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ORIGINAL STUDY

Reliability of the hip-to-ankle radiograph in determining the knee and implant alignment after total knee arthroplasty

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Study conducted at Helsinki University Central Hospital, Helsinki, Finland

Hip-to-ankle radiographs have been used to evaluate lower limb alignment before and after total knee arthroplasty. However, earlier studies have inappropriately used correlation to assess the reproducibility of the radiographs. We determined the reliability of the hip-to-ankle radiograph using the Bland-Altman analysis. Two consecutive hip-to-ankle radiographs were obtained in 52 patients (52 knees) after total knee arthroplasty. There was an excellent agreement between mechanical axis angles, tibiofemoral angles, and femoral and tibial component alignment in the two radiographs. There was also an excellent agreement between all intra and interobserver analyses. The hip-to-ankle radiograph appears to be a reliable and reproducible means for determining the alignment of the knee in the coronal plane after total knee arthroplasty. In routine follow-up, the short anteroposterior knee radiograph may provide sufficient information. However, only the hip-to-ankle radiograph provides accurate information on the weight-bearing mechanical axis in patients with suspected lower limb malalignment.

Keywords : TKA ; HKA angle ; alignment.

INTRODUCTION

Both the weight-bearing hip-to-ankle (HTA) radiograph and a short knee radiograph are used for assessment of the coronal plane alignment (*3,6,7,11, 13,14,17,19*). The HTA radiograph is regarded as the gold standard for acquiring accurate information on the weight-bearing mechanical axis (MA) in patients with suspected lower limb malalignment (*11,17,19*). However, the reliability of these radiographic methods in determining knee and total knee arthroplasty (TKA) implant alignment may not have been evaluated optimally using correlation with or without linear regression (*2*).

The aim of the present study was to assess the intra and inter observer variation and test-retest reliability of an HTA radiograph in measurement of knee and implant alignment in the coronal plane in knees with a TKA using Bland-Altman analysis (*2*).

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PATIENTS AND METHODS

During the period from December 2006 to April 2007, 52 consecutive patients (38 women and 14 men) with advanced degenerative osteoarthritis of the knee joint refractory to conservative treatment underwent 52 primary TKAs at our institution. The average age of patients at the time of TKA was 69.8 (range : 50.7 to 88.6) years. All the TKA implant systems used (AGC (Biomet, Warsaw, Ind, USA ; n = 5), NexGen (Zimmer, Warsaw, Ind, USA ; n = 1), and Duracon and Triathlon (Stryker, Kalamazoo, Mich, USA ; n = 29 and n = 17, respectively)) aim at reconstruction of a 90° angle between the femoral implant condyles and the mechanical axis of the femur, and between the tibial implant plateau and the mechanical axis of the tibia.

Image material for this study consisted of weight-bearing HTA radiographs on three 35 × 43 cm cassettes in a full-leg holder, obtained at a focal distance of 2.5 m. All radiographs were obtained with a consistent technique : the patients were standing on both legs with the medial aspects of the feet parallel and with their knees in full extension. The HTA radiograph was centered so that the entire leg was included on the film. For each patient, the HTA radiography was performed twice : the radiography was repeated approximately one hour after completion of the first examination.

Angle measurements were performed on digital screen images using clinical workstations (Impax DS3000 v. 4.5 ; Agfa-Gevaert N.V., Mortsel, Belgium). Two experienced musculoskeletal radiologists (V.H. and M.K.) analysed the radiographs. For an analysis of the intra- and inter-observer variability, both radiologists completed blinded independent reviews of all the radiographs.

The tibiofemoral (TF) angle and the coronal alignment of the femoral and tibial components in relation to the femoral and tibial shaft axes were evaluated from both radiographs. The TF angle is formed by the intersection of the line of the proximal shaft of the tibia and a line through the femoral midcondylar point and the center of the distal femoral shaft *(14)*. The coronal alignments of the femoral and tibial components were analyzed according to the recommendations of the Knee Society *(4)*. The MA angle was calculated according to Hagstedt *et al* *(5)*. For this calculation the center of the femoral head was defined by using Mose circles *(15)*, the midpoint of the knee was defined by the midpoint between the femoral condyles at the level of the top of the intercondylar notch, and the midpoint of the ankle defined by the center of the superior facet of the talus.

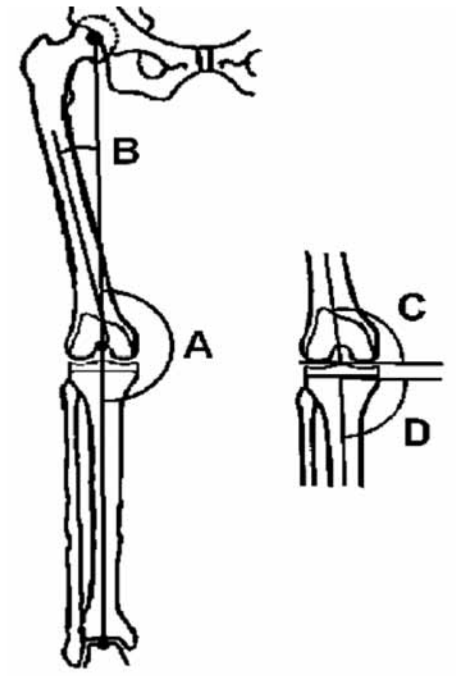


Fig. 1. — Schematic pictures showing the methods for radiographic assessment of mechanical axis (A), tibiofemoral angle (A + B) and femoral (C) and tibial (D) implant alignment.

Mechanical axis angle and tibiofemoral angle values over 180° represent valgus alignment. Implant alignment angles over 90° represent valgus alignment (Fig. 1).

The study was approved by the Research Board of our institution and was performed in accordance with the ethical standards in the 1975 Declaration of Helsinki. Patients gave their written informed consent after oral and written information.

A Bland-Altman assessment for agreement was used to compare the measurements (mechanical axis angle, tibiofemoral angle, and femoral and tibial implant alignment) made on each of the two HTA radiographs *(2)*. In the plots, the average measurement of the two radiographs is presented along the x-axis and the difference between the two radiographs is presented along the y-axis. The limits of agreement provide two values within which the differences between two single readings are expected to fall for 95% of subjects. If the measurement differences are small, the agreement is acceptable. The descriptive data are presented as mean and range and, when plausible for comparison with earlier reports, as standard deviation (SD). We used STATA 8.2 statistical software (StataCorp, College Station, Texas, USA) for the statistical analyses.

Table I. — Alignment characteristics of the cohort according to each measurement procedure. Higher values represent a more valgus knee or implant alignment

Measurement	Mean	Range
Hip-to-ankle radiograph		
mechanical axis	180.9°	174.5°-188.5°
tibiofemoral angle	187.3°	181°-195°
difference between mechanical and anatomic axes of femur	6.5°	4°-9°
femoral component tilt	96.4°	92°-100.5°
tibial component tilt	90.7°	87.5°-95°

Table II. — Results of Bland-Altman analyses with 95 per cent limit of agreement in measurements of the two hip-to-knee radiographs

Measurement	Test-retest reliability n = 52	Intraobserver reliability n = 208	Interobserver reliability n = 104
Hip-to-ankle radiograph			
mechanical axis	-2.3° to 2.2°	-1.0° to 1.0°	-1.2° to 1.2°
tibiofemoral angle	-2.8° to 2.8°	-1.3° to 1.3°	-2.3° to 1.8°
femoral component alignment	-2.2° to 2.2°	-2.2° to 2.3°	-2.4° to 2.2°
tibial component alignment	-1.8° to 2.1°	-1.4° to 1.6°	-1.9° to 1.8°

RESULTS

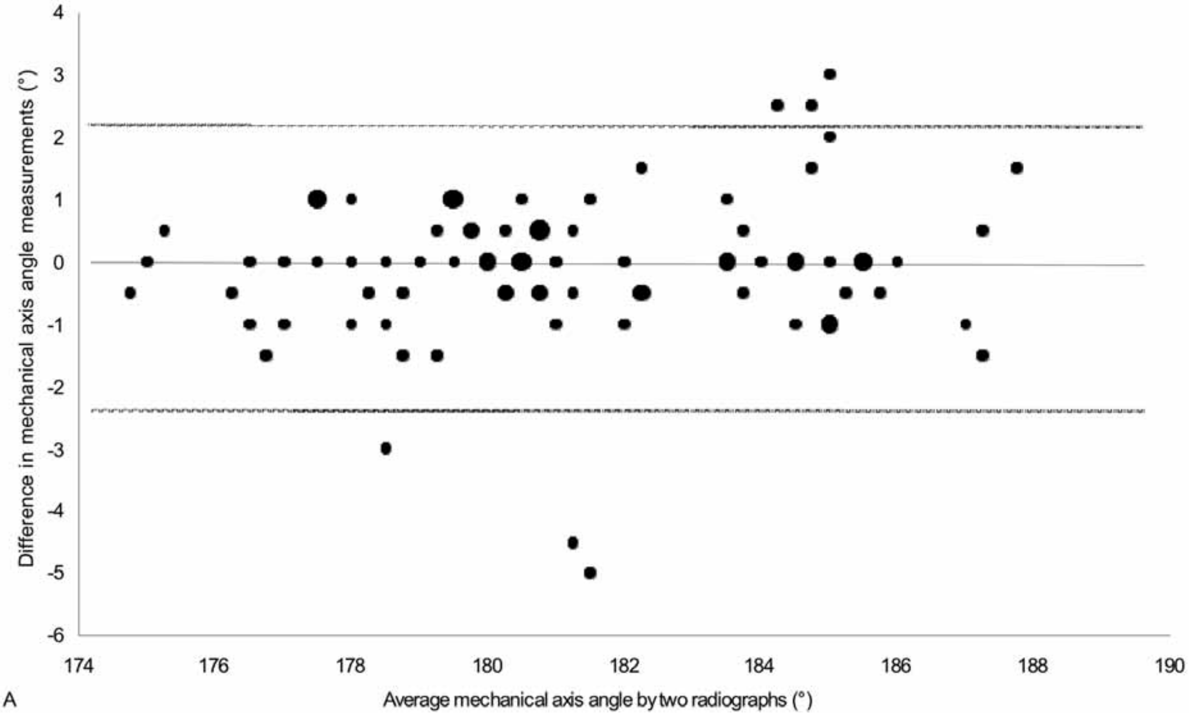
The mean mechanical axis angle of the lower extremity after TKA was 180.9° (SD 3.0° ; range, 174.5° to 188.5°). Seven knees (13%) had an angle of 180°. Thirty-two knees (62%) had an angle between 178° and 182°. In eighteen (35%) knees the mechanical axis showed a varus deviation and in 27 (52%) a valgus deviation. The detailed results of the angles and implant alignment are presented in Table I. The mean difference between MA angles measured from the two HTA radiographs was 0.5° (SD 0.7° ; range 0 to 5.0°). The mean difference between the mechanical and anatomic axes of the femur was 6.4° (SD 1.0° ; range, 3.5° to 9.0°).

The Bland-Altman analysis of test-retest reliability indicated that the 95% limits of agreement between the MA measurements from the two HTA radiographs ranged from -2.3° to 2.2°. An HTA radiograph thus produces reliable information on the MA angle for clinical purposes. Other analyses are shown in Table II. Figure 2 A-D demonstrates test-retest analyses in Bland-Altman plots.

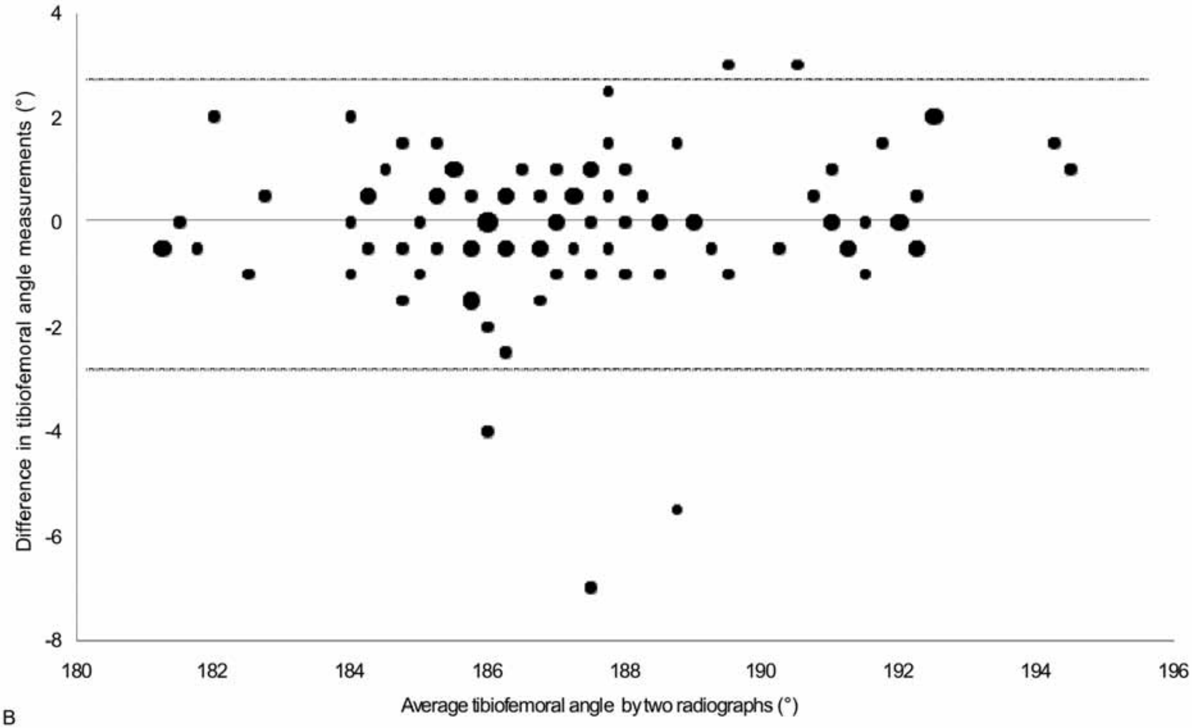
DISCUSSION

Our results suggest that the MA and TF angles as well as the alignment of implants can be reliably and repeatably measured from HTA radiographs. Intra and inter observer MA measurements from radiographs fall within ± 1° and Test-Retest measurements within ± 2°. The long HTA radiograph should be taken weight-bearing in order to provide accurate information on the alignment of the joint and the alignment of the TKA components. Additionally, computerized measurements from digital radiographs may be more reliable than manual measurements from traditional radiographs.

It is commonly believed that postoperative knee alignment affects the outcome and survival of TKA. Lotke and Ecker emphasized the need for achieving a normal alignment after TKA to ensure its longevity (*12*). However, normal lower limb alignment in healthy subjects has been hard to define because of its wide variation among normal individuals (*9*). Radiographic assessment of knees with symptomatic OA imposes even more variation due to pain


Difference in mechanical axis angle measurements (°)
4
3
2
1
0
-1
-2
-3
-4
-5
-6
174
176
178
180
182
184
186
188
190
Average mechanical axis angle by two radiographs (°)

A


Difference in tibiofemoral angle measurements (°)
4
2
0
-2
-4
-6
-8
180
182
184
186
188
190
192
194
196
Average tibiofemoral angle by two radiographs (°)

B

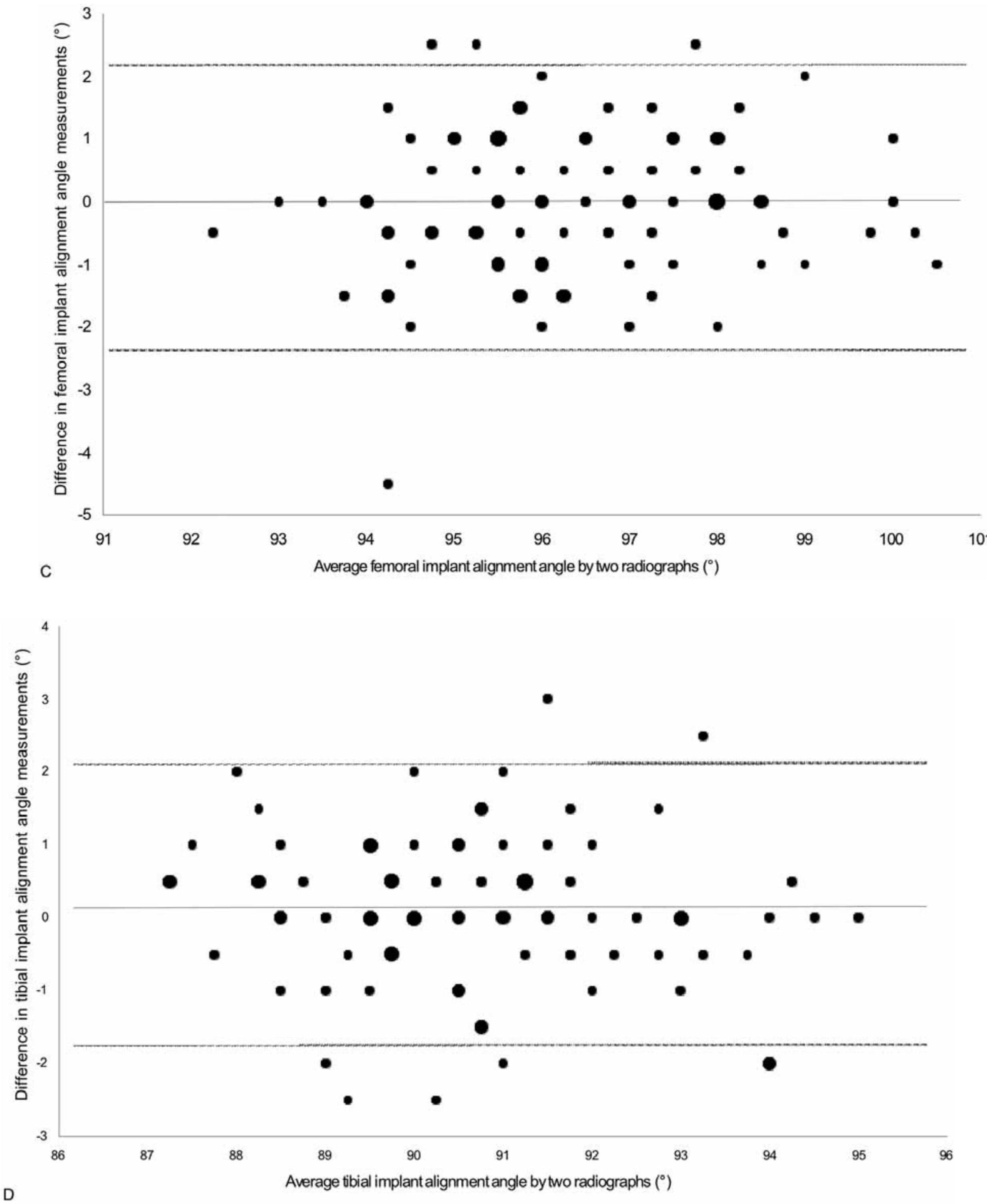


***Fig. 2*A-D.** — Bland-Altman plots demonstrating excellent test-retest agreement between mechanical axis angle (A), tibiofemoral angle (B), and femoral (C) and tibial (D) implant alignment measurements from the two hip-to-ankle radiographs. Middle horizontal line shows the mean of the measurements and the upper and lower lines show 95 per cent limits of agreement.

and difficulties in positioning the malaligned limb for the radiographs (*6,19*). Several authors have associated varus alignment with TKA failure and recommended neutral or slight valgus as the optimal alignment (*1,10,18*). The mechanical axis of the lower limb can only be assessed using HTA radiographs. However, the repeatability of an HTA radiograph has not been demonstrated, and positioning, flexion and rotation of the extremity significantly affect the radiographs (*11*). In a comparison of different measurement methods, Huang *et al* found that errors in measurement of the MA were attributable both to the radiographic procedure and the radiologist, the former accounting for 1.3° and the latter for 1.02° of variability (*8*). Petersen and Engh (*16*) found a 1.4° discrepancy between TF angle measured from HTA and knee radiographs with a SD of 2.2°. In our study, both the discrepancy (0.5°) and SD (0.7°) were clearly smaller. We had a standardized technique for taking the radiographs and positioning the patient, yielding high repeatability between MA angle measurements from the two HTA radiographs. It is important to emphasize that a true AP projection is essential and that even a slight rotation or flexion of the knee distorts the alignment and affects the measurements. Centering the x-ray beam at the knee joint is not as important as fitting both the hip joint and ankle joint on the film.

Use of different methods for assessing lower limb alignment has been studied and debated in several papers (*3,6,7,11,13,14,17,19*). However, the statistical indicators used for demonstrating relationship between radiographs (and other techniques) have been product-moment correlation coefficients or linear regression, both of which are inappropriate. When correlation or linear regression is used for testing of the agreement between two measurements, the null hypothesis is that the measurements by the two methods are not linearly related. The probability is very small and even without testing it can be stated that the measurements are related. However, this high correlation does not mean that the two methods agree. Correlation coefficient measures the strength of a relation between two variables, not the agreement between them. For example, a change in scale of measurement does not affect the correlation, but it certainly affects the agreement. Furthermore, correlation depends on the range of the true quantity in the sample. If this is wide, the correlation will be greater than if it is narrow. As investigators usually try to compare two methods over the whole range of values typically encountered, a high correlation is almost guaranteed. The test of significance may show that the two methods are related, but it would be amazing if two methods designed to measure the same quantity were not related. The test of significance is irrelevant to the question of agreement. And what is crucial, correlation does not provide any practical information for the clinician ; limits of agreement from Bland-Altman assessment, however, immediately demonstrate the magnitude of variation between measurements (*2*).

In conclusion, assessment of the weight-bearing mechanical axis and alignment of TKA implants can be accurately performed with HTA radiographs. Radiographs obtained using strictly standardised techniques and consistent positioning and orientation of the extremity, modern digital radiography and measured utilizing computerized analysis tools provide more reproducible measurement than previously reported for traditional radiographs. For further comparisons of measurement techniques, the Bland-Altman assessment of agreement is recommended instead of inappropriate and misleading correlation coefficients and linear regression.

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