Radiographic Issues in Imaging the Progression of Hip and Knee Osteoarthritis

ERIC VIGNON

Interruption of the processes underlying destruction of articular cartilage is the main purpose of structure-modifying drugs for osteoarthritis [SMOAD, also commonly called disease-modifying OA drugs (DMOAD)]. Demonstration of a pharmacologic effect on these processes requires accurate measurement of cartilage destruction over time. Today, demonstration of "chondroprotection" still relies on conventional radiography with, for example, observation of a difference between active treatment and placebo in the rate of narrowing of joint space width (JSW), i.e., the interbone distance of the joint space.

JSW can be measured either with calipers and micrometer eyepiece or by computer. Several computer programs have been developed for this purpose. It is also possible to measure the mean, rather than the minimum JSW or the area of a space in a region of interest defined by the investigator.

We have found that minimum JSW as measured by computer is a more sensitive measure, as indicated by the standardized response mean (SRM), than either mean JSW or joint space area. I will not discuss various approaches to measurement of minimum JSW, and will use the SRM as a measure of sensitivity to change in serial radiographs. For purposes of clarification, an SRM < 0.5 depicts poor sensitivity to change; 0.5 is considered to be the minimum SRM value of good sensitivity to change.

Repeated measurements of minimum JSW made by a single observer may exhibit a standard deviation (SD) as small as ± 0.14 mm, resulting in a smallest detectable difference (SDD) of < 0.3 mm. Results for radiographs of hip joints and knee joints are similar. Thus, repeated measurement of the same radiograph by the same observer exhibits very good reliability, with a coefficient of variation (CV) < 5%. However, the SDD of 0.3 mm is relatively large, considering that the average annual rate of joint space narrowing (JSN) in patients with osteoarthritis (OA) is only 0.1–0.2 mm.

Next, let us consider measurements by different observers evaluating minimum JSW in the same hip radiograph. What is the interobserver reproducibility? Clearly, measurement of minimum JSW is observer-dependent. Figure 1 depicts measurements of minimum JSW made manually by Michel Lequesne and by a technician in our laboratory using an image analysis system. The mean difference between the 2 measurements was 0.26 ± 0.63 mm. However, differences > 1 mm (sometimes > 2 mm) were not uncommon. The discrepancy is difficult to explain, except that measurements by the 2 techniques were not at identical locations, i.e., the 2 examiners defined the point of minimum JSW differently.

That explanation was confirmed in a study[1] in which we examined the magnitude of agreement — or of the difference — between the 2 techniques in relation to the topography of JSN in radiographs of subjects with hip OA. It provides a comparison of results in cases in which narrowing was either medial or central. Although agreement was generally good (nearly 80%), in cases of concentric narrowing, in which determination of the point of minimum JSW is often difficult, agreement between the manual measurement and the measurement made from image analysis was only about 60%. In summary, the value for minimum JSW varies largely with the site at which the measurement is made and is observer-dependent. Accurate determination of the site of minimum JSW is of major importance and requires an expert reader.

In the ECHODIAH study[1], when manual measurements were used the results indicated that the drug, diacerein, was more effective than placebo in slowing the rate of JSN. However, when measurements were determined by image analysis, rather than manually, values for minimum JSW appeared to exhibit less sensitivity to change, and no difference was demonstrable between drug and placebo. This may have been because the expert reader was better able to determine the appropriate site for measurement for minimum JSW than the technician using image analysis. The data for the knee joint are similar. Measurements of minimum JSW in the medial femorotibial compartment, made manually using the Lequesne technique, generally agreed well with measurements made by computer. However, in some cases the difference between the 2 measurements was > 1 mm.

Even repeated computerized analyses of minimum JSW in the same radiograph may show large variation between measurements, reflecting that the area that is selected manually, within which the computer is instructed to search for the point of minimum JSW, may vary from examiner to examiner. Localization of the point of minimum JSW is considerably more difficult in the knee than in the hip. Thus, measurements of JSN vary greatly, based upon the point

From the Service de Rhumatologie, Centre Hospitalier, Lyon-Sud, France.
E. Vignon, MD, Professor of Rheumatology.
Address reprint requests to Prof. E. Vignon, e-mail: eric.vignon@chu.lyon.fr

Personal, non-commercial use only. The Journal of Rheumatology Copyright © 2004. All rights reserved.

Downloaded on April 16, 2024 from www.jrheum.org

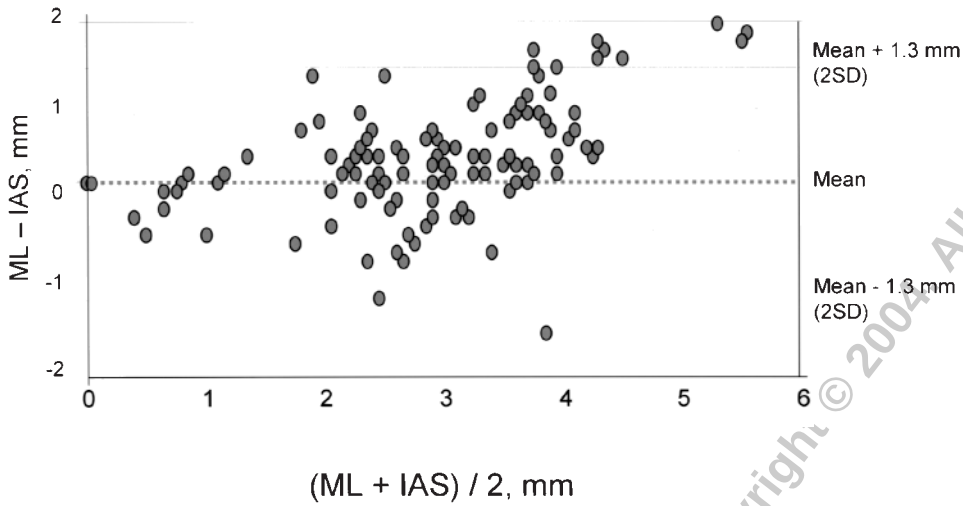

Figure 1. Manual measurements of minimum JSW (by ML) in radiographs of patients with hip OA, compared with measurements of the same image derived with an image analysis system (IAS). The broken line represents the mean value. The mean difference between the 2 readings was 0.26 ± 0.63 mm. However, the difference was often > 1 mm and occasionally as great as 2 mm.

selected as the minimum interbone distance. This is an issue of major importance, requiring expert readers, and presents an even greater problem in the knee than in the hip.

In evaluating a knee radiograph it is necessary to determine not only the point of minimum JSW, but also to ascertain whether JSN occurs in the medial or lateral compartment. Because changes in minimum JSW of the 2 tibiofemoral compartments are inversely related (Figure 2), measurements of serial radiographs of a knee in which the lateral compartment is diseased at the outset are likely to show an increase in JSW of the medial compartment at followup examination. Although this is not an issue in radiography of hip OA, because the minimum JSW occurs in the lateral compartment in nearly 20% of OA knees, routine measurements of medial compartment JSW may not infrequently result in unrealistic increases in JSW over time.

We assume that changes in JSW in serial radiographs reflect the progression of articular cartilage destruction. However, they may be related also to changes in weight-bearing, positioning of the joint, and the quality of the radiograph. In the hip, differences in JSW between radiographs obtained in weight-bearing and in the supine position are minimal, except in patients in whom the minimum JSW is < 0.5 mm. For the knee joint, however, weight bearing makes a profound difference: comparison of JSW measurements in bipedal and monopedal stance may show a difference as great as 0.3 to 0.4 mm — comparable to 2 years of true JSN due to disease.

In serial knee radiographs obtained with the semiflexed AP view[2], a marked increase in joint space may occasionally be seen — even when the radiographs are of excellent quality with respect to alignment of the anterior and poste-

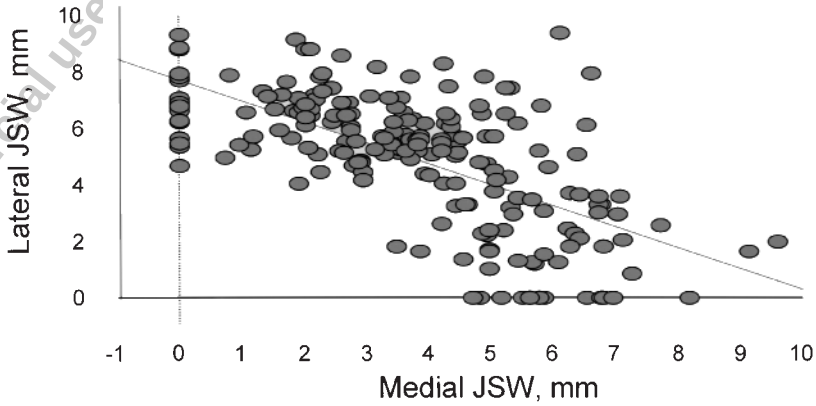

Figure 2. Inverse correlation between JSW of the medial and lateral tibiofemoral compartments in the same OA knees.

Personal, non-commercial use only. The Journal of Rheumatology Copyright © 2004. All rights reserved.

Downloaded on April 16, 2024 from www.jrheum.org

rior margins of the mediotibial plateau with the x-ray beam, control of magnification, and knee rotation (Figure 3). One possibility for this increase in JSW is the presence of greater joint pain during the baseline examination, limiting loading of the knee to a greater extent than in a subsequent examination performed when the patient is having less pain. It is also possible that the increase in JSW is due to an increase in the tibiofemoral angle in the second examination, relative to the initial examination.

Joint positioning is also an important variable. Generally, the hip joint is imaged with an AP pelvic radiograph. Figure 4 depicts 2 images of a hip joint obtained at the same visit. In the AP view, marked JSN is apparent medially; in the profile view[3], however, JSN is not medial, but superior. This indicates the AP pelvic radiograph can be misleading for accurate determination of location of the minimum JSW, especially when JSN is not superolateral. However, we have extensive experience with AP radiographs of normal hips, and with the analysis of multiple radiographs of the same normal hip obtained in different centers. The SD for minimum JSW is 0.25 mm, with an SDD of 0.5 mm — a value larger than the 0.3 mm obtained for repeated measurements of the same radiograph, but still very acceptable.

In summary, either the weight-bearing or supine AP view of the hip provides a good assessment of the progression of JSN in patients with hip OA, because there is little change between repeated images. For the knee, however, the standing AP radiograph presents a much greater problem: JSW varies largely with the degree of joint flexion.

Figure 5 (A and B) shows a posteroanterior (PA) view of the knee in about 20° to 30° of flexion (the Lyon schuss view). The decrease in JSW, compared to that in a concurrent standing AP view of the same knee, is striking, indicating the significant effect of knee flexion on JSW. We found that the mean difference between the standing AP view and Lyon schuss view with respect to medial compartment JSW (Table 1) was 0.7 mm — the equivalent of > 3 years of OA progression[4]; for the lateral compartment, the difference was 2.5 mm — the equivalent of 10 years of disease progression!

In the Lyon schuss view, the greater angle of flexion places the posterior aspect of the femoral condyle (the site at which maximum cartilage destruction occurs in most patients with knee OA) in contact with the tibial plateau (Figure 6A). In contrast, in images obtained with the knee joint in full extension, this region of the condyle is not in contact with the tibia. Based on our experience, we would emphasize the importance of selecting patients for clinical trials by using a view of the knee obtained in flexion, e.g., the Lyon schuss, rather than the standing AP view. A radiograph of the knee without a significant degree of flexion will miss early medial or lateral compartment OA.

Another point with respect to knee radiography relates to the importance of alignment of the medial tibial plateau with the central beam of the x-ray. This is evaluated by measuring the distance between the anterior and posterior margins of the plateau. There is general agreement that if this interval is ≤ 1 mm, the quality of the radioanatomic positioning of the knee is good, and if the distance is > 1 mm, the quality is not satisfactory. The influence of alignment is evident in the example shown in Figure 7, of a patient whose knee was imaged over a period of 2 years. A striking increase in JSW seemed to occur during in this interval. However, although alignment of the tibial plateau in the second radiograph was excellent, alignment in the baseline image was unsatisfactory.

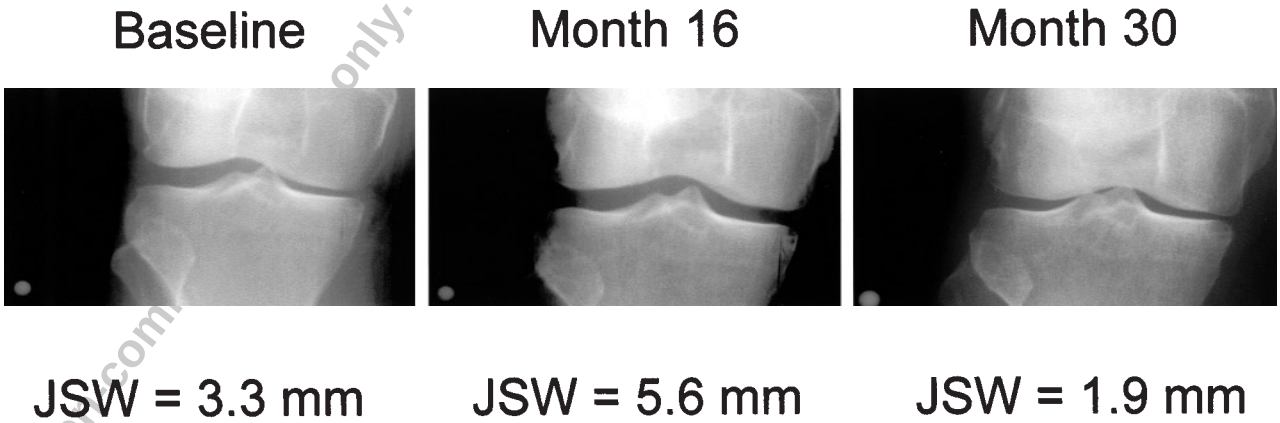

Figure 3. Serial semiflexed AP views of a knee, obtained at the time intervals indicated. Note the increase in JSW of the medial tibiofemoral compartment in the 16 month examination, versus baseline examination, and subsequent narrowing of the joint space in the 30 month radiograph. Although alignment of the medial tibial plateau with the x-ray beam was satisfactory in all 3 images, they did not vary appreciably with respect to knee rotation, and each was adjusted for radiographic magnification. It is apparent that the 16 month radiograph was obtained in a smaller degree of knee flexion (i.e., with a larger tibiofemoral angle) than the baseline or 30 month examinations.

Personal, non-commercial use only. The Journal of Rheumatology Copyright © 2004. All rights reserved.

Downloaded on April 16, 2024 from www.jrheum.org

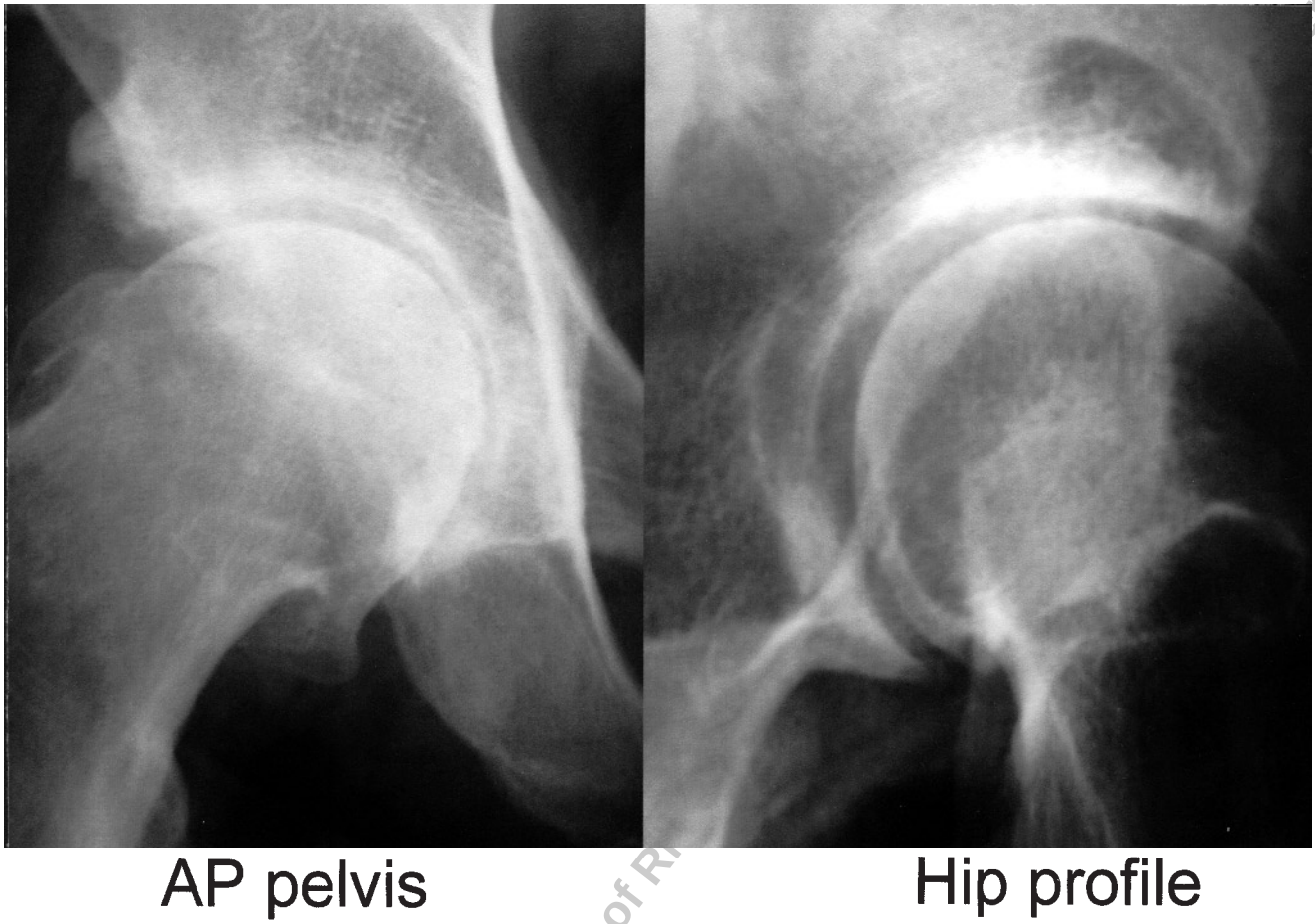

Figure 4. Hip joint of a patient imaged during the same visit with an AP view of the pelvis (left) and a profile view (right). (With permission from Lequesne, *et al*. Ann Rheum Dis 1998;57:676-81.) In the AP view, joint space narrowing is greatest medially, while in the profile view it is greatest at the superior pole.

As noted in Table 2, when the medial tibial plateau was aligned correctly, the SD for JSW was about 0.3 mm and the SDD was 0.6 mm (a value close to that for the hip joint). However, when alignment was unsatisfactory, the SD for JSW was larger and the SDD was about 1 mm, i.e., much greater than that for the hip.

In a longitudinal study of patients with knee OA who were imaged with standing AP radiographs, Mazzuca, *et al*[5] found that when good alignment was (fortuitously) present in both members of a pair of radiographs obtained over a 2 to 3 year interval, the SD for JSN was about 0.7 mm, i.e., about the same as the rate of JSN. However, when alignment was unsatisfactory, the mean rate of JSN was only about half as great as, and the SD more than 4 times greater than, the mean value. We have confirmed this in a study in our unit, in which a SRM of 0.9 (reflecting very high sensitivity to change) was found in paired radiographs that exhibited excellent alignment, with a much lower SRM when alignment was not achieved[6].

Further evidence of the importance of good alignment of the medial tibial plateau is provided by an analysis of sensitivity to change, as reflected by the SRM, in the fluoroscopically assisted semiflexed AP view of the knee — the chief virtue of which is that it results in superimposition (± 1 mm) of the anterior and posterior margins of the medial tibial plateau in more than 90% of examinations. As indicated in Table 3, the SD for JSN in osteoarthritic knees imaged by this technique was no more than twice as great as the mean rate of narrowing and the SRM were good to excellent (0.45 at 16 mo and 0.76 at 30 mo)[7].

In summary, with the conventional AP radiograph of the knee, the SRM is unacceptably low at < 0.4. It seems clear that use of the conventional standing AP radiograph of the knee for clinical trials that require evaluation of JSN is unrealistic. The method provides no standardization of weight-bearing or control of the degree of knee flexion and, in the majority of cases, results in poor alignment of the medial tibial plateau. For these reasons, differences as great as 1 to 2 mm may be observed in measurements of medial tibiofemoral compartment JSW in radiographs of the same knee obtained within a short period of time.

Our data indicate that the Lyon schuss view represents a

Personal, non-commercial use only. The Journal of Rheumatology Copyright © 2004. All rights reserved.

Downloaded on April 16, 2024 from www.jrheum.org

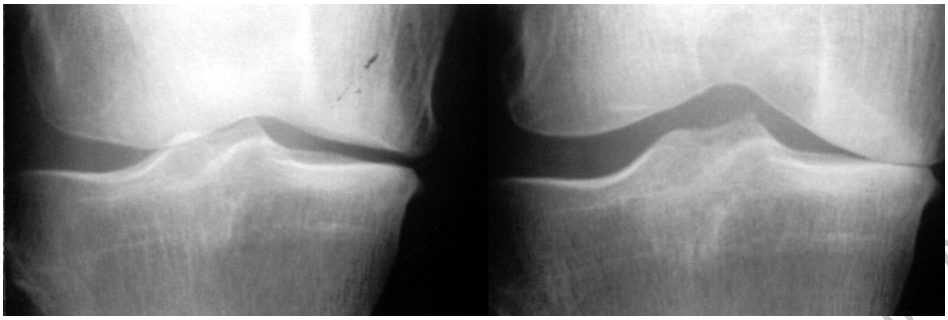

Figure 5A. JSW in the medial tibiofemoral compartment. Conventional standing AP view with the knee in extension (left) and concurrent Lyon schuss view (right). The latter provides a posteroanterior (PA) view, with the knee in 20° to 30° of flexion. Note the loss of medial compartment joint space in the schuss view.

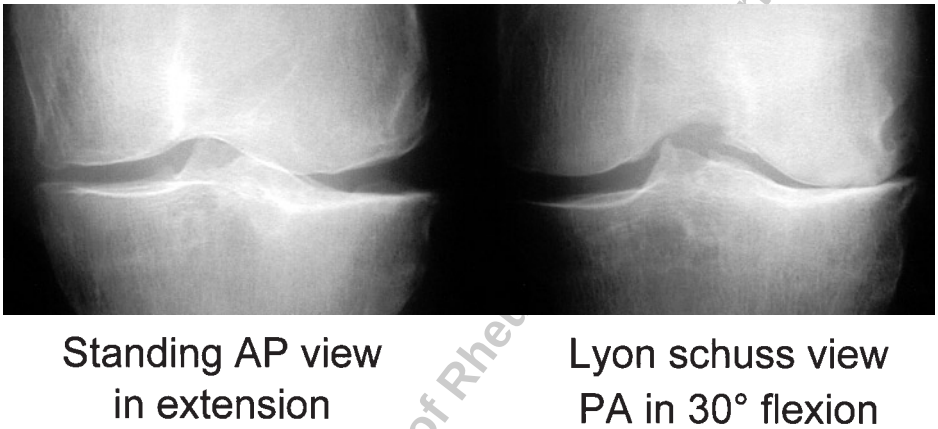

Figure 5B. Differences between a standing AP view of the knee in extension and of concurrent Lyon schuss view with respect to localization of joint pathology to medial versus lateral tibiofemoral compartment. The standing AP view shows mild narrowing of the medial compartment, while the Lyon schuss view of the same knee shows complete loss of the joint space in the lateral compartment. The difference is due to the increase in knee flexion (i.e., decrease in tibiofemoral angle) in the Lyon schuss view.

Table 1. Effect of knee flexion on minimum joint space width (JSW). Comparison of the Lyon schuss view and standing AP view in 47 OA knees with medial or lateral joint space narrowing (JSN). From Piperno M, *et al. Osteoarthritis Cartilage 1998*;6:252-9.

Site of JSN	Minimum JSW, mm, Standing AP View	Mean difference in JSW, mm, Between Standing AP and Lyon Schuss Views	p
Site of JSN			
Medial	3.5 ± 1.5	0.7	< 0.0001
Lateral	3.7 ± 1.7	2.5	< 0.0001

great improvement over both the conventional standing AP and the semiflexed AP view. In the latter, the x-ray beam is parallel to the floor and the patient is asked to flex the knee to a point at which the medial tibial plateau is parallel to the central beam of the x-ray (Figure 8). In the Lyon schuss view, in contrast, the patient is asked to flex the knee so as to bring the anterior aspect of both thighs in contact with the x-ray table. This results in a much greater degree of flexion (20° to 30°) than is generally achieved in the semiflexed view. As a result, the image reflects the interbone distance at the most likely site of maximum cartilage destruction (Figure 6), improving sensitivity to change in serial measurements of JSN (Table 4).

In a study comparing the conventional standing AP view

Personal, non-commercial use only. The Journal of Rheumatology Copyright © 2004. All rights reserved.

Downloaded on April 16, 2024 from www.jrheum.org

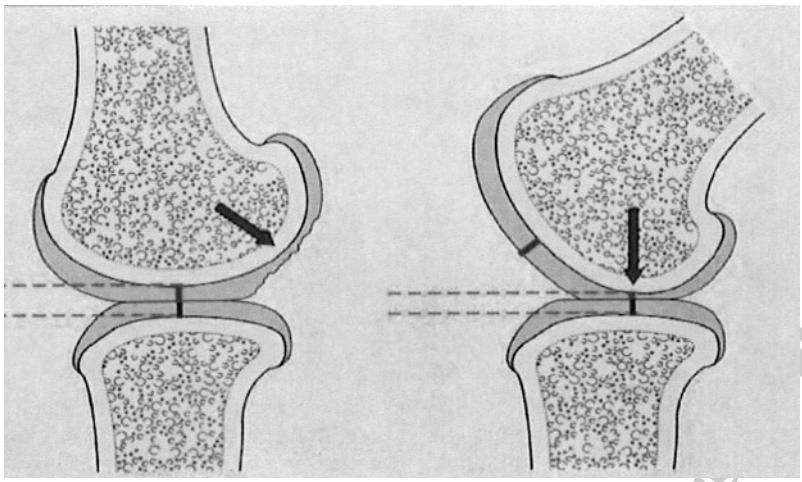

Figure 6. Diagram indicating why radiography of the knee in flexion more accurately depicts the attrition of articular cartilage in OA than an image obtained with the knee in full extension. The site of maximum thinning of the articular cartilage on the femoral condyle in OA usually occurs on the posterior aspect of the medial femoral condyle. With the knee in extension, however, this area is not in contact with the tibia. In contrast, with the knee in 20° to 30° of flexion, the posterior area of the condyle is weight-bearing and the interbone distance is diminished. For this reason, radiographs obtained in knee flexion provide greater sensitivity to change in JSW than those obtained in extension.

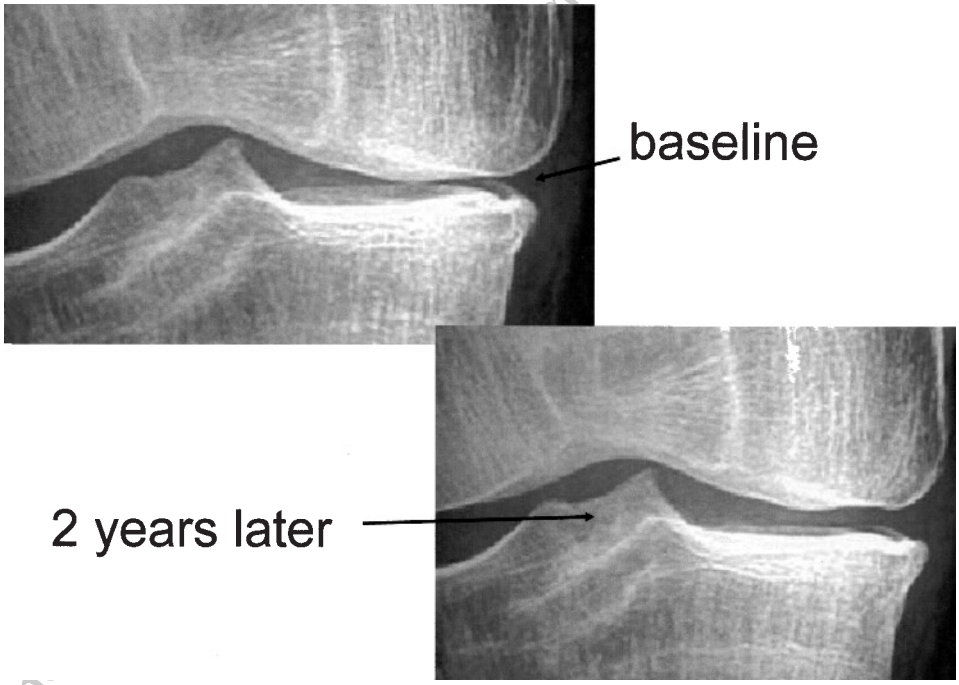

Figure 7. Importance of alignment of the anterior and posterior margins of the medial tibial plateau with the central x-ray beam. Note the 1 mm increase in JSW in the medial tibiofemoral compartment upon comparison of the baseline image and a radiograph obtained 2 years later. Both images were obtained with a conventional standing AP radiograph of the knee in extension. Poor alignment of the plateau is obvious in the baseline radiograph. Good alignment was present (by chance) in the later film.

and Lyon schuss view in 58 patients who were examined at baseline and again 2 years later (Table 4), in which good alignment of the medial plateau was not frequent, the mean rate of JSN (0.24 ± 0.50 mm) in the Lyon schuss view was significantly greater than that seen with the standing AP view (0.16 ± 0.74 mm), and the sensitivity to change, shown by the SRM (0.48), was more than twice as great[7]. Because fluoroscopy was used in both techniques in this study, the

Personal, non-commercial use only. The Journal of Rheumatology Copyright © 2004. All rights reserved.

Downloaded on April 16, 2024 from www.jrheum.org

Table 2. Effect of alignment of the medial tibial plateau on medial tibiofemoral compartment joint space width.

	Alignment	n	Mean JSW, mm	SD, mm	SDD, mm
Diagnosis					
Normal*	Yes	16	0.0	0.3	0.6
	No	32	0.1	0.5	1.0
OA, 2-3 year follow-up**	Yes	60	0.7	0.7	—
	No	342	0.3	1.3	—

SD: standard deviation; SDD: smallest detectable difference. * Vignon E. Unpublished data. ** Derived from Mazzuca S, *et al*. *Arthritis Rheum 2001*;44:1786-94.

Table 3. Sensitivity to change in JSN with the fluoroscopically-assisted semi-flexed AP view of the knee. From Mazzuca, et al. *Arthritis Rheum 2002;* 46 Suppl 9:S568.

	Interval from Baseline Exam, mo	Minimum JSN, mm mean ± SD	SRM
Number of Knees			
285	16	0.31 ± 0.64	0.45
206	30	0.54 ± 0.75	0.76

SRM: standardized response mean.

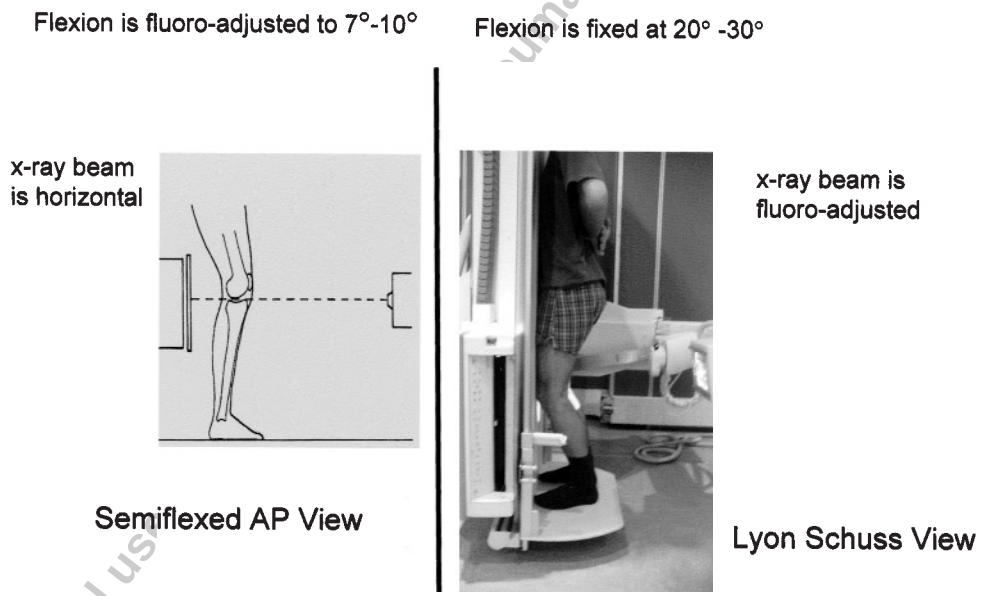

Figure 8. Positioning of the knee for the semiflexed AP and Lyon schuss views.

quality of medial tibial plateau alignment was similar with both protocols. The differences between the 2 views with respect to the alignment rate of narrowing and to the SRM, therefore, were due mainly to differences in the degree of knee flexion (i.e., femorotibial angle).

Notably, the fixed flexion view of Peterfy, *et al*[8] (Figure 9), in which the beam is angled 10° downward, achieves a position of the knee that is essentially identical to that obtained with the Lyon schuss view, although the former does not utilize fluoroscopy. The metatarsophalangeal (MTP) joint view proposed by Buckland-Wright, *et al*[9] is also similar, and differs from the fixed flexion PA view mainly by the length of the great toe (Figure 9). In the MTP view, however, as in the fixed flexion PA view, fluoroscopy is not employed.

In our opinion, a strong rationale exists for the use of fluoroscopy in knee radiography; to obtain a good knee radiograph without fluoroscopy is a pipe dream. Only with

Personal, non-commercial use only. The Journal of Rheumatology Copyright © 2004. All rights reserved.

Downloaded on April 16, 2024 from www.jrheum.org

Table 4. Increase in knee flexion improves the sensitivity in the radiograph to change in joint space narrowing (JSN).

	Percentage of films with satisfactory alignment of the medial tibial plateau	JSN, mm, mean ± SD over 2 yrs	p	SRM
View				
Standing AP	57	0.16 ± 0.74	NS	0.22
Lyon schuss	66	0.24 ± 0.50	< 0.02	0.48

SRM: standardized response mean, 58 OA knees imaged by both techniques at baseline and 2 years later.

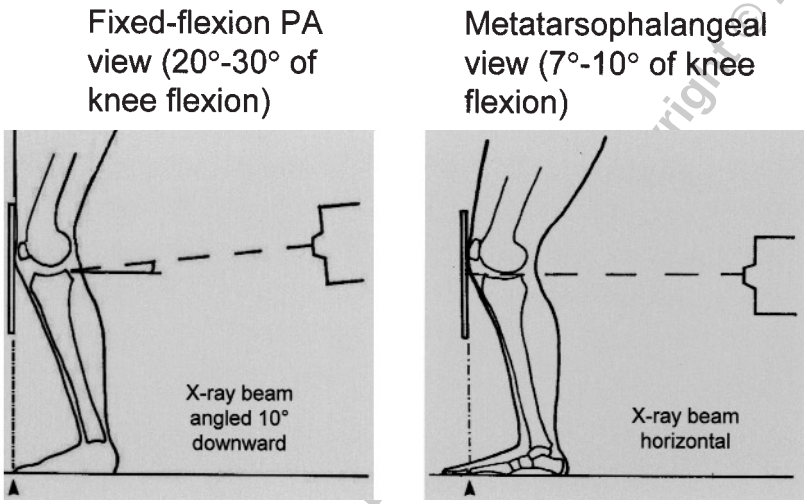

Figure 9. Recently proposed standardized radiographic views of the knee that do not utilize fluoroscopically assisted positioning.

fluoroscopically assisted positioning can we assure alignment of the medial tibial plateau with the x-ray beam. Without fluoroscopy, because of the variation among individuals, the angle of the plane of the tibial plateau will vary considerably. We found the mean inclination of the tibial plateau to be 29°, with a range of 3° to 35°. Therefore, in any nonfluoroscopically assisted view the tibial plateau is aligned with the x-ray beam in only a proportion of patients. Indeed, in many cases, alignment is not achieved with either the MTP or fixed flexion view. In the MTP view, fewer than 30% of radiographs exhibit satisfactory alignment[9].

In a head-to-head longitudinal comparison of the MTP and semiflexed AP views in paired radiographs of subjects with knee OA, with a 14 month interval between the baseline and followup examinations, as indicated by an SRM value of 0.12, sensitivity to change in the radiographs obtained without fluoroscopic positioning (i.e., the MTP view) was not appreciably greater than that seen with the conventional standing AP view.

In conclusion, to measure a decrease in JSW of 0.1 to 0.2 mm per year (i.e., a rate commonly reported from OA knees) using a method in which the most accurate measurement cannot detect a true change that is smaller than the expected measurement error of ≤ 0.5 mm is difficult — although not impossible. It will require a 2 to 3 year interval between examinations and a relatively large number of subjects. The central requirement for knee radiography is an image of excellent quality. To achieve this, fluoroscopy and a reproducible degree of knee flexion are mandatory, and determination of the site of minimum JSW by an expert is of utmost importance.

REFERENCES

1. Dougados M, Nguyen M, Berdah L, Maziéres B, Vignon E, Lequesne M. Evaluation of the structure-modifying effects of diacerein in hip osteoarthritis: ECHODIAH, a 3 year placebo-controlled trial. Arthritis Rheum 2001;44:2539-45.
2. Buckland-Wright JC, Macfarlane DG, Jasani MK, Lynch JA. Quantitative microfocal radiographic assessment of osteoarthritis of the knee from weight bearing tunnel and semi-flexed standing views. J Rheumatol 1994;21:1734-41.
3. Lequesne M, Larédo JD. The faux profil (oblique view) of the hip in standing position. Contribution to the evaluation of osteoarthritis of the adult hip. Ann Rheum Dis 1998;57:676-81.
4. Piperno M, Hellio MP, Conrozier T, Mathieu P, Bochu M, Vignon

Personal, non-commercial use only. The Journal of Rheumatology Copyright © 2004. All rights reserved.

Downloaded on April 16, 2024 from www.jrheum.org

E. Quantitative evaluation of joint space width in femorotibial osteoarthritis: Comparison of three radiographic views. Osteoarthritis Cartilage 1998;6:252-9.
5. Mazzuca SA, Brandt KD, Dieppe PA, et al. Effect of alignment of the medial tibial plateau and x-ray beam on apparent progression of osteoarthritis in the standing anteroposterior knee radiograph. Arthritis Rheum 2001;44:1786-94.
6. Vignon E, Piperno M, Hellio Le Graverand M-P, et al. Measurement of radiographic joint space width in the tibiofemoral compartment of the osteoarthritic knee: Comparison of standing anteroposterior and Lyon-schuss views. Arthritis Rheum 2003;48:370-7.
7. Mazzuca SA, Brandt KD, Buckwalter A. Longitudinal study of the variability of joint space narrowing (JSN) in osteoarthritic (OA) knees imaged over 30 months with fluoroscopically standardized knee radiography [abstract]. Arthritis Rheum 2002;46 Suppl 9:S568.
8. Peterfy CG, Li J, Duryea J. Nonfluoroscopic method for flexed radiography of the knee that allows reproducible joint space width measurement [abstract]. Arthritis Rheum 1998;41 Suppl 9:S361.
9. Buckland-Wright JC, Wolfe F, Ward RJ, et al. Substantial superiority of semiflexed (MTP) views in knee osteoarthritis: a comparative radiographic study, without fluoroscopy, of standing extended, semiflexed AP, and schuss views. J Rheumatol 1999;26:2664-74.
10. Mazzuca SA, Brandt KD, Buckwalter KA. Longitudinal comparison of the metarsophalangeal (MTP) and semi-flexed anteroposterior (AP) views: detection of radiographic joint space narrowing (JSN) in osteoarthritic (OA) knees [abstract]. Arthritis Rheum 2002;46 Suppl 9:S150.

Personal, non-commercial use only. The Journal of Rheumatology. Copyright © 2004. All rights reserved.

Personal, non-commercial use only. The Journal of Rheumatology Copyright © 2004. All rights reserved.

Downloaded on April 16, 2024 from www.jrheum.org