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Reliability of lower extremity alignment measurement using radiographs and PACS

R. G. Marx · P. Grimm · K. A. Lillemoe · C. M. Robertson · O. R. Ayeni · S. Lyman · E. A. Bogner · H. Pavlov

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Abstract

Purpose Lower extremity alignment is an important consideration prior to cartilage surgery and/or osteotomy about the knee. This is measured on full length standing hip to ankle radiographs, which has traditionally been done using hard copy radiographs. However, the advent of PACS (Picture Archiving and Communication Systems) has allowed these measurements to be done on computer based digital radiographs. The objectives of this study were to evaluate the intra- and inter-observer reliability of lower limb alignment measures manually obtained from hard copy radiographs versus using the Philips Easy Vision system, and to assess the subjective ease of use for the two methods.

Methods Forty-two patients who underwent surgery and who had a standing hip to ankle radiograph on file were identified. Four raters, including two radiologists and two orthopaedic surgeons, measured each hard copy radiograph and computer image on two separate occasions. Three measurements were recorded for each hard copy radiograph and computer image—width of tibial plateau, the distance from the medial aspect of the tibial plateau to the weight-bearing line, and the mechanical axis.

Results All correlations for this study were high. For tibial plateau data, the hard copy radiographs compared to PACS demonstrated intra-class correlation coefficients (ICC) ranging from 0.93 to 0.99 for inter-rater reliability for the four raters. The ICC for intra-rater reliability for hard copies ranged from 0.90 to 0.99 and for PACS from 0.94 to 0.99. The inter-rater data comparing raters ranged from 0.87 to 0.98 for hard copy radiographs and from 0.98 to 0.99 for PACS. For mechanical axis data, the ICC for hard copy radiograph compared to PACS ranged from 0.93 to 0.97 for the intra-rater reliability for the four raters. The intra-rater reliability for mechanical axis data on hard copy radiograph ranged from an ICC of 0.86 to 0.96, and for PACS the ICC ranged from 0.93 to 0.99. The inter-observer data for hard copy radiographs using the mechanical axis ranged from 0.88 to 0.94 and for PACS ranged from 0.93 to 0.97. The physicians rated PACS as statistically significantly easier to use when compared to hard copy ($P = 0.03$).

R. G. Marx (✉)
Sports Medicine and Shoulder Service, Hospital for Special Surgery, 535 East 70th St, New York, NY 10021, USA
e-mail: marxr@hss.edu

P. Grimm · K. A. Lillemoe
Clinical Research, Hospital for Special Surgery, 535 East 70th St, New York, NY 10021, USA

C. M. Robertson
Orthopedic Surgery and Sports Medicine, UCSD Medical Center, Hillcrest, 200 West Arbor Dr, San Diego, CA 92103, USA

O. R. Ayeni
Orthopaedic Surgery and Sports Medicine, McMaster University Medical Centre, 1200 Main St West, 4E17, Hamilton, ON L8N 3Z5, Canada
e-mail: ruffolo@mcmaster.ca

S. Lyman
Epidemiology and Biostatistics, Hospital for Special Surgery, 535 East 70th St, New York, NY 10021, USA
e-mail: lymans@hss.edu

E. A. Bogner · H. Pavlov
Radiology and Imaging, Hospital for Special Surgery, 535 East 70th St, New York, NY 10021, USA
e-mail: bognere@hss.edu

H. Pavlov
e-mail: pavlovh@hss.edu

Conclusion Evaluation of lower extremity alignment using two techniques prior to knee surgery was found to have higher inter- and intra-observer reliability using PACS software. PACS is now used prior to cartilage surgery and/or osteotomy to measure both alignment and the location of the weight bearing line on the tibial plateau both before and after surgery.
Level of evidence Diagnostic study, Level I.

Keywords Alignment · Osteotomy · PACS · Surgery · Measurement · Knee

Introduction

Lower extremity alignment is an important consideration prior to cartilage surgery and/or osteotomy about the knee. This is measured on full length standing hip to ankle radiographs. Traditionally, these measurements were obtained using hard copy radiographs. With the advent of PACS (Picture Archiving and Communication Systems), these measurements can be made on computer based digital radiographs using software packages [2, 6].

Computer based measurements of digital radiographs present several clear advantages [1, 5, 9]. First, it eliminates the necessity of producing large, bulky hard copy radiographs, thereby saving both time and money. Secondly, digital radiographs can be retrieved and stored with much greater ease than hard copy films. Finally, magnification and contrast tools included in the software make for easier manipulation of the image [7]. What is less well known is whether measurements of alignment can be made on digital radiographs with the same accuracy as on hard copy radiographs. As a result, some surgeons have been reticent to embrace the use of this new technology for pre-operative planning. A previous study analyzed the agreement between hard copy radiograph measurements and those made using the software package HTO Pro [8]. To the authors' knowledge, no study has compared hard copy radiograph measurements and those made using the PACS Easy Vision system.

The objective of this study was to evaluate the intra- and inter-observer reliability of lower limb alignment measures manually obtained from hard copy radiographs versus measurements obtained using the Philips Easy Vision system. A secondary objective was to assess the subjective ease of use for the two methods. The hypothesis was that digital radiographs would have similar reliability to hard copy radiographs for the measurement of lower extremity alignment.

Materials and methods

Forty-two patients (17 women and 25 men; 21 left knees and 21 right knees) who underwent surgery and who had a standing hip to ankle radiograph on file were identified. The procedures include fourteen high tibial osteotomies, nine mosaicplasties, seven meniscal allografts, five microfractures, four osteochondral allografts, and three primary OBI mosaicplasties. Hard copy radiographs were then organized alphabetically and labeled by study number. The patient name was covered to prevent the raters from identifying the patient.

Four raters, including two radiologists and two orthopaedic surgeons, measured each hard copy radiograph and computer image (using the Philips Easy Vision system) on two separate occasions separated by a minimum of 2 weeks. The presentation order of the radiographs was changed between the first and second readings to further minimize recall bias. Three measurements were recorded

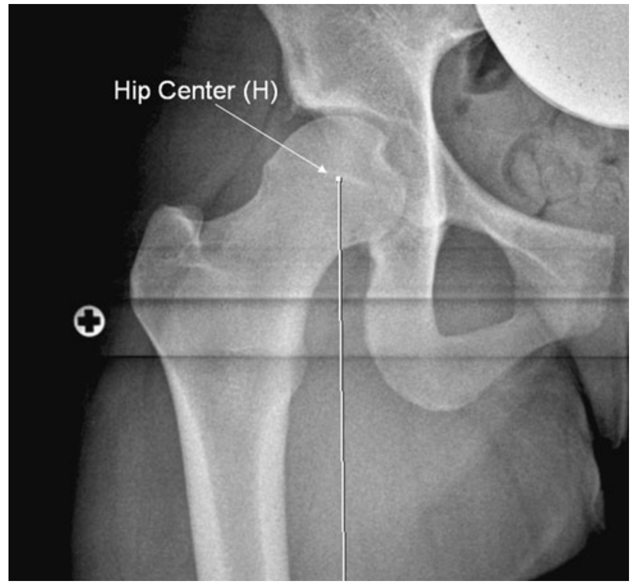

Fig. 1 Hip center (H)

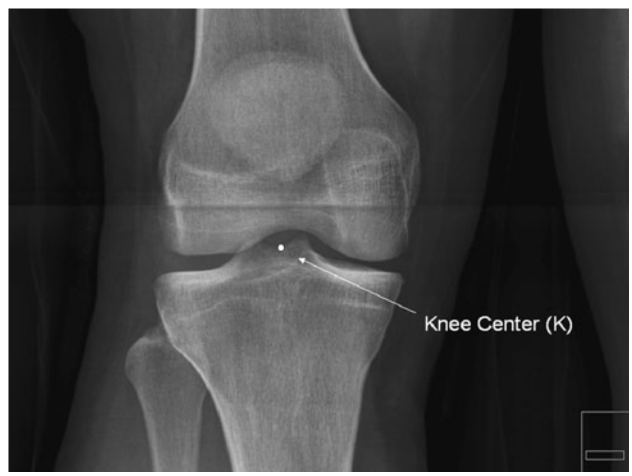

Fig. 2 Knee center (K)

Fig. 3 Ankle center (A)

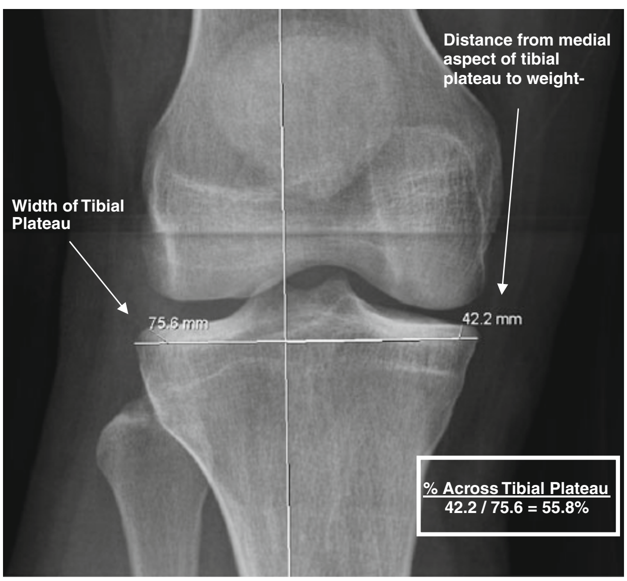

Fig. 4 Measurement of percent across tibial plateau

for each hard copy radiograph and computer image—width of tibial plateau, the distance from the medial aspect of the tibial plateau to the weight-bearing line, and the mechanical axis.

The following points were used to conduct all measurements:

- Center of Hip (H)—Center of femoral head, in best judgment of the observer (Figs. 1, 5).
- Center of Knee (K)—Midpoint of the tibial spines halfway between the intercondylar notch (Figs. 2, 5).
- Center of Ankle (A)—Midpoint between inner edges of malleoli, ½ height of talus [Figs. 3, 5].

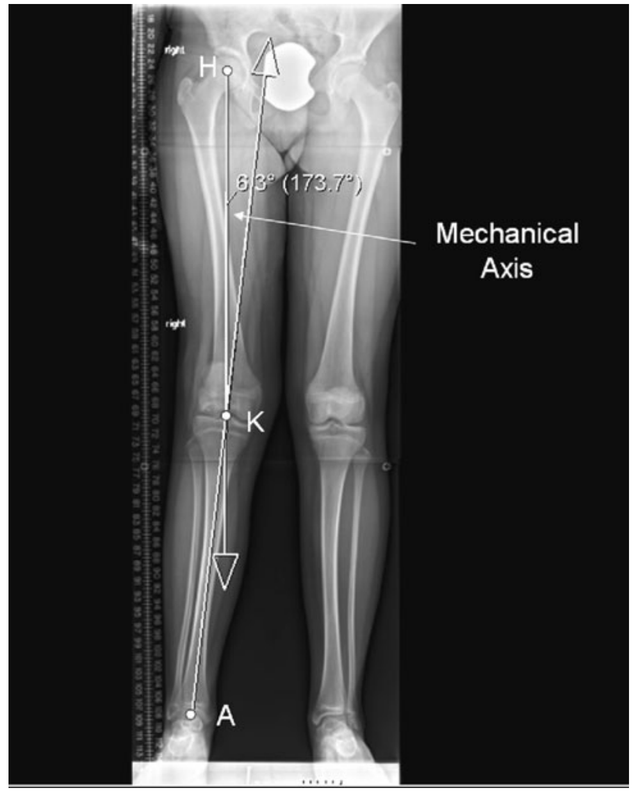

Fig. 5 Example of the calculation of mechanical axis

The following measurements were made on both hard copy radiographs and digital images:

1. Percent Across Tibial Plateau—Measured in the following manner:

i. Draw weight-bearing line from hip center (H) to ankle center (A).

ii. Measure width of Tibial Plateau at its widest point (Fig. 4).

iii. Measure distance from medial aspect of the tibial plateau to the intersection with the weight-bearing line. If the weight-bearing line falls to the medial side of the joint, the distance is measured as a negative distance.

Formula = [(Distance from Medial Aspect of Tibial Plateau)/(Width of Tibial Plateau (mm))] * 100

1. Mechanical Axis—Measured in the following manner:

i. Draw Femoral Mechanical Axis from hip center (H) to knee center (K).

ii. Draw the Tibial Mechanical Axis from the ankle center (A) to knee center (K).

iii. Measure the angle between the Femoral Mechanical Axis and the Tibial Mechanical Axis. This is known as the mechanical axis of the lower limb [2]. Express as its angular deviation from 180°. Varus deviations are negative. Valgus deviations are positive (see Fig. 5).

Table 1 Tibia plateau data

HC versus PACS	Intraclass correlation	95% Confidence interval	
		Lower bound	Upper bound
Radiologist A	0.99	0.98	0.99
Radiologist B	0.97	0.95	0.99
Orthopod A	0.98	0.97	0.99
Orthopod B	0.93	0.87	0.96

Scale % across tibia plateau

Table 2 Tibia plateau data

HC intra-rater	Intraclass correlation	95% Confidence interval	
		Lower bound	Upper bound
a			
Radiologist A	0.99	0.99	0.99
Radiologist B	0.97	0.95	0.98
Orthopod A	0.90	0.82	0.94
Orthopod B	0.92	0.85	0.95
PACS intra-rater	Intraclass correlation	95% Confidence interval	
		Lower bound	Upper bound
b			
Radiologist A	0.99	0.99	0.99
Radiologist B	0.99	0.99	0.99
Orthopod A	0.94	0.89	0.97
Orthopod B	0.99	0.98	0.99

Scale % across tibia plateau

For hard copy radiographs, a sharpened soft lead film marking pencil was used for all measurements. These markings were erased after each measurement. A straightedge was used to mark the weight-bearing line, femoral mechanical axis, and tibial mechanical axis. A transparent metric ruler with millimeter markings was used to measure tibial width and the distance from the medial aspect of the tibia to the weight-bearing line. A goniometer (Whitehall Manufacturing, Model G300) was used to measure the angle between the mechanical axis of the femur and the mechanical axis of the tibia.

For computer images, all radiographs were loaded onto the Philips Easy Vision system at the time they were produced. Using the tools provided in this system, clinicians can measure distances, angles, and digitally mark anatomical landmarks. The same measurements as described above were made using these tools.

Statistical analysis

Inter- and intra-rater reliability were measured using one way random single measure intraclass correlation coefficients (ICCs) with associated 95% confidence intervals to gauge the precisions of the ICCs. Reviewers were not pooled for this analysis in order to evaluate individual inter-rater reliability, especially in examining differences between radiologists and orthopedic surgeons. All analyses were conducted using SPSS for windows 17.0 (Chicago, IL). Each of the four raters was also asked to rate the ease of use of the two methods on a Likert Scale ranging from

Table 3 Tibia plateau data

HC inter-rater	Intraclass correlation	95% Confidence interval	
		Lower bound	Upper bound
a			
Radiologist A versus Radiologist B	0.97	0.94	0.98
Orthopod A versus Orthopod B	0.91	0.84	0.95
Radiologist A versus Orthopod A	0.98	0.97	0.99
Radiologist A versus Orthopod B	0.92	0.85	0.95
Radiologist B versus Orthopod A	0.95	0.91	0.97
Radiologist B versus Orthopod B	0.87	0.78	0.93
PACS inter-rater	Intraclass correlation	95% Confidence interval	
		Lower bound	Upper bound
b			
Radiologist A versus Radiologist B	0.99	0.98	0.99
Orthopod A versus Orthopod B	0.99	0.98	0.99
Radiologist A versus Orthopod A	0.99	0.98	0.99
Radiologist A versus Orthopod B	0.98	0.96	0.99
Radiologist B versus Orthopod A	0.99	0.99	0.99
Radiologist B versus Orthopod B	0.98	0.97	0.99

Scale % across tibia plateau

Table 4 Mechanical axis data

HC versus PACS	Intraclass correlation	95% Confidence interval	
		Lower bound	Upper bound
Radiologist A	0.95	0.91	0.97
Radiologist B	0.93	0.87	0.96
Orthopod A	0.97	0.95	0.99
Orthopod B	0.97	0.94	0.98

Table 5 Mechanical axis data

HC intra-rater	Intraclass correlation	95% Confidence interval	
		Lower bound	Upper bound
a			
Radiologist A	0.96	0.92	0.98
Radiologist B	0.93	0.88	0.96
Orthopod A	0.96	0.93	0.98
Orthopod B	0.86	0.76	0.92
PACS intra-rater	Intraclass correlation	95% Confidence interval	
		Lower bound	Upper bound
b			
Radiologist A	0.98	0.96	0.99
Radiologist B	0.97	0.95	0.98
Orthopod A	0.99	0.99	0.99
Orthopod B	0.93	0.87	0.96

one to ten, with one being very difficult and ten being very easy.

Results

All correlations for this study were high. The results were divided into mechanical axis data and tibial plateau data. For tibial plateau data, the hard copy radiographs compared to PACS demonstrated intra-class correlation coefficients (ICC) ranging from 0.93 to 0.99 for inter-rater reliability for the four raters (see Table 1). The ICC for intra-rater reliability for hard copies ranged from 0.90 to 0.99 and for PACS from 0.94 to 0.99 (see Table 2a, b). The inter-rater data comparing raters ranged from 0.87 to 0.98 for hard copy radiographs and from 0.98 to 0.99 for PACS (see Table 3a, b).

For mechanical axis data, the ICC for hard copy radiograph compared to PACS ranged from 0.93 to 0.97 for the intra-rater reliability for the four raters (see Table 4). The intra-rater reliability for mechanical axis data on hard copy radiograph ranged from an ICC of 0.86 to 0.96 and for PACS the ICC ranged from 0.93 to 0.99 (see Table 5a, b). The inter-observer data for hard copy radiographs using the mechanical axis ranged from 0.88 to 0.94 and for PACS ranged from 0.93 to 0.97 (see Table 6a, b).

The physicians rated PACS as statistically significantly easier to use when compared to hard copy ($P = 0.03$). The median rating for PACS was 10 (range 8.5–10). For hard copy, the median was 4 (range 2–6).

Table 6 Mechanical axis data

HC inter-rater	Intraclass correlation	95% Confidence interval	
		Lower bound	Upper bound
a			
Radiologist A versus Radiologist B	0.88	0.79	0.93
Orthopod A versus Orthopod B	0.90	0.82	0.95
Radiologist A versus Orthopod A	0.92	0.85	0.95
Radiologist A versus Orthopod B	0.94	0.89	0.97
Radiologist B versus Orthopod A	0.89	0.81	0.94
Radiologist B versus Orthopod B	0.88	0.78	0.93
PACS inter-rater	Intraclass correlation	95% Confidence interval	
		Lower bound	Upper bound
b			
Radiologist A versus Radiologist B	0.93	0.87	0.96
Orthopod A versus Orthopod B	0.97	0.94	0.98
Radiologist A versus Orthopod A	0.96	0.94	0.98
Radiologist A versus Orthopod B	0.96	0.93	0.98
Radiologist B versus Orthopod A	0.97	0.95	0.99
Radiologist B versus Orthopod B	0.95	0.91	0.97

Discussion

The present study demonstrated that both PACS and hard copy radiographs were highly reliable in the measurement of lower extremity alignment.

Preoperative planning for cartilage surgery and/or osteotomy about the knee has traditionally used long leg radiographs measured on 34–51 inch cassettes. This is a specialized radiograph requiring specific equipment and a long view box to evaluate the film. With the advent of PACS, radiographs can be archived digitally with greater ease, and measurements can be made directly on the film using standard PACS software. Surgeons at the authors' institution have been reluctant to move away from the hard copy radiographs due to familiarity. This study was performed to evaluate whether the intra- and inter-observer reliability using long leg alignment radiographs was adequate using PACS measurements compared to the standard technique using a pencil and a long leg, hard copy radiograph.

The results demonstrate very high ICC for both intra-observer and inter-observer reliability. The lowest ICC measured was 0.86 (95% confidence interval 0.76–0.92) for the intra-rater of one observer using hard copy radiographs. This ICC is acceptable for intra-observer reliability [4]. Furthermore, the PACS intra- and inter-observer reliability was slightly higher overall than it was for hard copy radiographs, although this was not evaluated for statistical significance. PACS was found to be easier to use when measuring alignment, with each physician rating in favor of PACS by a minimum of 4 points on a 10 point rating scale.

Limitations of this study include the fact that the radiographs were evaluated consecutively by the clinicians in an articificial setting. However, there should not have been any bias related to markings on the radiographs or on the computer screen, since both were completely erasable, or removable in the case of the computer graphics.

The clinical relevance of this work is that clinicians can now utilize PACS to measure long leg alignment rather than obtaining long hard copy views, which are more difficult to manage and costly.

In summary, evaluation of lower extremity alignment using two techniques prior to knee surgery was found to be acceptable using PACS software. Hard copy radiographs are therefore not required for improved accuracy. PACS is now used prior to cartilage surgery and/or osteotomy to measure both alignment and the location of the weight bearing line on the tibial plateau both before and after surgery.

Conclusion

PACS should be used rather than hard copy radiographs, because the reliability is at least equal, and PACS is easier to work with.

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