Lyon Schuss Radiographic View of the Knee. Utility of Fluoroscopy for the Quality of Tibial Plateau Alignment

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ABSTRACT. ***Objective.*** The "Lyon schuss" (LS) view is a fluoroscopically assisted radiographic technique of the knee in flexion. The quality of medial tibial plateau (MTP) alignment is a key element for accuracy and sensitivity to change of knee radiography. We collected data on the geometry of the osteoarthritic (OA) knee when positioned under fluoroscopy according to the LS protocol, then applied the results to develop an angulation standard for a nonfluoroscopically guided examination, and evaluated the performance of fluoroscopic and nonfluoroscopic alternatives for good alignment of the MTP.

Methods. 1. For 50 patients with knee pain (100 knee radiographs): Standardized radiographic procedure under fluoroscopy (LS view and lateral weight-bearing radiograph of the 2 knees); measurement of the tibial plateau inclination with the horizontal (TPI-h); evaluation of the quality of MTP alignment; assessment of the mean x-ray beam angle to obtain satisfactory MTP alignment. 2. For 30 patients with knee OA: LS radiograph of the knee performed without fluoroscopy, using a fixed 11° downward x-ray beam angle (mean value of the angle obtained in the first part of the study) and standardized procedure; then assessment of the quality of MTP alignment.

Results. With the fluoroscopically assisted protocol, MTP alignment was satisfactory in 88% of cases. The mean x-ray beam angle was 11.2° downward (SD 3.3°, range 4–22°) and was unrelated to sex, height, weight, body mass index, and joint space width. The mean TPI-h was 19.6° (SD 6.9°, range 3–35°). Beam angle and TPI-h were correlated only in the satisfactorily aligned radiographs. In the 30 knees radiographed using a standardized procedure without fluoroscopy, the MTP alignment was satisfactory in 60% of cases.

Conclusion. Fluoroscopy is useful to obtain satisfactory MTP alignment in LS radiographs because of large interindividual variations in anatomy of the knee. (J Rheumatol 2004;31:584–90)

Key Indexing Terms:
OSTEOARTHRITIS KNEE RADIOGRAPH JOINT SPACE SCHUSS

Accurate anatomical measurement of progression of joint damage in osteoarthritis (OA) is a major issue for assessment of the disease and for development of disease-modifying drugs for OA (DMOAD)[1], and it is generally accepted that measurement of joint space width (JSW) on radiographics is the best available surrogate for evaluation of cartilage thickness[2] and the progression of cartilage destruction in OA[3,4]. Various techniques of measurement have been designed to quantitatively assess knee and hip JSW from standard radiographs[3,5-10]. However, irrespective of the method of measurement chosen, both accuracy (validity) and reproducibility (precision) of JSW measurement were shown to depend significantly on the quality of the radiographic procedure and the positioning of the joint[11,12], especially concerning knee OA. On radiographics, JSW of the medial tibiofemoral compartment varies with weight-bearing, alignment of the medial tibial plateau (MTP), x-ray beam angle, rotation of the feet, and degree of knee flexion[12,13]. An adequate protocol for radiographic assessment must fulfill 2 essential conditions: first, it must give a good superimposition of serial radiographs, which can be achieved by standardization of the joint positioning (degree of knee flexion and feet rotation) and the radiographic procedure (beam height and inclination, focus-to-film distance, joint-to-film distance). Second, it must permit good alignment of the tibial plateau, that is to say, a perfect superimposition of the anterior and posterior rims of the plateau. Nevertheless, these conditions have not always been achieved, even when a precise program of training for radiology technologists was developed[14].

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For these reasons, a number of radiographic protocols have been designed[10,13-18], using various degrees of knee flexion with or without fluoroscopy. Among these techniques, the most widely evaluated have been the semiflexed anteroposterior (AP) view[10], the semiflexed metatarsophalangeal view[16], the fixed-flexion AP view[17], and the "Lyon schuss" (LS) view[15], the 3 first views without fluoroscopy. Advantages and limitations of these protocols have been extensively described[19]. Fluoroscopy can be used to modify the x-ray beam angle in order to obtain good alignment of the anterior and posterior margins of the MTP. The use of a constant degree of beam angle for a given patient is crucial for serial examinations[13], and its value must be recorded in the radiological report. Mazzuca, *et al*[20] have recently shown that the sensitivity to measure joint space narrowing over 14 months of nonfluoroscopically assisted metatarsophalangeal radiographs (measurement using calipers and magnifying lens) was lower than that observed in views obtained concurrently with a fluoroscopically assisted semiflexed AP view and measured by digital image analysis. However, the fluoroscopic equipment may not be available in some radiographic centers, and the technique exposes patients to greater doses of x-rays.

We evaluated the importance of fluoroscopy for good alignment of the MTP in LS view knee radiographs. We collected data on the geometry of the OA knee when positioned under fluoroscopy according to the LS protocol, applied the results to develop an angulation standard for a nonfluoroscopically guided examination, and evaluated the performance of fluoroscopic and nonfluoroscopic alternatives.

MATERIALS AND METHODS

Fluoroscopically assisted LS view radiographs. Radiographs of both knees were performed in 50 consecutive subjects (population 1) aged 40 years or older (mean 59.8, SD 11.1) referred to a rheumatology outpatient department for chronic (> 3 mo) knee pain. Radiographs were performed in a single radiology department by 2 specifically trained, experienced radiology technicians. The protocol included an LS view[15] and a standing lateral view of the knees in full extension. In the latter, the patients, in weight-bearing position, were asked to contract their quadriceps as strongly as possible. Patient positioning for LS radiographs was performed as described[15]. The method was slightly modified by the use of a trapezoidal toe-clip whose base measured 22 cm in length that was in contact with the radiographic table, to obtain a fixed 10° external rotation of the feet (Figure 1). Source-to-film distance was 100 cm. The central x-ray beam was directed at the center of the joint, in the space between the tibial spines and the femoral notch. The angle of the x-ray beam was then adjusted fluoroscopically to provide optimal alignment with the MTP. The angle of inclination of the x-ray beam was then recorded.

Nonfluoroscopically assisted LS radiographs using a standardized x-ray beam angle. LS radiography was performed in 30 additional consecutive patients (population 2; 19 women, 11 men), mean age 61.3 (SD 9.7) years, referred to the same rheumatology outpatient department for symptomatic medial tibiofemoral OA. Patients with clinical evidence of OA flare were excluded. Radiographs were performed by the same 2 technicians without assistance of fluoroscopy. Patient positioning was not modified. The central x-ray beam was directed at the center of the popliteal line using the radiographic tube's positioning light. A constant x-ray beam inclination (mean value of beam inclinations previously observed) was used for all the patients.

Assessment of MTP alignment. The degree of alignment of the MTP with the x-ray beam was assessed by the same observer (TC). Alignment of the tibial plateau was graded according to the method of Buckland-Wright, *et al*[10], based on the distance between the anterior and posterior rims of the tibial plateau. MTP alignment was assessed at the middle of the MTP, and was considered satisfactory or unsatisfactory when the distances between the rims were, respectively, nil and ≤ 1 mm (good, fair), or > 1 and < 2 mm (poor) and ≥ 2 mm (bad) (Figure 2). The intraobserver reproducibility (kappa statistic) obtained from the blind assessment of 20 knee radiographs twice 2 weeks apart (satisfactory/unsatisfactory) was 0.97.

Assessment of OA score. The same observer also classified patients as having OA or not. Using the American College of Rheumatology (ACR) criteria for knee OA[21], patients with at least one definite osteophyte of the femorotibial joint were considered as having knee OA. Narrowing of the medial and/or the lateral femorotibial joint was considered only as an additional criterion.

Measurement of JSW. Minimum JSW was measured by an experienced observer (HF) using a digitized image analysis system (Holy's software™, Actibase, Lyon, France) as described[22]. The outer limit of the measured region was delineated by the nonosteophytic medial edge of the tibiofemoral compartment. The inner limit was then delineated at a constant distance from the outer limit by the computer. After the joint space margins had been delineated by the examiner using the mouse, the computer automatically calculated the measurements (Figure 3). The minimal relevant change between 2 measurements of a single radiograph (= 2 standard deviations) was 0.22 mm[23]. The intraclass correlation coefficient between repeated measurements of the same radiograph (20 radiographs measured twice 2 weeks apart) was 0.996.

Measurement of tibial plateau inclination in population 1. The tibial plateau inclination angle with the horizontal (TPI-h) in full extension is dependent on both the anatomical TP inclination (TPI-a) and the degree of recurvatum (VR, the angle between the axis of the tibia diaphysis and the vertical; Figure 4). The MTP, which is concave, was easily distinguished from the lateral plateau, which is flat. Measurements were performed by computer from the standing lateral radiograph of the knee. The minimal relevant change between 2 measurements (i.e., 2 SD) was 4.8° for TPI-h and 3.2° for TPI-a. With reference to the vertical, the TP inclination angle was considered upwards (+) and the VR downwards (–).

Statistical analysis. A computer data base containing all measured data was created in StatView© 5.0 format (SAS Institute Inc., Cary, NC, USA). Relationships between the inclination angle of the x-ray beam (dependent variable) and the TPI-h, TPI-a, JSN score, JSW, height, weight, and body mass index (BMI), were analyzed by analysis of variance, first in the whole population 1, then according to the quality of MTP alignment (satisfactory/unsatisfactory). P values were considered statistically significant at < 0.05 level.

RESULTS

Fluoroscopically assisted LS view radiographs. One hundred knees from 50 patients were assessed (32 women, 18 men). Eighty-two knees were classified as osteoarthritic. Characteristics of the patients are summarized in Table 1. In the entire population assessed, the mean value (SD, range, median) of the x-ray beam angle was 11.2° downward (–) (3.3, –4 to –22, –10.5°). In the 82 knees with OA it was –11.0° (3.3, –4 to –22, –10°). There was no difference in the mean between right and left knees (p = 0.32, paired t test) or between OA and non-OA knees (p = 0.40, Student t test).

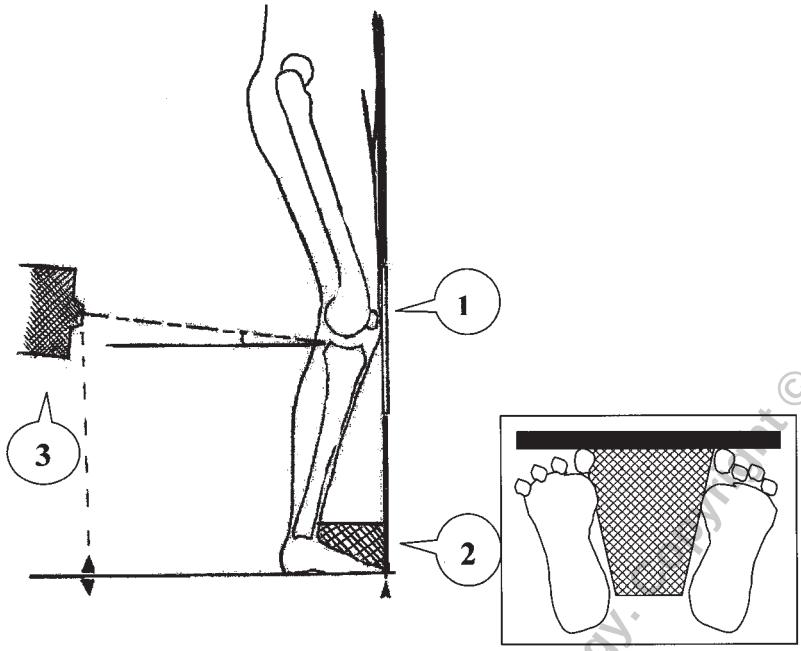

Figure 1. Lyon schuss view acquisition protocol and patient positioning: (1) x-ray cassette, (2) trapezoidal toe-clip, (3) fluoroscopy.

The x-ray beam angle was unrelated to sex, height, weight, BMI, or JSW (all $p > 0.05$).

The mean anatomical inclination of the tibial plateau was +4.3° (range –5.5° to +14.4°). The mean recurvatum was –15° (range 0 to –28°). The mean tibial plateau inclination with horizontal was +19.6° (range +3° to +35°).

Eighty-eight radiographs (88%) were classified as satisfactory for MTP alignment. The percentage was similar in knees with OA (87.8%). The x-ray beam angle was not statistically different between satisfactory and unsatisfactory alignment of radiographs ($p = 0.90$, Student t test). The beam angle was negatively correlated with TPI-h ($r = –0.26$, $p = 0.007$). The correlation was stronger in patients with satisfactory alignment ($r = –0.35$, $p = 0.003$), and was no longer detectable ($p = 0.19$) in patients with unsatisfactory alignment. Beam angle and TPI-a were correlated only in patients with satisfactory alignment ($r = –0.37$, $p = 0.018$). The beam angle, TPI-h and TPI-a between right and left knees were highly correlated ($r = 0.85$, $r = 0.84$, $r = 0.81$, respectively, all $p < 0.001$).

Nonfluoroscopically assisted LS view radiographs using a standardized x-ray beam angle. The selected x-ray beam angle was 11° downward (see above) for all patients. The MTP alignment was satisfactory in 18 cases (60%) and unsatisfactory in 12 (40%). The difference with the fluoroscopically assisted protocol was highly significant (chi-square = 14.2, $p < 0.001$). The quality of the alignment was unrelated to patient's sex, height, weight, BMI, and JSW.

DISCUSSION

Our results show that fluoroscopy results in good alignment of the MTP in 88% of knees, whether they have signs of OA or not. Without fluoroscopy, and using an 11° downward angle (the mean value of the beam angle that yields a satisfactory MTP alignment) for all knees, a satisfactory alignment was obtained in only 60%, despite rigorous standardization of radiographic procedure and patient positioning.

The posteroanterior (PA) Lyon schuss (LS) view is a radiographic technique that has been shown to improve both sensitivity to change and approach to accuracy of knee JSW measurement in comparison with the standard AP view in full extension[15,20]. Fluoroscopy is usually recommended to adjust the angle of the x-ray beam downward, in order to obtain accurate alignment of the anterior and posterior margins of the tibial plateau. The technique yields measurements of JSW with a good degree of precision. Piperno, *et al*[15] reported a coefficient of variation (CV) of JSW measurement of 3.5% on 3 radiographs performed within a single day in 32 patients with OA and 5 healthy subjects. In a one-year prospective study[15] the CV of JSN was much smaller than those obtained in trials using other acquisition protocols[19].

There are numerous limitations to the use of fluoroscopically assisted protocols in multicenter clinical studies. Notably, many clinical centers do not have access to fluoroscopic equipment, and the high turnover rate of well trained

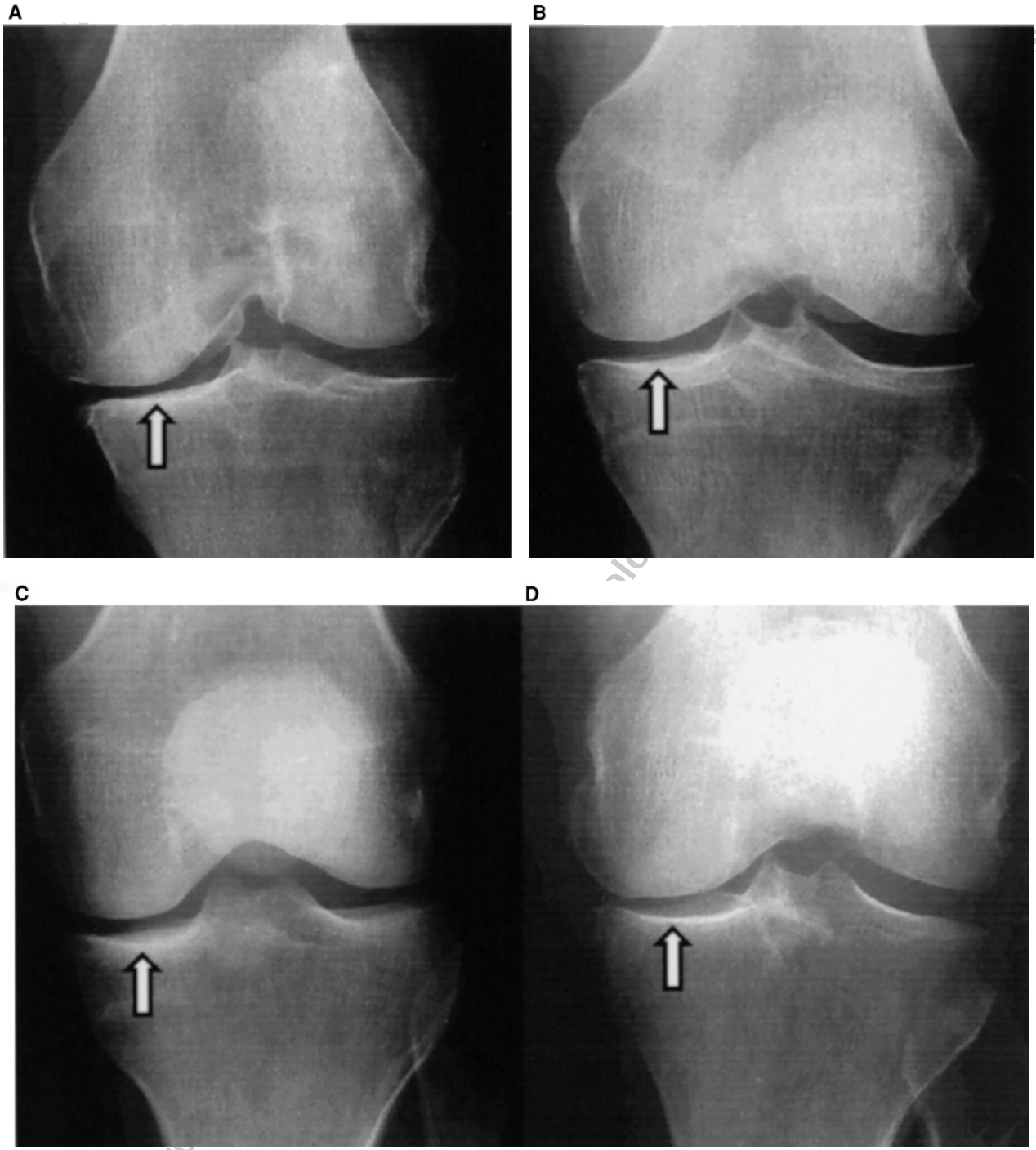

Figure 2. Quality of the medial plateau alignment in the Lyon schuss radiographs based on distance between the anterior and posterior rims of the medial plateau. A. Good: separation nil. B. Fair: < 1 mm. C. Poor: ≥ 1 and < 2 mm. D. Bad: ≥ 2 mm.

radiology technicians makes it very difficult to maintain acceptable levels of quality control of radiographs, with respect to criteria for radioanatomic positioning. Further, ethical considerations such as cumulative radiation exposure and willingness of subjects and practical issues made it necessary to assess whether fluoroscopy is required to obtain LS view radiographs of good quality. Our results clearly show that fluoroscopy is appropriate for obtaining good MTP alignment. The optimal beam angle to achieve a good MTP alignment was –11.2° ± 3.3°, which is similar to that determined by Peterfy, *et al*[17], –9° ± 3.6°. The discrepancies between MTP alignments from fluoroscopically and nonfluoroscopically assisted protocols can easily be explained by the high interindividual variations of the tibial

Figure 3. Computer measurement method of joint space width of the medial tibial plateau from Lyon schuss radiograph of the knee.

plateau inclinations, with horizontal that varied from +3° to +33°. The mean TPI-h was +19.6°, but only 55% ranged between +15° and +25°, and this depended on both the anatomical inclination of the tibial plateau (mean +4.3°, range –5.5° to +14.4°) and the presence of physiological genu recurvatum (mean –15°, range 0 to –28°). The x-ray beam angle was negatively correlated with TPI-h in satisfactorily aligned radiographs, indicating that the degree of beam inclination for obtaining good alignment does depend on the anatomical characteristics of the knee joint, and therefore must be adjusted for each subject. The median of the TPI-h was +20°, so that a 20° knee flexion theoretically positions the MTP horizontally. The approximate degree of knee flexion obtained with the LS view being 30° [15], a 10° downward inclination of the x-ray beam seems to be appropriate.

Previous studies showed that the quality of MTP alignment was of great importance for apparent progression of OA over 2–3 years on the standing AP knee radiograph[22]. Indeed, in a prospective study[20] of serial LS views the sensitivity to change of JSW, determined by calculating the standard response mean (mean change/SD of change), was directly related to the quality of alignment: i.e., 0.72 for satisfactory and 0.38 for unsatisfactory alignment. Notably, unexpected increases in JSW of > 0.5 mm were noted in paired images with poor alignment, although no increase was observed in pairs with good alignment[20]. The "fixed-flexion PA view"[17] is a nonfluoroscopically assisted protocol in which the radiograph of the knee is carried out in a position identical to that in the LS view, but in which the x-ray beam is angled downward 10° for all knees. With this technique, the reproducibility of joint positioning and, accordingly, of JSW measurement appears to be very good. Nevertheless, the lack of fluoroscopic control could explain the finding that the dispersion (CV) of JSN values with the fixed-flexion PA view (360%) was twice that with the LS view (171%)[19], and this would confirm that fluoroscopy improves the quality of radiographs and thus the sensitivity to change. The recent study by Mazzuca, *et al*[23] prospectively comparing nonfluoroscopically assisted metatarsophalangeal radiographs and fluoroscopically assisted semiflexed AP views over 14 months led to the same conclusion, showing that the good short-term reproducibility of a radiographic protocol is insufficient to predict the quality of its longterm performance.

Our data show that the fluoroscopically assisted Lyon schuss view provides MTP alignment that is nearly 90% satisfactory; that is, one-third better than with a standard protocol using a downward angle of the x-ray beam of 11°. This is especially important with respect to calculation of the number of subjects to enroll and the duration of their

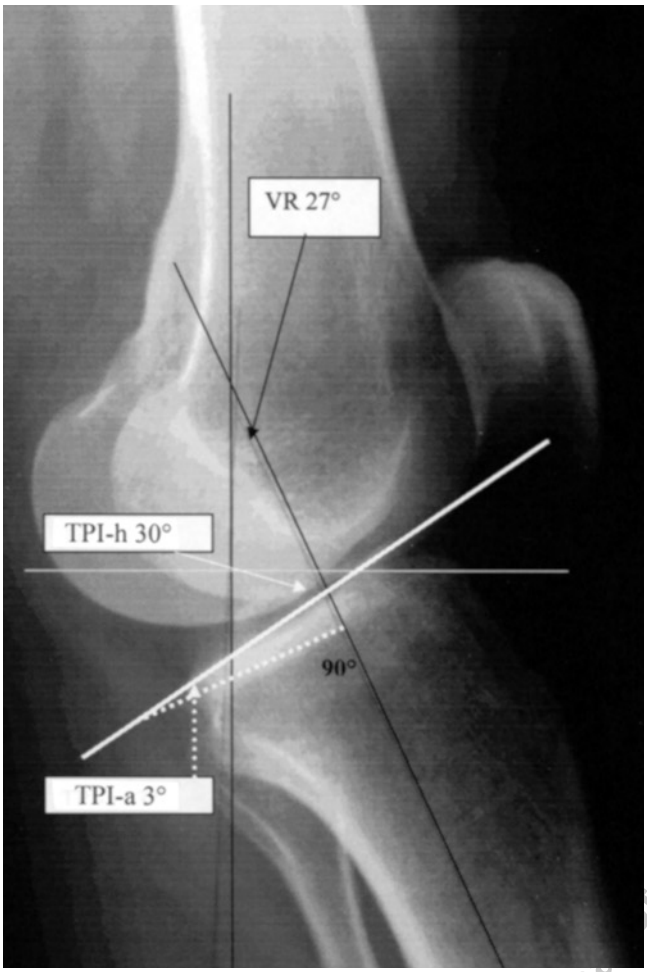

Figure 4. Measurement of angles of tibial plateau showing inclination with horizontal (TPI-h), anatomical tibial plateau inclination (TPI-a), and recurvatum with vertical (VR), from a lateral standing radiograph of the knee in full extension.

followup in the design of clinical trials for DMOAD, since the quality of MTP alignment is one of the key elements of the sensitivity to change for knee OA. However, our conclusions need to be verified in a longitudinal head-to-head comparison of these 2 methods.

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Table 1. Characteristics of patients.

	With Fluoroscopy (population 1)			Without Fluoroscopy (population 2)			
	Mean	SD	Range	Mean	SD	Range	p
Weight, kg	71.1	11.2	46/102	69.7	12.9	45/98	NS
BMI	26.7	4.4	18.4/43.3	25	3.6	16.5/32.4	NS
JSW, mm	2.7	1.5	0/6.3	3.0	1.1	0/5.7	NS
X-ray beam angle (°)	–11.2	3.3	–4/–22	–11	0	–11	NS
TPI–h (°)	19.6	6.9	3/35	NA			
TPI–a (°)	4.3	4.1	–5.5/14	NA			
Recurvatum (°)	–15.3	7.8	0/–28	NA			

BMI: body mass index; JSW: joint space width; TPI-h: tibial plateau inclination angle with horizontal; TPI-a: anatomical tibial plateau inclination angle; NA: not applicable; NS: not significant.

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