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Original Article

# Comparative radiographic analysis on the anatomical axis in knee osteoarthritis cases: inter and intraobserver evaluation☆

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ABSTRACT

*Objective:* To make a comparative inter and intraobserver analysis on measurements of the anatomical axis between panoramic radiographs of the lower limbs in anteroposterior (AP) view with bipedal weight-bearing, on short film.

*Methods:* An accuracy study comparing radiographic measurements on 47 knees of patients attending the knee surgery outpatient clinic due to osteoarthritis. The radiographic evaluation used was as standardized for the total knee arthroplasty program, including panoramic AP views of the lower limbs and short radiographs of the knees in AP and lateral views, all with bipedal weight-bearing. Following this, the anatomical axis of the lower limbs or the femorotibial angle was measured by five independent examiners on the panoramic and short AP radiographs; three of the examiners were considered to be more experienced and two, less experienced. All the measurements were made again by the same examiners after an interval of not less than 15 days. The statistical analysis was performed using the intraclass correlation coefficient, in order to evaluate the inter and intraobserver concordance of the anatomical axis measurements.

*Results:* From the statistical analysis, it was observed that there was strongly significant concordance between the anatomical axis measurements on the panoramic and short radiographs, for all the five examiners and for both measurements.

*Conclusions:* Under the conditions studied, short radiographs were equivalent to panoramic radiographs for evaluating the anatomical axis of the lower limbs in patients with advanced osteoarthritis. The measurements used also showed high rates of inter and intraobserver concordance and reproducibility.

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## Análise radiográfica comparativa do eixo anatômico na osteoartrite do joelho. Avaliação inter e intraobservadores

*Palavras-chave:*
Osteoartrite/radiografia
Joelho
Extremidade inferior

R E S U M O

*Objetivo:* Fazer a análise comparativa inter e intraobservador da medida do eixo anatômico entre as radiografias panorâmica, dos membros inferiores (MMII) com raio anteroposterior (AP) e apoio bipodálico e AP com carga bipodal em filme curto.
*Métodos:* Foi feito estudo de acurácia que comparou medidas radiográficas em 47 joelhos de pacientes do ambulatório de cirurgia do joelho, por osteoartrite (OA). A avaliação radiográfica usada foi a padronizada para a programação de ATJ, incluindo as incidências panorâmica dos MMII em AP e as radiografias curtas dos joelhos em AP e perfil, todas com apoio bipodálico. Em seguida, as radiografias panorâmicas e curtas em AP tiveram os eixos anatômicos dos MMII ou ângulo femorotibial (AFT) medidos por cinco examinadores independentes, dos quais três eram considerados mais experientes e dois menos experientes. Todas as medidas foram refeitas pelos mesmos examinadores em um intervalo não menor do que 15 dias. A análise estatística foi feita com o uso do coeficiente de correlação intraclasses (ICC) para avaliar a concordância na medida do eixo anatômico inter e intraobservadores.
*Resultados:* Após análise estatística observou-se forte concordância significativa entre o eixo anatômico medido nas radiografias panorâmica e curta para todos os cinco examinadores e para ambas as medidas.
*Conclusões:* Nas condições estudadas a radiografia curta equipara-se à panorâmica na avaliação do eixo anatômico dos MMII em pacientes com OA avançada. A mensuração usada também mostra alta taxa de concordância e reprodutibilidade inter e intraobsevadores.
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## Introduction

The alignment of the lower limbs, evaluated according to their anatomical and mechanical axes, is considered to be a fundamental element in the genesis and progression of degenerative joint disease or osteoarthritis (OA) of the knee.[1–6] Valgus or varus deformities of the knee are related to the risk that the lateral and medial compartments, respectively, may be affected.[2,3,5,6] Knowledge of this alignment also becomes essential for adequate therapeutic planning for patients with knee OA, especially for those who are awaiting osteotomy or arthroplasty, as well as for their postoperative follow-up.[3,7–10]

Although clinical assessment is correct and necessary, radiographic examination is a fundamental tool for preoperative planning.[3,7–10] Panoramic radiography of the lower limbs in AP view with weight borne either on one foot or on two feet is considered to be the gold standard and is widely recommended in these situations.[1–4,7–13] However, short radiographs of the knees remain essential for better understanding, staging and classification of degenerative disease, in AP and lateral views, also with weight-bearing.[2,5,6,14–18] There are logistic difficulties in producing panoramic radiographs, which may be of dubious quality when performed. The hips or ankles are often omitted, which may be because of poor positioning between the apparatus and the patient, inadequate penetration of one of the extremities or incompatibility between the sizes of the film and patient. Moreover, panoramic radiography exposes patients to greater quantities of ionizing radiation and leads to additional costs.[5,6,15] In this light, we conceptualized a study with the following objectives: to evaluate the reliability of measurements of the femorotibial angle (FTA) on short radiographs in comparison with the values found on panoramic radiographs of the lower limbs; and to evaluate the reproducibility of interobserver and intraobserver measurements.

## Materials and methods

An accuracy study was conducted to compare radiographic measurements on 50 knees, from the first patients who presented at the knee surgery outpatient clinic of our institution with an indication for total knee arthroplasty (TKA) because of OA: Kellgren and Lawrence[19] 3 or 4 and Ahlbäck[20] 3–5, as assessed by the senior researcher (MNG). The only exclusion criterion was a radiographic examination of inadequate quality, and three knees were thus eliminated from this study. The radiographic evaluation used was the one standardized for scheduling TKA, including panoramic radiographs of the lower limbs in AP view (long radiographs) and short radiographs of the knees in AP in lateral views, all with weight borne on two feet.

The radiographic examinations were performed in the radiology sector of our service using the Prestige SI apparatus. The equipment was operated by a single radiology technician, without the aid of radioscopy. Care was taken to ensure that the knees were extended to their maximum and that the patients' patellae were facing forwards. The films for the panoramic radiographs all measured 130 cm × 35 cm (Kodak®) and the films for the short radiographs, 24 cm × 30 cm (Kodak®). Following this, the anatomical axes of the lower limbs (or FTA) were measured on all the AP radiographs by

**Fig. 1 – Panoramic radiograph of the lower limb.**

**Fig. 2 – Short radiograph of the knee in AP view, with weight-bearing on two feet and using the technique of FTA measurement.**

five independent examiners. Two of these (MNG and RPA) were considered to be more experienced and had been titular members of the Brazilian Society of Orthopedics and Traumatology (SBOT) for more than 5 years; one (LFM) was considered to have intermediate-level experience and had been a titular member of the SBOT for less than 1 year, and was doing specialization training in knee training; and two (GNC and RBF) were considered to be less experienced and were studying in the third year of medical residency in orthopedics and traumatology. All of the measurements were made again by the same examiners after an interval of not less than 15 days.

The anatomical axis was evaluated on the panoramic radiographs by means of lines traced out along the long axes of the femur and tibia (Fig. 1). The measurement technique for the short radiographs was as suggested by Khan et al.,[6] based on the previous studies of Hsu et al.[11] and Kraus et al.[5] A point was defined on the femur at the center of the intercondylar space, and another one 10 cm proximally, at the midpoint of the distance between the two external cortexes. The measurement on the tibia started from a point marked at the center of the tibial eminences, with a second point marked 10 cm distally, at the midpoint of the distance between the two external cortexes. Lines joining the femoral and tibial points were traced out and their intersection corresponded to the anatomical axis or femorotibial angle (FTA) (Fig. 2).

Twenty-seven patients were evaluated, of whom 24 were women (88.9%) and 3 were men (11.1%), with a mean age of 73 years and 4 months (range: from 48 years and 5 months to 88 years and 2 months) (Table 1).

In relation to the staging of the OA, 30 knees (63.8%) were classified as Kellgren and Lawrence[19] grade III and 17 (36.2%) as grade IV. According to the Ahlbäck classification,[20] as modified by Keyes et al.,[21] five knees were grade III (10.6%), 30 grade IV (63.9%) and 12 grade V (25.5%) (Table 1).

In the statistical methodology, the inter and intraobserver concordance regarding the measurements of the anatomical axis were evaluated using the intraclass correlation coefficient (ICC).[22] The criterion adopted for determining significance was the level of 1%. The analysis was processed using the SPSS statistical package, version 13.0.

It is known that the closer the ICC is to one, the stronger (or more perfect) the concordance is between the observers. In this case, the techniques were similar from a numerical (quantitative) point of view. On the other hand, the closer to zero the ICC is, the greater the discordance will be, meaning that the values cannot be reproduced and the differences observed are not random.

Through several studies and simulations, it can be said that:

$ICC \leq 0.20$ – no concordance;
$0.20 < ICC \leq 0.40$ – weak concordance;
$0.40 < ICC \leq 0.60$ – moderate concordance;
$0.60 < ICC \leq 0.80$ – strong (good) concordance;
$ICC > 0.80$ – very strong (excellent) concordance.

## Results

Taking into account all the initial measurements made, the mean FTA on the short radiographs was 7.6°, while on the long

**Table 1 – Demographic data, including staging of the OA.**

| Patient number | Age (years) | Right knee Ahlbäck | Right knee Kellgren and Lawrence | Left knee Ahlbäck | Left knee Kellgren and Lawrence |
|---|---|---|---|---|---|
| 1 | 68.7 | | | 4 | 3 |
| 2 | 67.8 | 4 | 3 | 4 | 3 |
| 3 | 88.2 | 5 | 4 | 5 | 4 |
| 4 | 76.4 | 4 | 3 | 5 | 4 |
| 5 | 61.4 | 3 | 3 | 3 | 3 |
| 6 | 71.1 | | | 4 | 4 |
| 7 | 82.2 | 5 | 4 | | |
| 8 | 74.2 | 4 | 3 | 5 | 4 |
| 9 | 74 | 4 | 3 | 4 | 3 |
| 10 | 72 | 4 | 4 | 4 | 3 |
| 11 | 65 | 3 | 3 | 4 | 3 |
| 12 | 74.6 | 4 | 4 | 4 | 3 |
| 13 | 69.7 | 4 | 3 | 4 | 3 |
| 14 | 76.9 | 5 | 4 | | |
| 15 | 83.2 | | | 5 | 4 |
| 16 | 74.1 | 4 | 3 | 4 | 3 |
| 17 | 75.6 | 4 | 4 | 4 | 3 |
| 18 | 60.7 | 3 | 3 | 3 | 3 |
| 19 | 71.8 | 4 | 3 | 4 | 3 |
| 20 | 83.7 | 5 | 4 | 5 | 4 |
| 21 | 69 | 4 | 3 | 4 | 3 |
| 22 | 74.3 | 4 | 4 | 5 | 4 |
| 23 | 85 | 5 | 4 | 5 | 4 |
| 24 | 72.7 | 4 | 3 | 4 | 3 |
| 25 | 48.4 | 4 | 3 | 4 | 3 |
| 26 | 66 | | | 4 | 3 |
| 27 | 85.2 | 4 | 3 | | |

Source: hospital files, 2013.

radiographs, it was 7.7°. In the final measurements, the mean FTA on the short radiographs was 7.5° and on the long radiographs, 7.6°. Considering each examiner separately, the anatomical axis measurement varied by a maximum of 13° between the long and short radiographs and by a maximum of 6° between the initial and final measurements. From the statistical analysis, it was observed that there was strongly significant concordance (ICC > 0.88, as a minimum) between the evaluations using short and panoramic radiographs ($p < 0.001$), for all the five observers and for both of the measurements (Table 2).

It was also observed that there was strongly significant concordance (ICC > 0.97, as a minimum) between measurements 1 and 2 ($p < 0.001$), for all the five observers and for both types of radiograph (Table 3).

Finally, it was observed that there was strongly significant concordance (ICC > 0.96, as a minimum) between all pairs of observers ($p < 0.001$), for both types of radiograph and using measurements 1 and 2 (Tables 4 and 5).

**Table 2 – Concordance between radiographs: short versus panoramic.**

| | Observer | ICC | 95% CI | *p* Value |
|---|---|---|---|---|
| Measurement 1 | RBF | 0.885 | 0.804–0.934 | <0.001 |
| | GNC | 0.915 | 0.853–0.952 | <0.001 |
| | MNG | 0.941 | 0.897–0.967 | <0.001 |
| | LFM | 0.914 | 0.851–0.951 | <0.001 |
| | RPA | 0.945 | 0.903–0.969 | <0.001 |
| Measurement 2 | RBF | 0.928 | 0.874–0.959 | <0.001 |
| | GNC | 0.944 | 0.902–0.968 | <0.001 |
| | MNG | 0.953 | 0.918–0.974 | <0.001 |
| | LFM | 0.916 | 0.854–0.952 | <0.001 |
| | RPA | 0.945 | 0.903–0.969 | <0.001 |

Source: hospital files, 2013.

ICC, intraclass correlation coefficient; 95% CI, 95% confidence interval for ICC.

**Table 3 – Intraobserver concordance: measurement 1 (initial) versus measurement 2 (final).**

| Radiograph | Observer | ICC | 95% CI | *p* Value |
|---|---|---|---|---|
| Short | RBF | 0.989 | 0.980–0.994 | <0.001 |
| | GNC | 0.986 | 0.975–0.992 | <0.001 |
| | MNG | 0.996 | 0.992–0.998 | <0.001 |
| | LFM | 0.989 | 0.980–0.994 | <0.001 |
| | RPA | 0.998 | 0.997–0.999 | <0.001 |
| Panoramic | RBF | 0.977 | 0.959–0.987 | <0.001 |
| | GNC | 0.988 | 0.979–0.994 | <0.001 |
| | MNG | 0.997 | 0.995–0.999 | <0.001 |
| | LFM | 0.986 | 0.975–0.992 | <0.001 |
| | RPA | 0.998 | 0.997–0.999 | <0.001 |

Source: hospital files, 2013.

ICC, intraclass correlation coefficient; 95% CI, 95% confidence interval for ICC.

**Table 4 – Interobserver concordance for measurement 1 (initial).**

| Radiograph | Observer 1 vs. observer 2 | | ICC | 95% CI | *p* Value |
|---|---|---|---|---|---|
| Short | RBF | GNC | 0.984 | 0.972–0.991 | <0.001 |
| | RBF | MNG | 0.987 | 0.977–0.993 | <0.001 |
| | RBF | LFM | 0.977 | 0.959–0.987 | <0.001 |
| | RBF | RPA | 0.979 | 0.963–0.988 | <0.001 |
| | GNC | MNG | 0.982 | 0.968–0.990 | <0.001 |
| | GNC | LFM | 0.973 | 0.952–0.985 | <0.001 |
| | GNC | RPA | 0.976 | 0.957–0.986 | <0.001 |
| | MNG | LFM | 0.972 | 0.951–0.984 | <0.001 |
| | MNG | RPA | 0.993 | 0.988–0.996 | <0.001 |
| | LFM | RPA | 0.968 | 0.943–0.982 | <0.001 |
| Panoramic | RBF | GNC | 0.981 | 0.966–0.989 | <0.001 |
| | RBF | MNG | 0.978 | 0.960–0.987 | <0.001 |
| | RBF | LFM | 0.977 | 0.960–0.987 | <0.001 |
| | RBF | RPA | 0.981 | 0.966–0.989 | <0.001 |
| | GNC | MNG | 0.989 | 0.980–0.994 | <0.001 |
| | GNC | LFM | 0.981 | 0.967–0.989 | <0.001 |
| | GNC | RPA | 0.990 | 0.982–0.994 | <0.001 |
| | MNG | LFM | 0.980 | 0.964–0.989 | <0.001 |
| | MNG | RPA | 0.997 | 0.994–0.998 | <0.001 |
| | LFM | RPA | 0.981 | 0.967–0.989 | <0.001 |

Source: hospital files, 2013.
ICC, intraclass correlation coefficient; 95% CI, 95% confidence interval for ICC.

## Discussion

The appropriate radiographic method for evaluating patients with knee OA is still a matter of debate.[5,6,9,13–16,18] Panoramic radiography is traditionally recommended when there is a need to assess the lower-limb alignment.[1–4,7–13] Moreland et al.[7] stated that it was essential for measuring the axial alignment of the lower limbs. However, it is difficult to perform, often presents deficient quality, exposes patients to greater amounts of ionizing radiation and is more expensive.[5,6,15]

Kraus et al.[5] compared knee alignments using panoramic radiographs on the lower limbs in AP view and using short radiographs in a flexed position in posteroanterior (PA) view, and also compared these with clinical measurements. They observed that the results from clinical measurements and from short radiographs correlated well with those from panoramic radiographs. They therefore concluded that these

**Table 5 – Interobserver concordance for measurement 2 (final).**

| Radiograph | Observer 1 vs. observer 2 | | ICC | 95% CI | *p* Value |
|---|---|---|---|---|---|
| Short | RBF | GNC | 0.989 | 0.980–0.994 | <0.001 |
| | RBF | MNG | 0.990 | 0.981–0.994 | <0.001 |
| | RBF | LFM | 0.980 | 0.964–0.989 | <0.001 |
| | RBF | RPA | 0.982 | 0.968–0.990 | <0.001 |
| | GNC | MNG | 0.990 | 0.982–0.994 | <0.001 |
| | GNC | LFM | 0.987 | 0.977–0.993 | <0.001 |
| | GNC | RPA | 0.983 | 0.969–0.990 | <0.001 |
| | MNG | LFM | 0.982 | 0.968–0.990 | <0.001 |
| | MNG | RPA | 0.992 | 0.986–0.995 | <0.001 |
| | LFM | RPA | 0.970 | 0.947–0.983 | <0.001 |
| Panoramic | RBF | GNC | 0.993 | 0.988–0.996 | <0.001 |
| | RBF | MNG | 0.990 | 0.982–0.994 | <0.001 |
| | RBF | LFM | 0.983 | 0.970–0.991 | <0.001 |
| | RBF | RPA | 0.991 | 0.984–0.995 | <0.001 |
| | GNC | MNG | 0.991 | 0.983–0.995 | <0.001 |
| | GNC | LFM | 0.980 | 0.964–0.989 | <0.001 |
| | GNC | RPA | 0.992 | 0.985–0.995 | <0.001 |
| | MNG | LFM | 0.977 | 0.959–0.987 | <0.001 |
| | MNG | RPA | 0.997 | 0.994–0.998 | <0.001 |
| | LFM | RPA | 0.980 | 0.964–0.989 | <0.001 |

Source: hospital files, 2013.
ICC, intraclass correlation coefficient; 95% CI, 95% confidence interval for ICC.

two methods were useful options for situations in which panoramic radiographs were unavailable.[5] McGrory et al.[15] were unable to demonstrate any advantage for long radiographs over short radiographs for preoperative planning.

Furthermore, in a general manner, short radiographs on the knees are indispensable at any phase of degenerative joint disease.[2,5,6,14–18] Therefore, if short radiographs can provide reliable information on alignments, panoramic radiographs become unnecessary. This was our motivation for the present study.

From a methodological point of view, we attempted as much as possible to reproduce the situation encountered by orthopedists in their daily clinical practice. The patients' positioning was not checked using radioscopy before producing the radiographs, given that this is a resources found in very few centers in Brazil. The patients were simply instructed to keep their knees extended as much as possible, with the patellae orthogonal to the X-ray tube, so as to minimize the possibility of rotational deviation.

Moreland et al.[7] postulated that rotation of the lower limbs affects the apparent alignment. In knees with poor flexion, external rotation simulates an increase in varus, while internal rotation accentuates valgus. This emphasizes the importance of properly directing the patellae forwards, so as to attenuate this problem.[7] Similar results were presented by Brouwer et al.,[13] who recommended that fluoroscopy should only be used on knees with contractures when flexed.

Specogna et al.[9] demonstrated that radiographs produced with weight-bearing on one foot were not superior to those with weight-bearing on both feet, in evaluations on 40 patients with knee OA in association with varus deformity. They even recommended that weight-bearing on both feet should be used routinely in preoperative assessments. Based on this finding, we also chose to use radiographs with weight-bearing on both feet.

With regard to the results, it was observed that the FTA measurements on the short radiographs using the method described here were concordant with those obtained from long radiographs. In relation to the strength of concordance, it was noticed that there was an improvement when the measurements were made for the second time, probably because of greater familiarity with the method presented. Another important finding was that better results were obtained by the more experienced examiners in both measurements. However, even the measurements made by the less experienced examiners presented a high concordance index.

Khan et al.[6] were able to demonstrate an association between the evolution of the knee OA and the angular deviations measured on short radiographs using the technique described in the present study. However, they did not venture to indicate this radiographic technique alone for preoperative planning of osteotomy.[6]

Regarding the interobserver evaluation, it was again observed that for both measurements, there was greater concordance (i.e. greater ICC) between the two examiners with greater experience. However, independent of the level of experience, there was high concordance between all the pairs of examiners.

Finally, the intraobserver concordance presented the same behavior as seen in the preceding evaluation, with high reproducibility for all the examiners and the strongest correlation obtained among those with greatest experience.

Thus, the results from the present study demonstrated that the method proposed for measuring the FTA on short radiographs was reliable and reproducible, independent of the experience of the examining physician. Other correlated evaluations would serve to strengthen the data seen in the present study and would open up the prospect of simplifying evaluations on the angular deviations of the lower limbs in patients with knee OA.

## Conclusions

Under the conditions of this study, short radiographs were equal to panoramic radiographs for evaluating the anatomical axis of the lower limbs in patients with advanced OA. The measurement used also showed high inter and intraobserver concordance and reproducibility.

## Conflicts of interest

The authors declare no conflicts of interest.

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