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A Comparison of Conventional and Digital Radiographic Methods and Cephalometric Analysis Software: II. Soft Tissue

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Although digital radiographs and cephalometric analysis software are becoming increasingly popular in orthodontic offices, there is little information concerning their reliability of measurement of soft tissue or concerning comparison with conventional techniques. Our study shows good reliability of each imaging system (conventional and storage phosphor digital) and cephalometric analysis modality (manual tracing, Dolphin Imaging v. 7.0 and Vistadent Image Management system v. 8.0) with no statistical differences in reliability among the modalities. In the second part of our research comparing the means of the modalities using different subjects, there was no difference in mean Dolphin scanned values when compared with manual traced values whereas the other imaging modalities (Dolphin digital, Vistadent scanned, and Vistadent digital) were significantly different from the manual traced values. Dolphin digital was significantly different from Vistadent scanned and Vistadent digital, although there were no differences between Vistadent scanned and digital. In general, except for facial angle, these differences in modalities do not appear to be clinically significant.
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Soft tissue profile analysis[1,2] is an essential part of orthodontic diagnosis and treatment planning. Depending only on cephalometric dentoskeletal analysis for treatment planning may not eliminate all aesthetic problems because of great variations in facial soft tissue.[3] Understanding the soft tissue features and their normal ranges allows a treatment plan to be designed so that it can normalize the facial characteristics for a given individual.[4] Therefore, it is important that the modalities of cephalometric imaging and measurement can be used reliably to identify and measure these parameters.

During the last decade, digital radiographs and cephalometric analysis software have become popular in orthodontic offices. There is, however, little information concerning their reliability of measurement of soft tissue. Most studies comparing the reliability of cephalometric measurements between conventional and digital cephalometric analysis[5,6] have dealt primarily with skeletal reference points. Few authors[7] have studied the reproducibility of soft tissue measurements although Mostafa and coworkers[8] reported excellent reliability of soft tissue landmarks on digital images acquired by digitizing videotapes of conventional cephalograms.

In addition to converting conventional film to electronic format using a digitizing pad or using a camera or a flatbed scanner, there are two additional types of technology used in current digital imaging. One method utilizes charged couple device (CCD) sensors, and the other utilizes a photo-stimulable phosphor plates. The CCD sensor was invented by Bell Laboratories in 1970[9] and was mainly used in video records and cameras. The first dental application of the CCD sensors occurred in the mid-80s.[10] CCD technology is known as direct digital imaging because the signal output is transferred directly to a computer via cables as an electrical system and digitized by the frame grabber.[11] CCDs are relatively expensive for cephalometric use because numerous sensors are needed for a cephalometric unit. The CCD sensors usually cannot be retrofitted into old conventional radiographic machines making the purchase of a new unit necessary.[10]

Storage phosphor technology was first used in the 1980s. Storage phosphor plate is made of a flexible, reusable polymer material that is less than 1 mm thick and is covered with a photo-stimulable phosphor compound.[10] This thinness al-

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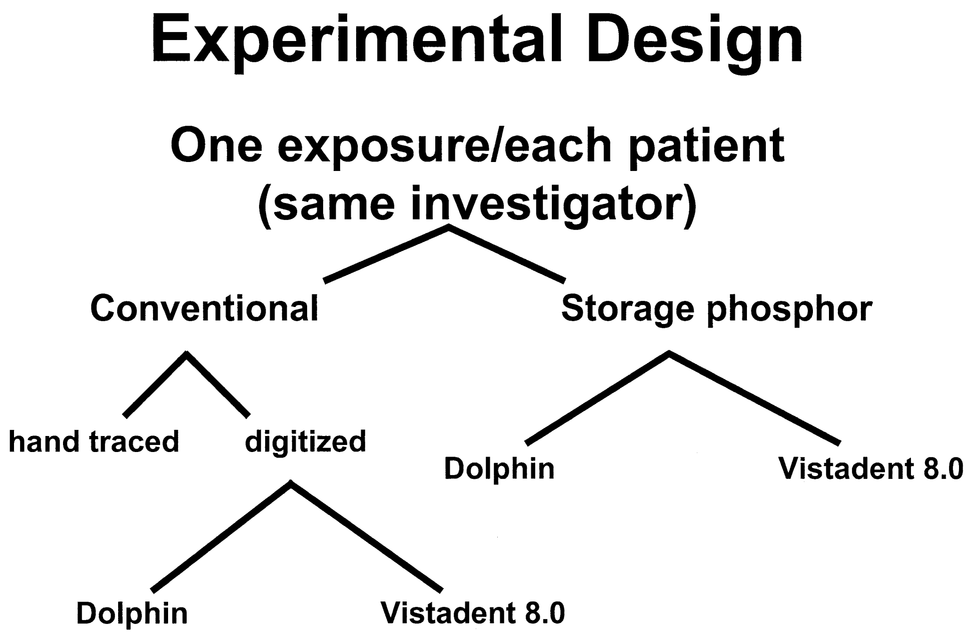

Figure 1 Experimental design.

lows the phosphor plate to be placed into a standard cassette used with conventional film. Unlike a CCD, it can be used with a preexisting conventional cephalometric unit and it does not need additional cable connections because it can store images.

On exposure, the image is stored on the phosphor. The plate is scanned by a laser beam to release the photoluminescence. The released luminescence is collected in a photomultiplier that produces electrical signals. These signals are transformed into a digital form and analyzed by the image processor. Compared with conventional film, storage phosphor does not need a dark room for processing, although it does need a semidark room, and no chemical processing is required. Because the phosphor plate must be developed by the laser scanner, this method is called indirect digital radiography.

There is a linear response between radiation dose and image density of the storage phosphor screen, compared with conventional film, which has a nonlinear response.[12] Both hard and soft tissues are shown more clearly than with conventional film.[13] It is possible to underexpose or overexpose storage phosphor and still produce clinically acceptable images.[12] This property has led to a considerable reduction in the radiation dose.[13]

Soft tissue landmark identification is equally reliable on digital and conventional radiographs, even with dramatically reduced radiation. Lim and Foong,[14] in a controlled, prospective study, investigated the reliability of landmark identification on storage phosphor and conventional lateral cephalometric radiographs. Twenty conventional images were compared with 20 computed images taken at 30% reduced radiation. In addition to hard tissue landmarks, five soft tissue landmarks were identified. Two-way analysis of variance (ANOVA) showed that there was no significant difference between the two imaging systems in x–y Cartesian coordinates, but soft tissue landmarks were more reliable in the x-coordinate than the y-coordinate. Seki and Okano[13] found that three soft tissue cephalometric landmarks could be reliably identified on printed phosphor images of 40 patients exposed to different amounts of radiation. Diagnostically acceptable images were produced on storage phosphor even with a considerable reduction in radiation. Naslund and coworkers[15] suggested that identification of such soft tissue points as nose and upper and lower lip were not influenced by exposure reduction because of their low structural density.

Few studies have determined the reliability of identifying soft tissue landmarks or parameters on monitor-displayed images.[16] Forsyth and coworkers[16] used a video camera to convert a conventional cephalogram to a digital format. The random errors of measurement of the two soft tissue parameters when measured on a monitor-displayed image and on a conventional cephalogram were not significant, although the systematic errors were.

There are limited data comparing the reproducibility of soft tissue parameters by using available contemporary cephalometric imaging techniques including digitization of conventional films and indirect digital radiography by using the storage phosphor plates. The reliability of commercially accessible software programs used for cephalometric analysis needs to be tested using monitor-based images as well. The first purpose of the present study was to compare the reliability of soft tissue measurements between storage phosphor digital cephalometric images and conventional cephalometric images by using commercially available cephalometric analysis software as well as hand tracing. The second purpose of the study was to determine if there were differences in the measurements among the various modes of imaging and analysis.

Table 1 Soft Tissue Landmarks and Parameters

Soft tissue landmarks	
G	Glabella
Stms	Stomion superius
N′	Soft tissue nasion
Stmi	Stomion inferiorus
Pr	Pronasale
ILS	Inferior labial sulcus
Sn	Subnasale
Pog′	Soft tissue pogonion
SLS	Superior labial sulcus
Me	Soft tissue menton
Ls	Labrale superius
Li	Labrale inferius
Soft tissue parameters	
Middle to lower facial third ratio	G-Sn to Sn-Me′
Nasolabial angle	Columella tangent to upper lip tangent
Interlabial gap	Vertical distance between the upper and the lower lip
Angle of facial convexity	G-Sn to Sn-soft tissue pogonion
Upper lip to E-line	Distance from upper lip to soft tissue pogonion to pronasale line
Lower lip to E-line	Distance from lower lip to soft tissue pogonion to pronasale line
Facial angle	FH to N′-Pog′
H line angle	Pog′-Ls to N′-Pog′
Nose prominence	Measured by means of a line perpendicular to FH and running tangent to the vermilion border of the upper lip
Upper sulcus depth	SLS to H line
Lower sulcus depth	ILS to H-line
Upper lip thickness	2 mm below A point, horizontal to the outer border of the upper lip
Upper lip strain	Labial surface of the U central incisor to vermilion border, horizontal line
Lower lip to H-line	Measured from the most prominent outline of L lip
Soft tissue chin thickness	Pog to Pog′

Materials and Methods

Subjects

The images used in this study were the same as those used in previous research on the reliability of hard tissue landmarks[17] except that one subject's image with a small file size was replaced with a new subject. Eleven white patients, six males and five females, between 13 and 18 years of age were selected from the clinic patients scheduled for orthodontic records. Obese subjects and those with craniofacial defects were excluded to minimize soft tissue interference with locating anatomic points.

Each subject had one radiographic exposure using the hybrid cassette technique with both the conventional film and the digital film placed within the same cassette. The conventional film is closer to the subject and the digital film is placed further within the cassette from the subject. The images were exposed and processed as previously reported.[17] Preliminary experiments with a 21-step wedge and a densitometer (X-Rite Model 301, 3100 44th Street SW, Grandville, MI) were used to determine that the images using the hybrid cassette technique had the same density as exposing the storage phosphor screen by itself.

Intrarater Reliability

The conventional and the digital images of one subject were used to determine intrarater reliability (Fig. 1). All measurements were made by a single investigator to minimize variability of measurement. The manual tracing of the conventional film was considered the "reference cephalogram." The scanned image of the conventional cephalogram as well as the digital cephalogram was imported into each of two cephalometric software programs: Dolphin Imaging v. 7.0 (Dolphin Imaging, Canoga Park, CA) and Vistadent Image Management System v. 8.0 (Dentsply International Inc, York, PA) as described previously.[17] Each image was manually traced or digitized 10 times on different days using both software programs (Fig. 1).

Comparison of Modalities by Using Different Subjects

Similar to the intrarater reliability measures, the modalities were compared by manual tracing of cephalograms of 10 patients and by analyzing their scanned and digital images on separate days (Fig. 1) with Dolphin and Vistadent. To reduce

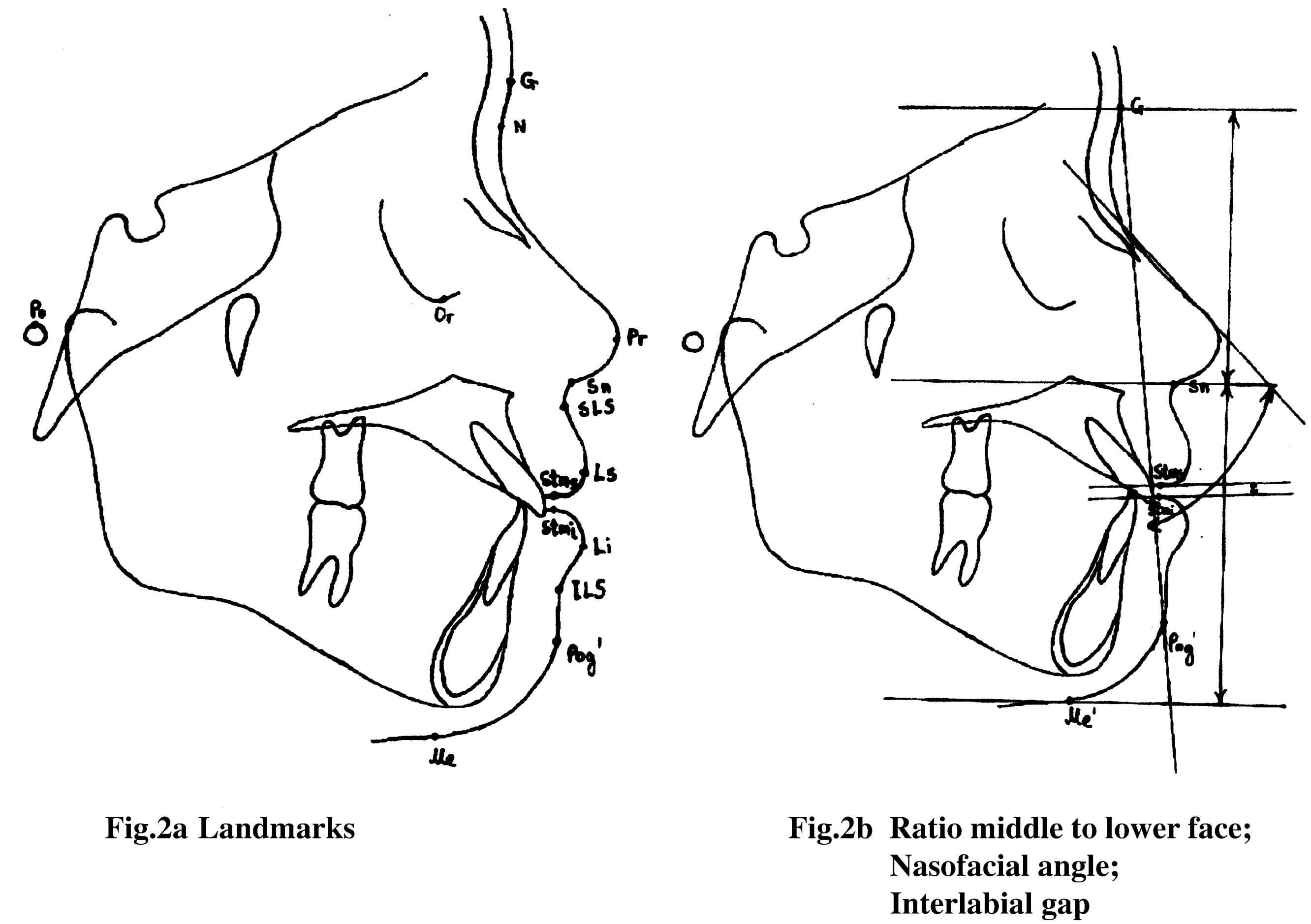

Figure 2 Soft tissue cephalometric parameters.

bias by the investigator, the images were measured in a random order.

Cephalometric Analysis

A total of 12 soft tissue landmarks and two hard tissue landmarks were identified (Table 1) to measure 11 linear and four angular parameters. The same procedure was repeated with Dolphin v. 7.0 and Vistadent v. 8.0. The soft tissue analyses of Holdaway[18] and Steiner[19] were performed (Fig. 2). However, soft tissue measurements were limited in both software programs. Vistadent created the analysis needed for this research. We eliminated some soft tissue parameters that were initially discussed because they were not available in Dolphin 7.0.

Statistical Analysis

To assess the reliability of the different modalities, coefficients of variation (CVs) were computed for all the parameters, by imaging and analysis modality. To determine whether the values reported by the imaging modalities differed, the means of all the modalities for one subject were subjected to a one-way ANOVA, accepting $P < 0.05$ as significant.

For the cephalograms of 10 patients, differences in parameter measurements were obtained by comparing the values of the mean of the manual tracing with the values of the remaining images. Cumulative difference scores were then subjected to a one-way ANOVA. Student-Newman-Keuls procedures were used to determine where the differences existed ($P < 0.05$). Differences of more than 2 mm or 2° were considered to be clinically significant.

Results

Intrarater Reliability

The CVs for the single image that was measured 10 times (intrarater reliability) are reported in Table 2. The CVs for three parameters (interlabial gap, upper sulcus depth, and lower lip to H-line) were consistently high across all modalities of images and analysis. These three parameters were removed from statistical analysis of intrarater reliability. The CVs for the remaining parameters were less than 0.10, suggesting a high degree of intrarater reliability for all modes of imaging and analyses. No differences in reliability were found among the modalities. Both the scanned and the digital images generally showed a high degree of intrarater reliability.

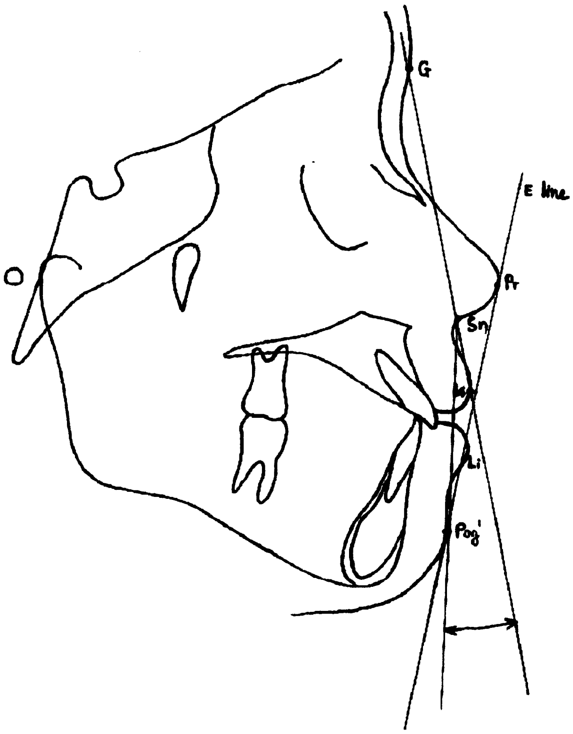

Fig.2c
Angle of facial convexity;
Ricketts' upper lip to E-line;
Ricketts' lower lip to E-line

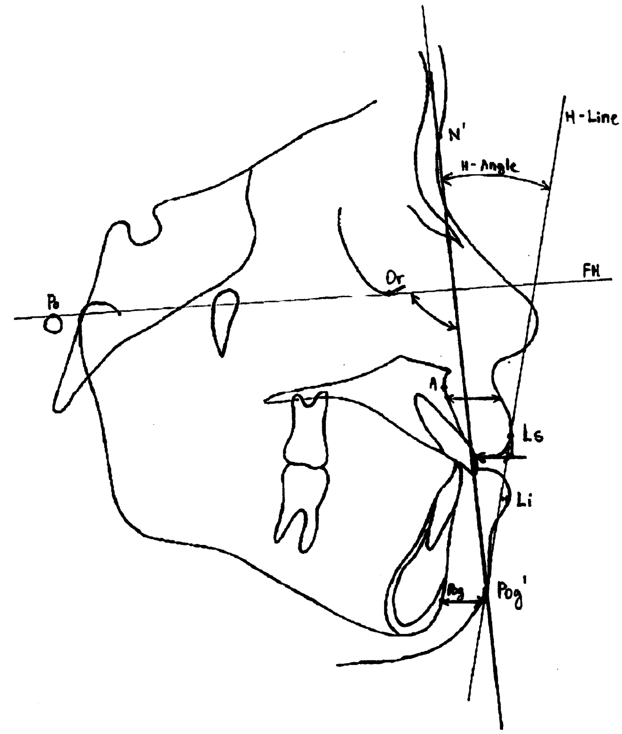

Fig.2d
Holdaway's analysis:
H-line angle
Upper lip thickness
Upper lip strain
Facial angle
Soft-tissue chin thickness
Lower lip to H-line

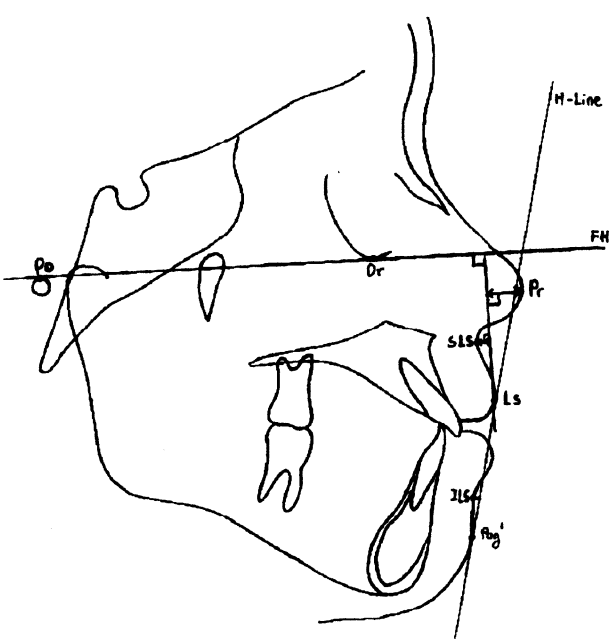

Fig.2e
Holdaway's analysis:
Nose prominence
Upper sulcus depth
Lower sulcus depth

Figure 2 (continued)

Table 2 Intrarater Reliability of Cephalometric Parameters by Using Various Methods of Analysis

Parameters	Coefficient of Variation*				
	MT (N = 10)	DS (N = 10)	DD (N = 10)	VS (N = 10)	VD (N = 10)
G-Sn/Sn-Me	0.04	0.04	0	0	0
Nasolabial angle (°)	0.02	0.02	0.01	0.03	0.03
Interlabial gap (mm)	0.24†	0.18†	0.19†	0.67†	0.65†
Angle of facial conv (°)	0.04	0.07	0.05	0.07	0.05
Upper lip to E-line (mm)	−0.05	−0.03	−0.05	−0.05	−0.07
Lower lip to E-line (mm)	−0.07	−0.06	−0.06	−0.06	−0.09
Facial angle (°)	0.01	0.01	0.01	0.01	0.02
H-line angle (°)	0.04	0.06	0.06	0.03	0.06
Nose prominence (mm)	0.02	0.03	0.03	0.03	0.05
Upper sulcus depth (mm)	0.25†	0.15†	0.33†	0.13†	0.33†
Lower sulcus depth (mm)	0.05	0.03	0.04	0.06	0.03
Upper lip thickness (mm)	0.03	0.04	0.03	0.03	0.03
Upper lip strain (mm)	0.02	0.03	0.02	0.02	0.02
Lower lip to H-line (mm)	0.3†	0.25†	0.5†	0.23†	0.29†
Soft tissue chin thickness (mm)	0.04	0.02	0.03	0.04	0.04

MT, manual traced; DS, Dolphin scanned; DD, Dolphin digital; VS, Vistadent scanned; VD, Vistadent digital.
*No significant differences among the imaging modalities ($P > 0.05$; analysis of variance).
†Parameters with large coefficients of variation.

Comparison of Modalities by Using Different Patients

The differences between the mean of the manual tracing and each of the imaging modalities for the parameters measured on images of 10 patients are reported in Table 3. The difference scores for Dolphin scanned did not differ significantly from zero (manual tracing). The difference scores for Dolphin digital were significantly different from zero and Dolphin scanned and from Vistadent scanned and Vistadent digital ($F_{14,135} = 2.19$ and 5.46, 8.27, respectively; $P < 0.05$). The difference scores for Vistadent scanned and Vistadent digital were not significantly different from each other. These findings indicate that the scores for these three techniques differed significantly from manual tracing values.

Table 3 Comparison of Differences in Cephalometric Parameter Measurements of Various Methods of Radiographic Modes and Cephalometric Software From Manual Tracing

Parameter	Mean Difference in Method of Analysis from Manual Traced Mean*			
	DS (X ± SD; N = 10)	DD (X ± SD; N = 10)	VS (X ± SD; N = 10)	VD (X ± SD; N = 10)
G-Sn/Sn-Me (°)	0.0 ± 0.0	−0.1 ± 0.0	−0.1 ± 0.0	−0.1 ± 0.0
Nasolabial angle (°)	1.6 ± 7.5	1.9 ± 5.4	3.1 ± 5.1†	4.5 ± 4.2†
Interlabial gap (mm)	−0.2 ± 0.4	−0.2 ± 0.4	0.0 ± 0.4	0.1 ± 0.4
Angle of facial conv (°)	1.3 ± 1.3	1.7 ± 1.6	1.9 ± 1.6	1.4 ± 1.7
Upper lip to E-line (mm)	−0.3 ± 0.4	−0.4 ± 0.5	0.5 ± 0.8	0.5 ± 0.5
Lower lip to E-line (mm)	−0.2 ± 0.7	−0.4 ± 0.6	0.5 ± 0.8	0.3 ± 0.6
Facial angle (°)	−0.5 ± 1.0	1.9 ± 4.1	5.7 ± 7.7†	6.2 ± 7.4†
H-line angle (°)	−0.5 ± 0.7	−0.6 ± 1.1	0.0 ± 0.7	−0.2 ± 0.7
Nose prominence (mm)	0.3 ± 0.8	−1.0 ± 1.7	0.1 ± 1.2	0.1 ± 1.3
Upper sulcus depth (mm)	0.4 ± 1.3	0.6 ± 1.5	0.2 ± 1.2	0.3 ± 1.2
Lower sulcus depth (mm)	−0.1 ± 1.3	0.2 ± 1.0	−0.5 ± 0.7	−0.3 ± 0.8
Upper lip thickness (mm)	0.3 ± 0.8	0.2 ± 1.1	−1.8 ± 1.9	−1.8 ± 1.9
Upper lip strain (mm)	0.4 ± 0.5	0.3 ± 0.5	1.1 ± 1.0	1.1 ± 1.0
Lower lip to H-line (mm)	0.5 ± 0.8	0.3 ± 0.7	0.6 ± 0.7	0.5 ± 0.5
Soft tissue chin thickness (mm)	−0.6 ± 0.8	−0.8 ± 1.1	−0.3 ± 0.9	−0.2 ± 0.6

DS, Dolphin scanned; DD, Dolphin digital; VS, Vistadent scanned; VD, Vistadent digital.
*Significant differences among imaging modalities (manual tracing = Dolphin scanned < Dolphin digital < Vistadent scanned = Vistadent digital; $P < 0.05$, analysis of variance; Student-Newman-Keuls).
†Differences exceeding 2 mm or 2 degrees from manual tracing.

Discussion

Reliability means that a measure can be reproduced consistently. Any technology used in the diagnosis of a disease or disorder, such as malocclusion, requires high reliability. In clinical practices such as orthodontics, a great deal of money and time can be lost using unreliable technology. Some authors[12] have suggested that digital radiography is the technology of choice for most imaging applications. In general, our study shows that the soft tissue measurement using Dolphin v. 7.0 and Vistadent v. 8.0 on digital images, whether scanned conventional film or phosphor images, is as reliable as manual tracing. No statistically significant differences in reliability were found across the imaging modalities.

Determining CVs is one method of reporting reliability. In general, the CVs for each parameter, regardless of the imaging or analysis modalities, were less than 0.10, suggesting a reasonably high level of intrarater reliability for each modality. The CVs for three parameters, interlabial gap, upper sulcus depth, and lower lip to H-line, exceeded 0.10, indicating lower reliability across all modalities. However, these CVs could have been influenced by the small mean value of each of these parameters because the standard deviations of each of the parameters were similar to those of the other parameters. CVs are calculated by dividing the mean into the standard deviation. Therefore, when a parameter with a small mean and one with a large mean are divided into standard deviations with the same value, the parameter with a small mean would have a larger CV.

However, similar to other studies,[7] we found statistically significant differences among the mean values of the imaging modalities when compared with manual tracings of the 10 patients. In other words, the measurements within each modality were consistently similar, although they were different from another modality. These differences could be caused by the better visibility of soft tissue on the digital images.[6,7] It is well known[20] that soft tissue measurements are more dependent on the quality of the conventional cephalogram than are hard tissue measurements. Eppley and Sadove[7] found statistically significant differences in several soft tissue parameters on conventional film compared with digital phosphor images of the same patients. They reported that the soft tissue was more clearly visible on the digital image compared with the conventional image. Hageman and coworkers[6] reported that the average reproducibility of two soft tissue cephalometric landmarks, pronasale and pogonion, was better on phosphor digital images when compared with conventional film. However, they identified landmarks on prints of the phosphor image, not on the monitor, and the cephalometric parameters were not measured. These differences could also be caused by the algorithms of the two software programs in loading digital images, in identifying the landmarks, or in measuring angles or lines.

Although there were statistically significant differences between modes of analysis and imaging format, only two parameters, facial angle and nasolabial angle, exceeded our criterion for clinical significance. These differences were found in both Vistadent modalities. The differences in nasolabial angle would probably not affect clinical decisions, whereas the differences in facial angle could affect clinical decisions. The obscurity of porion and orbitale, two landmarks used in facial angle, both of which can be difficult to see, could have influenced the measurement of these parameters. These differences could also be due to a difference in algorithms within Vistadent, compared with Dolphin, or to a difference in ability to view various landmarks in Vistadent.

Landmark identification is one of the sources of measurement error in conventional cephalometric analysis. Baumrind and Frantz[21] indicated that the geometric form of the error distribution around a landmark is reflected by the definition of the landmark, that a point situated on a curvature will be relatively well defined in one direction or axis, whereas its other axis will be more uncertain. Thus, the cephalometric variables will display a varying degree of measurement error, depending on how the lines, constituting the linear or angular variable, intersect the reference points. Mostafa and coworkers[8] suggested that angular measurements have more error than linear measurements. This is in agreement with our findings in which the facial angle and nasolabial angle showed the greatest differences.

Increasingly, orthodontists use computer programs to digitize anatomical landmarks and produce cephalometric analyses. Computerized cephalometric analysis can be simple, efficient, accurate, and reliable.[22,23] However, each software program needs to be evaluated. Both cephalometric software in this study were equally easy to use. Some of the variables included the type of registration pointer. Dolphin 7.0 uses a crosshair cursor while Vistadent 8.0 uses a conventional pointer. Contrary to Gregston and coworkers,[17] who indicated that the conventional pointer obscured some points, the conventional pointer did not appear to be a problem. The new analysis that Vistadent created for this research was not based on landmarks that they had previously programmed. The new algorithms may have caused measurement differences even though the new analysis was based on drawings and definitions we provided. This suggests that new programs must be checked before relying on their outcome.

Digital radiography using storage phosphor offers many advantages over conventional radiography: patient's x-ray exposure is greatly reduced[14]; image storage is simplified; the digital image can be displayed on the computer screen and can be enlarged, filtered, and enhanced for easier viewing[7]; the image can be transmitted over the internet without loss of quality; digital radiographs can be archived avoiding damage of x-ray film emulsion that occurs over time.[12] Despite so many advantages that digital radiography provides, it is computer dependent, needs additional software and hardware, and is more expensive. The file size is large and requires considerable storage space.

Similar to learning to manually trace a cephalometric radiograph, there is a learning process required to use digital radiography. The expansion to computer-based programs continues the direction of dental practice into the world of technology. Because storage phosphor images are obtained at reduced exposure, can be easily enhanced, and require no

chemical processing, they appear to be a feasible alternative to dental film.

Conclusions

There was no significant difference in intrarater reliability measurements of soft tissue cephalometric parameters between storage phosphor digital cephalometric images and conventional cephalometric images by using the different modes of analysis in our study. Difference of means studies revealed that there was no difference in Dolphin scanned values compared with manual traced values, whereas the other imaging modalities (Dolphin digital, Vistadent scanned, and Vistadent digital) were significantly different from the manual traced values. Dolphin digital was significantly different from Vistadent scanned and Vistadent digital, although there were no differences between Vistadent scanned or digital. In general, except for facial angle, these differences in modalities do not appear to be clinically significant.

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References

1. Burstone CJ: Lip posture and its significance in treatment planning. Am J Orthod 53:262-284, 1967
2. Ricketts RM: Esthetics, environment, and the law of lip relation. Am J Orthod 54:272-289, 1968
3. Bergman RT: Cephalometric soft tissue facial analysis. Am J Orthod Dentofac Orthop 116:373-389, 1999
4. Subtelny JD: A soft tissue profile, growth and treatment changes. Angle Orthod 31:105-122, 1961
5. Geelen W, Wenzel A, Gotfredsen E, et al: Reproducibility of cephalometric landmarks on conventional film, hardcopy, and monitor-displayed images obtained by the storage phosphor technique. Eur J Orthod 20:331-340, 1998
6. Hagemann K, Vollmer D, Niegel T, et al: Prospective study on the reproducibility of cephalometric landmarks on conventional and digital lateral headfilms. J Orofac Orthoped 61:91-99, 2000
7. Eppley B, Sadove M: Computerized digital enhancement in craniofacial cephalometric radiography. J Oral Maxillofac Surg 49:1038-1043, 1991
8. Mostafa YA, Mangoury NH, Salah A, et al: Automated cephalometric soft-tissue analysis. J Clin Orthod 9:539-543, 1990
9. Farman A, Farman T: Extraoral and panoramic systems. Dent Clin N Am 44:257-272, 2000
10. Menig J: The DenOptix digital radiographic system. J Clin Orthod 33:407-410, 1999
11. Van der Stelt P: Principles of digital imaging. Dent Clin N Am 44:237-248, 2000
12. Hildebolt CF, Couture RA, Whiting BR: Dental photostimulable phosphor radiography. Dent Clin North Am 44:273-297, 2000
13. Seki K, Okano T: Exposure reduction in cephalography with a digital photostimulable phosphor imaging system. Dentomaxillofac Radiol 22:127-130, 1993
14. Lim KF, Foong KW: Phosphor-stimulated computed cephalometry: reliability of landmark identification. Br J Orthod 24:301-308, 1997
15. Naslund EB, Kruger M, Petersson A, et al: Analysis of low-dose digital lateral cephalometric radiographs. Dentomaxillofac Radiol 27:136-139, 1998
16. Forsyth DB, Morth FDC, Shaw WC, et al: Digital imaging of cephalometric radiographs, part 2: Image quality. Angle Orthod 66:43-50, 1996
17. Gregston M, Kula T, Hardman P, et al: A comparison of conventional and digital radiographic methods and cephalometric analysis software: Hard tissue landmarks. Semin Orthod 10:204-211, 2004
18. Holdaway RA: A soft-tissue cephalometric analysis and its use in orthodontic treatment planning. Part I. Am J Orthod 84:1-28, 1983
19. Steiner CC: The use of cephalometrics as an aid to planning and assessing orthodontic treatment. Am J Orthod 46:721-735, 1960
20. Wisth PJ, Boe OE: The reliability of cephalometric soft tissue measurements. Arch Oral Biol 20:595-599, 1975
21. Baumrind S, Frantz R: The reliability of head film measurements, 2.conventional angular and linear measures. Am J Orthod 60:505-517, 1971
22. Gottlieb EL, Nelson AH, Vogels DS III: Study of orthodontic diagnosis and treatment procedures. Clin Orthod 30:615-629, 1996
23. Baskin HN, Cisneros GJ: A comparison of two computer programs. J Clin Orthod 231-233, 1997