Osteoarthritis and Cartilage (1999) **7,** 239–246
© 1999 OsteoArthritis Research Society International
Article No. joca.1998.0152, available online at http://www.idealibrary.com on IDEAL
1063–4584/99/020239+08 $12.00/0

Osteoarthritis and Cartilage
Journal of the OsteoArthritis Research Society International

Reliability of radiographic assessment in hip and knee osteoarthritis

By Klaus P. Günther* and Yi Sun†
*Department of Orthopaedic Surgery (RKU), University of Ulm, Germany
†Department of Epidemiology, University of Ulm, Germany

Summary

Objective: To evaluate the reproducibility of commonly used radiographic measures in hip and knee OA and to overcome certain limits of existing knowledge on their reliability from previous studies.

Design: Three readers evaluated 100 hip joints (50 pelvic X-rays) and 100 antero-posterior and lateral knee films of a hospital-based sample of patients with radiographic OA at two time points 3 months apart. They retrospectively estimated the presence and severity of joint specific individual radiographic features (osteophyte formation and joint space narrowing at different sites, cysts, subchondral sclerosis, bony deformity and chondrocalcinosis) and two different overall scores. Within and between observer reproducibility was calculated by intra-class correlation coefficient.

Results: At the hip joint excellent intra- as well as inter-observer reliability for superior joint space narrowing (JSN) and femoral head deformity could be demonstrated, while the assessment of medial JSN, osteophytes and acetabular sclerosis depends on the level of the investigator's experience. At the knee joint, femorotibial and patellofemoral osteophytes showed a high intra- and inter-observer reliability. Grading of JSN is highly reader dependent; rating of subchondral sclerosis and chondrocalcinosis does not seem to be reproducible enough. The overall scores showed an excellent reproducibility both at hip and knee joints.

Conclusion: A reliable radiographic severity grading of hip and knee OA is possible with the application of global scores and individual features, if joint specific items are selected and readers are trained enough.

Key words: Osteoarthritis, Hip joint, Knee joint, Radiographic reading, Reproducibility.

Introduction

According to recent recommendations regarding the methodology of clinical trials in patients with osteoarthritis [1, 2], radiographs should currently be used not only as an entry criterion but also as a principal outcome measure. Since Kellgren and Lawrence developed the first radiographic grading scale about four decades ago [3], different scoring systems have been published, to assess morphological changes of hip and knee joints in clinical and epidemiological studies (Table I). They are mainly based on individual or overall grading of radiographic features, which represent various aspects of cartilage loss and subchondral bone reaction in osteoarthritis.

One of the most inevitable prerequisites for the application of those grading scales in single- as well as multi-centre trials is an appropriate reproducibility of the recorded features. But in a recent review of radiographic grading scores in hip and knee OA [4] we could show that reliability studies were reported for only 12 among the identified 26 scores. It seems also very difficult to compare the results of these reliability studies due to wide variations of setting and study design. In particular, information on number and qualification of involved observers as well as time intervals between repeat readings is often different or even missing, the number of patients included is rather small in some studies, and another difficulty in comparison results from the different statistical measures used. Additionally, with the exception of performed reliability studies of the Kellgren and Lawrence score, all identified reliability studies within the past 10 years were carried out by the authors of those scores. Assuming a relatively high training of readers in these investigations, one must be cautious transferring the results into routine practice, although it is hard to speculate from the published data to which extent this would apply.

Received 8 December 1997; accepted 8 July 1998.
Corresponding Address: PD Dr Klaus P. Günther, Department of Orthopaedic Surgery at the University of Ulm (RKU), Oberer Eselsberg 45, 89081 Ulm. Tel: +49 731/177-1106; Fax: +49 731/177-1103.

Table I
Radiographic scores of cox- and gonarthrosis (modified by Sun et al.*, 1997)*

Type of score	Joints	Author(s)	Year	Reference
Overall grading	Hip/knee	Kellgren and Lawrence	1975	3
		Summers *et al.*	1988	44
	Knee	Jonasch	1964	45
		Mohing	1966	46
		Jäger *et al.*	1978	47
		Sundaram *et al.*	1986	48
		Büll	1986	49
		Satku *et al.*	1986	50
		Kannus *et al.*	1988	51
		Merchant *et al.*	1989	53
		Brandt *et al.*	1991	53
	Hip	Lies *et al.*	1984	54
		Calvert *et al.*	1987	55
		Mose	1987	56
		Croft *et al.*	1990	9
		Scher *et al.*	1991	57
		Lane *et al.*	1993	58
Individual grading*	Hip/knee	Burnett *et al.*	1994	7
		Altman *et al.*	1995	20
	Knee	Thomas *et al.*	1975	59
		Altman *et al.*	1987	24
		Spector *et al.*	1992	60
		Cooper *et al.*	1992	21
		Scott *et al.*	1993	6
	Hip	Altman *et al.*	1987	24
		Ledingham *et al.*	1992	61

*Individual grading: separate severity grading of single radiographic OA variables.

For that reason we decided to perform a reliability study within a subgroup of the 'German Society of Orthopaedic Surgery and Traumatology' as part of our efforts, to support the application of standardized and reproducible criteria in diagnosis and therapy of osteoarthritis. The aim of this investigation was therefore, to assess the reproducibility of commonly used individual radiographic features and overall scores in a hospital-based sample of patients with radiographic hip and knee osteoarthritis and to overcome identified limits of existing knowledge on their reliability.

Material and methods

PATIENTS AND RADIOGRAPHS

From the outpatient clinic of the Department of Orthopaedic Surgery (RKU) at the University of Ulm, 50 anteroposterior films of the pelvis (mean age of the patients 57.4 years, range 25–75 years) and 100 single anteroposterior and lateral knee radiographs (mean age of the patients 55.2 years, range 25–75 years) were selected. The X-rays were chosen by an orthopaedic surgeon, who did not participate in the study, to represent a range of severity of hip and knee osteoarthritis (random distribution to the 5 severity grades according to Kellgren and Lawrence [3]. Exclusion criteria included evidence of other types of arthritis, previous fractures, surgical intervention and treatment with steroids.

The following views of the studied joints have been obtained: a non-weightbearing anteroposterior radiograph of the pelvis (70 kV, 40 mAs, film-focus distance FFD 100 cm), a single standing anteroposterior radiograph of the tibiofemoral joint (60 kV, 25 mAs, FFD 100 cm) and a single lateral radiograph of the knee taken in 30° of flexion (52 kV, 8 mAs, FFD 100 cm).

RADIOGRAPHIC SCORING

Three observers with different training levels (one orthopaedic surgeon familiar with radiographic reading in clinical studies and two orthopaedic residents) performed the study. They retrospectively scored the 100 hip and 100 knee radiographs on two separate occasions, after they had held three training sessions—each of two hours duration—where they agreed on criteria for radiographic evaluation. During this training period the readers discussed extensively the atlases of Kellgren and Lawrence [5], Scott *et al.* [6] and Burnett *et al.* [7].

Table II
Intra- and inter-observer reliability of individual features and overall scores in hip osteoarthritis (intraclass correlation coefficient=ICC)

Radiographic feature	Intra-rater reliability			Inter-rater reliability			
	At1At2	Bt1Bt2	Ct1Ct2	At1Bt1	At1Ct1	Bt1Ct1	Total t1
Joint space narrowing superior	0.96	0.85	0.79	0.84	0.88	0.87	0.78
Joint space narrowing medial	0.85	0.67	0.51	0.46	0.53	0.51	0.36
Osteophyte superior	0.83	0.68	0.81	0.68	0.64	0.78	0.61
Osteophyte inferior	0.87	0.83	0.85	0.80	0.78	0.86	0.77
Perifoveal osteophyte	0.67	0.16	0.49	0.47	0.45	0.56	0.37
Acetabular sclerosis	0.88	0.00	0.25	0.35	0.38	0.52	0.11
Acetabular cyst	0.56	0.27	0.54	0.46	0.52	0.45	0.42
Cyst femoral head	0.71	0.64	0.74	0.54	0.44	0.67	0.50
Deformity	0.83	0.76	0.90	0.86	0.89	0.86	0.83
Kellgren and Lawrence score*	0.88	0.91	0.85	0.91	0.93	0.93	0.88
Overall grading†	0.89	0.82	0.84	0.85	0.86	0.87	0.82

Intra-rater reliability was calculated after two separate readings (t1, t2) of three different observers, A=orthopaedic consultant; B, C=orthopaedic residents.

Inter-rater reliablity was calculated for three pairs of readers at time t1 and for all readers together (total t1) according to the technique of multiple ratings per subject (Fleiss and Cohen 1973).

*According to Kellgren and Lawrence 1957, Empire Rheumatism Council 1963.

†According to Scott *et al.* 1992, modified according to Croft *et al.* 1990.

All hip joints were scored for the presence and severity of six individual radiographic features of osteoarthritis: superior and medial joint space narrowing (medial joint space measured to the lateral edge of the acetabular teardrop along a line joining the centres of the femoral heads [8]), superolateral and inferomedial femoral osteophytes, perifoveal osteophyte, acetabular sclerosis, subchondral cysts at the femoral and acetabular joint surface, and deformity of the femoral head. Osteophytes and joint space narrowing were graded from 0–3 for increasing severity (according to Scott *et al.* [9]; perifoveal osteophytes, sclerosis, subchondral cysts and bony deformity were graded as absent or present (0 or 1). Assessment of JSN as well as other features in scored hips was performed in comparison to the healthy opposite side. Radiographs also were scored using overall grading systems developed by Kellgren and Lawrence [5] and Croft *et al.* [8] as modified by Scott *et al.* [9].

For each knee, the following variables were evaluated on a 4 grade scale (assessment in comparison to the atlas as published by Scott *et al.* [6]): medial and lateral femurotibial osteophytes, patellar osteophytes (on the lateral radiograph) and medial as well as lateral femurotibial joint space narrowing. Medial and lateral subchondral sclerosis, osteophytes of tibial spines and chondrocalcinosis were scored as absent or present (0–1).

For an overall grading purpose the Kellgren and Lawrence score alone was used at the knee joint [5].

Each reader graded hip and knee radiographs at different times in random order. To assess intra-observer reliability, all three investigators repeated their reading three months later without knowledge of the previous results.

DATA ANALYSIS

Measurement of inter-rater as well as intra-rater agreement for summary scores and individual radiographic features was assessed using the intraclass correlation coefficient (ICC) as described by Bartko [10]. This coefficient quantifies the proportion of variance of ratings that is due to between-subjects variability, and it can therefore take values from 0 (variance entirely due to imperfect reliability) to 1 (variance entirely due to between-subject variability). ICC can also be used for two or more measurements per study participant. For ordinal variables the ICC is equivalent to the weighted kappa coefficient under certain conditions and values greater than 0.75 are generally considered to represent good agreement beyond chance, while values below 0.40 are considered to reflect poor agreement [11, 12].

Results

Table II shows the within- and between-observer reproducibility of individual radiographic features and overall grading in hip radiographs, Table III in knee radiographs. In general, reproducibility was lower between than within observers for all single features and summary scores at both joint sites and the most experienced reader rated most variables with the highest reliability.

Table III
Intra- and inter-observer reliability of individual features and overall scores in knee osteoarthritis (intraclass correlation coefficient=ICC)

Radiographic feature	Intra-rater reliability			Inter-rater reliability			
	At1At2	Bt1Bt2	Ct1Ct2	At1Bt1	At1Ct1	Bt1Ct1	Total t1
Medial femorotibial osteophyte	0.81	0.79	0.82	0.73	0.73	0.80	0.75
Lateral femorotibial osteophyte	0.84	0.76	0.64	0.65	0.76	0.81	0.74
Tibial spine osteophyte	0.77	0.79	0.62	0.57	0.68	0.64	0.63
Medial joint space narrowing	0.86	0.76	0.64	0.60	0.62	0.63	0.62
Lateral joint space narrowing	0.92	0.41	0.62	0.24	0.72	0.34	0.47
Medial tibial sclerosis	0.55	0.00	0.41	0.27	− 0.03	− 0.04	0.27
Lateral tibial sclerosis	0.86	0.63	0.65	0.44	0.67	0.15	0.44
Chondrocalcinosis	0.74	0.57	0.79	0.61	0.57	0.36	0.52
Patellar osteophyte	0.85	0.77	0.81	0.71	0.81	0.66	0.73
Kellgren and Lawrence score	0.93	0.85	0.85	0.76	0.84	0.82	0.81

Intra-rater reliability was calculated after two separate readings (t1, t2) of three different observers, A=orthopaedic consultant; B, C=orthopaedic residents.

Inter-rater reliablity was calculated for three pairs of readers at time t1 and for all readers together (total t1) according to the technique of multiple ratings per subject (Fleiss and Cohen 1973).

At the hip joint the intraclass correlation coefficient for intra-reader reliability of individual features by the most experienced reader ranged from 0.96 for superior joint space narrowing (JSN) to 0.56 for acetabular cysts. JSN, osteophytes, femoral cysts and deformity showed a high within observer reproducibility for experienced as well as less trained readers, while values of perifoveal osteophytes, acetabular cysts and sclerosis in trainees were not acceptable.

Inter-reader reliability for individual features at the hip joint was best for superior JSN (average ICC 0.78) and deformity of the femoral head (0.83), followed by superolateral and inferomedial osteophytes (0.61 and 0.77). Between observer reproducibility is worse for medial JSN (average ICC 0.36), perifoveal osteophytes (0.37) and sclerosis (0.11), while acetabular as well as femoral cysts show moderate results (0.42 and 0.50). Overall grading at the hip joint was performed with a very high intra-rater as well as inter-rater reliability for both scores (within observer reproducibility ranged from 0.82–0.91 for all readers and average between observer reproducibility was 0.88 for the Kellgren and Lawrence score [3] and 0.82 for the score of Croft *et al.* [8] as modified by Scott *et al.* [9].

At the knee joint the intra-observer reliability of both femorotibial osteophytes and JSN was equally high only in the most experienced reader (ranging from 0.81 for medial osteophytes to 0.92 for lateral JSN), while the less experienced investigators graded osteophytes with a high reproducibility than JSN. Patellar osteophytes showed a high within observer reproducibility on lateral knee radiographs (range 0.77–0.85 for all readers) and so did tibial spine osteophytes (0.62–0.79) as well as subchondral sclerosis of the lateral compartment (0.63–0.86).

In contrast to a high intra-observer reliability, the inter-observer values for femorotibial JSN were less satisfactory (average ICC for medial compartment 0.62 and for lateral compartment 0.47). Even between observer reproducibility for osteophytes was somewhat lower than in the hip joint (average ICC 0.75 and 0.74 for medial and lateral osteophytes). The average values of inter-observer reliability for other features ranged from 0.27 for subchondral sclerosis in the medial compartment to 0.73 for patellar osteophytes.

The Kellgren and Lawrence overall score [3] again showed a high between observer reproducibility (average ICC 0.81) and values for within observer reproducibility ranged from 0.85–0.93.

Discussion

Since the first radiographic grading system in an epidemiological osteoarthritis study was presented by Kellgren and Lawrence in 1957 [3], a total of 27 different scores have been published to assess individual radiographic features and overall severity of hip and knee joint OA (see Table I). Although the clinical significance of all those specific evaluation techniques and scoring systems is still discussed controversially [13], a standardized approach to the categorization of those radiographic features at different joint sites is crucial [14]. Besides already established measures to standardize patient positioning and radiographic recording [1, 2, 15] it is very important to select reading parameters with a high reproducibility in order to achieve consistent results in clinical and

epidemiological studies. In a recent review of studies on reliability of radiographic assessment of hip and knee osteoarthritis we could show however, that reported results do not exist for all identified scores, and comparison of reliability from performed investigations should be made with caution given obvious differences in their design [4].

As a consequence from these identified limitations in the recent literature, members of the study group 'Osteoarthritis' of the German Society of Orthopaedic Surgery and Traumatology decided to investigate the reproducibility of commonly used individual radiographic features and overall scores in hip and knee joint osteoarthritis in consideration of a highly standardized setting [16, 17].

To our knowledge, this is also the first reliability study where radiographic assessment of both hip and knee joint osteoarthritis together is performed by a group not involved in the development of specific scores.

Based on our results we can confirm some previous data on the high intra- as well as inter-observer reliability of superolateral joint space assessment in hips and femorotibial osteophytes in knee joints, which are important features in measuring disease progression and predicting clinically manifest disease [8, 13, 18].

At the hip joint however, superolateral or inferomedial femoral osteophytes and acetabular or femoral cysts should be reported in consideration of their somewhat lower reproducibility, while grading of medial joint space narrowing, perifoveal osteophytes [19] and subchondral sclerosis can not be recommended as a routine procedure due to their insufficient within and between observer reproducibility. Whether the introduction of four severity grades for an ordinal rating of cysts and sclerosis as recommended in the recently published OARS atlas [20] will improve their reproducibility in comparison to dichotomous reading as performed in our as well as most other studies, must be further analyzed.

At the knee joint our rating of femorotibial joint space narrowing seems to be highly influenced by the experience of the reader, which results in a wide range of within observer reproducibility and an only moderate to intermediate between observer reproducibility. Although other groups have described sufficient reliability for this important feature [21–23] they did not separately read the medial and lateral femorotibial compartments. In a reliability study of the 'Baltimore Longitudinal Study of Aging Atlas of Knee Osteoarthritis' Scott *et al.* [6] could demonstrate different results for both compartments with a higher reproducibility of JSN on the medial side, but they did not comment this interesting phenomenon.

Progression of joint space narrowing can be regarded as the hallmark for progression of hip and knee joint OA, as Altman *et al.* [24] and other investigators [23, 25, 26, 28] could demonstrate. Therefore it is mandatory to assess JSN especially in structure-modifying drug trials with a high precision and reproducibility. In addition to a grading of joint space width based on the described semi-quantitative approach newer measurement techniques have therefore been developed for applicaiton in hip as well as knee joints [25, 27–32]. Until these techniques, for example the promising approach of quantitative microfocal radiographic assessment [32], become routinely available, a ruler or calliper measurement in addition to the use of magnifying glass is strongly recommended for inter-bone distance in knees and hip joints [2]. According to recent investigations it is furthermore adviseable to perform standing X-rays not only in knee joints but also in hips [27], as weightbearing seems to improve the accuracy of joint space measurement in these joints as well [33].

In our investigation, subchondral sclerosis as well as joint space width was rated with a different reliability in the medial and lateral femorotibial compartment. It might be possible however to achieve results with a more satisfying reproducibility, if this feature would also be graded on an ordinal scale instead of a dichotomous one as advocated by Altman and the OARS study group [20].

Radiographic assessment of patellofemoral osteoarthritis can be performed on lateral as well as skyline views. A drawback of our study is the restriction on lateral X-rays and the exclusion of other radiographic features than patellofemoral osteophytes. Although the results revealed a sufficient reproducibility and lateral views might nevertheless provide additional information [34], there is a tendency towards assessment of JSN, osteophytes and patellar subluxation separately in the medial as well as lateral patellofemoral compartment [20]. Since this detailed assessment is only possible on axial radiographs and their high sensitivity for predicting knee pain has already been proven [35], the skyline view should be the preferred method of assessing the patellofemoral joint in future radiological OA surveys [2, 35, 36].

The reproducibility results of overall grading from our study are in conflict with some other reports [8, 21, 37–40], who point at a relatively low reliability of the Kellgren and Lawrence score especially at the hip joint. It is possible that

poor results are mainly due to inconsistencies in definition of severity grades by Kellgren and Lawrence themselves in different publications [41, 42] as discussed extensively by Spector and Cooper [13]. However, our results show that precise definition of the features and severity grades with the help of standardized atlases can lead to a high reproducibility of overall scoring systems in hip and knee osteoarthritis. Whether this observation strengthens the application of summary scores in epidemiological studies depends on some additional aspects, for example their debated sensitivity to change [25].

Finally our investigation confirms recent recommendations [1, 43], that radiographic reading in multicentre studies should always be performed centrally by an experienced investigator, as intra-observer reliability of nearly all recorded features is clearly depending on the individual experience of the reader.

In conclusion, our investigation has tried to overcome some identified limitations of former reliability studies of scoring systems. The results show that a reliable radiographic classification of the severity of hip and knee osteoarthritis is possible by relevant and joint site specific individual features as well as overall assessment. A standardized setting and training of involved readers is mandatory. The limited reproducibility of certain features however (subchrondral sclerosis, cysts and medial JSN at the hip) necessitates further improvement of classification systems and measurement techniques.

Acknowledgments

The authors would like to thank all involved members of the study group 'Osteoarthritis' of the German Society of Orthopaedic Surgery and Traumatology (K. Glueckert, H. P. Scharf, W. Willauschus) and additional members of our faculties (Y. Kalke, S. Sauerland, T. Stürmer, I. Zeissig) for their help and assistance throughout this investigation. Results of this study have already been published in parts (4, 16, 17). This work was supported in part by a grant from the German Ministry of Research and Technology (01 EF 9406).

References

1. Altman R, Brandt K, Hochberg M, Moskowitz R. Design and conduct of clinical trials in patients with osteoarthritis. Recommendations from a task force of the osteoarthritis Research Society. Osteoarthritis Cart 1996;4:217–43.
2. Dieppe PA, Altman RD, Buckwalter JA, Felson DT, Hascall V, Lohmander LS, et al. Standardization of methods used to access the progression of osteoarthritis of the hip and knee joints. In: Keuttner KE, Goldberg VM, Eds. Osteoarthritic Disorders, Rosemont: American Academy of Orthopaedic Surgeons 1995:481–97.
3. Kellgren JH, Lawrence JS. Radiological assessment of osteoarthrosis. Ann Rheum Dis 1957;16:494–501.
4. Sun Y, Günther KP, Brenner H. Reliability of radiographic grading of osteoarthritis of the hip and knee—a review of the literature. Scand J Rheumatol 1997;26:155–65.
5. Empire Rheumatism Council. The epidemiology of chronic rheumatism. Atlas of standard radiographs of arthritis. Oxford: Blackwell Scientific Publications 1963.
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. Burnett S, Har DJ, Cooper C, Spector TD. A radiographic atlas of osteoarthritis. London: Springer 1994.
8. Croft P, Cooper C, Wickham C, Coggon D. Defining osteoarthritis of the hip for epidemiologic studies. Am J Epidemiol 1990;132:514–22.
9. Scott JC, Nevitt MC, Lane E, Genant HK, Hochberg MC. Association of individual radiographic features of hip osteoarthritis with pain. Arthritis Rheum 1992;35:81.
10. Bartko JJ. The intraclass correlation coefficient as a measure of reliability. Psychol Rep 1966;19:3–11.
11. Fleiss JL, Cohen J. The equivalence of weighted kappa and the intraclass correlation coefficient as measures of reliability. Educ Psychol Meas 1973;33:613–19.
12. Spector TD, Cooper C. Radiographic assessment of osteoarthritis in population studies: whither Kellgren and Lawrence? Osteoarthritis Cart 1993;1:203–6.
13. Cooper C. Radiographic atlases for the assessment of osteoarthritis. Osteoarthritis Cart 1995;3 (suppl A):1–2.
14. Fleiss JL. Statistical methods for rates and proportions. New York: Wiley and Sons 1981.
15. Günther KP, Scharf HP, Puhl W. Standardisierung der Röntgendiagnostik bei Coxarthrose und Gonarthrose in klinischen Studien. Z Orthop 1997;135:9–11.
16. Günther KP, Scharf HP, Puhl W, Willauschus W, Sauerland S, Glückert K, et al. Reproduzierbarkeit der röntgenologischen Beurteilung von Coxarthrosen. Z Orthop 1997;135:3–8.
17. Günther KP, Scharf HP, Puhl W, Willauschus W, Kalke Y, Glueckert K, et al. Reproduzierbarkeit der radiologischen Diagnostik bei Gonarthrose. Z Orthop 1997;135:3–8.
18. Spector T. Measuring joint space in knee osteoarthritis: position or precision? J Rheumatology 1995;22:5–6.
19. Diehlmann W, Frik W. Das Plaquezeichen am Hüftgelenk (Spezielle, weniger beachtete Röntgenbefunde am Stütz- und Gleitgewebe). Fortschr Roentgenstr 1971;114:297–304.
20. Altman RD, Hochberg M, Murphy WA, Wolfe F, Lequesne M. Atlas of individual radiographic features in osteoarthritis. Osteoarthritis Cart 1995;3 (suppl A):3–70.

21. Cooper C, Cushnaghan J, Kirwan JR, Dieppe PA, Rogers J, McAlidon T, et al. Radiographic assessment of the knee joint in osteoarthritis. Ann Rheum Dis 1992;51:80–2.
22. Kallman DA, Wigley FM, Scott WW, Hochberg M, Tobin JD. New radiographic grading scales for osteoarthritis of the hand. Arthritis Rheum 1989;32:1584–91.
23. Dougados M, Gueguen A, Nguyen M, Thiesce A, Listrat V, Jakob L, et al. Longitudinal radiologic evaluation of osteoarthritis of the knee. J Rheumatol 1992;19:3–10.
24. Altman RD, Fries JF, Bloch DA, Carstens J, Cooke TD, Genant H, et al. Radiographic assessment of progression in osteoarthritis. Arthritis Rheum 1987;30:1214–25.
25. Dougados M, Villers C, Amor B. Sensitivity of change of various roentgenological severity scoring systems for osteoarthritis of the hip. Rev Rhum (Engl Ed) 1995;62:169–73.
26. Schouten JSAG, van den Ouwland FA, Valkenburg HA. A 12 year follow up study in the general population on prognostic factors of cartilage loss in osteoarthritis of the knee. Ann Rheum Dis 1992;51:932–7.
27. Conrozier R, Tron AM, Mathieu P, Vignon E. Quantitative assessment of radiographic normal and osteoarthritis hip joint space. Osteoarthritis Cart 1995;3 (suppl A):81–7.
28. Lequesne M. Quantitative measurement of joint space during progression of osteoarthritis: ''chondrometry''. In: Kuettner KE, Goldberg V, Eds. Osteoarthritic Disorders, Rosemont: American Academy of Orthopedic Surgeons 1995:427–44.
29. Lynch JA, Buckland-Wright JC, Macfarlane DG. Precision of joint space width measurement in knee osteoarthritis from digital image analysis of high definition macroradiographs. Osteoarthritis Cart 1993;1:209–18.
30. Buckland-Wright JC. Quantitative radiography of osteoarthritis. Ann Rheum Dis 1994;53:268–75.
31. Dacre JE, Huskisson EC. The automatic assessment of knee radiographs in osteoarthritis using digital image analysis. Br J Rheumatol 1989;28: 506–10.
32. Buckland-Wright JC, MacFarlane DG, Jasani MK, Lynch JA. Quantitative microfocal radiographic assessment of osteoarthritis of the knee from weight bearing tunnel and semiflexed standing views. J Rheumatol 1994;21:1734–41.
33. Ravaud P, Dougados M. Radiographic assessment in osteoarthritis. J Rheumatol 1997;24:786–91.
34. Speake SC, Szebenyi B, Dieppe P. Quantitative serial assessment of patellofemoral joint osteoarthritis from lateral knee radiographs. Osteoarthritis Cart 1995;3:89–96.
35. Cicuttini FM, Baker J, Hart DJ, Spencer TD. Choosing the best method for radiological assessment of patellofemoral osteoarthritis. Ann Rheum Dis 1996;55:134–6.
36. Jones AC, McAlindon T, Regan M, Hart D, MacMillan PJ, Doherty M. Radiographic assessment of patellofemoral osteoarthritis. Ann Rheum Dis 1993;52:655–8.
37. Bagge E, Bjelle A, Valkenburg HA, Svanborg A. Prevalence of radiographic osteoarthritis in two elderly european populations. Rheumatol Int 1992;12:33–8.
38. Cerhan JR, Wallace RB, El-Khoury GY, Moore TE, Long CR. Decreased survival with increasing prevalence of full-body radiographically defined osteoarthritis in women. Am J Epidemiol 1995;141:225–34.
39. Cerhan JR, Wallace RB, El-Khoury GY, Moore TE. Risk factors for progression to new sites of radiographically defined osteoarthritis in women. J Rheumatol 1996;23:1565–78.
40. Spector TD, Darce JE, Harris PA, Huskisson EC. The radiological progression of OA: an 11 year follow up study of the knee. Arthritis Rheum 1991;34 (Suppl):85.
41. Kellgren JH, Bremner JM, Bler F. Osteoarthritis: Prevalence in the population and relationship between symptoms and x-ray changes. Ann Rheum Dis 1966;25:1–24.
42. Lawrence JS. Rheumatism in populations. London: Heinemann 1977.
43. Dieppe PA. Recommended methodology for assessing the progression of osteoarthritis of the hip and knee joints. Osteoarthritis Cart 1995;3:73–7.
44. Summers NM, Haley WE, Reveille JD, Alacron GS. Radiographic assessment and psychologic variables as predictors of pain and functional impairment in osteoarthritis of the knee or hip. Arthritis Rheum 1988;31:204–9.
45. Jonasch E. Das Kniegelenk. Berlin: De Gruyter 1964.
46. Mohing W. Die Arthrosis deformans des Kniegelenkes. Berlin–Heidelberg–New York: Springer 1966.
47. Jäger M, Wirth CJ. Kapselbandläsionen. Biomechanik, Diagnostik und Therapie. Stuttgart: Thieme 1978.
48. Sundaram NA, Hallett JP, Sullivan MF. Dome osteotomy of the tibia for osteoarthritis of the knee. J Bone Joint Surg 1986;68-B:782–286.
49. Büll U. Spezielle Methoden röntgendiagnostischer und nuklerarmedizinischer Untersuchungsverfahren des Bewegungsapparates, des Skeletts und der Gelenke. In: Lissner J, Ed. Radiologie II. Stuttgart: Enke 1986:354–78.
50. Satku K, Kumar VP, Ngoi SS. Anterior cruciate ligament injuries. To counsel or to operate? J Bone Joint Surg 1986;68-B:458–61.
51. Kannus P, Järvinen M, Paakkala T. A radiological scoring scale for evaluation of posttraumatic osteoarthritis after knee ligament injuries. Int Orthop 1988;12:291–7.
52. Merchant TC, Dietz FR. Long-term follow-up after fractures of the tibial and fibular shafts. J Bone Joint Surg 1989;71-A:599–606.
53. Brandt KD, Fife RS, Braunstien EM, Katz B. Radiographic grading of the severity of knee osteo arthritis. 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;34:1381–6.
54. Lies A, Scheuer I. Ergebnisse bei hüftgelenknahen Femurosteotomien nach Traumen. In: Hierholzer G, Müll KH, Eds. Korrekturosteotomien nach Traumen an der unteren Extremität. Berlin–Heidelberg–New York: Springer 1984:93–102.

55. Calvert PT, August AC, Albert JS. The chiari pelvic osteotomy. A review of the long-term results. J Bone Jt Surg 1987;69-B:551–5.
56. Debrunner HU. Orthopädisches Diagnostikum. Stuttgart–New York: Thieme 1987.
57. Scher MA, Jakim I. Combined intertrochanteric and chiari pelvic osteotomies for hip dysplasia. J Bone Jt Surg 1991;73-B:626–31.
58. 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;20:1911–18.
59. Thomas RH, Resnick D, Alazraki NP, Daniel D, Greenfield R. Compartmental evaluation of osteoarthritis of the knee. Radiology 1975;116:585–94.
60. Spector TD, Cooper C, Cushnaghan J, Hart DJ, Dieppe PA. A radiographic atlas for knee osteoarthritis. London: Springer Verlag 1992.
61. Ledingham J, Dawson S, Preston B, Milligan G, Doherty M. Radiographic patterns and associations of osteoarthritis of the hip. Ann Rheum Dis 1992;51:111–16.