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Assessment of the radioanatomic positioning of the osteoarthritic knee in serial radiographs: comparison of three acquisition techniques

Radiography Working Group of the OARSI-OMERACT Imaging Workshop

M.-P. H. Le Graverand M.D., D.Sc., Ph.D.†, S. Mazzuca Ph.D.‡, M. Lassere M.D.§, A. Guermazi M.D.||, E. Pickering Ph.D.†, K. Brandt M.D.‡, C. Peterfy M.D., Ph.D.||*, G. Cline Ph.D.¶, M. Nevitt Ph.D.#, T. Woodworth M.D.††, P. Conaghan M.D.‡‡ and E. Vignon M.D.§§

† *Pfizer Global Research & Development, Michigan Laboratories, USA*
‡ *Indiana University School of Medicine, Indianapolis, IN 46202-5100, USA*
§ *Department of Rheumatology, St. George Hospital, University of New South Wales, Sydney, Australia*
|| *Synarc, Inc., 575 Market Street, 17th Floor, San Francisco, CA 94105, USA*
¶ *Procter & Gamble Pharmaceuticals, Mason, Ohio, USA*
# *University of California, San Francisco, San Francisco, CA 94105, USA*
†† *Novartis Institutes for BioMedical Research, CH-4002 Basel, Switzerland*
‡‡ *Academic Unit of Musculoskeletal Disease, University of Leeds, Leeds, UK*
§§ *Claude Bernard University Lyon, Service de Rhumatologie, Centre Hospitalier Lyon-Sud, 165 chemin du Grand Revoyet, 69495 Pierre Benite Cedex, France*

Summary

Objective: Recent studies using various standardized radiographic acquisition techniques have demonstrated the necessity of reproducible radioanatomic alignment of the knee to assure precise measurements of medial tibiofemoral joint space width (JSW). The objective of the present study was to characterize the longitudinal performance of several acquisition techniques with respect to long-term reproducibility of positioning of the knee, and the impact of changes in positioning on the rate and variability of joint space narrowing (JSN).

Methods: Eighty subjects were randomly selected from each of three cohorts followed in recent studies of the radiographic progression of knee osteoarthritis (OA): the Health ABC study (paired fixed-flexion [FF] radiographs taken at a 36-month interval); the Glucosamine Arthritis Intervention Trial (GAIT) (paired metatarsophalangeal [MTP] radiographs obtained at a 12-month interval), and a randomized clinical trial of doxycycline (fluoroscopically assisted semiflexed anteroposterior (AP) radiographs taken at a 16-month interval).
Manual measurements were obtained from each radiograph to represent markers of radioanatomic positioning of the knee (alignment of the medial tibial plateau and X-ray beam, knee rotation, femorotibial angle) and to evaluate minimum JSW (mJSW) in the medial tibiofemoral compartment. The effects on the mean annualized rate of JSN and on the variability of that rate of highly reproduced vs variable positioning of the knee in serial radiographs were evaluated.

Results: Parallel or near-parallel alignment was achieved significantly more frequently with the fluoroscopically guided positioning used in the semiflexed AP protocol than with either the non-fluoroscopic FF or MTP protocol (68% vs 14% for both FF and MTP protocols when measured at the midpoint of the medial compartment; 75% vs 26% and 34% for the FF and MTP protocols, respectively, when measured at the site of mJSW; $P < 0.001$ for each). Knee rotation was reproduced more frequently in semiflexed AP radiographs than in FF radiographs (66% vs 45%, $P < 0.01$). In contrast, the FF technique yielded a greater proportion of paired radiographs in which the femorotibial angle was accurately reproduced than the semiflexed AP or MTP protocol (78% vs 59% and 56%, respectively, $P < 0.01$ for each). Notably, only paired radiographs with parallel or near-parallel alignment exhibited a mean rate of JSN (±SD) in the OA knee that was more rapid and less variable than that measured in all knees (0.186 ± 0.274 mm/year, standardized response to mean [SRM] = 0.68 vs 0.128 ± 0.291 mm/year, SRM = 0.44).

Conclusion: This study confirms the importance of parallel radioanatomic alignment of the anterior and posterior margins of the medial tibial plateau in detecting JSN in subjects with knee OA. The use of radiographic methods that assure parallel alignment during serial X-ray examinations will permit the design of more efficient studies of biomarkers of OA progression and of structure modification in knee OA.

*Address correspondence and reprint requests to: Charles Peterfy, Synarc, Inc., 575 Market Street, 17th Floor, San Francisco, CA 94105, USA. Tel: 1-415-817-8901; Fax: 1-415-817-8999; E-mail: charles.peterfy@synarc.com
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Introduction

The limitations of the conventional standing anteroposterior (AP) radiograph for measurement of the thinning of articular cartilage in subjects with knee osteoarthritis (OA) have been described previously[1,2]. Therefore, recent longitudinal studies of disease progression and structure modification in subjects with knee OA have employed a variety of radiographic protocols aimed at standardizing the radioanatomic position of the knee in serial examinations[1,2]. Some currently employed standardized protocols entail fluoroscopically assisted positioning of the knee (i.e., the semiflexed AP view[3] and Lyon schuss view[4]). Others use empirically derived standards for knee flexion and rotation (i.e., the semiflexed posteroanterior [PA] metatarsophalangeal [MTP] view[5] and PA fixed-flexion [FF] view[6,7]). Adoption of these protocols has been justified, in part, by evidence that they afford superior reproducibility of measurements of radiographic joint space width (JSW) in repeated examinations over a short period of time, in comparison with the conventional standing AP view[1]. However, data concerning the longitudinal performance of these protocols in providing reproducible positioning of the knee joint and reduced measurement error in estimates of joint space narrowing (JSN) are sparse.

Evaluating the progression of JSN involves measurement of JSW in serial radiographs of the same knee. Changes in JSW may occur either due to disease progression or because of differences in radioanatomic positioning of the knee between examinations[4,8,9]. This point is emphasized by recent studies using various acquisition techniques that have investigated the impact of alignment of the medial tibial plateau on the sensitivity to change in JSN and have shown that the rate of JSN is greater in OA knees in which parallel alignment of the medial tibial plateau (i.e., superimposition ± 1 mm of the anterior and posterior margins of the medial tibial plateau) is achieved in the paired images than when misalignment exists in one or both radiographs[2,10].

Because poor radioanatomic re-positioning may represent an important source of error in the measurement of JSW in serial radiographs, we collected data from existing pairs of radiographs that had been acquired with one of three radiographic techniques (i.e., the semiflexed AP, MTP and FF views) to characterize their longitudinal performance with respect to the long-term reproducibility of radioanatomic positioning of the knee. Using pre-defined markers of knee positioning, we investigated the reproducibility of positioning of the knee in serial radiographs with respect to the following criteria: alignment of the medial tibial plateau and X-ray beam; knee rotation; and femorotibial angle. The effects of reproduced vs variable positioning on the mean rate and variability of JSN in serial radiographs were examined.

Methods

STUDIES AND SUBJECTS

Three contemporaneous NIH-sponsored longitudinal studies of the progression of knee OA contributed data to the present study: the Glucosamine Arthritis Intervention Trial (GAIT), the Health ABC study and a randomized controlled trial (RCT) of doxycycline in knee OA. Two hundred and forty subjects (80/cohort) were selected at random from among participants who had undergone a follow-up radiographic examination. Key eligibility criteria and other study parameters are shown in Table I. Each study used a different standardized radiographic acquisition technique (Table I, Fig. 1).

POSITIONING MARKERS

Reproducibility of positioning in serial radiographs was assessed using pre-defined markers of knee positioning. The degree of alignment of the medial tibial plateau and central X-ray beam was expressed as the distance between the anterior and posterior margins of the medial tibial plateau. The inter-margin distance (IMD) was measured both at the midpoint of the medial compartment and at the point at which medial JSW appeared narrowest [Fig. 2(a)]. Knees with IMD < 0.50 mm were considered to have perfect parallel alignment. Those with IMD ≥ 0.50 mm but <1.5 mm were classified as exhibiting near-perfect alignment. Knees with IMD ≥ 1.5 mm were classified as having skewed alignment or misalignment.

Knee rotation was measured as the shortest distance, in mm, between parallel lines drawn tangent to the lateral aspects of the tibia and head of the fibula [Fig. 2(b)]. The marker of the femorotibial angle was the height of the femoral notch. Two estimates of the height of the notch were examined: one relative to a line drawn tangent to the nadirs of the medial and lateral tibial plateau [Fig. 2(c)], the other relative to a line drawn tangent to the medial and lateral femoral condyles [Fig. 2(d)].

For each of these markers, inter-reader reproducibility (three readers [CP, EV, SM]) was initially determined using 30 radiographs exhibiting varying degrees of severity of knee OA. The intra-class correlation coefficients were good to very good, ranging from 0.71 to 0.95 (Table II).

When evaluating whether measurements of each positioning marker in the baseline radiograph was satisfactorily reproduced (± 1 mm) in the follow-up radiograph, an

Table I
Features of participating studies

	Cohort		
	Health ABC	GAIT RCT	Doxycycline RCT
Radiographic technique	FF PA	MTP PA	Semiflexed AP
Study type	Community-based cohort study	RCT	RCT
Total length of study (months)	36	24	30
Interval between paired baseline and follow-up radiographs, examined in this study (months)	36	12	16
Eligibility criterion for age at baseline (years)	70–79	>40	46–64
Eligibility criterion for sex	Men and women	Men and women	Women only
Number of centers	2	13	7

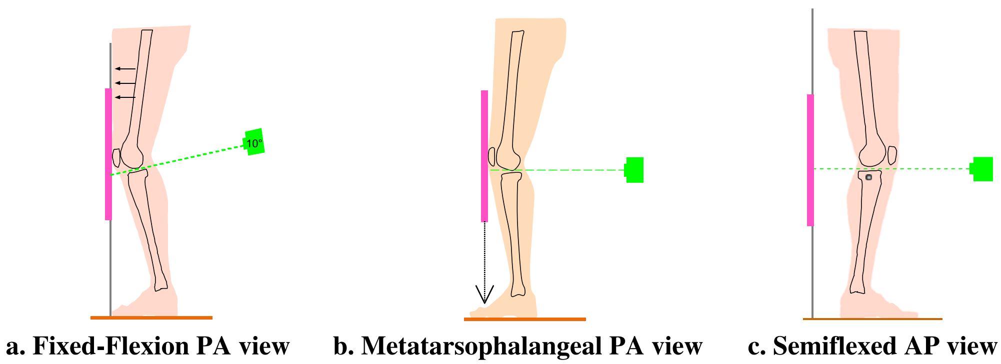

Fig. 1. Description of the positioning of the subjects for the FF PA view, the MTP PA view and the semiflexed AP view. (a) The FF protocol uses a fixed 10° caudal X-ray beam and positions the thighs, patellae and pelvis flush with the film cassette, and coplanar with the tips of the great toes, resulting in a fixed knee angulation of approximately 20° flexion. (b) The MTP protocol uses a horizontal X-ray beam and positions the first MTP joints beneath the front surface of the film cassette, the patellae in contact with the cassette and aligned vertically with the first MTP joints resulting in a knee angulation of approximately 7–10° flexion. (c) The semiflexed AP protocol uses a horizontal X-ray beam and fluoroscopy to guide the flexion of the knee to superimpose the anterior and posterior margins of the medial tibial plateau within 1 mm resulting in a knee angulation of approximately 7–10° flexion.

additional tolerance for measurement error of 0.4 mm was added, based on the reproducibility of the measures.

PROCEDURES

Two readers (AG, SM) made blinded, independent measurements of the positioning markers and of JSW on radiographs in which all identifying information and dates were masked. The semiflexed AP radiographs were unilateral views of the index (OA) knee of subjects in the doxycycline trial. In the FF and MTP radiographs, which were bilateral views, measurements were taken of the right knee. A random sample of serial pairs of radiographs from each study was used to establish the intra-reader

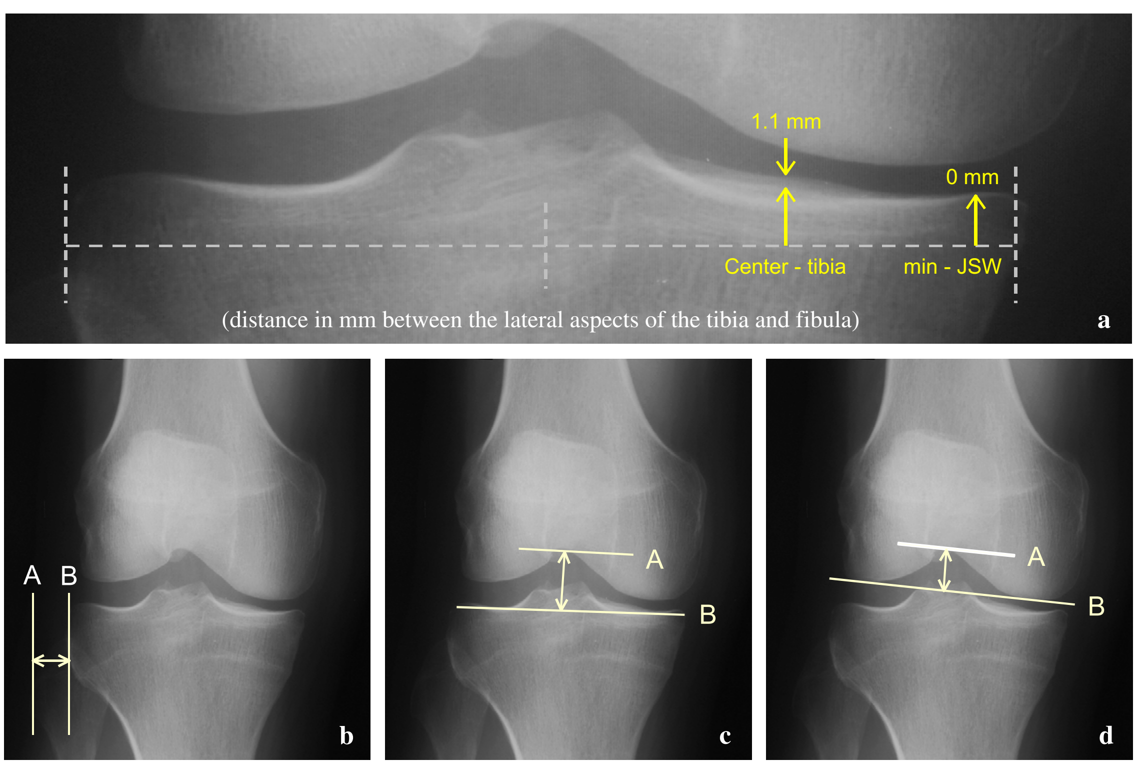

Fig. 2. Radioanatomic positioning markers. (a) Alignment of the medial tibial plateau and X-ray beam: The degree of alignment of the medial tibial plateau and central X-ray beam was expressed as the distance between the anterior and posterior margins of the medial tibial plateau. The IMD was measured both at the midpoint of the medial compartment and at the point at which medial JSW appeared narrowest. (b) Knee rotation: Knee rotation was measured as the shortest distance, in mm, between parallel lines drawn tangent to the lateral aspects of the tibia and head of the fibula. (c and d) Femorotibial angle: The marker of the femorotibial angle was the height of the femoral notch. Two estimates of the height of the notch were examined: one relative to a line drawn tangent to the nadirs of the medial and lateral tibial plateau (c), the other relative to a line drawn tangent to the medial and lateral femoral condyles (d).

Table II
Inter-reader reproducibility of measurements of mJSW and positioning markers

	Intra-class correlation	
	3 Raters 30 radiographs	2 Raters 240 radiographs
Minimum tibiofemoral JSW	0.87	0.98
IMD at center of tibia	0.89	0.88
IMD at mJSW location	0.84	0.65
Fibulo-tibial distance	0.71	0.95
Femoral notch−tibial plateau distance	0.86	0.96
Femoral notch−intercondylar line distance	0.95	0.97

reproducibility of minimum JSW (mJSW) and positioning marker measurements. The intra-class correlation coefficients ranged from 0.77 to 0.90.

Preliminary assessments of the paired knee radiographs included:

(1) The presence of an osteophyte (including possible or minute osteophytes) as definite evidence of radiographic OA according to Kellgren and Lawrence criteria[11].
(2) The grade of JSN severity, based on the OARSI atlas[12].
(3) Location of JSN: medial or lateral compartment, or both.

Both examiners measured mJSW manually on the MTP and FF radiographs, using a ruler (AG) or a screw-adjustable pair of calipers and magnifying lens (SM). In the semiflexed AP radiographs, manual estimates of mJSW were corrected for magnification, as reflected by the projected diameter of a magnification marker (a 6.35-mm chrome steel ball) affixed to the skin over the head of the fibula at the time of the examination.

When analyzing the effect of positioning on JSN, data from the GAIT were not included because the mean change in JSW indicated an increase in average cartilage thickness over the 12-month interval between the two MTP exams (Table III). Furthermore, only subjects with radiographic OA (defined as $KL \geq 1$) were considered in this analysis ($N = 132$). Finally, because the duration of the HABC and doxy studies differed by 20 months, JSN estimates were annualized prior to combining data from the two studies.

Table III
Radiographic severity of knee OA baseline

	Cohort		
	Health ABC	GAIT RCT	Doxycycline RCT
Percent knees with $KL \geq 1$ at BL	72	89	100
Distribution of OARSI scores for medial JSN (%)	0 = 39 (49) 1 = 23 (29) 2 = 9 (11) 3 = 9 (11) 4 = 0 (0)	0 = 41 (51) 1 = 18 (23) 2 = 17 (21) 3 = 4 (5) 4 = (0)	0 = 48 (60) 1 = 19 (24) 2 = 13 (16) 3 = 0 (0) 4 = 0 (0)
Percent knees with lateral JSN	6	5	10
Interval between exams (months)	36	12	16
JSN (mm) (mean ± SD)	0.21 ± 0.59	−0.11 ± 0.82	0.20 ± 0.51
Annualized mean mJSN (mean ± SD)	0.068 ± 0.19	−0.11 ± 0.82	0.15 ± 0.38

STATISTICAL ANALYSIS

After sorting the data by knee and sequence of the exam, standard tests of agreement and reliability were performed to characterize the inter-exam reproducibility of the positioning marker and mJSW measurements. Data collected by the two readers were analyzed separately. The results for both readers were in good to excellent agreement across studies (ICC's ranged from 0.65 to 0.98 for measurements of the positioning marker and of JSN) (Table II).

Inter-reader reproducibility for measurements of IMD at the mJSW location ($ICC = 0.65$) was not as good as that in the initial exercise ($ICC = 0.84$). The data reported herein are the result of the analysis of the data set by the reader (SM) who participated in both the initial inter-reader reproducibility exercise and the final study. Change was quantified by the use of the standardized response mean (SRM) which was calculated as the mean JSN divided by the standard deviation. One-way analysis of variance (ANOVA) was used to assess the effects of positioning on JSN. The reported *P*-values are unadjusted for multiple comparisons.

Results

CHARACTERISTICS OF THE CLINICAL STUDIES

Table III describes the status of knee OA in each of the three longitudinal studies. The prevalence of radiographic knee OA (ROA) (defined as $KL \geq 1$) at baseline was 72% in HABC, 89% in GAIT and 100% in the doxycycline trial. The lower percentages in HABC and GAIT studies are due to the fact that the readers arbitrarily measured only the right knee which, in some cases, exhibited no radiographic evidence of OA. In addition, because the HABC study did not require that a subject have knee OA to undergo a knee radiography, some HABC subjects exhibited no radiographic evidence of OA. Medial tibiofemoral compartment JSN (OARSI scores 1−4) was observed in 51% of the knees from Health ABC, 49% of the knees from GAIT and 40% of the knees from the doxycycline trial. ROA was observed in the lateral compartment in 6% of knees for Health ABC, 5% of knees in GAIT and 10% of knees in the doxycycline trial. JSN was expressed as the magnitude of loss of baseline JSW (i.e., JSW at baseline minus JSW at follow-up). The mean JSN (±SD) was 0.21 ± 0.59 mm over 36 months for Health ABC, -0.11 ± 0.82 mm over 12 months for GAIT (i.e., an increase in mean JSW) and 0.20 ± 0.51 mm over 16 months for the doxycycline trial (see Table III for annualized JSN).

RADIOANATOMIC POSITIONING MARKERS

Table IV describes the mean and SD for each of the positioning markers at the baseline and follow-up visit. The mean IMD at the point of mJSW and at the center of the medial tibial plateau were both significantly smaller ($P < 0.0001$) with the semiflexed AP technique than with either the FF or MTP technique. The latter were not significantly different from one another. The mean fibulo-tibial distance and the mean height of the femoral notch were also similar with all three techniques, regardless of whether

Table IV

Markers or radioanatomic positioning at baseline and follow-up, by X-ray protocol

		X-ray protocol		
		FF PA	MTP PA	Semiflexed AP
Medial tibial plateau alignment	IMD at midpoint of tibia (mm) (mean ± SD)	BL: 2.2 ± 1.5 FU: 2.9 ± 2.1	BL: 2.5 ± 1.9 FU: 2.9 ± 2.1	BL: 0.8 ± 1.1 FU: 1.0 ± 1.4
Medial tibial plateau alignment	IMD at location of mJSW (mm) (mean ± SD)	BL: 1.7 ± 1.5 FU: 2.2 ± 1.8	BL: 1.5 ± 1.5 FU: 2.1 ± 2.1	BL: 0.5 ± 0.8 FU: 0.6 ± 1.1
Knee rotation	Distance between lateral margins of tibia and fibular head (mm) (mean ± SD)	BL: 11.4 ± 3.2 FU: 11.1 ± 3.3	BL: 12.2 ± 2.9 FU: 12.2 ± 3.2	BL: 10.4 ± 4.9 FU: 10.1 ± 5.2
Knee flexion	Height of the femoral notch, relative to a line tangent to the femoral condyles (mm) (mean ± SD)	BL: 12.7 ± 2.1 FU: 12.7 ± 2.3	BL: 12.3 ± 2.5 FU: 12.4 ± 2.6	BL: 11.5 ± 2.8 FU: 11.6 ± 2.9

the latter was measured relative to reference lines drawn tangent to the femoral condyles or to the tibial plateau.

REPRODUCIBILITY OF RADIOANATOMIC POSITIONING

Table V contains the results of an analysis of the reproducibility of positioning with each protocol. Alignment of the medial tibial plateau and central X-ray beam in the baseline radiograph, as reflected in the IMD at the midpoint of the medial tibial plateau, was reproduced ±1.4 mm in 86% of follow-up FF radiographs, 92% of MTP radiographs and 93% of semiflexed AP radiographs. These differences were not significant. However, parallel or near-parallel alignment (i.e., IMD ≤ 1.4 mm) was achieved in 68% of paired semiflexed AP views but in significantly smaller percentages of paired FF and MTP views (14% of each) ($P < 0.001$). Similar results were observed when the IMD was measured at the location of mJSW.

Rotation of the knee, as reflected by the distance between the lateral margins of the tibia and the fibular head, was reproduced ±1.4 mm in 66% of paired semiflexed AP views and 53% of MTP views (Table V). The frequency of reproduced rotation in paired FF views (45%) was significantly lower than with the semiflexed AP view ($P < 0.01$).

On the other hand, the femorotibial angle was more frequently reproduced in serial FF radiographs than in serial MTP or semiflexed AP radiographs (Table V), regardless of whether the height of the femoral notch was measured from the plane of the tibial plateau or from a line tangent to the femoral condyles ($P < 0.01$ for each).

EFFECT OF POSITIONING ON JSN

Table VI shows the effect on the rate of JSN of reproducible positioning of the knee in serial examinations.

Among all knees, regardless of the quality and reproducibility of positioning, the mean rate of JSN (±SD) was 0.128 ± 0.291 mm/year. This represents an SRM of 0.44. In knees in which perfect parallel alignment was apparent in both radiographs, the mean rate of JSN was 0.186 mm/year (SRM = 0.68). The values were only slightly lower in serial radiographs with near-parallel alignment (0.162 mm/year, SRM = 0.53). In contrast, the mean rates of JSN and SRM were both lowest (and not appreciably different from the value for all knees) when alignment was skewed in the baseline radiograph, even if the degree of misalignment was highly reproduced (±1.4 mm) in the follow-up exam (Table VI).

The marker of knee rotation (distance between the lateral margins of the tibia and the fibular head) was reproduced ±1.4 mm in serial radiographs of 50 knees (38%) (Table VI). When rotation was not reproduced, the mean rate of JSN was slightly greater, but the SMR was decreased.

The height of the femoral notch, relative to a line tangent to the femoral condyles (a marker of femorotibial angulation) was reproduced ±1.4 mm in 88 knees (67%) (Table VI). Surprisingly, the rate of JSN was significantly less rapid (0.080 mm/year vs 0.224 mm/year, $P < 0.05$) and the SMR lower (0.33 vs 0.64) in knees in which the femorotibial angle was reproduced than in those in which the angle changed despite standardization of the radioanatomic positioning

Table V

Percentage of knees in which positioning in the baseline radiograph was reproduced ±1.4 mm in the follow-up radiograph

Positioning marker	X-ray protocol		
	FF PA ($N = 73$)	MTP PA ($N = 73$)	Semiflexed AP ($N = 80$)
IMD at midpoint of the medial tibia			
Reproduced alignment in both radiographs, *N* (%)	63 (86)	67 (92)	74 (93)
Perfect parallel or near-parallel alignment reproduced, *N* (%)	11 (14)	10 (14)	54 (68)
IMD at location of mJSW			
Reproduced alignment in both radiographs, *N* (%)	62 (85)	64 (87)	70 (88)
Perfect parallel or near-parallel alignment reproduced, *N* (%)	19 (26)	25 (34)	60 (75)
Rotation			
Rotation reproduced, *N* (%)	40 (55)	34 (47)	27 (34)
Femorotibial angle (notch height, from tibia)			
Notch height reproduced, *N* (%)	52 (71)	36 (49)	37 (46)
Femorotibial angle (notch height, from femoral condyles)			
Notch height reproduced, *N* (%)	57 (78)	41 (56)	47 (59)

Table VI

Effect of reproduced radioanatomic positioning in serial X-ray examinations on the rate of JSN in OA knees: combined data from the Health ABC study and doxycycline RCT

Positioning marker Position subgroups	*N* (%)	Rate of JSN (mm/year) (mean ± SD)	SRM
All knees	132 (100)	0.128 ± 0.291	0.44
Alignment at the midpoint of the medial tibia			
Reproduced perfect parallel alignment *	25 (19)	0.186 ± 0.274	0.68
Reproduced near-parallel alignment†	36 (27)	0.162 ± 0.308	0.53
Reproduced skewed alignment (misalignment) ‡	68 (52)	0.134 ± 0.321	0.42
Alignment at the location of minimum medial JSW			
Reproduced perfect parallel alignment *	44 (33)	0.184 ± 0.303	0.61
Reproduced near-parallel alignment†	30 (23)	0.168 ± 0.274	0.61
Reproduced skewed alignment (misalignment) ‡	60 (45)	0.130 ± 0.268	0.49
Knee rotation			
Rotation reproduced ±1.4 mm	50 (38)	0.113 ± 0.218	0.52
Rotation not reproduced	80 (61)	0.138 ± 0.332	0.42
Femorotibial angle (notch height, relative to femoral condyles)			
Notch height reproduced ±1.4 mm	88 (67)	0.080 ± 0.242	0.33
Notch height not reproduced	44 (33)	0.224 ± 0.351	0.64
Femorotibial angle (notch height, relative to the tibial plateau)			
Notch height reproduced ±1.4 mm	74 (56)	0.084 ± 0.264	0.32
Notch height not reproduced	58 (44)	0.182 ± 0.317	0.57

*IMD $<$ 0.5 mm in both radiographs.

†0.5 $\leq$ IMD $\leq$ 1.4 mm in both radiographs.

‡IMD $\geq$ 1.5 mm in both radiographs, but within ±1.4 mm of each other.

procedures. Results were similar when notch height was measured from the plane of the tibial plateau ($P = 0.06$).

When using the mJSW measurements of the second reader, the association of JSN with positioning markers was nearly identical to that in Table VI, except that tibial rim alignment at the location of the minimum medial JSW was not associated with the SRM of JSN.

Discussion

The purpose of this study was to describe the longitudinal performance of various acquisition techniques for standardized knee radiography with respect to the long-term reproducibility of radioanatomic positioning of the joint, and the effect on sensitivity to JSN of changes in positioning of the knee in serial examinations. Based on the present analysis, we conclude that the fluoroscopically assisted semiflexed AP technique provides significantly greater assurance of parallel or near-parallel alignment of the medial tibial plateau with the X-ray beam than either the FF or MTP technique. Notably, among the positioning markers examined (i.e., alignment, rotation and femorotibial angle), only positioning of the medial tibial plateau in parallel or near-parallel alignment with the central X-ray beam contributed toward greater sensitivity to change in JSN.

This study has several limitations. The perfect study would have included a head-to-head comparison of all three radiographic techniques in a single longitudinal cohort of knee OA patients. Such a data set does not exist. The present analysis was performed using separate cohorts that varied from each other in several aspects, including age, gender, disease status, time to follow-up (12 months vs 16 months vs 36 months), the number of centers involved (2–13), the quality control criteria employed and use of concomitant medications by the subjects (Table I). Therefore, it is not possible to directly compare the three studies with respect to the mean rate and variability of JSN. However, a comparison of the reproducibility of radioanatomic positioning achieved by the respective standardization protocols is less problematic.

The distance between the anterior and posterior margins of the medial tibial plateau (both at the midpoint of the tibia and at the site of mJSW) was significantly smaller in baseline and follow-up semiflexed AP radiographs than in those acquired using the FF or MTP protocol. Smaller, less variable IMDs with the semiflexed AP technique are consistent with the use of fluoroscopy to vary the flexion angle of the knee until the anterior and posterior margins of the medial tibial plateau are superimposed ±1 mm. Positioning the knee according to this standard places the medial tibial plateau in parallel (or near-parallel) alignment with the central ray of the X-ray beam. The quality control protocol for the semiflexed AP view required that the technologist repeat the exam if the IMD was $>$1 mm at the point of mJSW. In contrast, standards for flexion and rotation of the knee with the non-fluoroscopically assisted FF and MTP protocols were derived empirically[5,6]. Therefore, biologic variations in the inclination of the medial tibial plateau, relative to the long axis of the tibia, will result in variation between subjects with respect to IMD. While IMD appears stable within individuals over time, the relatively frequent occurrence of large values for IMD in FF and MTP radiographs, indicating non-parallel alignment, introduces some error in measurement of JSN that is not present in radiographs with stable parallel alignment.

The present results confirm similar findings that showed the importance of medial tibial plateau alignment in measurement of JSN[2,10]. In the standing AP radiograph, OA knees with parallel alignment in both images showed a mean rate of JSN over 2–3 years that was significantly greater than that in OA knees with non-parallel alignment in one or both radiographs[10]. Similarly, in the Lyon schuss radiograph (fluoroscopic PA view with fixed knee flexion), sensitivity to change in mJSW was notably increased by aligning the medial tibial plateau with the X-ray beam[2]. It is important to note that in the present study, the preponderance of knees with medial tibial plateau in parallel (or near-parallel) alignment with the X-ray beam came from the doxycycline study while the preponderance of knees with skewed alignment came from the HABC study, in which many of the subjects did not have OA, and therefore lacked any potential for radiographic progression. Possible cohort effects notwithstanding, the benefit of parallel alignment was apparent in measurements taken either at the midpoint of the medial tibial plateau or at the location of mJSW. We conclude that either definition of alignment, if used as a quality control standard in a study of radiographic progression of knee OA, will help maintain optimal sensitivity to radiographic JSN.

In contrast to the positive effect of consistent parallel alignment of the medial tibial plateau and X-ray beam in the present study, reproducible knee rotation did not have an effect on the mean rate or variability of JSN. Rather, paired radiographs in which the femorotibial angle was reproduced yielded smaller and more variable rates of JSN than those in which a change in angulation occurred. This finding was unexpected. As for the association between tibial plateau alignment and JSN, insofar as most radiographs with reproduced femorotibial angles came primarily from the Health ABC study, in which many of the patients did not have OA, the finding may, in part, be a study cohort effect.

In conclusion, this study confirms the importance of parallel radioanatomic alignment of the medial tibial plateau in detection of JSN in knee OA. The use of radiographic methods that assure reproducible alignment of the medial tibial plateau, i.e., minimal IMD, in serial examinations will permit the design of more efficient studies of biomarkers of progression and/or structure modification in knee OA. These benefits, of course, must be weighed against the practical challenges and additional costs of performing fluoroscopic alignment reproducibly in large multicenter studies.

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