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Validity of Clinical Measures of Frontal Plane Knee Alignment: Data from the Osteoarthritis Initiative

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Abstract

Clinicians frequently assess frontal plane knee alignment of patients suspected of having knee osteoarthritis. However, there is little data to indicate whether simple to obtain clinical measures of frontal plane alignment indicate the actual bony alignment of the knee or the extent and type of knee osteoarthritis. The purpose of this study was to assess the validity of goniometric measures of frontal plane knee position as a simple clinical tool to assess lower limb alignment and tibiofemoral OA status. Data from the Osteoarthritis Initiative were used to assess concurrent and diagnostic validity of goniometric measures. Data from 142 persons with symptomatic knee OA were used to examine concurrent validity, based on comparison to whole limb radiographs. Diagnostic validity was examined using data from 1,390 persons with symptomatic knee OA, based on comparison to tibiofemoral joint space narrowing obtained from standardized radiographs. Associations between goniometric measures and whole limb radiographs was moderate ($r = 0.43$ for right knee and $r = 0.46$ for left knee). Goniometric measurements explained approximately 20% of the variation in lower limb alignment as measured by whole limb radiography suggesting that simple clinical measures of lower limb alignment contain too much error for inferring actual lower limb alignment. Diagnostic validity indicated positive likelihood ratios of 3.3 or less for detecting isolated severe medial or lateral joint space narrowing and a high rate of misclassification. Simple clinical assessments of frontal plane lower limb alignment or tibiofemoral OA status, in isolation, contain substantial error and likely do not inform clinical practice.

Introduction

Frontal plane knee alignment measured radiographically indicates both presence and severity of knee osteoarthritis OA and is prognostic of future worsening in persons with knee OA (Sharma et al., 2001, Teichtahl et al., 2006, Issa et al., 2007, Brouwer et al., 2007, Janakiraman et al., 2008, Sharma et al., 2010). Frontal plane alignment also is frequently considered during surgical and non-surgical approaches to treating knee pain (Pollo et al., 2002, Bennell et al., 2011). Because of the risks associated with ionizing radiation, cheaper and safer non-radiographic methods would aid clinicians in assessing knee alignment and changes in knee alignment and disease status.

Mechanical alignment measurements of the hip-knee-ankle angle from whole limb radiographs is arguably superior to all other forms of radiographic measurement of frontal

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plane alignment though controversy exists (Issa et al., 2007, Felson et al., 2009, Sheehy et al., 2011). Low-cost non-ionizing clinical measures have been explored with varying degrees of success (Kraus et al., 2005, Hinman et al., 2006) to determine their association with measures obtained with whole limb radiography. One clinical approach for quantifying frontal plane alignment is a goniometric measurement obtained with the patient in a standing position. Kraus and colleagues reported Pearson correlations of 0.70 between mechanical axis whole limb radiographic measures and goniometric measures (Kraus et al., 2005). Inter-session reliability of goniometric measures of frontal plane knee alignment have been reported to be 0.9 or higher (Cibere et al., 2004, Kraus et al., 2005) which is adequate for clinical use on individual patients (Nunnally, 1978). However, in both studies, the measures were repeated on the same day which likely inflated reliability given the risk for recall and subject familiarity.

While these data suggest goniometric measures of frontal plane alignment may have potential for use on patients with knee OA, no study was found that examined the concurrent and diagnostic validity of goniometric measures for quantifying frontal plane alignment and disease status. As an initial impression, clinicians sometimes infer the presence of knee OA in either the medial or lateral compartment of middle-aged or elderly patients with knee pain based on clinical assessments of frontal plane knee alignment. No research was found to demonstrate whether clinicians can identify persons with selective medial or lateral compartment knee OA. Studies of diagnostic validity are advantageous because they provide estimates that can be applied to individual patients in contrast to studies that are designed for group level comparisons. To demonstrate concurrent validity, goniometric measurements would correlate highly with whole limb radiographic measures. To demonstrate diagnostic validity, goniometric measurements of frontal plane knee alignment would distinguish knees with joint space narrowing on either the medial or lateral side from knees with either no joint space narrowing or symmetrical joint space narrowing. The purpose of this study was to examine the concurrent validity of goniometric measures of standing frontal plane knee position for inferring frontal plane lower limb alignment. In addition, diagnostic validity was examined by determining if goniometric measurements could be used to predict the presence of isolated medial or lateral joint space narrowing of the tibiofemoral joint in a large sample of persons with symptomatic knee OA. While other data from the clinical examination can provide insights into the presence or absence of knee OA, (Zhang and Jordan, 2008) assessments of knee alignment are a necessary adjunct to judging the state of OA in the medial versus lateral compartments and changes in alignment with treatment.

Method

The Osteoarthritis Initiative

The Osteoarthritis Initiative (OAI) is a publicly and privately funded prospective longitudinal cohort study with a 4 year follow-up. A primary objective of the OAI study is to develop diverse cohorts of persons for the study of the natural history, risk factors, onset and progression of knee tibiofemoral OA.

The current study focused on the progression cohort, a group of 1,390 persons between the ages of 45 and 79 years at baseline with radiographically confirmed symptomatic knee OA, defined as having both of the following in at least one knee (Hunter et al., 2009): 1) frequent knee symptoms in the past 12 months, defined as “pain, aching or stiffness in or around the knee on most days” for at least one month during the past 12 months, and 2) radiographic tibiofemoral knee OA defined as Osteoarthritis Research Society International (OARSI) atlas grades 1 to 3 which are similar to Kellgren-Lawrence (KL) grades 2 or higher as measured on a fixed flexion radiograph (KELLGREN and LAWRENCE, 1957, Altman et al., 1995). Exclusion criteria included the presence of rheumatoid arthritis, bilateral knee

arthroplasty or plans to undergo bilateral knee arthroplasty in the next 3 years, bilateral OARSI stage 3 knee OA. All subjects also had medial and lateral tibiofemoral joint space narrowing assessments conducted as defined by OARSI (Altman, et al., 1995) and coded as 0 (normal), 1 or 2 (mild or moderate narrowing) or 3 (severe narrowing). In addition, 142 of the 1,390 persons were randomly selected by OAI investigators to undergo whole limb radiography for the purposes of measuring frontal plane knee alignment.

Subjects were recruited from four clinical sites: 1) the University of Maryland School of Medicine in Baltimore, Maryland, 2) the Ohio State University in Columbus, Ohio, 3) the University of Pittsburgh in Pittsburgh, Pennsylvania, and 4) Memorial Hospital of Rhode Island, in Pawtucket, Rhode Island. A total of 474 (34.1%) of the 1390 persons had symptomatic knee OA on the right side, 427 (30.7%) had symptomatic left sided knee OA and 489 (35.2%) had bilateral symptomatic knee OA. A flowchart of the patients included in the study appears in Figure 1.

OAI Measurements Used in the Current Study

Data for the progression cohort were obtained at the baseline clinic visit and during the 1-year follow-up visit. The baseline data used were the knee radiographic data and the goniometric measurements of frontal plane knee alignment. The 1-year follow-up data used were the 142 whole limb radiographic measures of frontal plane lower limb alignment. In addition, baseline and 1-year follow-up data from the 88 subjects with isolated medial or lateral compartment end-stage OA and no 1-year changes in knee disease status, as measured via radiographs, were used to judge reliability of goniometric measures. I used the clinical datasets 0.2.2 and 1.2.1 and the imaging dataset 1.1 from the OAI website. (, 2012)

At baseline, all persons underwent standardized radiographic assessment of both knees using a fixed flexion protocol (Peterfy et al., 2003, Kothari et al., 2004) and all clinician examiners (either a radiologists or rheumatologists) were required to complete a training protocol for reading radiographs prior to starting the study. Before the study, each site examiner read 30 knee radiographs and provided modified KL and OARSI grades. They were then given feedback and the correct answers with annotated images and interpretive comments by an experienced musculoskeletal radiologist. During the validation process, examiners read different sets of 30 knee radiographs and their results were compared against the gold standard readings made by an experienced musculoskeletal radiologist. All site investigators had to pass the validation test by demonstrating concordance with the expert before reading OAI radiographs.

At baseline (for all subjects) and at the 1-year follow-up (for those with whole limb radiographs), goniometric measurements of the frontal plane alignment of the knees were obtained. Subjects were instructed to stand with their legs fully extended, shoulder width apart, weight equally distributed and feet facing straight ahead, the same position required for the whole limb radiographs. A large universal goniometer was positioned such that the axis was centered on the tibiofemoral joint line. The proximal arm of the goniometer was aligned with the center of the mid thigh and the distal arm was aligned with the center of the ankle. The angle was then read and interpreted, as indicating either a neutral measurement (0 degrees), a varus measurement (coded as a positive number) or a valgus measurement (coded as a negative number) depending on whether the angle opened medially or laterally. All examiners underwent a training and certification program to enhance consistency within and across examiners. In addition, all examiners were required to recertify during the study period and to demonstrate agreement and competence in the presence of knee examination experts (OAI rheumatologists) involved with the study.

A total of 142 persons in the progression cohort were randomly selected from one site and underwent whole limb radiographs of the lower extremities at the 1-year follow-up visit. These data were used to examine the concurrent validity of goniometric measures for inferring hip, knee, ankle (lower limb) alignment of the lower limb using the centers of the hip joint, knee joint and ankle joint as anatomical landmarks to measure anatomical angle. Because there was no report of the reliability of goniometric measures within OAI, reliability of the goniometric measures obtained with a 1-year time interval was examined. I selected persons from the dataset with end-stage unicompartmental disease of the right knee and an OARSI grade of 0 joint space narrowing in the other compartment along with no change in their radiographs over a 1-year period, as measured by OAI investigators. This approach was chosen as a rigorous test of reliability over an extended time period (ie. 1-year) which greatly reduced risk of recall and assured, to the extent possible, that knee alignment should not have changed over the 1-year period. Average narrowing of the tibiofemoral joint space over a 1-year period is 0.10 to 0.15-mm suggesting that any changes in OA over a year would be unlikely to influence goniometric measures. (Conrozier et al., 2004, Zhang and Jordan, 2008) A total of 88 persons met the criteria of endstage unicompartmental disease and no subsequent change in joint spaces during the 1-year follow-up. The ICC_{2,1} (Shrout and Fleiss, 1979) for repeated goniometric measures (n=88) was 0.63 (95% CI, 0.47, 0.74) with SEM = 3.4 degrees and MDC₆₈ = 5 degrees. (Haley and Frigala-Pinkham, 2006)

Data Analysis

To assess concurrent validity, Pearson correlation coefficients were used to determine associations between whole limb radiographic measures of lower limb alignment and goniometric measures of knee alignment. Associations were calculated separately for the left and the right limbs.

To assess diagnostic validity, the relationship between the goniometric measures of each knee and the radiographic assessment of the extent of medial and lateral joint space narrowing were determined. Because two knees of each person are dependent and scores obtained on two knees of a person could potentially influence each other, the data for each knee is reported separately. Analyzing each knee separately would appear to also be clinically valid because clinicians may measure either the right or the left knee in isolation depending on the clinical rationale for assessment. For this analysis, knees with severe medial joint space narrowing in the medial compartment (OARSI grade 3) and no lateral joint space narrowing (OARSI grade 0) were identified. Similarly, knees with no medial joint space narrowing (OARSI grade 0) and with severe lateral joint space narrowing (OARSI grade 3) were identified. The analysis compared the first group of knees (OARSI 3 medial, OARSI 0 lateral) to persons with OARSI grade 0 in both compartments. A similar analysis was done comparing the second group of knees (OARSI 3 lateral, OARSI 0 medial) to knees with OARSI 0 in both compartments. These analyses were conducted to determine if goniometric measurements could distinguish between knees with severe unicompartmental OA from those with no tibiofemoral joint space narrowing. This approach can best be described as a “best case scenario” analysis: end-stage knee OA in one compartment and no OA in the other compartment as compared to persons with no OA should lead to the highest validity of goniometric measurements for inferring extent and type of knee OA. Worded another way, if goniometric measures cannot distinguish between persons with end-stage disease in one compartment and no disease in the other from persons with no OA then it is unlikely that goniometric measures of alignment will be useful for inferring extent and type of knee OA.

Part 2 of the diagnostic validity analytic approach was designed to most closely replicate clinical practice. The data were examined to determine if the knees with isolated severe joint

space narrowing in either the medial or lateral compartment (OARSI grade of 3 in one compartment and 0 in the other compartment) could be identified from all other knees in the sample.

For all diagnostic validity analyses, Receiver Operating Characteristic (ROC) analyses were conducted (Hanley and McNeil, 1982). The area under the curve (AUC), Standard Errors (se) and 95% Confidence Intervals (CI) were used to describe the ROC results. A test result is no better than random chance when a curve has an area of 0.5 and a test result is perfect when the area under the curve =1 (Hanley and McNeil, 1982). A general recommendation for interpreting AUC values is the following: 0.5 to 0.75 is fair, 0.75 to 0.92 is good, 0.92 to 0.97 is very good and 0.97 to 1.00 is excellent (Hanley and McNeil, 1982, Brubaker, 2008). The optimal cut-point for the goniometric measurement for each analysis was identified by selecting the measurement with the largest sensitivity + specificity)/2 from each curve. Likelihood ratios and sensitivity and specificity were used to describe the validity of goniometric measures for inferring OA disease status (Straus et al., 2005). To provide greater fidelity, the goniometric measures were divided into quintiles (-4 degrees, -3 to -1 degrees, 0 degrees, 1 to 3 degrees, 4 degrees) to assess the diagnostic validity for smaller intervals of the goniometric scale.

Positive likelihood ratios (+LRs) and negative likelihood ratios (-LRs) were used to describe the extent of validity of goniometric measures for inferring the type and extent of knee OA. Likelihood ratios are interpreted in the following way: +LRs between 1 and 2 (or -LRs between 0.5 and 1) result in small and rarely important changes in probability. Values between 2 and 5 (or -LRs between 0.5 and 0.2) result in small but sometimes important shifts in probability while +LRs of 5 to 10 (or -LRs between 0.2 and 0.1) result in moderate shifts in probability. Finally, +LRs of greater than 10 (or -LRs < 0.1) result in large and often conclusive changes from pre-test to post-test probability. (Jaeschke R, et al, 1994)

Results

The mean age of the 1,390 persons in the sample at baseline, and used in the diagnostic validity analysis was 61.3 years. Persons in the concurrent validation study of whole limb radiographs (n=142) had a mean age of 60.4 years, 51% of the sample was female. See Table 1 for a summary of both samples.

Concurrent validation

The Pearson correlation between the goniometric measurement of frontal plane alignment and the whole limb radiographic lower limb alignment, the gold standard, was $r=0.50$ for the right knee (n=142) and $r=0.54$ for the left knee (n=139). Approximately 25% of the variance in true lower limb alignment as measured with radiographs is explained by the goniometric measurement. The scatterplot along with the regression line for the right and left knees are presented in Figures 2 and 3.

Diagnostic validation

The ROC area under the curves for using goniometric measures to determine which knees have isolated severe (OARSI grade 3) medial joint space narrowing on the right side (n=70) from knees with no joint space narrowing (n=393) was 0.64 (se=0.03, 95% CI, 0.59, 0.70). For isolated severe lateral joint space narrowing of the right knee (n=32) the ROC curve area was 0.76 (se=.04, 95% CI, 0.68, 0.84). For left knees with isolated severe (OARSI grade 3) medial joint space narrowing (n=81) compared to those with no narrowing (n=440), the ROC curve area was 0.69 (se=0.04, 95% CI, 0.62, 0.76). For isolated severe narrowing on

the lateral side (n=21) compared to left knees with no narrowing the ROC curve area was 0.78 (se=0.05, 95% CI, 0.68, 0.89).

The more directly clinically relevant comparison (Part 2) examined the ROC curve areas for differentiating OARSI grade 3 joint space narrowing from all other right knees in the sample, including right knees with no joint space narrowing and other combinations of medial and lateral joint space narrowing. ROC curve areas were 0.65 (se=0.03, 95% CI, 0.59, 0.70) for medial narrowing and 0.67 (se=0.04, 95% CI, 0.60, 0.74) for lateral narrowing on the right knee. Values were similar for the left knee (see Table 2). In brief, all positive likelihood ratios are less than 2 and negative likelihood ratios are greater than 0.5 in all but one case. Likelihood ratios for the five intervals of the goniometric scale for identifying end stage medial compartment disease and no lateral disease from all other knees appear in Table 3. Unless the goniometric measure indicated varus of 4 degrees or greater, the measure had poor diagnostic validity. When the measure was 4 degrees or greater, the measure led to only a small shift from pre-test to post-test probability.

Discussion

The study found that goniometric measures are only moderately related to hip-knee-ankle measures obtained from whole limb radiographs. Approximately 20% of the variance in radiographic measures is explained by goniometric measures, an unacceptable level of concurrent validity for routine clinical use. In addition, the diagnostic validity of goniometric measurements of frontal plane knee alignment provided only slight improvements in prediction of OA disease status. The likelihood ratios indicated that the goniometric measure results in only a slight and, in almost all cases, rarely an important change in probability of making a correct diagnosis (Jaeschke et al., 1994). Judgments of disease status, even early on in the examination process or in situations where radiographs are unavailable require a radiographic analysis before accurate judgments can be made. Radiographs are required even in cases where joint space narrowing is severe in either the medial or lateral side and normal on the other side.

For example, the right knees of persons in the dataset who had severe medial joint space narrowing and no lateral joint space narrowing (n=69) had a valgus alignment based on goniometric measures in 24.6% of cases. These data would suggest that a goniometric measurement of frontal plane knee alignment is inadequate for clinical impressions of knee OA status in the absence of a knee radiograph. While the diagnostic indices suggest there is some predictive power with goniometric measures, particularly for varus measures of 4 degrees in persons with end-stage medial compartment disease, the extent of error in these measures for inferring disease status is simply too high for clinical use, particularly given the potential seriousness and costs of treatment decisions that are made based on knee OA status. Table 3 indicates that even when the highest quintile of scores are considered (4° or -4°) likelihood ratios still approximate 2 or 3 indicating these more extreme goniometric scores provide only a small amount of predictive power. In short, goniometric measures do not appear to provide an adequate amount of predictive power to provide initial clinical assessments of knee OA status.

One source of error in the study was the goniometric measurement. Reliability coefficients indicated that repeated measures over a 1-year period have fair to good but not high reliability with an MDC₆₈ of 5 degrees. (Fleiss, 1986) These data suggest that measurement error is an important contributor to the error found in this study. Given the challenges of consistently positioning the goniometer on sometimes difficult to precisely locate tibial and pelvic bony landmarks, the measurement error was not considered substantial but large enough to contribute error to the validity interpretations. When measures have a fairly small

range such as frontal plane knee alignment, variation of only a few degrees can contribute a relatively large proportion of error and this may be the case for goniometric measures of frontal plane knee alignment. A high degree of precision is needed for these measures and goniometry does not appear to provide the necessary precision. The poor validity of goniometric measures as found in this study was likely impacted by the less than optimal reliability. However, while goniometric measures show a fair to good reliability, validity for inferring alignment of disease status is poor.

In post hoc analyses, I examined whether body mass index (BMI) influenced the results by dichotomizing data into those at or above a BMI of 30 indicating obesity to those with a BMI below 30. Estimates for reliability and diagnostic validity were not appreciably changed for persons who were and were not classified as obese based on a BMI cutoff of 30. That is, there were some comparisons in which estimates for obese persons were slightly improved relative to non-obese persons and vice versa. These data suggest that BMI status did not influence the findings.

Goniometric measures are similar to visual assessments in that the examiner visually estimates bony alignment and landmarks prior to aligning the goniometer. Given that in most cases, the reliability of goniometric measurements are either similar to (Piriyaprasarth and Morris, 2007) or superior to visual assessment of knee joint alignment, (Watkins et al., 1991) this study would suggest that it is likely that visual assessments of knee alignment would demonstrate findings that are either similar to or worse than the findings reported here.

Recent evidence suggests that hip-knee-ankle angle measures from whole limb radiographic measures are the gold standard for quantifying lower limb alignment. (Felson et al., 2009, Sheehy et al., 2011) The primary basis for this finding was that offset in alignment of the femoral head relative to the femoral shaft cannot be accurately estimated from standard knee radiographs. A goniometric measurement also does not account for this offset and in addition, likely adds additional error.

The relationship between goniometric and whole limb radiographic measures of lower limb alignment has been studied previously. Hinman and colleagues (Hinman et al., 2006) found weaker correlations between these two measures (non-significant Pearson $r=0.32$) while Kraus and colleagues (Kraus et al., 2005) reported a significant Pearson $r=0.70$. Our estimates were approximately midway between these two estimates. One potential explanation for this variation may be the relatively small sample sizes ($n=40$) (Hinman et al., 2006) and $n=57$ (Kraus et al., 2005) of the two studies which may have led to point estimates with broad confidence intervals. The evidence, in total, would suggest only moderate associations between goniometric and whole limb radiographic assessments indicating that goniometric measures are likely to be unsuitable clinical surrogates for the radiographic lower limb alignment. When clinicians are unsure of the disease status of a person suspected of having knee OA, goniometric measures do not provide adequate data to infer type of extent of knee OA. Invasive diagnostic tests are needed to confirm the presence and severity of knee OA.

The key limitations of the current study are related primarily to sample size. Samples for some of the diagnostic validity estimates were small, particularly for the estimates reported in Table 2 and 3 which leads to greater uncertainty in the point estimates. The OAI was conducted in the context of a research environment with rigidly controlled procedures. It is likely that measurement variation in clinical practice would be greater than that seen in OAI which applied rigid controls, standardization and training throughout the study. The estimates provided in this study, therefore likely represent a “best-case scenario” for the

validity seen in clinical practice. In addition, there were only 142 persons with whole limb radiographic measures which precluded our ability to examine the relationship between whole limb alignment and disease status.

Conclusion

In summary, our study indicates that goniometric measures of knee joint alignment are not acceptable clinical surrogate measures for frontal plane whole limb alignment. Traditionally, clinical assessment based on visual assessment or, more formally, goniometric measurement is used to develop initial impressions of knee OA status. This study suggests that quick and simple clinical assessments of knee alignment are not predictive of knee compartmental OA status. The study did not examine other aspects of the clinical examination of persons with knee pain.

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Figure 1.
Flow of patients through the study

Figure 2.
Graph illustrating the correlation between goniometric measurements and full limb radiographic measurements of right knee alignment.

Figure 3.
Graph illustrating the correlation between goniometric measurements and full limb radiographic measurements of left knee alignment.

Table 1

Descriptive baseline data for the 1390 persons in the diagnostic validity study and 142 persons in the whole limb radiographic criterion related validity study

Variables	Diagnostic Validity (n=1,390)	Criterion Related Validity (n=142)
	Mean (sd, min, max) or N(%)	Mean (sd, min, max) or N(%)
Demographic		
Age in years*, mean (sd)	61.4 (9.1, 45, 79)	
Female, total (%)	793 (57.1)	73 (51.4)
Race, total (%)		
Other non-white	31 (2.2)	2 (1.4)
White or Caucasian	974 (70.1)	117 (82.4)
Black or African American	372 (26.8)	22 (15.5)
Asian	12 (0.9)	1 (0.7)
Hispanic or Latino (%)	21 (1.5)	3 (2.1)
Comorbidity score, mean (sd)	0.49 (0.92, 0, 10)	0.46, (0.88, 0, 5)
BMI, mean (sd)	30.2 (4.9, 18.2, 48.7)	30.16 (4.5, 20.9, 43)
Right Knee Goniometric Measurement of Frontal Plane Knee Alignment (– valgus, + varus)	–.52 (4.0, –22, 15)	–1.08 93.7, –10, 9)
Left Knee Goniometric Measurement of Frontal Plane Knee Alignment (– valgus, + varus)	–.49 (4.1, –15, 12)	–1.21 (3.7, –12, 11)
Right Radiograph limb alignment (–valgus, + varus)	—	–0.73 (3.6, –7.8, 8.8)
Left Radiograph limb alignment (–valgus, + varus)	—	–1.39 (3.9, –9.5, 8.8)
Self-Report Functional Status		
SF-12 Mental Summary Scale	57.02 (7.38, 34.3, 72.84)	54.1 (8.5, 15.2, 68.8)
SF-12 Physical Summary Scale	44.5 (10.2, 12.6, 67.8)	44.9 (10.6, 16.5, 60.7)
KOOS Quality of Life	50.8 (19.7, 0, 100)	50.2 (18.0, 0, 87.5)

Table 2

Validity Indices for Goniometric Measurements of Frontal Plane Alignment – Identifying Isolated Grade 3 OARSI Medial (or Lateral) Joint Space Narrowing

Knee	Sample Size	ROC Curve Area (SE, 95% CI)	+ Likelihood Ratio (95%CI)	Optimal Cut Point	– Likelihood Ratio (95%CI)	Sensitivity (95% CI)	Specificity (95% CI)
Right Knee							
Isolated Medial Joint Space Narrowing	70/1259	0.66 (0.03, 0.60, 0.73)	1.80 (1.40, 2.20)	+1 degree	0.70 (0.59, 0.84)	0.49 (0.40, 0.58)	0.73 (0.71, 0.75)
Isolated Lateral Joint Space Narrowing	32/1226	0.75 (0.04, 0.68, 0.82)	1.58 (1.22, 1.94)	– 1 degree	0.61 (0.44, 0.85)	0.63 (0.51, 0.75)	0.60 (0.57, 0.63)
Left Knee							
Isolated Medial Joint Space Narrowing	81/1265	0.69 (0.03, 0.62, 0.75)	1.92 (1.52, 2.32)	+ 1 degree	0.68 (0.57, 0.80)	0.50 (0.42, 0.58)	0.74 (0.72, 0.76)
Isolated Lateral Joint Space Narrowing	21/1244	0.77 (0.05, 0.68, 0.87)	1.88 (1.43, 2.33)	– 2 degrees	0.45 (0.27, 0.76)	0.72 (0.57, 0.87)	0.62 (0.59, 0.65)

Table 3

Diagnostic Validity of 5 levels of Goniometric Measurements for Identifying OARSI Grade 3 (End-Stage) Medial Knee OA with no Lateral Knee OA From all Other Knees.

Goniometric Measurement [*]	Target disorder present		Target disorder absent		Likelihood Ratio
	Number	%	Number	%	
Right knee					
–4 or less degrees (valgus)	7	10.1 (7/69)	219	17.4 (219/1259)	0.61
–3 to –1 degrees (valgus)	10	14.5 (10/69)	217	17.2 (217/1259)	0.84
0 degrees	17	24.6 (17/69)	340	27.0 (340/1259)	0.91
1 to 3 degrees (varus)	10	14.5 (10/69)	165	13.1 (165/1259)	0.72
4 or greater degrees (varus)	25	36.2 (25/69)	178	14.1 (178/1259)	2.6
Left knee					
–4 or less degrees (valgus)	11	13.6 (11/81)	289	22.8 (289/1265)	0.60
–3 to –1 degrees (valgus)	10	12.3 (10/81)	235	18.6 (235/1265)	0.66
0 degrees	12	14.8 (12/81)	342	27.0 (342/1265)	0.55
1 to 3 degrees (varus)	11	13.6 (11/81)	141	11.1 (141/1265)	1.23
4 or greater degrees (varus)	37	45.7 (37/81)	177	14.0 (177/1265)	3.3

* Sample sizes for isolated end-stage lateral compartment disease were too small for stable calculations of likelihood ratios.