Radiographic Methods in Knee Osteoarthritis: A Further Comparison of Semiflexed (MTP), Schuss-Tunnel, and Weight-Bearing Anteroposterior Views for Joint Space Narrowing and Osteophytes

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ABSTRACT. ***Objective.*** Current radiographic evaluation of knee osteoarthritis (OA) depends primarily on the presence and severity of joint space narrowing (JSN) and osteophytes. Radiographic JSN is a function of the actual JSN caused by articular cartilage loss and the observable JSN artifactually caused when the tibial and femoral surfaces diverge due to variations in patient's knee position. Views yielding the greatest JSN are the most accurate. Osteophytes are also dependent on positioning. This study investigated the consequences of positioning on JSN and osteophytes in clinical studies in which the outcome of OA knee is scored.

Methods. In total, 1105 patients underwent 1175 paired radiographic examinations using weight-bearing (WB) standard anterior-posterior (AP) extended knee views (AP-WB), semiflexed WB posterior-anterior views with the knee in contact with the film and the 1st metatarsophalangeal (MTP) joint under the film plane (MTP) (method of Buckland-Wright), and WB PA views with the tip of the great toe at the film plane, 20° of knee flexion and 5° downward angulation of the x-ray tube (schuss-tunnel view). Careful attention was given to proper positioning. JSN and osteophytes were scored on a 0–3 scale.

Results. JSN was significantly greater by the MTP and schuss-tunnel methods than by the AP-WB method, but no difference was found between the MTP and schuss-tunnel methods. In addition, disagreement was identified in 34% of MTP and AP-WB scores. In 69.3% of disagreements the scores were more abnormal in the MTP view. When the disagreements were studied, the mean MTP score was 1.68 compared to 1.12 for the AP-WB score. Fifty-seven knees were scored as 3 by the MTP view and as 2 by the AP-WB, and 8 knees were scored as 3 by the AP-WB view and 2 by the MTP view. Little difference in osteophytes was noted among the 3 methods, although fewer osteophytes were identified by the schuss-tunnel method than the AP-WB method.

Conclusion. Using the clinical reading methods of this study, the MTP and schuss-tunnel views were equivalent when compared to each other. When compared with the AP-WB view, the schuss-tunnel view resulted in a lower osteophyte score. These results, based on clinical readings, are similar to previous computerized analyses that indicated that the MTP and schuss-tunnel views were superior to the AP-WB, but that the MTP view was superior to the schuss-tunnel view. (J Rheumatol 2002;29:2597–601)

Key Indexing Terms:
OSTEOARTHRITIS KNEE RADIOGRAPHIC POSITIONING

The scoring and interpretation of plain radiographs of the knee depend on a number of technical factors that standardize the radiographic procedure[1-3], particularly the position of the knee relative to the x-ray tube and the film[3-9]. In addition, for comparison of films over time, reproducibility of positioning is essential and is controlled by beam centering at the joint, and joint rotation is controlled by means of a foot map[3,7,10]. The goal is to produce a time-consistent radiograph with the medial tibial plateau as near as possible to the horizontal and perpendicular to the film plane[7], since this allows the reader (or computerized reader) to most accurately ascertain the joint width.

The angle of inclination of the tibial plateau relative to the horizontal in the standing position is not the same in all subjects, so that no position (except those determined by fluoroscopic examination) will be satisfactory for all subjects. But certain views, positioned without fluoroscopic guidance, give a better picture of the joint by virtue of

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having a tibial plateau that is close to the horizontal and perpendicular to the film[7]. Recent studies have shown that the traditional extended anterior-posterior weight-bearing view (AP-WB) produces less accurate and less reproducible results than do flexed knee views[7].

The flexed knee radiographs, positioned without fluoroscopic guidance, are posterior-anterior views in which the anterior surface of the flexed knees are placed in contact with the film cassette. In the schuss-tunnel position, the tip of the 1st toe (hallux) is aligned with the film plane[11]. In the "MTP" view, the 1st metatarsophalangeal (MTP) joint is aligned with the film plane[7]. Using computerized analyses, we have recently shown that the MTP view is superior to the schuss-tunnel view, which in turn is superior to the AP-WB view. In this instance superiority refers to providing the most accurate radioanatomic joint positioning, the most reproducible joint repositioning and joint space width (JSW) measurement[7]. The superiority achieved with the MTP view was obtained by ensuring that the tibial plateau was as near to the horizontal position as possible, within the limits defined by the patient's anatomy, and importantly, the joint was reproducibly repositioned at repeat patient visits[7], compared on average to the poorer tibial plateau leveling and reproducibility achieved with the schuss-tunnel and to a greater degree in the AP-WB view.

In addition to tibial leveling, AP-WB radiographs are limited because they require the knees to be straight and the posterior surface of the joint to be placed against the film cassette[11,12]. This is not always possible in patients with osteoarthritis (OA) due either to osteophytosis resulting in a flexion deformity or to soft tissue in obese patients[13], and in practice is a requirement that may not be followed.

What are the consequences of poor tibial plateau leveling in nonfluoroscopically guided views of the knee? There would appear to be 2 consequences. The first is measurement error, since if the joint space cannot be clearly seen it cannot be accurately measured. The second (possible) consequence is a systematic over or underestimation of joint space narrowing (JSN). In such a circumstance one view would yield different results of the same knee compared to another view. Because the MTP is the most reliable and reproducible view[7], it is possible to use it as the standard to which other views will be compared. If the other views produce less JSN, then that difference will reflect measurement error brought about by the particular positioning and its effect upon the degree of tibial plateau leveling.

Knee radiographs are also used to identify and quantitate osteophytes, and it is possible that osteophyte size and identification may be altered by differences in tibial plateau leveling. This issue, as it is influenced by the 3 views, has not been studied previously. Clearly it would be desirable to determine which view is best for identifying and measuring osteophytes. We compare the 3 views, AP-WB, MTP, and schuss-tunnel, as to their effect on JSN and osteophytes in a large series of patients with OA. In addition, we test whether the results obtained in 74 patients using computer analysis[7] can be extended to a larger series of patients (1105 patients) when radiographs are read by clinicians rather than by computer.

MATERIALS AND METHODS

Patients. Patients in this study were those with knee pain who had radiographs made as part of initial and followup rheumatologic care at an outpatient rheumatology clinic. The clinical evaluation included data on demographic status, functional ability, and pain. In addition, some patients had radiographs made as part of a screening evaluation performed to detect knee OA among persons in the general community.

Patients in this study were those who had films taken on or after October 1, 1996. The radiographs were obtained in pairs or triplicates, and included simultaneous AP-WB and MTP, AP-WB and schuss-tunnel, MTP and schuss-tunnel, and AP-WB and MTP and schuss-tunnel views. After initial studies suggested the increased accuracy of the MTP views, schuss-tunnel views were discontinued as part of the radiographic profile. AP-WB views were continued for the purposes of backward compatibility. Therefore there are fewer radiographic pairs in this study that include the schuss-tunnel view, and not all patients had the paired AP-WB and MTP view. In addition, 257 patients had evidence of a total joint replacement. After excluding those patients, the total patients available for study were 918.

Radiographic methods. Both knees were radiographed at the same time. Following the initial radiograph obtained for each view, the outline of the foot was drawn on a large sheet of paper taped to the floor. The foot map was used to reposition the joint at the repeat examination. The x-ray film cassette was held in a vertical film-holder with a film-to-focus distance (FFD) of 100 cm. Patients were provided with hand support if required.

Standing extended knee (anteroposterior) view (AP-WB). The x-ray tube was positioned so that the central ray of the x-ray beam was horizontal, parallel to the floor and perpendicular to the x-ray film. Knee radiographs were taken with patients standing with their feet together and with the weight equally distributed on both feet[11]. Both knees were fully extended and the film cassette was positioned as close as possible to the posterior surface of the joint. Using the tube's positioning light, the central ray of the x-ray beam was centered midway between the inferior borders of both patellae.

Standing semiflexed knee or MTP position (posteroanterior view). The x-ray tube was positioned so that the central ray of the x-ray beam was horizontal, parallel to the floor and perpendicular to the x-ray film. The radiographic technician identified the position of the tibiofemoral joint space located midway between the inferior border of the patella and the superior margin of the tibial tuberosity. The line of the joint space was traced around to the side of the knee and the skin marked with a felt tip pen. This mark was used to help align the centre of the x-ray beam with joint space. The patient stood with both knees facing the film cassette, the feet slightly externally rotated at about 15°, as recommended by Ravaud, *et al*[6] in their assessment of the optimum foot position for knee radiography. The joint of the first MTP joint of each foot was positioned immediately below and in line with the front edge of the film cassette. The patient bent their knees so that the anterior surface of each knee touched the middle and front of the film cassette. The tube was positioned so that the x-ray beam was directed midway between the popliteal surface of the knees, and the tube's positioning light was aligned with the horizontal plane of the joint space (as described above). This plane lay above the horizontal skin crease of the popliteal fossa.

Schuss or tunnel position of the knee (posteroanterior view). The patients stood with their feet slightly externally rotated to about 15°. The front edge of the big toe of each foot was positioned immediately below and in line with the front edge of the film cassette. The patient bent their knees until the anterior surface of each knee touched the middle and front of the film cassette. The degree of knee flexion obtained was about 20°. The patient was provided with hand support if required. The x-ray beam was directed at 5° downward at a site midway between the popliteal fossae, and the tube's positioning light was aligned with the horizontal skin crease of the popliteal fossa.

There is some confusion about the term "schuss" or "schuss-tunnel." To clarify, in this report we have used the term "schuss-tunnel" as described above and as used previously[7,11]. Another radiographic view that has also been called the "schuss" view was proposed by Piperno, *et al*[9].

Film reading and scoring. Films were marked according to which of the 3 views were being presented. Films were blinded by covering the patient's name and the radiographic method code with opaque tape, and the radiographs were then presented to readers in random order. Readers called out the results, which were scored by a separate recorder. Readers (FW and NL) trained together until their results were similar. These readers were experienced and had read together previously. After an additional training session, each of 2 readers read roughly half of the knee radiographs. Ten films were selected and in a blinded fashion were read twice by each reader. Between-observer kappa values were 0.66 and 0.62 for JSN and osteophytes, respectively. Overall, within-observer values were 0.70 and 0.71, respectively. Values > 0.75 may be thought to represent excellent agreement, and values between 0.40 and 0.75 represent fair to good agreement[14]. Radiographs were scored according to the methods of the Osteoarthritis Research Society (OARS) *Atlas*[15]. In this method, scores range from 0 to 3 for JSN and osteophytes. Medial and lateral narrowing was scored separately. Medial and lateral tibial and femoral osteophytes were also scored separately.

Statistical methods. To compare radiographic methods, the paired radiographs were studied for marginal homogeneity by the symmetry test and the Stewart-Maxwell marginal homogeneity test[16]. In 2 × 2 tables the symmetry test reduces to the McNemar test. Marginal homogeneity refers to equality (lack of significant difference) between one or more of the row marginal proportions and the corresponding column proportions. Testing marginal homogeneity allows us to determine if the radiographic methods are in agreement. The symmetry test examines row/column homogeneity with respect to each individual category; the Stewart-Maxwell test tests marginal homogeneity for all categories simultaneously. The sign test was used to test the difference between matched pairs (2 methods of radiographic positioning). The null hypothesis is that the median of the differences is zero. The sign test makes no further assumptions about the distribution of the data. Data were analyzed using Stata version 7.0[16]. Statistical significance was set at 0.05, and all tests were 2 tailed.

RESULTS

Films from 1175 separate examinations of 1105 patients were studied. The mean age of patients was 63.2 (SD 11.2) years. Mean body mass index was 30.9 (SD 11.2); mean disability measured by the Stanford Health Assessment Questionnaire was 0.80 (SD 0.52); mean pain measured by visual analog scale was 1.3 (SD 0.78) and mean symptom duration was 12.9 (SD 11.3) years; 79.3% of patients were women.

Joint space narrowing. To evaluate JSN, the maximum narrowing and osteophyte value of the right and left medial and right and left lateral compartments were obtained for each of the 3 methods. As shown in Table 1, JSN was significantly greater by the MTP and schuss-tunnel methods than by the AP-WB method, but no difference was found between the MTP and schuss-tunnel methods.

To clarify the source of the disagreement between the flexed views and the AP-WB view, the distribution of scores was explored by comparing scores for the MTP and AP-WB views, as shown in Table 2. Of the 918 scores, 605 were in agreement and 313 disagreed. Of the disagreements, in 69.3% the scores were more abnormal in the MTP view and in 30.7% were more abnormal in the AP-WB view. When only the 313 disagreements were studied, the mean MTP score was 1.68 compared to 1.12 for the AP-WB score, a difference of 0.56 units or half a grade. Analysis of cell contribution to the symmetry chi-square showed that almost half (44%) of the chi-square came about in the disagreement between scores of 2 and 3. Fifty-seven knees scored 3 by the MTP view and 2 by the AP-WB, and 8 knees were scored 3 by the AP-WB view and 2 by the MTP view. Similar patterning was noted at the other levels.

The relation between the schuss-tunnel view and the AP-WB was similar, although the difference was not as strong as between the MTP and AP-WB view, being 0.11 units, as shown in Table 1. When only the disagreements between the schuss-tunnel and the AP-WB view were considered, the schuss-tunnel score was 1.36 versus 1.11. This difference of 0.25 was less than the difference noted for the MTP/AP-WB pairing of 0.56.

Figure 1 shows the differences between the 3 methods graphically. The total narrowing score in this illustration is the sum of the left and right medial and lateral compartment scores and ranges from 0 to 12. Since OA of the knee predominantly affects the medial or the lateral compartment, but not both, 99.5% of the cumulative score for the 4 compartments falls between 0 and 6. As shown in the figure, the cumulative probability of obtaining any score between 1 and 6 is greater for the MTP view (upper left) than the AP-WB view. The MTP view (upper left) also performs better in this respect than does the schuss-tunnel view (lower left). There is little difference to be seen in the direct comparison of the MTP and schuss-tunnel views (upper right).

Osteophytes. The MTP osteophyte scores were not different compared to the AP-WB view, and were not different from the schuss-tunnel view using the Stewart-Maxwell marginal homogeneity test, although a difference was noted using the symmetry test. Overall, the score difference between the MTP and schuss-tunnel views for osteophytes was slight (0.03 units). However, a lower osteophyte score was found using the schuss-tunnel view compared to the AP-WB view.

Detailed analyses of individual features. In addition to analyses using maximum scores of JSN and osteophytes, and the summed scores of Figure 1, we conducted separate analyses of medial and lateral components, and of the individual osteophyte locations. Because of the complexity and space requirements of the detailed analyses, we do not present them, except to note that the results of these analyses were very similar to those presented above (data on file), and that lateral and medial compartment results were similar to the data in Table 1.

Table 1. Comparison of semiflexed (MTP), extended anterior-posterior weight-bearing (AP-WB), and schuss-tunnel views in patients with OA.

	N	MTP (0–3)	AP-WB (0–3)	Symmetry, p	Marginal Homogeneity, p	Sign Test, p
Narrowing*	918	1.38	1.19	< 0.000	< 0.000	< 0.001
Osteophytes*	918	1.18	1.20	0.378	0.197	0.113
		MTP	Schuss			
Narrowing*	686	1.27	1.26	0.110	0.302	0.377
Osteophytes*	686	1.08	1.05	0.029	0.364	0.027
		Schuss	AP–WB			
Narrowing*	676	1.25	1.14	< 0.000	< 0.000	0.015
Osteophytes*	676	1.02	1.12	0.001	< 0.001	< 0.001

* Narrowing and osteophyte scores represent the maximum scores of the bilateral medial and lateral compartments for narrowing and of the bilateral medial and lateral regions of the tibia and femur. Test statistics are p values.

Table 2. Distribution of maximum* narrowing scores for MTP and AP weight-bearing views.

	AP Weight-bearing				
MTP View	0	1	2	3	Total
0	223	56	4	0	283
1	53	179	23	5	260
2	8	54	44	8	114
3	11	34	57	159	261
Total	295	323	128	172	918

* Narrowing scores represent the maximum scores of the bilateral medial and lateral compartments or a total of 4 compartments per knee survey.

DISCUSSION

Several assumptions underlie interpretation of our study results. First, if the purpose of radiographic examination is to identify the osteophytes, then there is little to choose between the views, although the schuss-tunnel view appears to yield a slightly lower osteophyte score. Although the radiographic image of osteophytes did not alter much with differences in the degree of knee flexion, it would have altered greatly if knee rotation had not been controlled using a foot map during the radiographic procedure. When it comes to the identification of JSN, the MTP view is substantially superior to the AP-WB view, and the schuss-tunnel view almost as good as the MTP view. In the authors' clinical experience, MTP and schuss-tunnel views reflect a truer picture of JSN. Practically, the MTP and schuss-tunnel views often display a completely narrowed joint space while the AP-WB view fails to detect this degree of narrowing. These clinical observations are supported by the marginal values shown in Table 2, and identified by the chi-square decomposition. This is an important point for clinicians who have to rely on radiographs for recommendations regarding surgical referrals. We have seen a number of patients who have had their radiographs interpreted as mildly abnormal by radiologists who relied on non-weight-bearing and/or weight-bearing films, only to find severe abnormality when the MTP or schuss-tunnel view was evaluated.

In spite of these statistical data, the MTP or schuss-tunnel view is not always the best view — assuming that best means the tibial plateau is horizontal, providing the clearest view of the joint space. Although, on average, the MTP view provides the most accurate assessment[7], in some instances the schuss-tunnel and in other instances the AP-WB provides the most open joint space. This observation arises from the variation found among individuals in the inclination of the tibial plateau relative to the horizontal, ranging from 0 to 10° with a mean (SD) of 7° (2.8°)[17]. Based on these observations we suggest there are 2 paths that might be followed. First, a series of views might be taken to determine which view is optimum for that patient, and followup views should then always be taken by that method. A second option favored by one of the authors (FW) is always to obtain the MTP and the AP-WB view. One advantage of this choice is that the 2 radiographs together will provide better information about JSN and osteophytes.

We should also point out that in this study the OARS *Atlas* developed for AP-WB views of the knee was successfully applied to osteophyte assessment of knees taken in the MTP and schuss-tunnel views. This underscores generally the applicability of that atlas[15].

In summary, using the reading methods of this study, the MTP and schuss-tunnel views were equivalent when compared to each other. When compared with the AP-WB view, the schuss-tunnel view resulted in a lower osteophyte score. These results, based on clinical readings, are similar to computerized analyses[7] that indicated that the MTP and schuss-tunnel views were superior to the AP-WB, but that the MTP view was superior to the schuss-tunnel view.

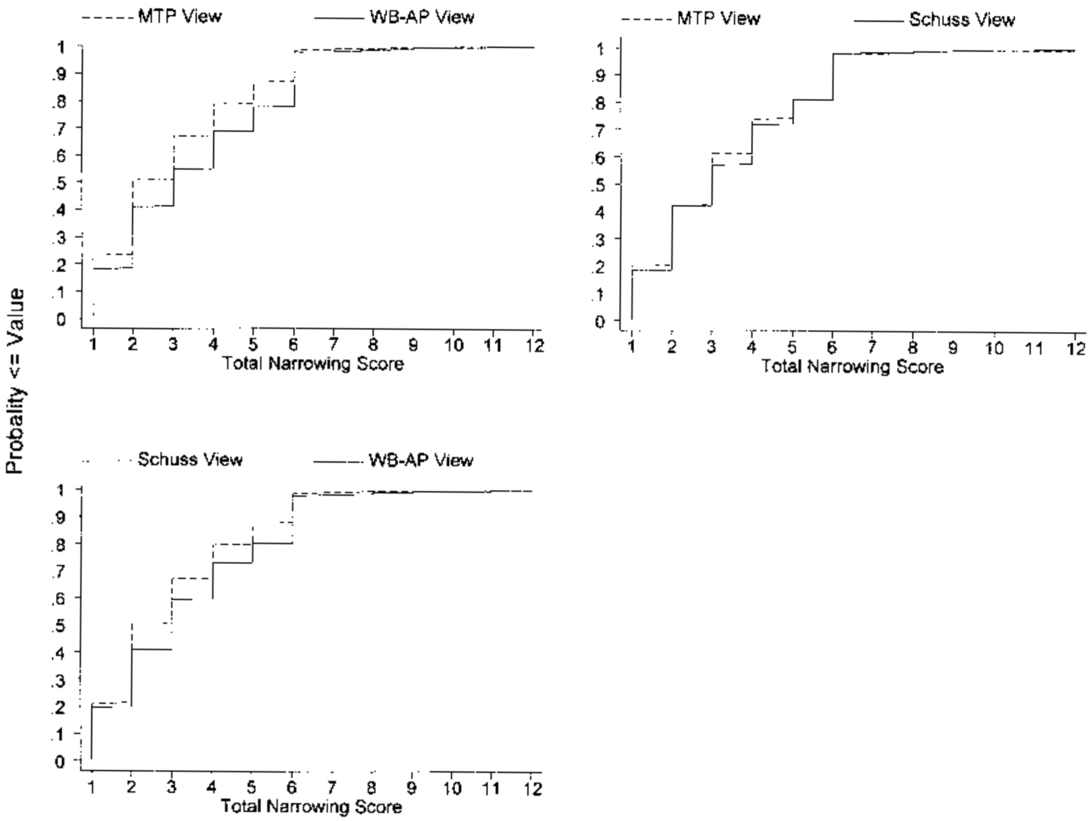

Figure 1. The total narrowing score is the sum of the left and right medial and lateral compartment scores and ranges from 0 to 12. Since OA of the knee predominantly affects the medial or the lateral compartment, but not both, 99.5% of the cumulative score for the 4 compartments falls between 0 and 6. As shown, the cumulative probability of obtaining any score between 1 and 6 is greater for the MTP view (upper left) than the AP-WB view. The MTP view (upper left) also performs better in this respect than does the schuss-tunnel view (lower left). There is little difference to be seen in the direct comparison of the MTP and schuss-tunnel views (upper right).

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