TBILISI STATE MEDICAL UNIVERSITY
ANNALS OF BIOMEDICAL RESEARCH AND EDUCATION
2002 October/December, *Volume 2, Issue 4*

Reliability of Soft Tissue Cephalometric Parameters Using Conventional and Digital Cephalometric Radiogram

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Abstract

The purpose of this study was to compare the intra-rater reliability of measurements of soft tissue cephalometric landmarks between storage phosphor digital cephalometric images and conventional cephalometric images using hand tracing and computerized cephalometric programs. Four angular and eleven linear (total of 15) cephalometric measurements were hand traced and digitized in two software programs (Dolphin 7.0 [D], Vistadent 8.0 [V]). A conventional film and a digital image were obtained simultaneously with single exposure (hybrid cassette technique). The conventional cephalogram was scanned; the phosphor plate was processed by laser scanner (Gendex). Scanned and storage phosphor images were saved to a Zip disc as JPG files. Two lateral cephalograms (one conventional and one digital) of the same patient were used. Every landmark was hand traced and digitized ten times on ten separate days. Holdaway's and Steiner's soft tissue analysis were performed. All measurements were made by a single investigator. To assess the reliability of the different techniques, coefficient of variation (CV) were computed for all measures, by imaging technique. Statistically significant differences among the groups were tested using Multivariate ANOVA with repeated measures accepting $p<0.05$ as significant. Although there were significant differences between various measurements, results showed no consistent difference between three techniques (Hand Tracing [HT], Vistadent Scanned [VS], Vistadent Digital [VD], Dolphin Scanned [DS] and Dolphin Digital [DD]).

Keywords: *orthodontics, cephalometrics, soft tissue, storage phosphor screen, digital radiography*

Introduction

The soft tissue profile analysis that began in 1950s (Burstone 1958; Ricketts 1957; Broadbent, Matthew 1957) plays a significant role in orthodontic consideration and it has become an essential part of orthodontic diagnosis and treatment planning. Depending only on cephalometric dentoskeletal analysis for treatment planning can cause esthetic problems, especially when the orthodontist tries to foresee soft tissue outcome using only hard tissue values. The dentoskeletal pattern may not provide adequate information to evaluate facial disharmony because of great variations in facial soft tissue (Bergman 1999). Upon understanding the soft tissue features and their normal ranges, a treatment plan can be designed so that it can normalize the facial characteristics for a given individual (Subtelny 1961).

Most investigations on the reliability of soft tissue cephalometric measurements using conventional and digital cephalometric analysis (Geelen, Wenzel, Godfredsen, Kruger, Hansson 1998; Houston 1982; Davis 1991) have dealt mainly with the skeletal reference points. Only a few authors (Hagemann, Vollmer, Niegel, Ehmer, Reuter 1999; Bunel, Sterling 1989; Mostafa, Mangoury, Salah, Rasmy 1990) have studied problems and benefits regarding the reproducibility of soft-tissue measurements.

Each radiographic exposure is a potential risk for the patient. The development of sensitive film/screen combination has led to a considerable reduction in the radiation dose. The goal is a further reduction in radiation without loss of diagnostic quality. Using digital radiography is one method of reducing patient exposure. Additional benefits of digital technology are the image processing, the storage improvement, and information access or transfer (Forsyth, Morth, Shaw, Richmond, Roberts 1996).

Storage phosphor technology was first applied in imaging by Sonada (1983). Storage phosphor plate is made of polymer material covered with a photo-stimulable phosphor compound. It is flexible, re-usable and less than 1 mm thick. This thickness helps usage of phosphor plate for standard screen-film system because it can be sandwiched into a standard cassette with the conventional film. A phosphor plate can store images. Compared to conventional film, storage phosphor doesn't need a dark room for processing and no chemical processing is required as well.

On exposure, the image is stored on the phosphor. The plate is scanned by a laser beam to release the photoluminescence. 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. Because of the wide exposure range of storage phosphor screen there is no determined relationship between radiation dose and image density. Both hard and soft tissues are shown more clearly than with conventional film (Seki, Okano 1993). It is possible to underexpose or overexpose storage phosphor and still produce clinically acceptable images (Hildebolt, Couture, Whiting 2000).

Lim et al (1997) in a controlled, prospective study investigated the reliability of landmark identification on the digital and conventional lateral cephalometric radiographs. Twenty conventional images were compared to 20 computed images taken at 30 percent reduced radiation. On each film, eight skeletal, four dental and five soft tissue landmarks were identified. Two-way ANOVA showed that there was no significant difference between the two imaging systems in X-Y Cartesian co-ordinates. Soft tissue landmarks were more reliable in the X-co-ordinate.

Naslund, Kruger, Petersson and Hansen (1998) examined the effects of the radiation dose reduction on the identification of cephalometric landmarks. Radiation dose was reduced using photostimulable phosphor computed radiography. The soft tissue points, nose, upper and lower lip, because of their low structural density, were not influenced by the exposure reduction.

There is limited data available about soft tissue landmark reproducibility with available contemporary cephalometric imaging techniques including digitization of conventional films and direct digital radiography using the storage phosphor plates. The efficacy/reliability of certain commercially accessible software programs used for cephalometric analysis needs to be tested as well.

The aim of this paper is to compare the intra-rater reliability of measurements in regards to soft tissue cephalometric landmarks between storage phosphor digital cephalometric images and conventional cephalometric images. Commercially available cephalometric analysis software as well as hand tracing will be used. The null hypothesis is that there is no significant difference in the intra-rater reliability of measurements derived from the various soft tissue landmarks between conventional and digital cephalometric images using the different modes of analysis.

Material and Methods

Subjects

Materials were obtained from the orthodontic department, UMKC dental school and included one conventional and one digital lateral cephalometric image of 13 year old Caucasian patient. Patient was selected from the clinic patients scheduled for orthodontic records. Routine orthodontic records include a lateral cephalogram as an important part of diagnosis.

Equipments

The cephalometric equipment included a Quint Sectograph Cephalometric-Tomographic X-ray Unit (322 West Twelfth, Los Angeles, California 90015) and tube (Duocon-M) with cephalostat. Radiographs were taken with the patient in the fixed head position in the cephalostat with constant source to object and object to cassette distance. The source to object distance was 150 cm and object to cassette distance was 15 cm.

For clear soft tissue contour, an aluminum wedge was placed between the soft tissue parts of the profile and the film. Cephalograms were taken with relaxed lips and with the teeth in maximum intercuspation. A conventional film and a digital image were obtained simultaneously with a single exposure. A storage phosphor plate (Densply International, Gendex dental X-ray Division, 901 W. Oakton Street, DesPlaines, IL 60018-1884) was sandwiched with the conventional film into a standard cassette (Kodak X-Omatic Cassette) with Lanex Regular Screens. The film was facing the tube head followed by the phosphor screen. The exposure parameters were 82Kvp 1/5 sec 50 ma. The above film/phosphor screen alignment was based on the assumption that the X-ray beam, although attenuated by the film, is adequate to create a clear image on the storage phosphor plate without any significant effect on the quality of the image (Naslund, Kruger, Petersson, Hansen 1995). Image was deemed to have density readings equivalent to that of exposing the storage phosphor screen by itself. This was completed by the use of a 21-step wedge and read via a densitometer (X-Rite Model 301,3100 44th Street SW, Grandville, Michigan). The hybrid cassette density reading was 148 while the storage phosphor screen alone had a density reading of 151. Thus, this method of image capture was felt to be a viable means to evaluate dual images while limiting the radiation exposure to the research subject.

Films were processed immediately after exposure. The conventional film was developed in an automatic film processor (Alpatek Ax700LE, USA). Fresh chemistry and standardized darkroom procedures were applied. The image plate was processed by a laser scanner (Densply International, Gendex Dental X-ray Division, 901 W. Oakton Street, DesPlaines, IL 60018-1884). The storage phosphor image was stored as JPEG and the compression format used was TIFF JPEG LOSSLESS, the default format for radiographic image. The digital image size was 762kilobites (KB). The conventional cephalogram was scanned by an Epson Expression 1600 Scanner professional using standardized image settings (Image type: 24-bit color (std); Document source: TPU for positive film; Destination: screen/web; and Resolution: 200). Scanned and storage phosphor images were saved to a Zip disc as .JPG files. Films were scanned at one setting to insure consistency.

Experimental

There were total of two images (1 conventional, 1 digital) of the same individual, conventional image was hand traced and digitized *(Fig. 1)*. The scanned image of the conventional cephalogram as well as the digital cephalogram was imported into each of the two cephalometric software: Dolphin 7.0(D) and Vistadent 8.0(V). (D-Dolphin Imaging, Canoga Park, CA; V-Dentsply International Inc., York, Pennsylvania).

Each software program was calibrated prior to each individual tracing following the manufacturer's instructions (page 108 of Vistadent Image Management system, Version 8.0 manual). For image calibration in Dolphin 7.0 calibration ruler was used (page 5-3 of the Dolphin Imaging User's Guide, Version 6.7- October 2000). All measurements were made by a single investigator to prevent variability in interpretation. The hand tracing was considered the "gold standard". The digital tracing landmarks were identified on a monitor (Dell, OptiPlex, GX110). Landmark sampling in Dolphin 7.0 was performed with a mouse controlled crosshair cursor. In Vistadent 8.0 conventional arrow pointer was used for the same purpose. 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 using the same computer (Dell OptiPlex BX 110, Dell Computer Corporation, Round Rock, Texas) with the monitor setting at True color (24 bit).

A view box (Slimlight, Image Marketing Corporation) was used for hand tracing. Landmarks were recorded on standard 8X10 inch sheet of 0.003-inch matte, acetate tracing paper with 0.5mm mechanical lead pencil. 3M Unitek cephalometric protractor with millimetric ruler nearest 0.5 mm was used for linear and angular measurements. Landmarks were identified on both the conventional and the monitor-displayed images in a dimmed room.

Intrarator Reliability

Two lateral cephalograms (one conventional and one digital) were used for determining intrarater reliability *(Fig.1)*. These two images were taken simultaneously on one individual. Scanned and digital cephalograms were loaded into Dolphin 7.0 and Vistadent 8.0. Every landmark was digitized ten times. Each digitization was done on separate day using both software programs.

Cephalometric Analysis

On hand tracing a total of 12 soft tissue landmarks and two hard tissue landmarks were used. Eleven linear and 4 angular (total of 15) parameters were measured. The same procedure was repeated with Dolphin (ceph Version 7.0) and Vistadent Image Management System (ceph Version 8.0). Holdaway's, and Steiner's soft tissue analysis were performed *(Fig.2).*

	Coefficient of Variation-CV				
	HT+	DS°	DD□	VS▲	VD◙
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

Tab.1 *Intrarater reliability of cephalometric parameters using various methods of analysis.*

*Highlighting indicates parameters deleted in intrarater reliability
+ HT-hand tracing; °DS-Dolphin scanned; □DD-Dolphin digital; ▲VS-Vistadent scanned; ◙ VD-Vistadent digital

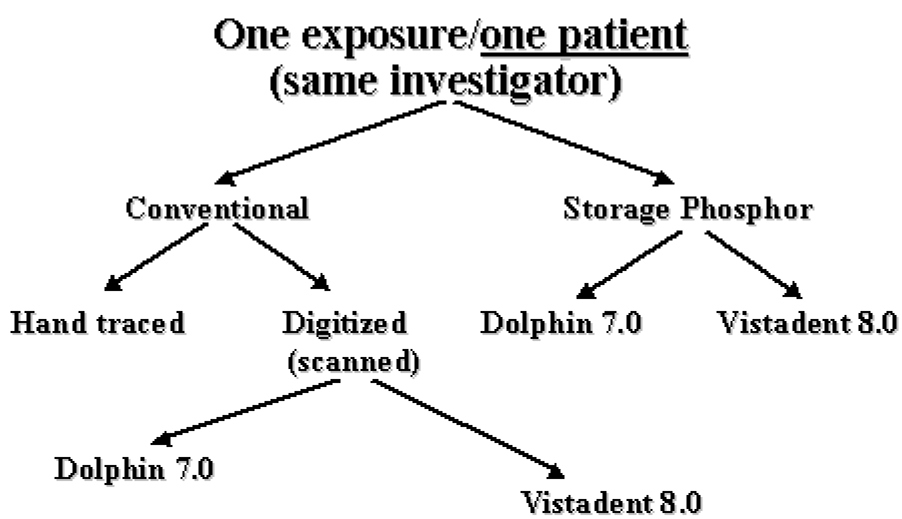

Fig.1 *Intra-rater reliability.*

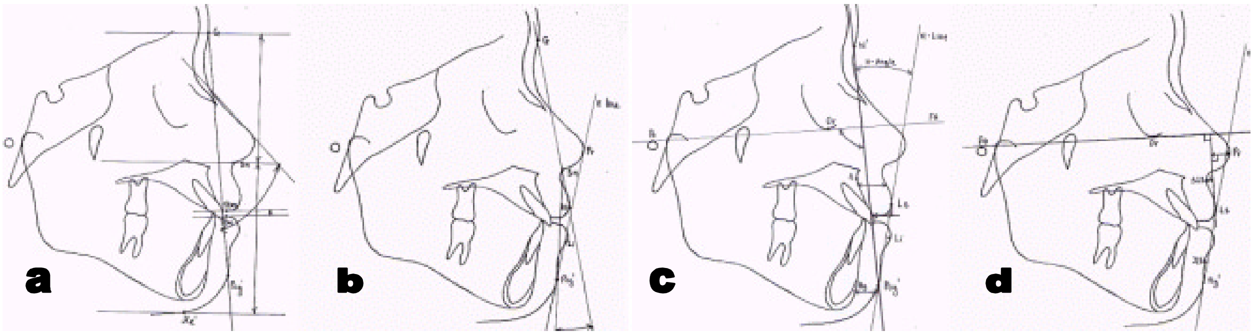

Fig.2 *Soft tissue landmarks and preformed analysis.*

a. Ratio middle to lower face; nasofacial angle; interlabial gap.
b. Angle of facial convexity; Ricketts' upper lip to E-line; Ricketts 'lower lip to E-line.
c. Holdaway's analysis: H-line angle, upper lip thickness, upper lip strain, facial angle soft-tissue chin thickness, lower lip to H-line.
d. Holdaway's analysis: nose prominence, upper sulcus depth, lower sulcus depth.

Results

To assess the relative variability of the different techniques, coefficients of variation (CV) were computed for all the parameters, by imaging technique. These values are reported in *Tab.1.* Three parameters interlabial gap, upper sulcus depth, lower lip to H-line, were eliminated because the CV for these measures was considerably higher than for the other measures, indicating that the variability within these three parameters was relatively greater than the relative variability for all remaining parameters. The actual variability of these parameters was similar to the other measures; however, the size of the measure was small causing the coefficient of variation to be relatively large.

To determine whether the values reported by the imaging techniques differed, the values for the remaining measures for one subject were subjected to a one-way analysis of variance. There were no differences between techniques in the intrarater reliability.

Discussion

Although some authors suggest that digital radiography is the technology of choice for most imaging applications (Hildebolt, Couture, Whiting 2000) our study shows that in comparison with hand tracing digital radiography is as reliable as hand tracing. The most used digital radiographic technique utilizes photostimulable phosphor plates instead of film. Photostimulable phosphor radiography can improve dental radiography and has potential to become popular over the next 5 years.

Digital radiography offers many advantages over conventional radiography: patient's x-ray exposure is greatly reduced (Lim 1997); image storage is simplified; the digital image can be displayed on the computer screen and can be enlarged, filtered and enhanced for easier viewing (Eppley, Sadove 1991); 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 (Hildebolt, Couture, Whiting 2000). Despite so many advantages that digital radiography provides, it is computer dependent, needs additional software/hardware and is more expensive. The file size is big and requires considerable storage space.

An increasing numbers of orthodontists use computer programs to digitize anatomical landmarks and produce cephalometric analyses. Computerized cephalometric analysis can be simple, efficient, accurate and reliable (Gottlieb 1996). Some sources of measurement error in cephalometric analysis are: radiographic film magnification, landmark identification, tracing, measuring and recording. Computer analysis is unlikely to produce more measurement error than hand tracing (Baumrind 1972).

In our study, intrarater reliability showed no consistent difference between three techniques: Hand Tracing (HT), Vistadent 8.0(V) and Dolphin 7.0 (D). Second part of research needs to be preformed where reliability using different subjects will be studied in order to reveal statistically significant differences among techniques and to find out which computer program is closest to hand tracing (Vistadent 8.0 or Dolphin7.0).

The use of both programs was equally easy. 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. However, this difference did not appear to be a problem. Soft tissue measurements were limited in both programs. Vistadent created the analysis needed for this research. We eliminated a couple of measurements, because they were not available in Dolphin 7.0.

Similar to learning to hand trace a cephalometric radiograph there is a learning process required to use/interpret digital radiography. Its introduction to the office evolves the practice of dentistry to a new level. 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 intrarator reliability of measurements in regards to soft tissue cephalometric landmarks between storage phosphor digital cephalometric images and conventional cephalometric images using the different modes of analysis.

Appendix

The key words used in the literature search were soft tissue, reliability, cephalometrics, and digital radiography.

Reference

1. Baumrid S, Frantz R. The reliability of head film measurements, 2.conventional angular and linear measures. Amer J Orthod, 1971; 60:505-517.

2. Bergman RT. Cephalometric soft tissue facial analysis. Amer J Orthod and Dentof Orthop, 1999; 116:373-89.

3. Eppley B, Sadove M. Computerized digital enhancement in craniofacial cephalometric radiography. J Oral Maxillofac Surg, 1991; 49:1038-1043.

4. Forsyth DB, Morth FDC, Shaw WC, Richmond S, Roberts CT. Digital imaging of cephalometric radiographs, Part 2:image quality. Angle Orthod, 1996; 66:43-50.

5. Geelen W, Wenzel A, Gotfredsen E, Kruger M, Hansson L. Reproducibility of cephalometric landmarks on conventional film, hardcopy, and monitor-displayed images obtained by the storage phosphor technique. Eur J Orthod, 1998; 20:331-340.

6. Gottlieb EL, Nelson AH, Vogels DS III. Study of orthodontic diagnosis and treatment procedures. Clin Orthod, 1996; 30:615-629.

7. Hagemann K, Vollmer D, Niegel T, Ehmer U, Reuter I. Prospective study on the reproducibility cephalometric landmarks on conventional and digital lateral headfilms. J Orofacial Orthopedics, 2000; 61:91-9.

8. Hildebolt CF, Couture RA, Whiting BR. Dental photostimulable phosphor radiography.m Dental Clinics North America, 2000; 44.

9. Holdaway RA. A soft-tissue cephalometric analysis and its use in orthodontic treatment planning. Part I. Amer J Orthod, 1983; 84:1-28.

10. Jacobson AL. Radiographic cephalometrics. Quintessence books, Chicago. 1995; 239-271.

11. Lim KF, Fuung KW. Phosphor-stimulated computed cephalometry: reliability of landmark identification. Br J Orthod, 1997; 24:301-308.

12. Naslund EB, Kruger M, Petersson A, Hansen K. Analysis of low-dose digital lateral cephalometric radiographs. Dentomaxillofacial Radiol, 1998; 27:136-139.

13. Proffit W, Fields H. Contemporary orthodontics. Mosby, St.Louis. 2000; 174-175.

14. Seki K, Okano T. Exposure reduction in cephalography with a digital photostimulable phosphor imaging system. Dentomaxillofac Radiol, 1993; 22:127-130.

15. Subtelny JD. A soft tissue profile, growth and treatment changes. Angle Orthod, 1961; 31:105-22.

Сравнительная характеристика различных методов определения точности цефалометрических параметров мягких тканей лица с использованием общепринятой и цифровой рентгенографии

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Р Е З Ю М Е

Изучена точность ориентировочных точек мягких тканей лица на общепринятой и цифровой рентгенограммах выполненых рукой и двумя компьютерными программами. Четыре угловых и одиннадцать линейных (всего 15) параметров были начертаны рукой и двумя компьютерными программами (Dolphin 7.0, Vistadent 8.0). Обычная и цифровая рентгенограммы были выполнены одновременно одноразовым облучением (техника гибридной кассеты). Обычная рентгенограмма была сканирована, а фосфорный экран обработан лазерным сканером (Densply International, Gendex dental X-ray Division, 901 W. Oakton Street, Desplaines, IL 60018-1884). Сканированный и цифровой имиджи были сохранены на Zip диске как .JPEG фаилы. Для определения точности цефалографических точек мягких тканей лица каждый параметр был начертан десять раз в разные дни рукой и двумя компьютерными программами (Dolphin 7.0, Vistadent 8.0). Результаты исследования обработаны с использованием коэффициента вариации. Статистичестки значительная разница определена статистическим тестом ANOVA. Исследование показало, что все изученные нами технические методы одинаково надёжны.

Ключевые слова: *ортодонтия, цефалография, мягкие ткани, профилт, цифровая рентгенография*