB, NBa-PTGn, U1-NA (mm), and L1-NB(° and mm). The presence of significant differences implies that values obtained from one or more imaging modalities differed from the values obtained from other imaging modalities. Although these differences are unlikely to have occurred by chance, the data in Table 3 suggest that the size of the difference is not likely to have clinical significance. Differences that exceeded 2 mm or degrees from manual tracing are indicated in Table 3. These differences tended to occur more often in several parameters [FH-GoMe, L1-NB (°), and U1-SN].

Discussion

Reliability is an important aspect of measurement. If a measure cannot be reproduced consistently, then the value (cost, time, and patient treatment decisions) of the methodology is questionable. In a clinical situation such as orthodontics, a reproducibility that is within 2° or 2 mm will probably not make a difference in treatment. Standard deviation can be used as a parameter to indicate variability in measurement of central tendency. Consider, for example, the standard deviations for NBa-PtGn and PoNB for manual tracing. The standard deviations are the same, but the absolute values of the two parameters are distinctly different. However, when the coefficients of variation that account for mean values are computed, the relative variability in PoNB far exceeds that of NBa-PtGn.

In general, the CVs for hand tracing and the other modalities were equal to or less than 0.10, suggesting a reasonably high level of intrarater reliability. Similar to other authors[8,12] who identified the root apices of incisors and gonion to be among the least reliable landmarks, we found that a parameter (L1-APog) that included the lower incisor root apices had the highest CVs. However, other parameters (eg, U1-NA, L1-NB, and IMPA) that include landmarks using incisor roots had acceptable CVs. This could also be related to the small mean value of L1-APog. The parameters (IMPA, L1-SN) that differed by more than 2° from the mean of the manual traced cephalograms were also parameters that included root apices as landmarks. The overlap of the roots of multiple incisors make exact identification of the apices difficult.

Accuracy is difficult to ascertain in cephalometrics, much less compare among modes of image capture and measurement techniques. If the manually traced conventional cephalogram is used as a reference, then comparison can be made among the groups. Again, a difference of 2° or 2 mm in means does not appear to cause a clinical difference in classification or treatment decisions in most of the parameters. Thus, there appear to be few differences in the means among the groups. The differences that exceeded the 2° or 2-mm cutoff occurred in the intrarator measurements (Phase I) using both Vistadent versions. However, these differences were not of a magnitude to be concerned about clinically since they exceeded the cutoff by only tenths of a millimeter. Most of these differences were involved with landmarks using root apices. However, measurement of facial growth direction (NBa-PtGn) in Vistadent also exceeded the arbitrary cutoff. This parameter required the identification of gnathion, which is usually identified on conventional film after drawing reference planes. Since the software programs did not draw reference planes on the monitor-displayed images during landmark identification, the investigator arbitrarily selected gnathion. Geelen and coworkers[8] also noted this difficulty with monitor-displayed images.

For the comparison of methods using 10 patients, there were statistically significant differences among the modes of capture and methods of analysis for numerous parameters. For many of these parameters among which statistically significant differences were found, the differences in means from the manual reference did not exceed 2 mm or degrees. Therefore, we did not believe that it was necessary to determine where the differences existed among the groups. The parameters where measures exceeded the cutoff were some that required identification of incisor root apices or gonion, which, similarly to gnathion, is usually identified manually by drawing planes. Other authors[12] reported low reliability of identifying gonion. The scanned Vistadent v. 7.33 group had no parameters that exceeded the cutoff.

Thus, it appears that storage phosphor digital images can be considered as clinically reliable as conventional images that were traced manually or scanned and digitized on the monitor. In addition, storage phosphor images eliminate the need for a film processor and the required chemicals.

Although some of the difficulties in landmark identification could be related to the lack of contrast in the areas of the incisor apices, the densitometer levels in our preliminary study revealed densities that were equivalent between the hybrid cassette technique and cassettes containing only the storage phosphor screen. Therefore, the hybrid cassette technique did not appear to contribute to problems in landmark identification. Image capture with the hybrid cassette was first described by Oestmann and coworkers,[9] and described again by Wilson and West[10] and Wilson and colleagues,[11] as

Table 2 Intrarater Reliability (n = 10 each)

			Scanned						Digital					
	Manual		Dolphin 6.7		Vistadent 7.33		Vistadent 8.01		Dolphin 6.7		Vistadent 7.33		Vistadent 8.01	
Parameter	**X ± SD**	**CV**	**X ± SD**	**CV**	**X ± SD**	**CV**	**X ± SD**	**CV**	**X ± SD**	**CV**	**X ± SD**	**CV**	**X ± SD**	**CV**
SN-GoMe	35.1 ± 0.2	.01	37.1 ± 1.2	.03	35.3 ± 0.7	.02	34.0 ± 0.9	.03	36.4 ± 0.7	.02	34.7 ± 0.6	.02	34.9 ± 0.9	.03
FH-GoMe	30.6 ± 0.4	.01	32.0 ± 1.2	.04	31.4 ± 0.7	.02	30.9 ± 0.9	.03	31.9 ± 1.2	.04	29.2 ± 0.5	.02	29.7 ± 1.0	.03
SNA	80.2 ± 0.4	.00	78.9 ± 1.1	.01	80.3 ± 0.5	.01	80.3 ± 0.5	.01	79.8 ± 0.4	.01	79.9 ± 0.6	.01	80.0 ± 0.7	.01
SNB	77.1 ± 0.5	.01	75.8 ± 1.0	.01	76.9 ± 0.4	.01	77.0 ± 0.4	.01	76.6 ± 0.3	.00	76.7 ± 0.6	.01	76.7 ± 0.7	.01
ANB	3.1 ± 0.2	.06	3.1 ± 0.3	.10	3.4 ± 0.2	.06	3.3 ± 0.2	.06	3.2 ± 0.2	.06	3.2 ± 0.2	.06	3.2 ± 0.2	.06
NBa-PTGn	82.5 ± 0.5	.01	80.8 ± 0.9	.01	79.4 ± 1.0*	.01	79.6 ± 0.6*	.01	82.0 ± 0.6	.01	80.8 ± 0.6	.01	80.5 ± 0.5	.01
U1-NA (deg)	18.2 ± 1.9	.10	18.2 ± 1.1	.06	16.8 ± 0.6	.04	16.2 ± 1.5	.09	18.6 ± 1.7	.09	16.5 ± 1.2	.07	16.5 ± 1.2	.07
U1-NA (mm)	4.5 ± 0.3	.07	3.1 ± 0.3	.10	4.5 ± 0.2	.04	4.6 ± 0.3	.07	3.2 ± 0.3	.09	4.4 ± 0.3	.07	4.5 ± 0.3	.07
L1-NB (deg)	22.8 ± 1.2	.05	22.7 ± 1.8	.08	22.8 ± 1.2	.05	23.6 ± 1.1	.04	23.6 ± 1.4	.06	24.2 ± 1.2	.04	24.3 ± 1.1	.04
L1-NB (mm)	4.7 ± 0.3	.06	3.9 ± 0.2	.05	4.5 ± 0.0	.00	4.5 ± 0.3	.07	4.1 ± 0.3	.07	4.5 ± 0.2	.04	4.6 ± 0.2	.04
PoNB	4.1 ± 0.5	.12†	4.3 ± 0.3	.07	4.2 ± 0.2	.04	4.0 ± 0.4	.10	4.6 ± 0.2	.04	4.2 ± 0.5	.12†	4.3 ± 0.2	.04
L1-APog	1.0 ± 0.0	.00	−0.1 ± 0.3	3.0†	0.3 ± 0.1	.33†	0.5 ± 0.3	.60†	0.0 ± 0.2	.00	0.5 ± 0.2	.40†	0.6 ± 0.1	.17†
IMPA	90.6 ± 0.9	.01	89.8 ± 2.1	.02	90.7 ± 1.5	.02	91.6 ± 1.2	.01	90.7 ± 1.6	.02	92.9 ± 1.1*	.01	92.7 ± 1.5*	.02
U1-SN	98.7 ± 1.5	.02	97.1 ± 1.2	.01	97.1 ± 0.8	.01	96.6 ± 1.3*	.01	98.3 ± 1.4	.01	96.4 ± 1.1*	.01	96.4 ± 1.0*	.01
E-line-lower lip	−5.9 ± 0.2	.03	−5.4 ± 0.3	.06	−5.3 ± 0.2	.04	−5.4 ± 0.3	.06	−5.4 ± 0.3	.06	−5.5 ± 0.3	.05	±5.5 ± 0.3	.05

CV = coefficient of variation.
*Differences of mean measurements exceeding 2 degrees or millimeters from mean of manual measurements.
†CV ≥ 0.10.

Table 3 Mean Values (n = 10 each) of Cephalometric Parameters of 10 Patients Using Conventional and Digital Radiographs and Commercially Available Cephalometric Software Programs

		Scanned			Digital				
Parameters	**Manual**	**Dolphin 6.7 X ± SD**	**Vistadent 7.33 X ± SD**	**Vistadent 8.01 X ± SD**	**Dolphin 6.7 X ± SD**	**Vistadent 7.33 X ± SD**	**Vistadent 8.01 X ± SD**	***P* Values ≤0.01**	**Eta Squared**
SN-GoMe	35.8 ± 5.0	38.0 ± 5.1*	37.3 ± 5.1	37.5 ± 5.2	37.1 ± 5.0	37.2 ± 5.1	36.6 ± 5.2	0.000	.436
FH-GoMe	27.2 ± 5.3	29.6 ± 6.2*	29.0 ± 5.9	29.7 ± 5.9*	29.2 ± 6.2	29.8 ± 5.8*	29.7 ± 6.3	0.000	.57
SNA	78.0 ± 3.9	78.6 ± 3.9	78.8 ± 3.4	78.4 ± 4.3	78.9 ± 2.8	79.2 ± 3.6	79.9 ± 2.8	0.007	.318
SNB	76.2 ± 4.3	76.4 ± 4.0	76.3 ± 4.3	76.7 ± 4.2	76.8 ± 3.4	77.0 ± 4.1	77.5 ± 3.7	0.001	.347
ANB	1.8 ± 1.6	2.2 ± 1.2	2.4 ± 1.6	1.8 ± 2.2	2.2 ± 1.6	2.2 ± 1.5	2.4 ± 1.7	NS	
NBa-PTGn	88.3 ± 4.5	86.9 ± 4.6	86.9 ± 4.6	87.0 ± 4.8	88.0 ± 4.3	87.6 ± 4.6	87.3 ± 4.6	0.000	.402
U1-NA (°)	28.2 ± 4.0	28.8 ± 5.7	27.9 ± 5.4	28.8 ± 5.6	29.8 ± 5.3	28.0 ± 5.4	28.7 ± 4.9	NS	
U1-NA (mm)	6.8 ± 1.8	5.4 ± 1.8	5.6 ± 1.7	6.3 ± 2.6	5.4 ± 1.8	5.7 ± 1.6	5.4 ± 1.8	0.01	.257
L1-NB (°)	24.2 ± 3.3	26.4 ± 3.8*	25.4 ± 3.9	26.6 ± 3.7*	26.5 ± 4.0*	27.4 ± 3.7*	27.7 ± 4.2*	0.000	.547
L1-NB (mm)	5.9 ± 2.2	5.3 ± 2.0	6.0 ± 2.0	5.8 ± 2.0	5.4 ± 2.1	5.9 ± 1.8	5.9 ± 1.9	0.000	.451
PoNB	4.8 ± 2.1	4.3 ± 2.0	4.4 ± 2.0	4.3 ± 2.0	4.4 ± 1.9	4.4 ± 2.0	4.4 ± 2.0	NS	
L1-APg	2.9 ± 2.2	2.1 ± 2.0	2.4 ± 2.2	2.8 ± 2.1	2.2 ± 2.0	2.6 ± 1.8	2.4 ± 2.0	NS	
IMPA	92.1 ± 4.7	92.1 ± 4.4	92.0 ± 5.1	92.4 ± 5.1	92.6 ± 5.2	93.2 ± 4.9	93.7 ± 5.7	NS	
UI-SN	106.6 ± 6.3	107.4 ± 7.4	106.7 ± 6.9	107.3 ± 6.2	108.8 ± 6.6*	107.2 ± 7.5	108.6 ± 6.5*	NS	
E-line-lower lip	−3.6 ± 3.0	−3.4 ± 2.8	−3.5 ± 3.0	−3.6 ± 3.0	−3.2 ± 3.0	−3.3 ± 3.1	−3.4 ± 3.3	NS	

Repeated measures ANOVA; $P \leq 0.01$, depending on the post hoc test (test of sphericity or Huynh-Feldt).

*Mean value differs by more than 2 degrees or millimeters from the mean of the manual values.

a suitable method to conduct research with digital chest radiography. This hybrid cassette allowed capture of two identical images of the same subject without losing diagnostic information.

Other variables that could have influenced landmark identification included the type of registration pointer used in the different software programs. Dolphin uses a crosshair cursor while Vistadent v. 7.33 and v. 8.01 use a conventional pointer that obscured the landmark. Other authors[13] related the same difficulties with the cursor obscuring landmarks. Vistadent also automatically superimposed the outline of an incisor over the image once the crown tip and apex have been located. This outline obscured the most facial aspect of the incisor, necessary for linear measurements from facial of lower incisor to nasion-point B and facial of lower incisor to point A-pogonion.

Some differences between digital and scanned images could be related to the scanning protocol since the digital images were saved using a gray scale image while the scanned images were saved as RGB color images. However, this did not appear to alter the image enough to enhance nor hinder landmark identification. In addition, other research[14] revealed that resolution setting and grayscale versus color when scanning radiographs does not matter significantly when standard settings are used.

As technology progresses, it becomes increasingly difficult to determine if there is adequate evidence to assess the efficacy of the technology before it becomes commercially available. Although a multitude of cephalometric analysis software programs have been on the market for several years, there are few studies[15] comparing their reliability and the similarity of measures across the programs. There are also few studies determining if there are differences between different versions of cephalometric analysis software. It can be difficult for the practitioner to select technology that is reliable and accurate unless appropriate studies are available. This study provides a basis for evaluation of the software programs and digital and conventional cephalometric imaging. Further studies in this area will, no doubt, improve our knowledge about the risks and limitations of storage phosphor technology. But, for now, the orthodontic office can depend on storage phosphor imaging and analysis with either Dolphin or Vistadent software.

Conclusions

The results of this study indicate that digital radiography using storage phosphor plates is a viable option for cephalometric films. Manual traced and scanned (digitized) conventional films and digital storage phosphor images are clinically reliable for measuring hard tissue parameters. There were no clinically significant differences from manual traced conventional film of conventional or storage phosphor images analyzed using Dolphin Imaging v. 6.7, Vistadent v. 7.33, and Vistadent v. 8.1 software programs when measuring hard tissue parameters.

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