Radiographic Grading for Knee Osteoarthritis. A Revised Scheme That Relates to Alignment and Deformity

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ABSTRACT. ***Objective.*** To develop a radiographic grading scheme for osteoarthritis of the knee that would relate to arthritic progression and deformity.

Methods. The scheme of Scott, *et al* was revised to include new fields of Tibial Erosion and Subluxation; the fields of Tibial Osteophytes and Sclerosis were removed. The worst affected compartment only was scored on frontal Standardized Knee Images, which were used to define knee alignment variables[9].

Results. The interreader reliability ($\kappa = 0.92$) and correlation for total scores ($r = 0.94$) were both excellent ($p < 0.001$). Individual field scores and total knee scores both correlated well with most limb alignment variables, especially the hip–knee–ankle angle ($r = 0.77$, $p < 0.001$).

Conclusion. These findings encourage further evaluations for outcome measurement, diagnostic sensitivity, and sensitivity to define arthritic change over time. (J Rheumatol 1999;26:641–4)

Key Indexing Terms:
RADIOGRAPH OSTEOARTHRITIS GRADING SCHEME
DEFORMITY BIOMECHANICS KNEE

In osteoarthritis (OA) a scheme for grading radiographs was first defined by Kellgren and Lawrence[1,2]. This helps in the diagnosis and classification of OA, but is limited in other respects by poor inter-reader consistency and the diversity of disease patterns seen in OA knees[3-5]. Scott, *et al*[6] have described a scheme for equal weight scoring of selected "fields" of the joint, i.e., joint space, tibiofemoral osteophytes, sclerosis, and tibial spine osteophytes. Applying this method we have been frustrated by poor agreement between readers. Also, it would be useful to have a total joint scoring system that was sensitive to progressive deterioration and to specific biomechanical variables of deformity. Such a system should be simple, employing only those radio-anatomic features that reflect disease progression and may be documented reliably.

We describe the elements of a scheme that may be viewed as a revision of Scott, *et al*[6]. First, only one of the tibiofemoral compartments was counted (that receiving the higher score), based on the fact that early knee changes in OA are typically focal[7]. We added tibial bone erosion and tibiofemoral subluxation to the fields, removing tibial osteophytes, sclerosis, and interspinous features. Tibial erosion was added because it is common and likely to contribute to biomechanical deterioration through joint instability. (Femoral erosion at the distal aspects of the condyles is seldom seen in the radiographs.) Subluxation is relevant since it is allied to instability in stance, manifest as lateral thrust during gait[8]. Tibial osteophytes were removed because of obvious interference with tibial bone erosion, and because documenting all tibiofemoral osteophytes overweights their representation in the final score. Sclerosis was removed because there is natural variation of bone density between people, and it is also related to obesity and poor technical control of image density from film to film. Finally, interspinous features may come and go, disappearing as the disease progresses with subluxation.

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MATERIALS AND METHODS

Bilateral anteroposterior views of the knees were obtained by a standardized method that corrects images for parallax error[9,10]. They were available from over 80 OA cases diagnosed according to Altman, *et al*[5]. A reader (not part of this study) reviewed these radiographs and removed those that were unclear due to malpositioning of the patient (usually in the presence of severe deformity, which is common in Saudi Arabia) or occasional poor image quality. Also excluded were cases with prior trauma or knee surgery. This left 53 cases (28 female, 25 male) having a mean age of 59 ± 12 years. Only one knee per patient was admissible. Two readers (LH and DC) trained themselves previously by trying out the method on other radiographs (not used in this study) and attempting to reach consensus in their scoring. For the study the readers were blinded to patient identification. They read the radiographs on 2 occasions, about a week apart.

Each compartment was scored for joint space change (0-3), femoral osteophytes (0-3), tibial erosion (0-4), and subluxation (0-3). For tibial erosion we looked for loss of bone; initial features are dishing, then marginal destruction, subsequent fragmentation and gross bone damage.

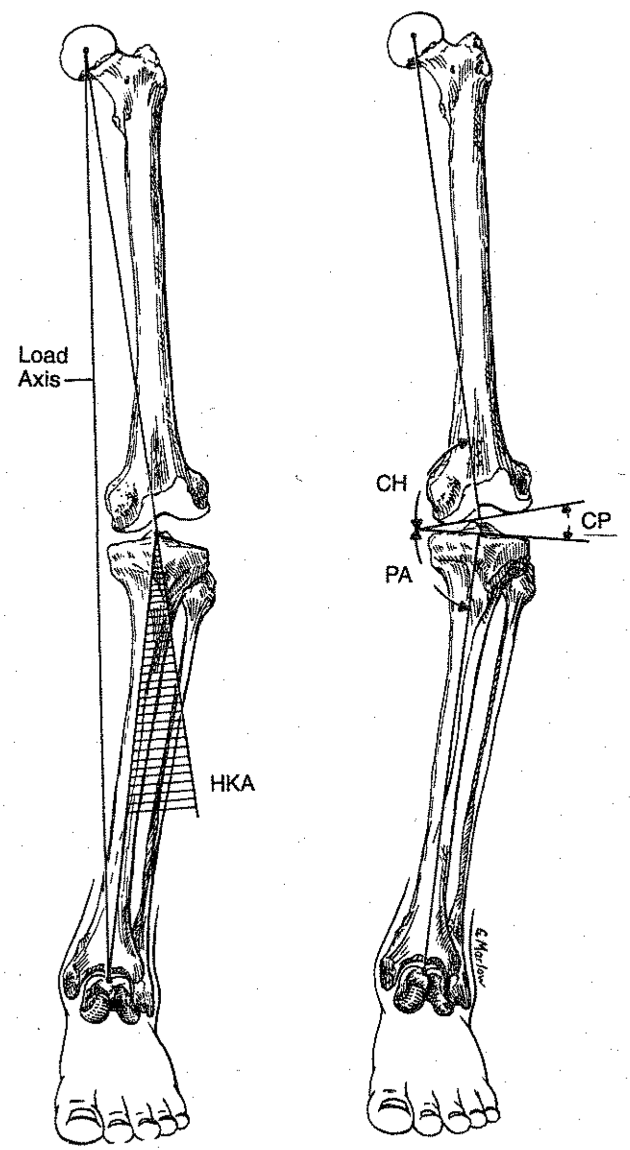

Figure 1. Frontal knee alignment and the angular variables used to describe it, with reference to the load axis. HKA (hip-knee-ankle) defines the angle between the femoral and tibial mechanical axes at the knee [degrees varus (–) or valgus (+) deviation from a straight line]. CH and PA are the tangents to the distal femoral condyles and proximal tibial plateau, respectively, measured as degrees varus (–) or valgus (+) deviation from 90° to the mechanical axes. CP depicts the angular surface geometry of femur and tibia; the angle between the surfaces is negative for medial convergence and positive for lateral convergence. The angles are related: HKA = CH + PA + CP. (Reproduced with permission, Osteoarthritis and Cartilage 1997;5:39-47, Figure 1.)

Subluxation was noted as the shift between the tibial spines and the femoral sulcus, medially or laterally. The grades ranged from definite misalignment to major displacement in which there was direct bone contact and translation. In the summation of field scores a normal knee compartment would total 0, and one with maximum damage would total 13. To relate these scores to extent of deformity they were compared to alignment angles obtained from standardized knee imaging (SKI)[9,11]. The angles were: hip-knee-ankle (HKA), condylar-hip (CH), plateau-ankle (PA), and condylar-plateau (CP) (Figure 1).

Scores and SKI angles reported by the 2 readers were entered independently (2 data entry personnel) to limit errors. Inter-reader reliability was measured by computing weighted kappa (reliability coefficient)[12,13]. The SKI angles were expressed for convenience as positive deviations from zero. StatXact 3 for Windows and JMP from SAS Institute were used for statistical analysis. The level of significance was set at $p < 0.05$.

RESULTS

Some examples of the scoring are shown in Figure 2. The overall results (Table 1) show the excellent agreement between readers in terms of correlation coefficients ($p < 0.001$). Overall scores correlated best with HKA (femorotibial alignment), but also well with PA (tibial plateau angle) and CP (angle between joint surfaces) ($p < 0.001$ in all cases). However, no score correlated with the angle of the femoral condylar surface (CH). Regarding individual fields the best correlation was between tibial bone erosion and HKA.

DISCUSSION

These results employing 2 readers are preliminary, but they tend to encourage further evaluations. The new organization of fields is promising with respect to inter-reader reliability, and validity arises from the correlation with the SKI angles that are themselves associated with biomechanics of progressing disease. Of the 4 fields, osteophytes were least reliably scored, a matter that requires further work.

No atlas was devised for this study since the 2 readers were able to practice beforehand, but wider use of the scheme could merit an atlas.

So far, the scheme has not been tested for diagnosis or classification of OA. Nor has it been related to clinical variables. At this stage we envisage applications that are mainly assessing deformity in OA knees, and following change over time, perhaps as an alert to the need for surgery. It may also have potential for use as an outcome measure for pharmaceutical and other nonsurgical interventions. Longitudinal studies are planned to evaluate sensitivity to changes. Patellofemoral changes are also important in OA, but they would require a separate grading scheme based on standardized images of that joint[14,15].

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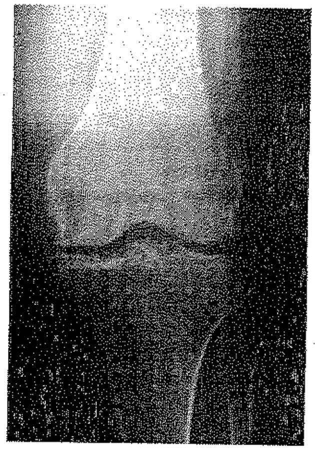
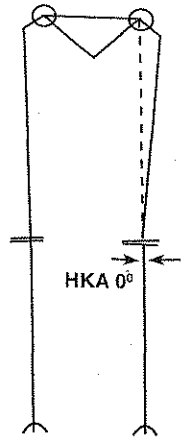
A



Joint Scores		
Field	Reader 1	Reader 2
Joint Space Loss	1	1
Osteophytes	2	2
Bone Erosion	1	0
Subluxation	0	1
Total:	4	4

Alignment Parameters	
Angle	Degrees
CH	2
PA	1
CP	-3
HKA	0



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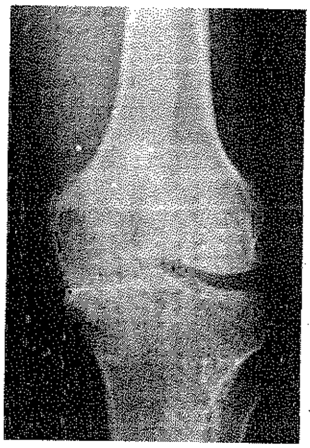
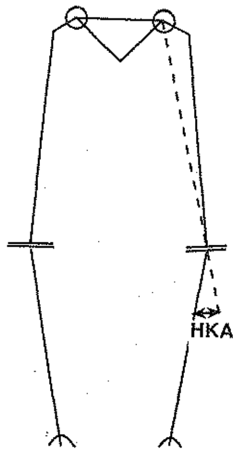


Joint Scores		
Field	Reader 1	Reader 2
Joint Space Loss	3	3
Osteophytes	3	2
Bone Erosion	2	2
Subluxation	0	0
Total:	8	7

Alignment Parameters	
Angle	Degrees
CH	-5
PA	-11
CP	-5
HKA	-20



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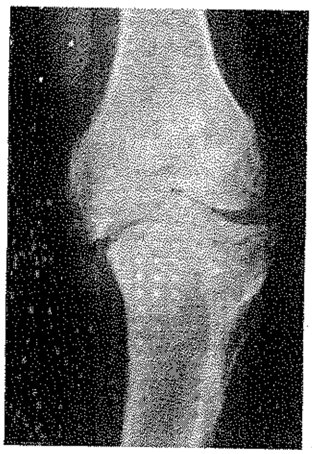

Joint Scores		
Field	Reader 1	Reader 2
Joint Space Loss	3	3
Osteophytes	3	3
Bone Erosion	4	4
Subluxation	2	1
Total:	12	11

Alignment Parameters	
Angle	Degrees
CH	-5
PA	-24
CP	-3
HKA	-32

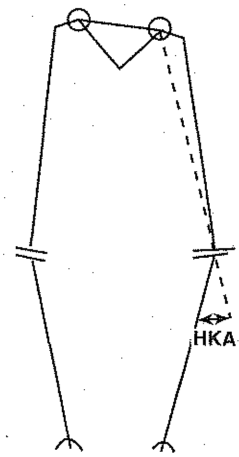

Figure 2. Composites of knee radiographs, reader scores, and SKI angles for 3 cases graded with mild (A), moderate (B), and severe (C) OA changes. In each case the worse-affected compartment is graded. Case A shows mild joint space narrowing (scored 1) and moderate femoral osteophytes (scored 2), with some possible tibial erosion and subluxation (mean score 0.5). Total = 4. The SKI data revealed no malalignment but mild medial compartment narrowing (CP = –3°). Case B has moderate OA changes: complete loss of joint space (scored 3), moderate osteophytes (mean score 2.5), and tibial erosion (scored 2) without subluxation. Total = 7.5. SKI showed pronounced varus malalignment (HKA = –20°) and an exaggerated negative PA angle (–11°), reflecting the medial bone erosion and contributing to the varus alignment. Case C featured severe changes: complete loss of joint space (scored 3), large femoral osteophytes (scored 3), severe tibial bone damage (scored 4), and definite subluxation (scored 1). Total = 11. SKI revealed severe varus malalignment (HKA = –32°); note the major contribution of PA to the varus alignment (–24°).

Table 1. Overall results show agreement of correlation coefficients between readers.

Field	Reliability	95% CI	Correlation Coefficient			
			HKA	PA	CP	CH
Joint space	0.8778*	0.8255–0.9300	0.70*	0.58*	0.58*	0.16 (N/S)
Osteophytes (femur)	0.6483*	0.5088–0.7879	0.64*	0.61*	0.51*	0.22 (N/S)
Bone erosion (tibia)	0.8452*	0.7469–0.9435	0.81*	0.72*	0.64*	0.28 (N/S)
Subluxation	0.7538*	0.5766–0.9310	0.51*	0.56*	0.44*	0.16 (N/S)
Total score	0.9235	0.8917–0.9553	0.77*	0.71*	0.63*	0.24 (N/S)

*p < 0.001. N/S: not significant, HKA: hip-knee-ankle, PA: plateau-ankle, CP: condylar-plateau, CH: condylar-hip.

REFERENCES

1. Kellgren JH, Lawrence JS. Radiological assessment of osteoarthrosis. Ann Rheum Dis 1957;16:494-502.
2. Kellgren JH, Lawrence JS. Atlas of standard radiographs: the epidemiology of chronic rheumatism. Oxford: Blackwell Scientific Publications; 1963.
3. Altman RD, Meenan RF, Hochberg MC, et al. An approach to developing criteria for the clinical diagnosis and classification of osteoarthritis. J Rheumatol 1983;10:180-3.
4. Altman RD, Fries JF, Bloch DA, et al. Radiographic assessment of progression in osteoarthritis. Arthritis Rheum 1987;30:1214-25.
5. Altman R, Asch E, Bloch D, et al. Development of criteria for the classification and reporting of osteoarthritis: classification of osteoarthritis of the knee. Arthritis Rheum 1986;29:1039-49.
6. Scott WW, 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.
7. White SH, Ludkowski PF, Goodfellow JW. Anteromedial osteoarthritis of the knee. J Bone Joint Surg 1991;73B:582-6.
8. Noyes FR, Schipplein OD, Andriacchi TP, Saddemi SR, Weise M. The anterior cruciate ligament-deficient knee with varus alignment. An analysis of gait adaptations and dynamic joint loadings. Am J Sports Med 1992;20:707-16.
9. Cooke TDV, Sorbie C, Scudamore RA, Bryant JT, Siu D, Fisher B. A quantitative approach to radiography of the lower limb. J Bone Joint Surg 1991;73B:715-20.
10. Siu D, Cooke TDV, Broekhoven LD, et al. A standardized technique for lower limb radiography. Practice, applications, and error analysis. Invest Radiol 1991;26:71-7.
11. Cooke TDV, Bryant JT, Scudamore RA. Biomechanical factors in alignment and arthritic disorders of the knee. In: Fu FH, Harner CD, Vince KG, editors. Knee surgery. Baltimore: Williams & Wilkins; 1994:1061-78.
12. James L, Demaree R, Wolfe G. Rwg: an assessment of within-group interrater agreement. J Appl Psychol 1993;78:306-9.
13. Sun Y, Gunther KP, Brenner H. Reliability of radiographic grading of osteoarthritis of the hip and knee. Scand J Rheumatol 1997;26:155-65.
14. McAlindon TE, Snow S, Cooper C, Dieppe PA. Radiographic patterns of osteoarthritis of the knee joint in the community: the importance of the patellofemoral joint. Ann Rheum Dis 1992;51:844-9.
15. Harrison MH, Cooke TDV, Fisher SB, Griffin MP. Patterns of knee arthrosis and patellar subluxation. Clin Orthop 1994;309:56-63.