Radiographic Predictability of Cartilage Damage in Medial Ankle Osteoarthritis

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Abstract

Background Radiographic grading has been used to assess and select between treatment options for ankle osteoarthritis. To use radiographic grading systems in clinical practice and scientific studies one must have reliable systems that predict the fate of the cartilage.

Questions/purposes We therefore asked whether (1) radiographic grading of ankle osteoarthritis is reliable and (2) grading reflects cartilage damage observed during arthroscopy. We then (3) determined the sensitivity, specificity, and predictive values of the radiographic findings.

Each author certifies that he or she has no commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc) that might pose a conflict of interest in connection with the submitted article.

Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

This work was performed at Seoul Paik Hospital.

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Patients and Methods We examined 74 ankles with medial osteoarthritis and 24 with normal articular cartilage based on arthroscopy. Arthroscopic findings were graded according to the modified Outerbridge grades and all radiographs were graded using the modified Kellgren-Lawrence, Takakura et al., and van Dijk et al. grading systems. The reliability of each radiographic grading system was evaluated. We correlated the radiographic grades and severity of cartilage damage for each radiographic grading system. Sensitivity, specificity, and predictive values of spurs and joint space narrowing with or without talar tilting then were determined.

Results The interobserver weighted kappa ranged from 0.58 to 0.89 and the intraobserver weighted kappa from 0.51 to 0.85. The correlation coefficients for the Kellgren-Lawrence, Takakura et al., and van Dijk et al. grades were 0.53, 0.42, and 0.42, respectively. Ankles with medial joint space narrowing (Stage 2 of Takakura et al. and van Dijk et al. grades) showed varying severity of cartilage damage. The positive predictive value of cartilage damage increased from 77% for medial joint space narrowing regardless of the presence of talar tilting to 98% for medial joint space narrowing with talar tilting.

Conclusions Our observations suggest the inclusion of talar tilting in grading schemes enhances the assessment of cartilage damage.

Level of Evidence Level II, diagnostic study. See the Guidelines for Authors for a complete description of level of evidence.

Introduction

Several studies of knee osteoarthritis (OA) have examined the relationship between arthroscopic and radiographic

cartilage damage [30, 31, 54] but with conflicting findings. Ayral et al. [2] and Wada et al. [54] described a correlation between arthroscopic and radiographic joint space narrowing and osteophytes. However, other studies [6, 16, 34] have shown radiographic findings of the tibiofemoral joint do not always accurately predict the status of the articular cartilage, particularly during the early stages of OA. Although several studies [23, 43, 53] have correlated arthroscopic, CT, MRI, and radiographic findings with osteochondral lesions of the talus, none of these attempted to correlate the severity of cartilage damage with radiographic joint space narrowing associated with diffuse cartilage damage. Thus, the reliability and accuracy (ie, compared with a gold standard) of radiographic grading of ankle OA is unknown.

The goals of grading OA are to predict the fate of the cartilage and the prognosis of the patient, and to select between alternative treatments. Grading of ankle OA has not been evaluated critically in the early stages possibly because most patients with OA of the ankle are treated at a late stage with arthrodesis or total ankle arthroplasty. However, newer joint-sparing treatment options [9, 40, 50] for mid-stage OA more likely need radiographic staging closely correlated with cartilage changes to determine whether a particular procedure is reasonable. Several such grading systems have been described: those of Kellgren and Lawrence [28], van Dijk et al. [52], Takakura et al. [48], and a modified version of the Takakura et al. system by Pagenstert et al. [40]. The Kellgren-Lawrence system emphasizes spurs, whereas the other systems focus mainly on joint space narrowing. The systems of Takakura et al. and van Dijk et al. differ in that the former was developed specifically for medial ankle OA; moreover, it subclassifies medial joint space obliteration in two stages according to the site of obliteration. Nevertheless, in both systems, mid-stage OA is described similarly as joint space narrowing. Although Pagenstert et al. [40] used the Takakura et al. system for grading, their system differs from the original of Takakura et al. in that they subdivided medial or lateral joint space narrowing into tilting without bone contact and tilting with bone contact. We agree that tilting should be included in the grading system. Anterior bony impingement is common in the ankles of active young people without joint space narrowing [35, 38, 45], and we also suspect ankle spurs indicate degenerative arthritis. However, the existing classifications do not reflect all observed cartilage changes or talar tilting.

We therefore (1) questioned whether radiographic grading of OA of the ankle is reproducible, and (2) whether the grading system reflects cartilage changes observed during arthroscopy, and we (3) determined the sensitivity, specificity, and predictive values of spurs, joint space narrowing, and talar tilting in medial ankle OA.

Patients and Methods

We retrospectively reviewed the radiographs and arthroscopic findings for all 404 patients (420 ankles) who underwent arthroscopic examination for chronic ankle pain at the beginning of the operation between September 2001 and September 2008. We included all patients with medial ankle OA with or without a history of lateral ankle instability. We excluded patients younger than 40 years because primary OA rarely occurs in this age group [7, 42]. We also excluded patients with advanced OA with obliteration of the entire joint space, lateral ankle OA, secondary OA subsequent to fracture, and osteochondral lesions of the talus. The exclusions left 83 patients (98 ankles), including 59 (74 ankles; 28 men, 31 women; age range, 40–75 years; average age, 54.3 years) with early- and mid-stage ankle OA according to the criteria of Takakura et al. [48] and 24 without any definite cartilage lesions of the ankle (24 ankles; 16 men, eight women; age range, 41–65 years; average age, 48.1 years). All surgical procedures were performed by the senior author (WCL). Surgical treatment of medial ankle OA consisted of debridement (16 ankles), total ankle arthroplasty (five ankles), ankle fusion (two ankles), and realignment surgery (51 ankles) including supramalleolar osteotomy (17 ankles), calcaneal and/or first metatarsal osteotomies (20 ankles), and ligament reconstruction (14 ankles). Surgical treatment for ankles without OA consisted of debridement (11 ankles), ligament reconstruction (11 ankles), first metatarsal osteotomy (one ankle), and syndesmotic transfixation (one ankle). This study was approved by the institutional review board at our hospital and informed consent for the use of medical information was obtained from all patients.

We assessed all ankles radiographically with weight-bearing AP radiographs of the ankle. All radiographs were obtained digitally using the Picture Archiving Communication System (Marosis Enterprise PACS; Infinitt, Seoul, Korea). The patient was positioned standing on a 2-inch wood block with the feet together and pointed straight ahead. The radiographic cassette was placed posterior to the ankle at a tube-to-film distance of 40 inches (102 cm) with the xray beam projecting parallel to the tibiotalar joint and centered between the ankles.

The weightbearing ankle radiographs were reviewed retrospectively in consensus by three authors for spurs, joint space narrowing, and tilting of the talus (Fig. 1). The reviewers consisted of a musculoskeletal radiologist (JCS) with 13 years of clinical experience, an orthopaedic surgeon (JSM) with 7 years of clinical experience, and a consensus reviewer. To establish a standard grading system that would be used to correlate with arthroscopic grading, the consensus reviewer was included in the interobserver and intraobserver reliabilities as a third observer who

performed interpretation of the same set of radiographs by mutual agreement. All reviewers were unaware of the arthroscopic findings when viewing the radiographs. The presence of medial joint space narrowing was determined visually, without measuring the width of the joint space. The talar tilt angle was measured between the tibial plafond and the upper surface of the talus on weightbearing AP radiographs of the ankle; more than 2° tilting was defined as talar tilting. To establish that, the former two observers estimated a cutoff angle of talar tilt by visual estimation, we selected 30 cases in which the observers agreed about the presence or absence of talar tilt. We used receiver operating characteristics (ROC) analysis to obtain the optimized cutoff angle. As a result of analysis, we

obtained a cutoff angle of 1.8° with a sensitivity of 1.0 and a specificity of 1.0. If we measured the angle with a 0.5° interval, the cutoff angle would be 2° . Therefore, we defined talar tilting as an angle greater than 2° . We performed interobserver and intraobserver reliability for the talar tilt angle using Cronbach's alpha. The intraobserver and interobserver reliabilities were 0.99 and 0.97, respectively. To evaluate the severity of OA of the ankle, we used the grading system of Kellgren and Lawrence [28] as modified by Kijowski et al. [29], the grading system of Takakura et al. as revised by Tanaka et al. [50], and the grading system of van Dijk et al. [52] (Table 1). The interobserver and intraobserver reliabilities were determined for these three grading systems.

Fig. 1A–B The radiographs show (A) a spur (arrow), joint space narrowing (arrowhead), and the absence or (B) presence of talar tilt (asterisks) in medial OA of the ankle.

Table 1. Radiographic grading systems for osteoarthritis of the ankle used in this study.

Grading systems	Description of grade/stage
Kellgren-Lawrence [28] modified by Kijowski et al. [29]	(0) No radiographic findings of osteoarthritis (1) Minute osteophytes of doubtful clinical significance (2) Definite osteophytes with unimpaired joint space (3) Definite osteophytes with moderate joint space narrowing (4) Definite osteophytes with severe joint space narrowing and subchondral sclerosis
Takakura et al. revised by Tanaka et al. [50]	(1) No joint space narrowing but early sclerosis and osteophyte formation (2) Narrowing of the joint space medially (3a) Obliteration of the joint space limited to the facet of medial malleolus with subchondral bone contact (3b) Obliteration of the joint space advanced to the roof of the talar dome with subchondral bone contact (4) Obliteration of the whole joint space with complete bone contact
van Dijk et al. [52]	(0) Normal joint or subchondral sclerosis (I) Osteophytes without joint space narrowing (II) Joint space narrowing with or without osteophytes (III) (Sub)total disappearance or deformation of the joint space

(The Kellgren-Lawrence system as modified by Kijowski et al. is adapted from and published with permission of The American Roentgen Ray Society from Kijowski R, Blankenbaker D, Stanton P, Fine J, De Smet A. Arthroscopic validation of radiographic grading scales of osteoarthritis of the tibiofemoral joint. *AJR Am J Roentgenol.* 2006;187:794–799.) (The Takakura et al. system as modified by Tanaka et al. is adapted from and published with permission from Tanaka Y, Takakura Y, Hayashi K, Taniguchi A, Kumai T, Sugimoto K. Low tibial osteotomy for varus-type osteoarthritis of the ankle. *J Bone Joint Surg Br.* 2006;88:909–913.) (The van Dijk et al. system is adapted from and published with permission from van Dijk CN, Verhagen RA, Tol JL. Arthroscopy for problems after ankle fracture. *J Bone Joint Surg Br.* 1997;79:280–284.)

At the beginning of the operation, an arthroscopic examination was performed within 1 month of the radiographic examination by an orthopaedic surgeon (WCL); that surgeon was aware of the radiographic findings for all patients at the time of the arthroscopic examination. Arthroscopic findings were recorded on compact disc (CD), and cartilage damage also was described on the operation record. We graded the severity of damage to the articular cartilage of the ankle using the Outerbridge system [39] modified by Curl et al. [13]: Grade 0, no cartilage damage; Grade 1, softening of the articular cartilage; Grade 2, superficial fibrillation or fissures of the cartilage; Grade 3, deep fissuring of the cartilage without exposed bone; Grade 4, exposed bone. We defined cartilage lesions involving greater than half the AP length of the talus and greater than 5 mm in mediolateral width as cartilage damage. The highest grade of cartilage damage was used to represent the severity of OA when there were various levels of severity of cartilage damage. We correlated grading of a modified Outerbridge classification with that of radiographic classifications. We categorized cartilage damage into ‘nonarthritic’ and ‘arthritic’ to determine the sensitivity, specificity, and predictive values of radiographic parameters. Outerbridge Grades 0 and 1 were categorized as ‘nonarthritic’. Outerbridge Grades 2, 3, and 4 were categorized as ‘arthritic’.

After a discussion of 10 radiographs showing different grades, the three observers graded all radiographs using the modified Kellgren-Lawrence, Takakura et al., and van Dijk et al. grading systems. To determine interobserver reliability, each observer reviewed 40 randomly selected radiographs twice with no questions or discussion between observers allowed during grading. To assess intraobserver reliability, the same radiographs were placed in a new order and were classified under the same conditions by each observer 1 month later. We determined agreement of the three observers using Cohen’s kappa statistical analysis [10]. As kappa can vary from 0 (complete disagreement) to 1 (complete agreement), we also used the weighted kappa [17] to take into account partial agreement; consequently, the weighted kappa is greater than kappa when calculated for the same cases.

Spearman’s rank order correlation coefficient was used to determine the correlation between the radiographic grades of OA (modified Kellgren-Lawrence, Takakura et al., and van Dijk et al.) and the severity of articular cartilage damage. Differences between the correlation coefficients and squared correlation coefficients of the three radiographic classifications were tested using Steiger’s Z-test [46]. A bar chart was constructed to obtain the distribution of cartilage damage based on each radiographic grading. The chi square test was used to evaluate the differences in the status of articular cartilage damage

according to talar tilting in the ankles with medial joint space narrowing. Using arthroscopy as the diagnostic standard reference (gold standard), we calculated the sensitivity, specificity, predictive value, and odds ratios (with 95% confidence intervals [CIs]) of the radiographic parameters for detecting arthritic change of the ankle. We compared values for sensitivity and specificity among the radiographic parameters using McNemar’s test. The level of significance was set at $p < 0.05$.

Results

For the interobserver comparisons, weighted kappa ranged from 0.58 to 0.89, and for intraobserver comparisons, weighted kappa ranged from 0.51 to 0.85 (Table 2).

The correlation coefficients between radiographic classifications and arthroscopic findings were similar for the modified Kellgren-Lawrence, Takakura et al., and van Dijk et al. grading systems (0.53, 0.42, and 0.42, respectively) (Table 3). Of 98 ankles, 70 (71%) with medial joint space narrowing, according to the Takakura et al. and van Dijk et al. grading systems, had a wide range of severity of cartilage damage (Fig. 2). Patients with medial joint space narrowing with talar tilting showed a higher ($p < 0.001$)

Table 2. Interobserver and intraobserver reliabilities using three radiographic grading systems

Grading system	Observer*	Weighted kappa	95% CI	p Value
Kellgren-Lawrence	1	0.51	0.39–0.63	0.000
	2	0.74	0.61–0.87	0.000
	3	0.81	0.68–0.94	0.000
	1 vs 2	0.58	0.47–0.69	0.000
	1 vs 3	0.68	0.56–0.80	0.000
	2 vs 3	0.80	0.67–0.92	0.000
Takakura et al.	1	0.65	0.53–0.78	0.000
	2	0.78	0.64–0.92	0.000
	3	0.85	0.71–0.98	0.000
	1 vs 2	0.79	0.65–0.92	0.000
	1 vs 3	0.87	0.74–1.00	0.000
	2 vs 3	0.88	0.75–1.02	0.000
van Dijk et al.	1	0.64	0.51–0.78	0.000
	2	0.78	0.63–0.93	0.000
	3	0.80	0.66–0.95	0.000
	1 vs 2	0.78	0.64–0.92	0.000
	1 vs 3	0.83	0.60–0.98	0.000
	2 vs 3	0.89	0.74–1.04	0.000

* 1 and 2 = Observer 1 and Observer 2, respectively, 3 = consensus reviewer as a third observer who interpreted radiographs by mutual agreement; CI = confidence interval.

Table 3. Relationship between each radiographic grade and severity of articular cartilage damage*

Grading system	Grade	Number of patients	Grades of modified Outerbridge system				
			Mean	SD	Correlation coefficient	95% CI	Squared correlation coefficient
Kellgren-Lawrence	0	3	0.33	0.58	0.53	0.38–0.66	0.28
	1	4	3.50	0.58			
	2	41	2.41	1.53			
	3	28	3.29	1.24			
	4	22	4.00	0.00			
Takakura et al.	1	7	2.00	1.92	0.42	0.24–0.57	0.18
	2	70	2.80	1.45			
	3A	12	4.00	0.00			
	3B	9	4.00	0.00			
van Dijk et al.	0	3	0.33	0.58	0.42	0.25–0.57	0.18
	I	4	3.25	1.50			
	II	70	2.80	1.45			
	III	21	4.00	0.00			

CI = confidence interval; * to compare correlation coefficients for each radiographic grading system, Steiger's Z-test was performed. As a result, the difference of the correlation coefficients among three grading systems was not significant ($Z = 1.184$, $p = 0.236$).

rating for arthritic change compared with medial joint space narrowing without talar tilting (Table 4).

The sensitivity of spurs and medial joint space narrowing was greater than that of the other radiographic parameters ($p < 0.001$ and $p < 0.001$, respectively). The specificity of medial joint space narrowing combined with talar tilting was greater than that of the other parameters ($p < 0.001$, $p < 0.001$, and $p < 0.001$, respectively). Medial joint space narrowing with talar tilting showed the highest positive predictive value (98%) for arthritic change and the highest odds ratio (71.6) (Table 5).

Discussion

Several radiographic grading systems have been used to evaluate OA of the ankle and select between treatment options [28, 40, 48, 52]. However, to be useful in clinical practice and scientific studies, such systems must be reliable and predict the fate of the cartilage and the prognosis of the patient. We therefore questioned (1) whether radiographic grading of OA of the ankle is reproducible, (2) whether the grading system reflects cartilage changes observed during arthroscopy, and (3) whether the spur, joint space narrowing, and talar tilting predict cartilage damage in medial ankle OA.

The major limitation of our study is that it did not explore the correlation between cartilage damage and pain or joint function of the patients. The literature suggests radiographic grading and arthroscopically verified cartilage damage do not predict pain or joint function [15, 20, 26,

33]. However, along with alignment, severity of cartilage damage is considered by some authors [9, 40, 50] as an important factor in determining whether to perform surgery in patients with mid-stage ankle OA. Realignment surgery has been performed for mid-stage ankle OA after confirmation of partial cartilage damage during the operation [40, 48]. Alignment is assessed easily on plain radiographs, however, the cartilage condition is difficult to assess particularly in mid-stage OA. Our data suggest we can improve predictability of cartilage damage before we examine the ankles arthroscopically. Second, our study is based on a small number of ankles. However, ankle OA occurs approximately eight to 10 times less than knee OA [14, 25, 42], and it was difficult to collect many cases of medial ankle OA. Third, we had only one observer judge the severity of cartilage damage by arthroscopy. We could not evaluate interobserver reliability in this study because we did not open the joint in most cases although high interobserver reliability has been described in grading cartilage damage of the knee [3, 8]. Therefore, it is reasonable for a well-trained observer to arthroscopically judge the severity of cartilage damage. Fourth, we did not subclassify the area of cartilage damage in the areas of the medial gutter and talar dome. This subclassification was omitted because we were unable to determine whether an ankle with denudation of the articular cartilage in the gutter and normal cartilage in the talar dome or an ankle with normal cartilage in the gutter and a partial-thickness defect of the cartilage in the talar dome was more advanced. We found many intermediate cases involving a spectrum ranging from cartilage damage confined to the medial

Fig. 2A–C The graphs show the relationship between the (A) modified Kellgren-Lawrence [29], (B) Takakura et al. [50], and (C) van Dijk et al. [52] grading systems and the severity of articular cartilage damage according to the modified Outerbridge system [13].

surface of the talus to cartilage damage only on the dome of the talus. Therefore, we did not subdivide the area of cartilage damage according to site. Finally, we did not include lateral OA in this study. Lateral OA frequently is seen in late-stage adult-acquired flatfoot. However, the

incidence of lateral OA is very low in the population in our country, and we performed arthroscopic examinations in only four such ankles during the same period. We suspect inclusion of lateral OA would be a confounding factor when analyzing features of medial OA. We know of no

Table 4. Status of articular cartilage damage according to talar tilting

Group	Nonarthritic (Grades 0, 1)	Arthritic (Grades 2, 3, 4)	Total
MJN without talar tilting	19	12	31
MJN with talar tilting	1	38	39
Total	20	50	70

MJN = medial joint space narrowing.

report of degenerative changes confined to the joint between the lateral malleolus and talus, and every case of lateral OA also has a tendency toward talar tilting. We therefore presume the severity of cartilage change would be similar to that in medial OA with medial joint space narrowing with talar tilting.

If a grading system is not reliable, correlations between the grades and the severity of OA determined by some independent method would not be meaningful. Therefore, we first performed observer reliability testing for each grading system. The description of each grade in this article was taken from those of Kijowski et al. [29], and we used the radiographs of the other joints shown in the original article by Kellgren and Lawrence [28] for reference because that article had no radiographs of ankles. Others [11, 21, 27] have used similar descriptions. We believe the terminology used in the Kellgren-Lawrence grading system is somewhat subjective, perhaps the explanation for lower intraobserver and interobserver reliability. For this reason, we recommend the system of Kijowski et al. [29] because we believe it has a clearer definition of each grade.

As a result of the focus on osteophytes and the assumption that OA would result in joint space narrowing with the Kellgren-Lawrence grading system, other grading systems have been developed [18, 19, 32, 44, 47]. The intraobserver and interobserver reliability of these systems reportedly ranges from 0.18 to 0.95 [18, 19, 32, 44]. We found that the modified Kellgren-Lawrence, Takakura

et al., and van Dijk et al. grading systems had reliability ranging from 0.51 to 0.89.

Ayral et al. [2] and Wada et al. [54] reported a correlation between arthroscopic and radiographic parameters; however, other investigators [6, 16, 34] suggest radiography of the tibiofemoral joint does not always accurately predict the status of the articular cartilage, particularly during the early stages of OA. Wu et al. [56] believed the American College of Rheumatology (ACR) clinical criteria for OA of the knee [1] could be used to identify early cartilage damage rather than the ACR clinical plus radiographic criteria. They observed a wide distribution of articular cartilage damage in the knees that fulfill the clinical plus radiographic criteria. We suspected that radiography of the ankle would have a better predictability than radiography of the knee because the ankle has a parallel linear joint line that is confined in an ankle mortise, as compared with a knee with round joint surfaces having variable joint space and a meniscus between the surfaces to allow more mobility. However, we found low predictability of the radiographic grading systems in early- and mid-stage medial ankle OA. The low correlation between radiographic grading and arthroscopic findings likely occurred because the majority of the subjects in our study had mid-stage OA, and the severity of cartilage damage in mid-stage OA is quite varied in each classification. As noted above, if we had included end-stage arthritis with diffuse narrowing of the joint space the correlation would likely have been greater because severe cartilage damage is obvious in an ankle with diffuse narrowing. We found all patients with radiographic loss of the joint space had Outerbridge Grade 4 cartilage damage (Stage 4 in the modified Kellgren-Lawrence system, Stages 3A and 3B in the Takakura et al. system, and Stage III in the van Dijk et al. system). However, our principal objective in studying the correlation between radiographic and arthroscopic findings was to predict cartilage change in mid-stage OA.

Since Kellgren and Lawrence classified OA based on osteophytes, some authors [5, 54] have reported the high

Table 5. Diagnostic value of the four radiographic parameters for osteoarthritis of the ankle

Parameter	Spurs	MJN*	MJN without talar tilting	MJN with talar tilting
Sensitivity	94.2 (84.9–98.4) [†]	96.0 (88.6–99.1) [†]	20.3 (11.8–31.2)	75.7 (64.3–84.9)
Specificity	29.2 (12.7–51.1)	12.5 (2.8–32.4)	16.7 (4.8–37.4)	95.8 (78.8–99.3) [†]
Positive PV [‡]	80.2 (70.3–88.0)	77.2 (67.3–85.3)	42.9 (26.3–60.6)	98.3 (90.6–99.7)
Negative PV [‡]	58.3 (27.8–84.7)	50.0 (12.4–87.6)	6.4 (1.8–15.5)	56.1 (39.8–71.5)
Odds ratio	5.7 (1.6–20.1)	3.4 (0.6–18.0)	0.1 (0.0–0.2)	71.6 (9.0–567.8)

Values other than odds ratios are expressed as percentages; values in parentheses = 95% confidence intervals; MJN = medial joint space narrowing; PV = predictive value; *all cases with medial joint space narrowing regardless of the presence of talar tilting; [†]p < 0.001 (two-tailed), comparison of variables with asterisks to those without asterisks in McNemar's test; [‡]the positive PV is the probability that the disease is present when the test is positive, the negative PV is the probability that the disease is not present when the test is negative.

Table 6. Sensitivity and specificity of medial joint space narrowing to detect articular cartilage damage

Study	Joint	Standing radiographs	Number of radiographs	Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative predictive value (%)
Lysholm et al. [34]	Knee	AP extension	63	57	89	87	63
Wright et al. [55]	Knee	Posteroanterior flexion	349	5	98	87	60
		AP extension	349	3	98	57	59
Rosenberg et al. [41]	Knee	Posteroanterior flexion	55	86	100	100	87
		AP extension	55	25	96	85	55
Fife et al. [16]	Knee	AP extension	161	67	61	42	81
Wada et al. [54]	Knee	AP extension	190	91	73	98	41

association of osteophytes with OA of the knee. However, others [4, 24] have questioned whether osteophytes reflect the severity of OA. Although some authors [2, 41, 54] suggest narrowing of the joint space, particularly in a weightbearing position, reflects the loss of the cartilage thickness, others [16, 34, 41, 55] have not supported this presumption (Table 6). We found a low odds ratio of spur and joint space narrowing. Although the odds ratio of spurs was comparable to that of medial joint space narrowing, we believe that ankle spurs do not reflect joint space narrowing, which is the fundamental element of OA. We frequently see young patients with spurs or subchondral sclerosis with normal articular cartilage, and numerous studies have failed to find a relationship between spurs and OA in the ankle [12, 36, 37, 49, 51]. Our series included only patients older than 40 years; if we did not limit the age, the sensitivity of spurs for detecting OA would have been reduced.

We presumed tilting of the talus in the ankle mortise would result in asymmetric overloading in the small area of cartilage; therefore, we examined the predictability of cartilage change based on medial joint space narrowing with or without talar tilting. Although several studies have reported talar tilting [22, 40, 50], none has clearly shown its clinical importance. Our data suggest the sensitivity and specificity of radiographs to predict arthroscopic damage improved when talar tilting was considered. The relatively low predictive power of medial joint space narrowing without talar tilting may be attributable to pseudo-narrowing of the medial joint space as a result of a deviated ankle mortise or spur changes on the medial malleolus or talus. However, joint space narrowing without talar tilting does not always indicate pseudo-narrowing. In our study, 12 (39%) of 31 ankles with joint space narrowing without talar tilting had cartilage damage, and most of them had narrowing greater than half of the medial gutter. We believe including talar tilting when radiographically assessing patients will enhance our ability to predict cartilage damage in medial ankle OA.

References

- Altman R. Classification of disease: osteoarthritis. *Semin Arthritis Rheum.* 1991;20:40–47.
- Ayral X, Dougados M, Llistrat V, Bonvarlet JP, Simonnet J, Amor B. Arthroscopic evaluation of chondropathy in osteoarthritis of the knee. *J Rheumatol.* 1996;23:698–706.
- Ayral X, Gueguen A, Ike RW, Bonvarlet JP, Frizziero L, Kalunian K, Moreland LW, Myers S, O'Rourke KS, Roos H, Altman R, Dougados M. Inter-observer reliability of the arthroscopic quantification of chondropathy of the knee. *Osteoarthritis Cartilage.* 1998;6:160–166.
- Blackburn WD Jr, Bernreuter WK, Rominger M, Loose LL. Arthroscopic evaluation of knee articular cartilage: a comparison with plain radiographs and magnetic resonance imaging. *J Rheumatol.* 1994;21:675–679.
- Boegard T, Rudling O, Petersson IF, Sanfridsson J, Saxne T, Svensson B, Jonsson K. Postero-anterior radiogram of the knee in weight-bearing and semiflexion: comparison with MR imaging. *Acta Radiol.* 1997;38:1063–1070.
- Brandt KD, Fife RS, Braunstein EM, Katz B. Radiographic grading of the severity of knee osteoarthritis: relation of the Kellgren and Lawrence grade to a grade based on joint space narrowing, and correlation with arthroscopic evidence of articular cartilage degeneration. *Arthritis Rheum.* 1991;34:1381–1386.
- Buckwalter JA, Saltzman C, Brown T. The impact of osteoarthritis: implications for research. *Clin Orthop Relat Res.* 2004;427(suppl):S6–S15.
- Cameron ML, Briggs KK, Steadman JR. Reproducibility and reliability of the outerbridge classification for grading chondral lesions of the knee arthroscopically. *Am J Sports Med.* 2003;31:83–86.
- Cheng YM, Huang PJ, Hung SH, Chen TB, Lin SY. The surgical treatment for degenerative disease of the ankle. *Int Orthop.* 2000;24:36–39.
- Cohen J. A coefficient of agreement for nominal scales. *Educ Psychol Measure.* 1960;20:37–47.
- Cooper C, Egger P, Coggon D, Hart DJ, Masud T, Cicuttini F, Doyle DV, Spector TD. Generalized osteoarthritis in women: pattern of joint involvement and approaches to definition for epidemiological studies. *J Rheumatol.* 1996;23:1938–1942.
- Coull R, Raffiq T, James LE, Stephens MM. Open treatment of anterior impingement of the ankle. *J Bone Joint Surg Br.* 2003;85:550–553.
- Curl WW, Krome J, Gordon ES, Rushing J, Smith BP, Poehling GG. Cartilage injuries: a review of 31,516 knee arthroscopies. *Arthroscopy.* 1997;13:456–460.

14. Cushnaghan J, Dieppe P. Study of 500 patients with limb joint osteoarthritis: I. Analysis by age, sex, distribution of symptomatic joint sites. *Ann Rheum Dis*. 1991;50:8–13.
15. Dieppe PA, Cushnaghan J, Shepstone L. The Bristol 'OA500' study: progression of osteoarthritis (OA) over 3 years and the relationship between clinical and radiographic changes at the knee joint. *Osteoarthritis Cartilage*. 1997;5:87–97.
16. Fife RS, Brandt KD, Braunstein EM, Katz BP, Shelbourne KD, Kalasinski LA, Ryan S. Relationship between arthroscopic evidence of cartilage damage and radiographic evidence of joint space narrowing in early osteoarthritis of the knee. *Arthritis Rheum*. 1991;34:377–382.
17. Fleiss JL. *Statistical Methods for Rates and Proportions*. Ed 2. New York, NY: Wiley; 1981:38–46.
18. Galli M, De Santis V, Tafuro L. Reliability of the Ahlback classification of knee osteoarthritis. *Osteoarthritis Cartilage*. 2003;11:580–584.
19. Gunther KP, Sun Y. Reliability of radiographic assessment in hip and knee osteoarthritis. *Osteoarthritis Cartilage*. 1999;7:239–246.
20. Hannan MT, Felson DT, Pincus T. Analysis of the discordance between radiographic changes and knee pain in osteoarthritis of the knee. *J Rheumatol*. 2000;27:1513–1517.
21. Hart DJ, Spector TD, Brown P, Wilson P, Doyle DV, Silman AJ. Clinical signs of early osteoarthritis: reproducibility and relation to x ray changes in 541 women in the general population. *Ann Rheum Dis*. 1991;50:467–470.
22. Hayashi K, Tanaka Y, Kumai T, Sugimoto K, Takakura Y. Correlation of compensatory alignment of the subtalar joint to the progression of primary osteoarthritis of the ankle. *Foot Ankle Int*. 2008;29:400–406.
23. Hepple S, Winson IG, Glew D. Osteochondral lesions of the talus: a revised classification. *Foot Ankle Int*. 1999;20:789–793.
24. Hernborg J, Nilsson BE. The relationship between osteophytes in the knee joint, osteoarthritis and aging. *Acta Orthop Scand*. 1973;44:69–74.
25. Huch K, Kuettner KE, Dieppe P. Osteoarthritis in ankle and knee joints. *Semin Arthritis Rheum*. 1997;26:667–674.
26. Hunter DJ, McDougall JJ, Keefe FJ. The symptoms of osteoarthritis and the genesis of pain. *Rheum Dis Clin North Am*. 2008;34:623–643.
27. Jordan JM, Luta G, Stabler T, Renner JB, Dragomir AD, Vilim V, Hochberg MC, Helmick CG, Kraus VB. Ethnic and sex differences in serum levels of cartilage oligomeric matrix protein: the Johnston County Osteoarthritis Project. *Arthritis Rheum*. 2003;48:675–681.
28. Kellgren JH, Lawrence JS. Radiological assessment of osteoarthritis. *Ann Rheum Dis*. 1957;16:494–502.
29. Kijowski R, Blankenbaker D, Stanton P, Fine J, De Smet A. Arthroscopic validation of radiographic grading scales of osteoarthritis of the tibiofemoral joint. *AJR Am J Roentgenol*. 2006;187:794–799.
30. Kijowski R, Blankenbaker D, Stanton P, Fine J, De Smet A. Correlation between radiographic findings of osteoarthritis and arthroscopic findings of articular cartilage degeneration within the patellofemoral joint. *Skeletal Radiol*. 2006;35:895–902.
31. Kijowski R, Blankenbaker DG, Stanton PT, Fine JP, De Smet AA. Radiographic findings of osteoarthritis versus arthroscopic findings of articular cartilage degeneration in the tibiofemoral joint. *Radiology*. 2006;239:818–824.
32. Lane NE, Nevitt MC, Genant HK, Hochberg MC. Reliability of new indices of radiographic osteoarthritis of the hand and hip and lumbar disc degeneration. *J Rheumatol*. 1993;20:1911–1918.
33. Lawrence JS, Bremner JM, Bier F. Osteo-arthritis: prevalence in the population and relationship between symptoms and x-ray changes. *Ann Rheum Dis*. 1966;25:1–24.
34. Lysholm J, Hamberg P, Gillquist J. The correlation between osteoarthritis as seen on radiographs and on arthroscopy. *Arthroscopy*. 1987;3:161–165.
35. Masciocchi C, Catalucci A, Barile A. Ankle impingement syndromes. *Eur J Radiol*. 1998;27(suppl 1):S70–S73.
36. Niek van Dijk C. Anterior and posterior ankle impingement. *Foot Ankle Clin*. 2006;11:663–683.
37. Nihal A, Rose DJ, Trepman E. Arthroscopic treatment of anterior ankle impingement syndrome in dancers. *Foot Ankle Int*. 2005;26:908–912.
38. Ogilvie-Harris DJ, Mahomed N, Demaziere A. Anterior impingement of the ankle treated by arthroscopic removal of bony spurs. *J Bone Joint Surg Br*. 1993;75:437–440.
39. Outerbridge RE. The etiology of chondromalacia patellae. *J Bone Joint Surg Br*. 1961;43:752–757.
40. Pagenstern GI, Hintermann B, Barg A, Leumann A, Valderrabano V. Realignment surgery as alternative treatment of varus and valgus ankle osteoarthritis. *Clin Orthop Relat Res*. 2007;462:156–168.
41. Rosenberg TD, Paulos LE, Parker RD, Coward DB, Scott SM. The forty-five-degree posteroanterior flexion weight-bearing radiograph of the knee. *J Bone Joint Surg Am*. 1988;70:1479–1483.
42. Saltzman CL, Salamon ML, Blanchard GM, Huff T, Hayes A, Buckwalter JA, Amendola A. Epidemiology of ankle arthritis: report of a consecutive series of 639 patients from a tertiary orthopaedic center. *Iowa Orthop J*. 2005;25:44–46.
43. Schäfer D, Boss A, Hintermann B. Accuracy of arthroscopic assessment of anterior ankle cartilage lesions. *Foot Ankle Int*. 2003;24:317–320.
44. Scott WW Jr, Lethbridge-Cejku M, Reichle R, Wigley FM, Tobin JD, Hochberg MC. Reliability of grading scales for individual radiographic features of osteoarthritis of the knee: the Baltimore longitudinal study of aging atlas of knee osteoarthritis. *Invest Radiol*. 1993;28:497–501.
45. Scranton PE Jr, McDermott JE, Rojers JV. The relationship between chronic ankle instability and variations in mortise anatomy and impingement spurs. *Foot Ankle Int*. 2000;21:657–664.
46. Steiger JH. Tests for comparing elements of a correlation matrix. *Psychol Bull*. 1980;87:245–251.
47. Sun Y, Gunther KP, Brenner H. Reliability of radiographic grading of osteoarthritis of the hip and knee. *Scand J Rheumatol*. 1997;26:155–165.
48. Takakura Y, Tanaka Y, Kumai T, Tamai S. Low tibial osteotomy for osteoarthritis of the ankle: results of a new operation in 18 patients. *J Bone Joint Surg Br*. 1995;77:50–54.
49. Takao M, Uchio Y, Naito K, Kono T, Oae K, Ochi M. Arthroscopic treatment for anterior impingement exostosis of the ankle: application of three-dimensional computed tomography. *Foot Ankle Int*. 2004;25:59–62.
50. Tanaka Y, Takakura Y, Hayashi K, Taniguchi A, Kumai T, Sugimoto K. Low tibial osteotomy for varus-type osteoarthritis of the ankle. *J Bone Joint Surg Br*. 2006;88:909–913.
51. Tol JL, Verhagen RA, Krips R, Maas M, Wessel R, Dijkgraaf MG, van Dijk CN. The anterior ankle impingement syndrome: diagnostic value of oblique radiographs. *Foot Ankle Int*. 2004;25:63–68.
52. van Dijk CN, Verhagen RA, Tol JL. Arthroscopy for problems after ankle fracture. *J Bone Joint Surg Br*. 1997;79:280–284.
53. Verhagen RA, Mass M, Dijkgraaf MG, Tol JL, Krips R, van Dijk CN. Prospective study on diagnostic strategies in osteochondral lesions of the talus: is MRI superior to helical CT? *J Bone Joint Surg Br*. 2005;87:41–46.
54. Wada M, Baba H, Imura S, Morita A, Kusaka Y. Relationship between radiographic classification and arthroscopic findings of

- articular cartilage lesions in osteoarthritis of the knee. *Clin Exp Rheumatol*. 1998;16:15–20.
55. Wright RW, Boyce RH, Michener T, Shyr Y, McCarty EC, Spindler KP. Radiographs are not useful in detecting arthroscopically confirmed mild chondral damage. *Clin Orthop Relat Res*. 2006;442:245–251.
56. Wu CW, Morrell MR, Heinze E, Concoff AL, Wollaston SJ, Arnold EL, Singh R, Charles C, Skovrun ML, Fitzgerald JD, Moreland LW, Kalunian KC. Validation of American College of Rheumatology classification criteria for knee osteoarthritis using arthroscopically defined cartilage damage scores. *Semin Arthritis Rheum*. 2005;35:197–201.