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Atlas of individual radiographic features in osteoarthritis, revised[1]

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Summary

Objective: Develop a radiographic atlas of osteoarthritis (OA) to be used as a template and guide for grading radiographs of osteoarthritic lesions of the hand, hip and knee.

Method: The 1995 atlas was reviewed for the images most useful for clinical trials. Replacement images were selected from the Stanford University Radiology Department Picture Archive and Communications System by reviewing consecutive radiographs obtained from patients. Selected images were downloaded without patient identification information. Images were organized by hand, hip and knee. They were reviewed for findings of OA and images grouped into image files by individual findings and degree of change. Both investigators individually selected the most promising images. Final images were selected by consensus. Original electronic images were then cropped and placed in sequence.

Results: Individual radiographic features (e.g., osteophytes, joint space narrowing) were recorded for hand (distal interphalangeal joint, proximal interphalangeal joint, trapeziometacarpal joint), hip (acetabular, femoral) and knee (medial compartment, lateral compartment, tibial, femoral); they were also sequenced for normal, 1+, 2+, and 3+ change. Images were made available in print and electronic formats.

Conclusion: An updated atlas of radiographic images was produced to assist in grading individual radiographic features of the hand, hip and knee for clinicians and for use in clinical trials.

Key words: Osteoarthritis, Atlas, Radiographs, X-ray, OARSI atlas, Radiographic atlas.

Introduction

Osteoarthritis (OA) was found in "Java man", one of our earliest known ancestors (ca 500,000 years ago)[1]. However, from a medical perspective, OA as a clinical entity was not separated from other arthritides such as rheumatoid arthritis until 1859 by Garrod. In addition, OA did not receive its name until 1888 from John Kent Spender, a physician in Bath who also used the same terminology for a variety of rheumatic conditions. The first radiographic description from "skiagrams" that separated OA from rheumatoid arthritis was in 1904 by Goldwaite, where he coined the term "hypertrophic arthritis"[2]. Additional radiographic descriptions evolved over a half of the century and were finally well defined in an atlas produced by Kellgren and Lawrence in 1957[3,4]. For the first time, clinicians and researchers were able to stage OA from a radiographic perspective. Their composite grading system continues to be used today. Criticisms of the Kellgren and Lawrence system are directed at the emphasis on the osteophyte, the overall grades in severity from normal to severe (0–3), and that the system is relatively insensitive to change. This limits the Kellgren and Lawrence scale to screening subjects for the radiographic diagnosis of OA and for grading gross clinical severity.

In the last decade, there has been an appreciation that increased detail is often more appropriate in the interpretation of radiographs of joint tissues[5,6]. Even though newer techniques have become available, the plain radiograph continues to be the most accessible tool in the evaluation of the OA joint. To increase the usefulness of the plain radiograph, there has been the development of radiographic atlases that can be used as guides in the evaluation of individual features of OA[5,7–13]. Atlases have been of value in screening patients for confirmation of OA and staging of OA, particularly for clinical trials.

An atlas from the Osteoarthritis Research Society International (OARSI) was published in 1996[10]. Over the last decade, the atlas was used for a variety of purposes, mostly for clinical trials. The original galley proofs are not available and the publisher is not able to reproduce quality images from the original atlas. Hence, new distribution of the 1996 OARSI atlas is no longer available. The OARSI Board of Directors commissioned the development of a new atlas, one that can replace the original OARSI atlas. The atlas below is intended to provide better quality images with the added ability to access electronic images.

Method

SELECTION OF RADIOGRAPHS

The 'Radiographic Atlas for Osteoarthritis of the Hand, Hip and Knee' was reviewed for images[10]. Those images felt to be most relevant were selected for replacement. The images of the 1996 Atlas were derived from photographic prints

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copied from celluloid radiographs. These were in turn photographed by the publisher for typesetting into the atlas. Each of the stages above potentially lead to reduced detail in reproduction. The images for this atlas were to be derived directly from electronically stored radiographic images. It is expected that this format will provide greater image detail.

The Stanford University Department of Radiology Picture Archive and Communications System (PACS) was screened for relevant images of hands, hips and knees by reviewing consecutive radiographs obtained from patients in the years 2004 and 2005. Images were obtained using Computed Radiography (CR) X-ray systems at Stanford University. Selected images were downloaded into Bitmapped (BMP) and Digital Imaging and Communication in Medicine (DICOM) format files and numerically labeled without any patient identification information: hand, $n = 32$; hip, $n = 27$; and knee, $n = 43$. Images were organized by hand, hip and knee. Images were then reviewed for individual findings of OA (Table I). Only selected changes are recorded in this atlas. For example, it was elected to not grade several abnormalities, other than to state that they are present or absent. Images were grouped by individual findings and sequenced by degree of change. Groups of BMP images with similar findings were organized within individual PowerPoint (Microsoft, Redmond, WA) files and graded for degree of change (i.e., 0 = normal, 1 = mild change, 2 = moderate change, 3 = severe change). Both investigators separately reviewed PowerPoint files. The most promising images were selected. Investigators met, reviewed image files, compared findings and selected final images by consensus. Once selected, the original DICOM electronic images were again reviewed, matched for contrast and brightness, cropped to match other images for the finding, potentially reversed so that all images faced the same direction and saved as uncompressed Tagged Image File Format (TIFF) files. The original DICOM files were used in the final image production to maximize image quality.

TECHNIQUES OF OBTAINING RADIOGRAPHS

Hand X-rays were obtained with one or both hands in a postero-anterior view using a General Electric (Milwaukee, WI) CR system. Most images contained both hands on a single X-ray film. As part of the processing of radiographs all X-ray films were transmitted to PACS within 24 h. Hip images were obtained with the subject reclined with an antero-posterior view. Most included both hips on a single view. Hip images were stored directly into the PACS system. The knee images were obtained with the patient standing with the CR system. Most images included both knees and all images were directly transmitted to the PACS.

Results

HAND

Hand osteophytes, graded 0–3, are pictured for the distal interphalangeal joints (DIP) (Fig. 1), proximal interphalangeal joints (PIP) (Fig. 2), and trapeziometacarpal joint (first carpometacarpal joint, first CMC) (Fig. 3). Joint space narrowing, graded 0–3, is pictured for the DIP (Fig. 4), PIP (Fig. 5) and first CMC (Fig. 6).

Other abnormalities of the hands are demonstrated. The interphalangeal joint (IP) of the thumb is pictured for normal, osteophyte formation and joint space narrowing (Fig. 7). The trapezionavicular joint on the proximal side of the trapezium is pictured (Fig. 8). Malalignment of the DIP and PIP with subluxation of the first CMC is pictured (Fig. 9). Additional changes of the DIP with erosions, the characteristic central erosion and associated pseudowidening, and subchondral

Table I
Evaluated radiographic features of OA

Hand
Osteophyte
DIP (0–3)
PIP (0–3)
First CMC (0–3)
Thumb (IP) (absent/present)
Naviculotrapezial joint (NTJ) (absent/present)
Joint space narrowing
DIP (0–3)
PIP (0–3)
First CMC (0–3)
IP (absent/present)
NTJ (absent/present)
Malalignment
DIP (absent/present)
PIP (absent/present)
First CMC (subluxation) (absent/present)
Erosion
DIP (absent/present)
DIP central erosion (absent/present)
DIP pseudowidening (absent/present)
PIP (absent/present)
First CMC (absent/present)
Subchondral sclerosis
DIP (absent/present)
PIP (absent/present)
First CMC (absent/present)
Subchondral cyst
PIP (absent/present)
First CMC (absent/present)
Hip
Marginal osteophytes
Superior acetabular (0–3+)
Superior femoral (0–3+)
Inferior femoral (0–3+)
Inferior acetabular (absent/present)
Joint space narrowing
Superior (0–3+)
Medial (0–3+)
Other
Acetabular subchondral cyst (absent/present)
Acetabular subchondral cyst (absent/present)
Femoral subchondral sclerosis (absent/present)
Flattening of the femoral head (absent/present)
Thickening of the medial femoral calcar (buttressing) (absent/present)
Knee—tibiofemoral
Marginal osteophytes
Medial femoral condyle (0–3+)
Medial tibial plateau (0–3+)
Lateral femoral condyle (0–3+)
Lateral tibial plateau (0–3+)
Joint space narrowing
Medial compartment (0–3+)
Lateral compartment (0–3+)
Other
Medial tibial attrition (absent/present)
Medial tibial sclerosis (absent/present)
Lateral femoral sclerosis (absent/present)

sclerosis are pictured on Fig. 10. Erosion, subchondral cyst formation and subchondral sclerosis are demonstrated for the PIP (Fig. 11) and first CMC (Fig. 12).

HIP

Hip images graded as 0–3 include marginal osteophytes of the superior acetabulum (Fig. 13), superior femoral head (Fig. 14), and inferior femoral head (Fig. 15). Joint space narrowing, also graded as 0–3, is pictured at the superior lateral femoroacetabular joint space (Fig. 16) and medial femoroacetabular joint space (Fig. 17). Axial views of the femoroacetabular joint were not obtained.

Additional figures of the hip (Figs. 18 and 19) include acetabular changes such as an inferior acetabular osteophyte [Fig. 18(B)], subchondral cyst formation [Fig. 18(C)], and subchondral sclerosis [Fig. 18(D)]. Additional femoral changes are pictured for subchondral femoral sclerosis [Fig. 19(B)], flattening of the femoral head [Fig. 19(C)] and thickening of the medial cortex or calcar (buttressing) [Fig. 19(D)].

KNEE

Knee images graded as 0–3 include marginal osteophytes of the medial femur, (Fig. 20), medial tibial plateau (Fig. 21), lateral femur (Fig. 22) and lateral tibial plateau (Fig. 23). Joint space narrowing, graded 0–3, are pictured for the medial tibiofemoral compartment (Fig. 24) and the lateral tibiofemoral compartment (Fig. 25). Additional knee changes (Fig. 26) are pictured for medial tibial attrition [Fig. 26(B)], medial tibial sclerosis [Fig. 26(C)] and lateral femoral sclerosis [Fig. 26(D)].


A
B

Fig. 1. Hand DIP: (A) grade 0 normal, (B) grade 1 marginal osteophyte, (C) grade 2 marginal osteophyte, and (D) grade 3 marginal osteophyte.


A
B

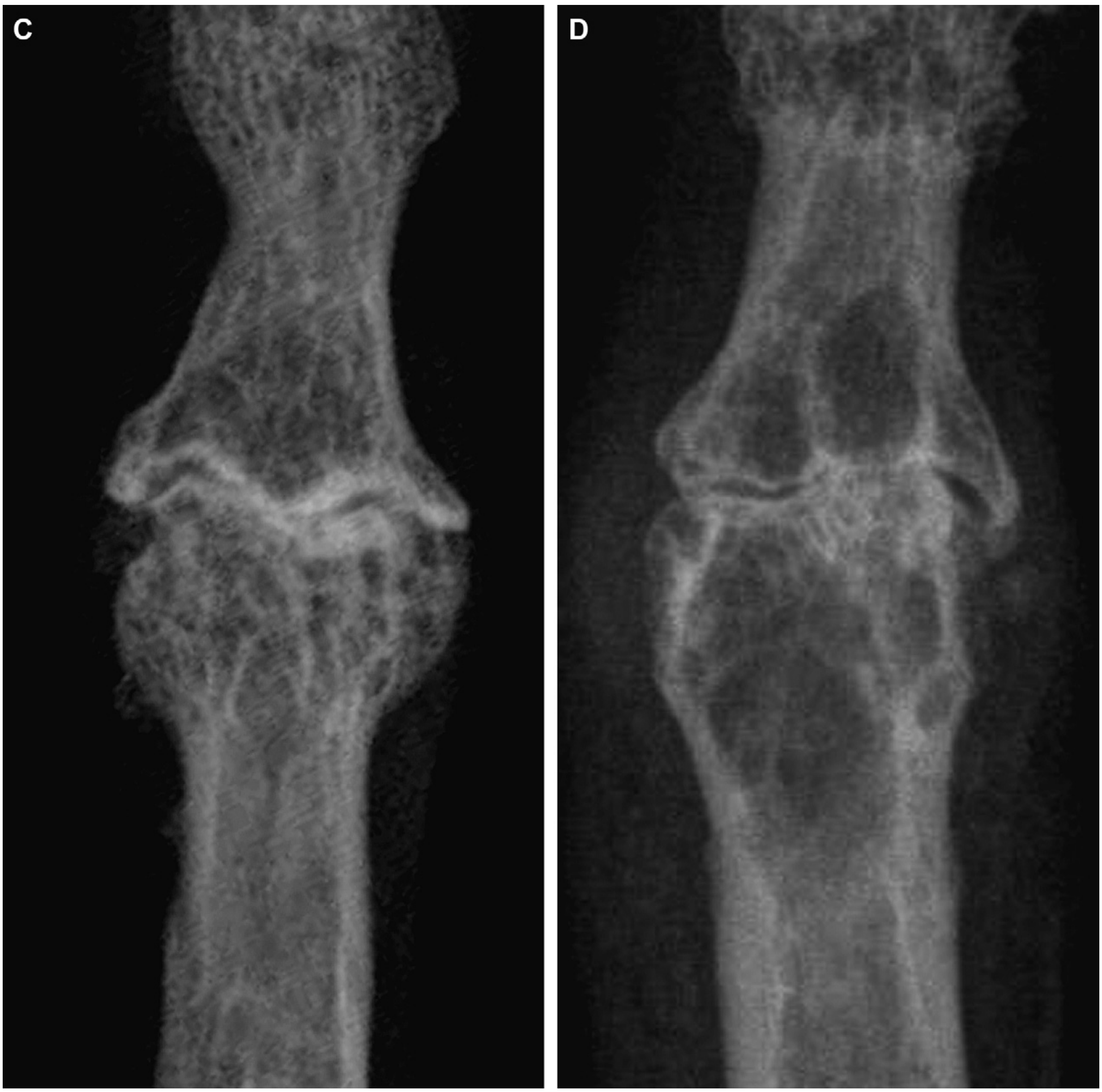


Fig. 2. Hand PIP: (A) grade 0 normal, (B) grade 1 marginal osteophyte, (C) grade 2 marginal osteophyte, and (D) grade 3 marginal osteophyte.


A
B

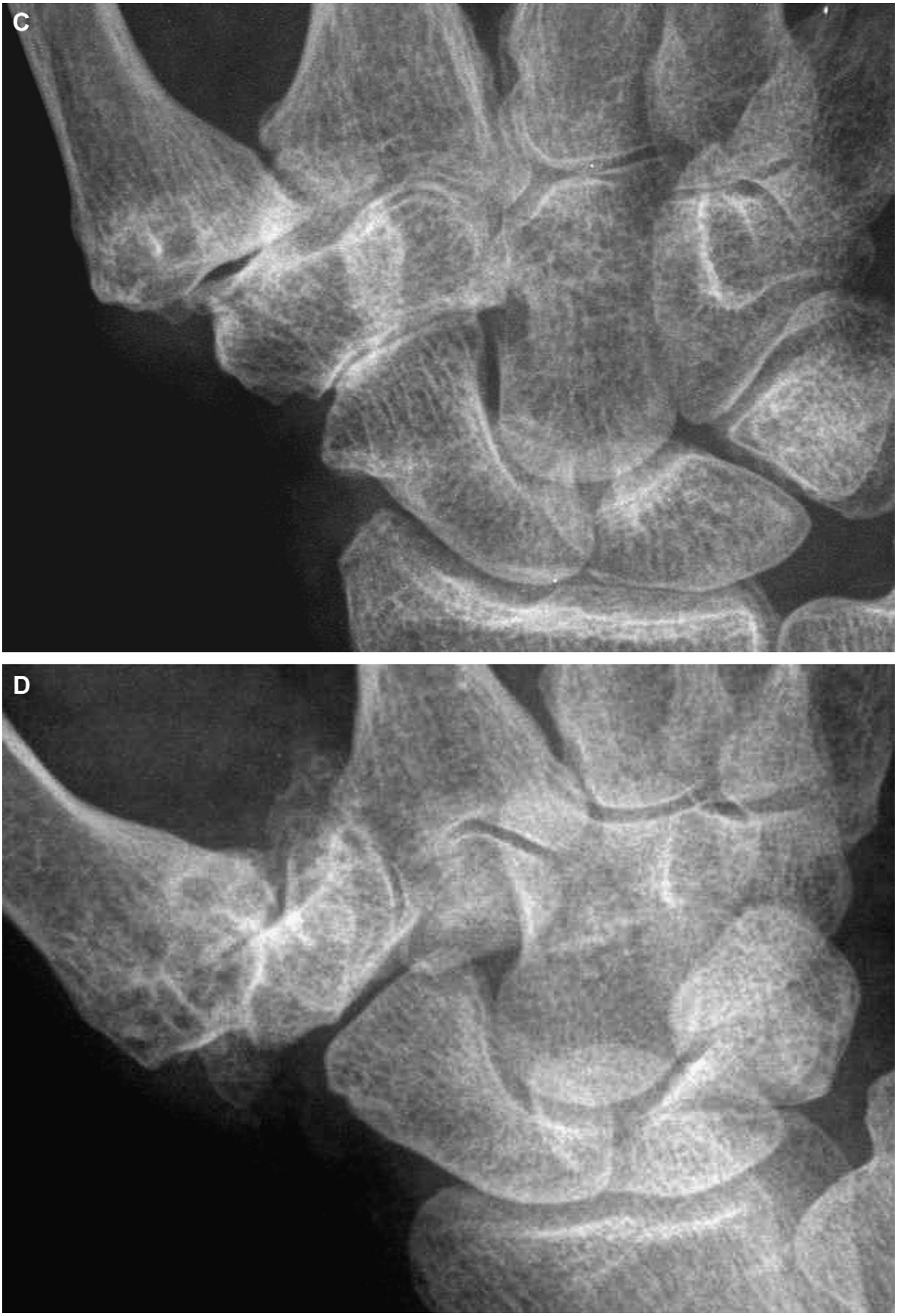


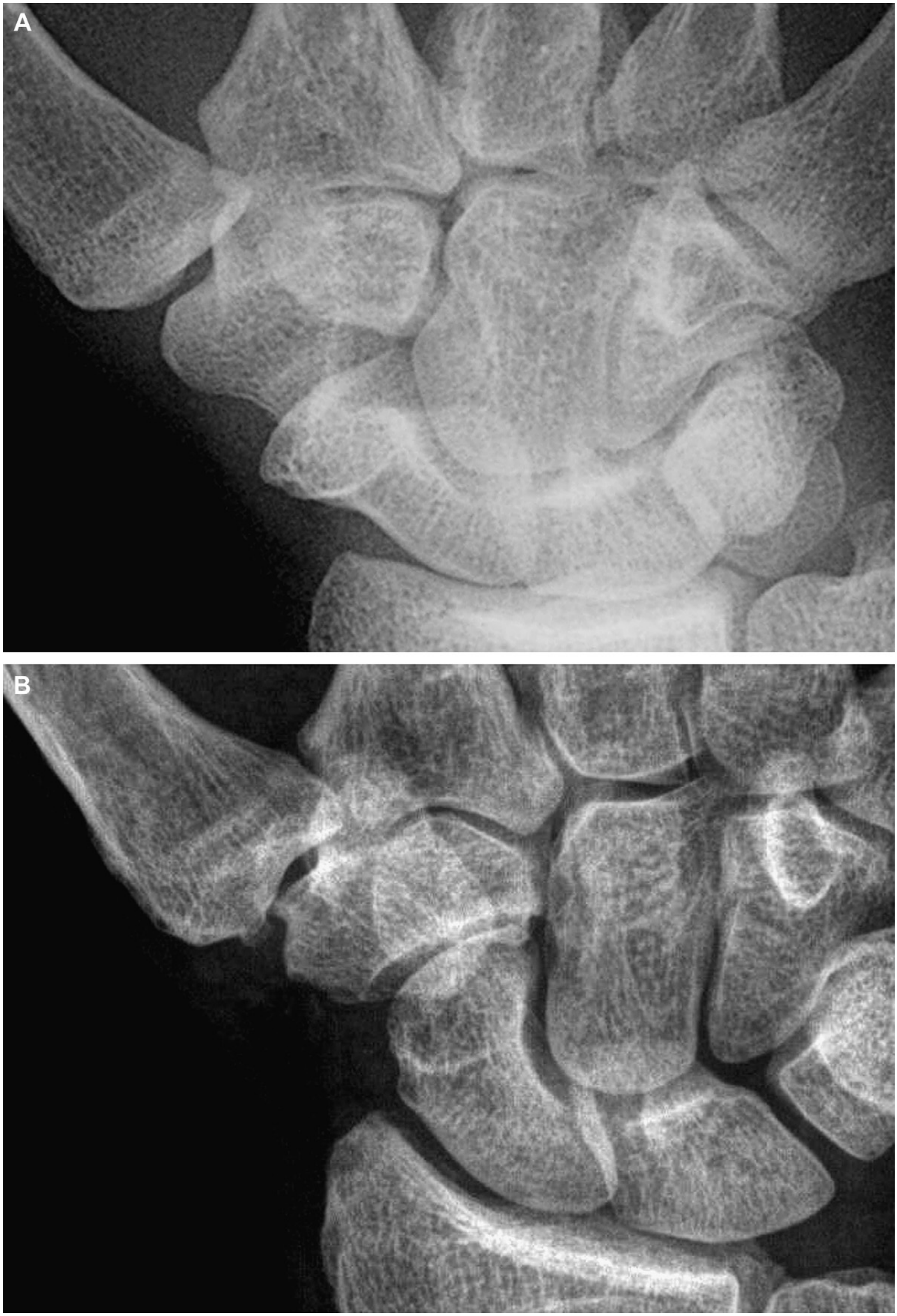
Fig. 3. Hand trapeziometacarpal joint: (A) grade 0 normal, (B) grade 1 marginal osteophyte, (C) grade 2 marginal osteophyte, and (D) grade 3 marginal osteophyte.


A
B

Fig. 4. Hand DIP: (A) grade 0 normal, (B) grade 1 joint space narrowing, (C) grade 2 joint space narrowing, and (D) grade 3 joint space narrowing.


A
B

Fig. 5. Hand PIP: (A) grade 0 normal, (B) grade 1 joint space narrowing, (C) grade 2 joint space narrowing, and (D) grade 3 joint space narrowing.


A
B

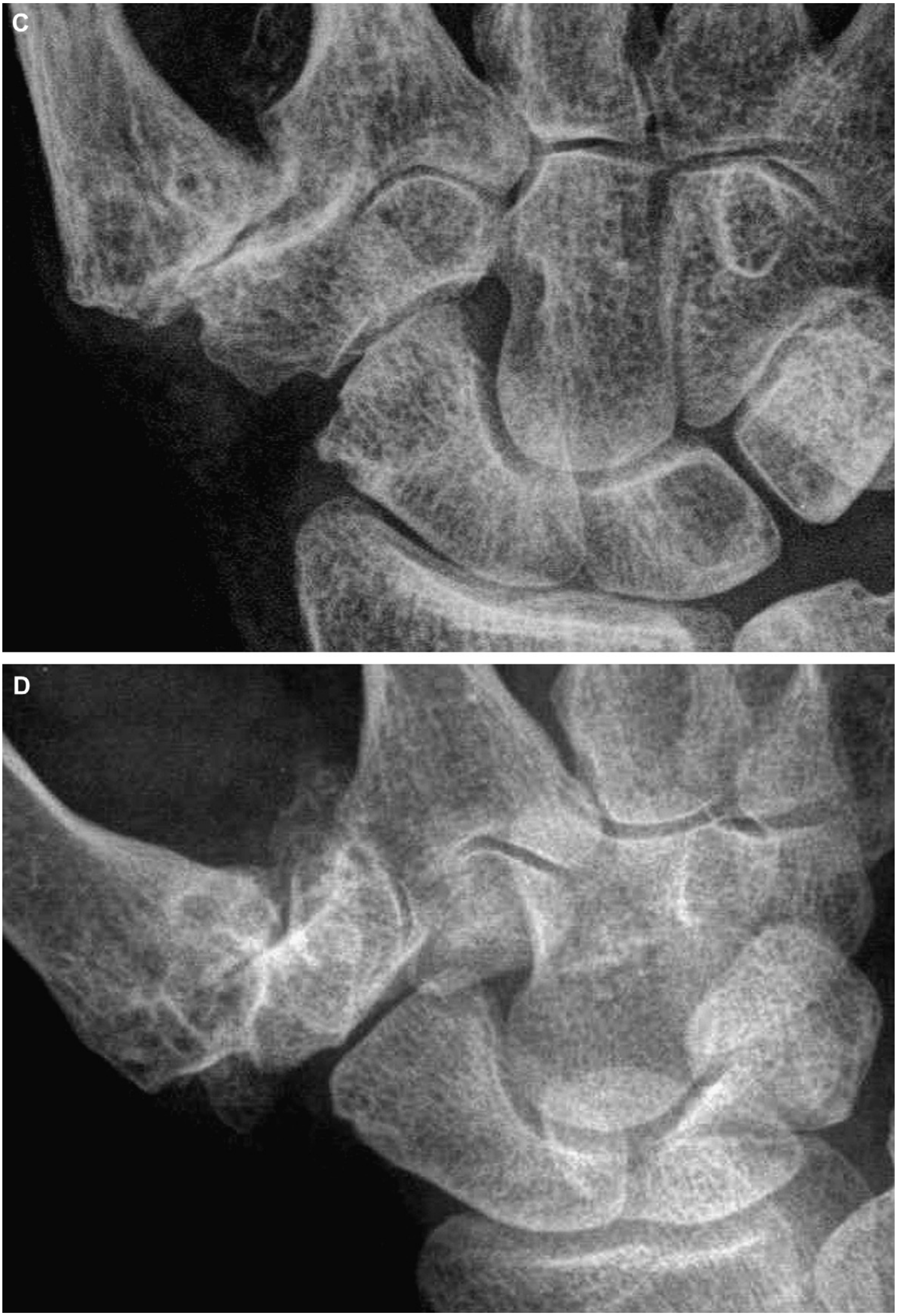


Fig. 6. Hand trapeziometacarpal joint: (A) grade 0 normal, (B) grade 1 joint space narrowing, (C) grade 2 joint space narrowing, and (D) grade 3 joint space narrowing.


A
B

Fig. 7. Hand IP of the thumb: (A) normal, (B) marginal osteophyte, and (C) joint space narrowing.

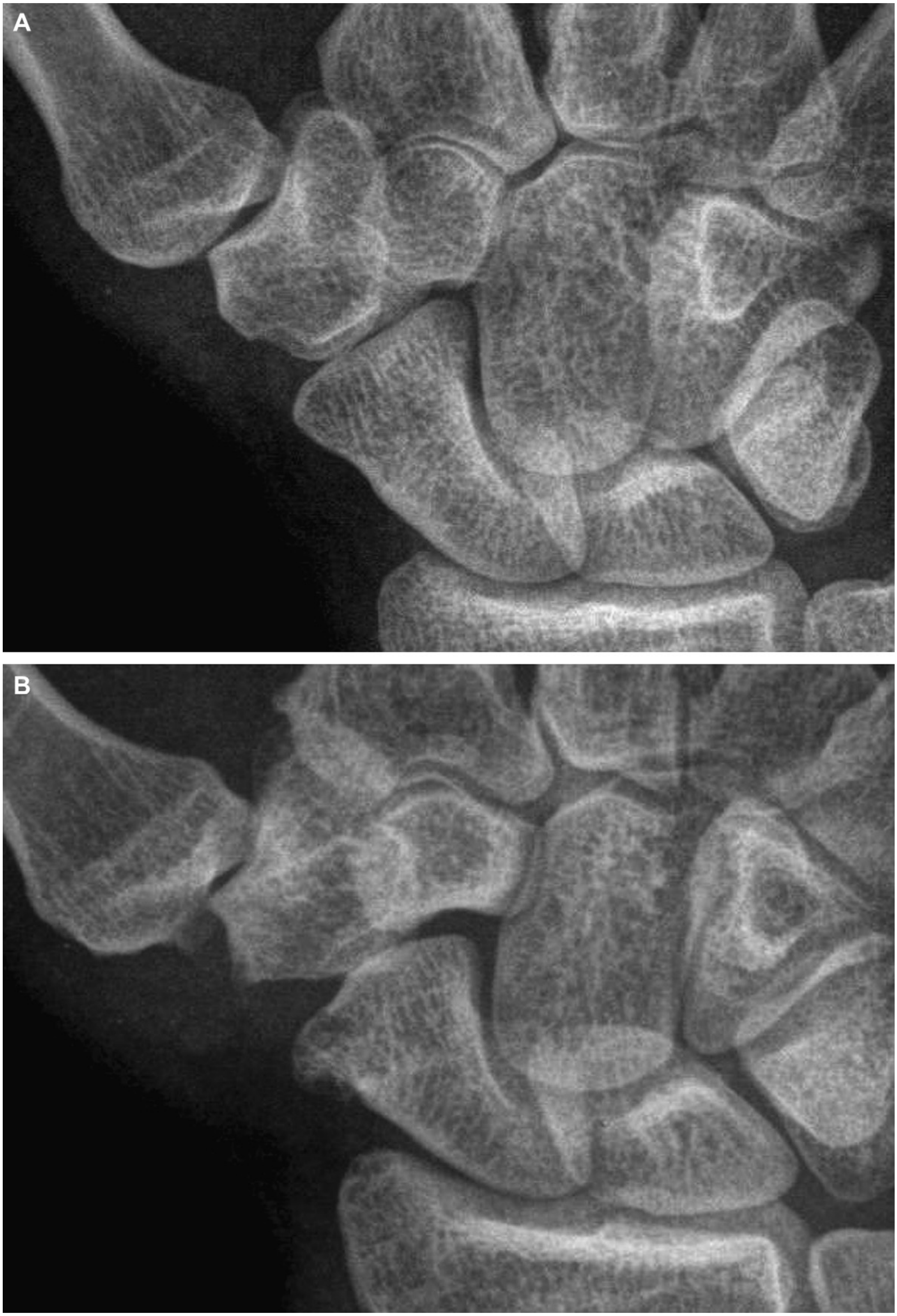

A
B

Fig. 8. Hand trapezionavicular joint: (A) normal, (B) marginal osteophyte, and (C) joint space narrowing.


A
B

Fig. 9. Hand malalignment of the (A) DIP, (B) PIP, and (C) (subluxation) trapeziometacarpal joint.

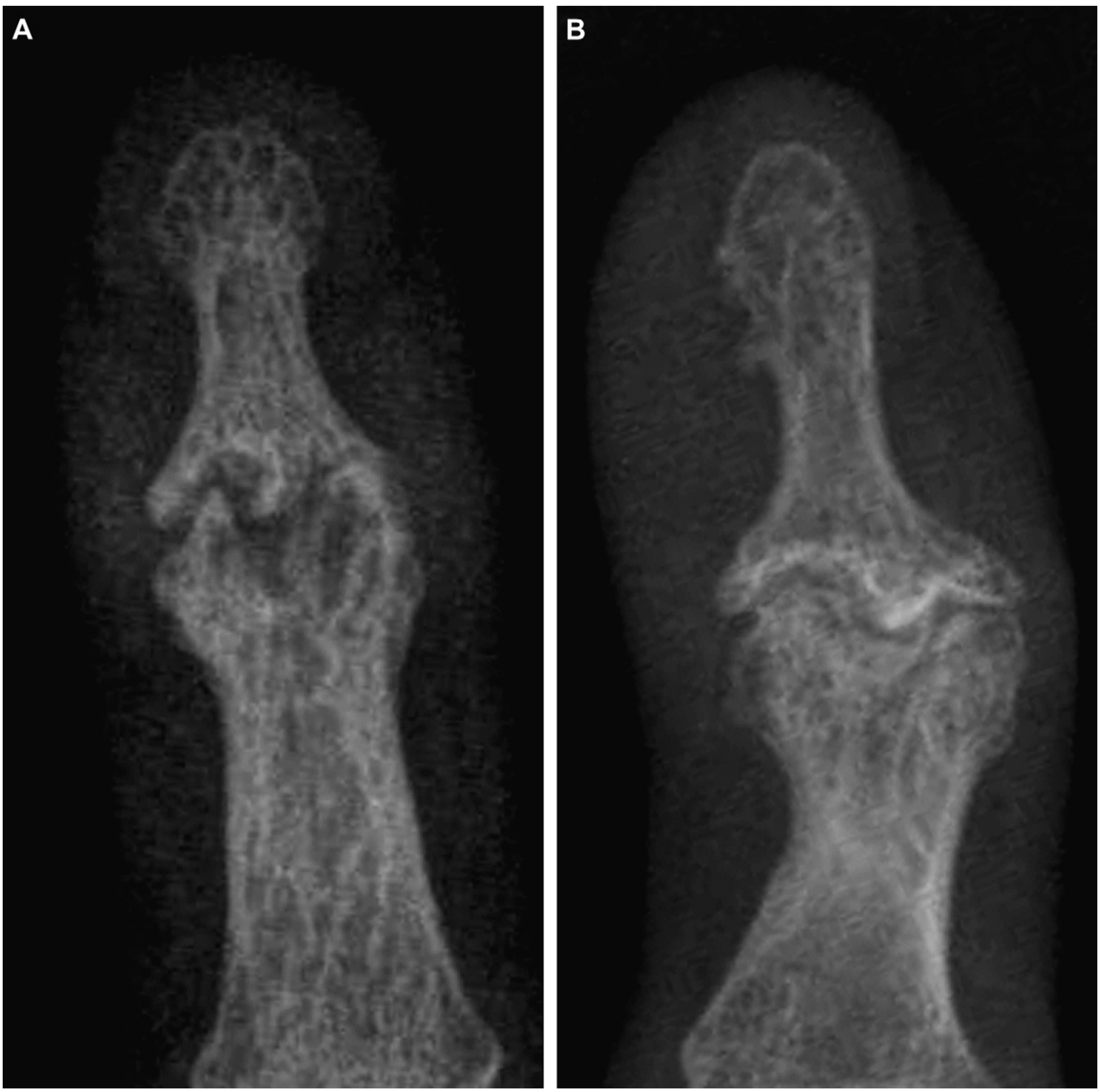

A
B

Fig. 10. Hand DIP: (A) erosion, (B) central erosion, (C) pseudowidening, and (D) subchondral sclerosis.


A
B

Fig. 11. Hand PIP: (A) erosion, (B) subchondral cyst, and (C) subchondral sclerosis.


A
B

Fig. 12. Hand trapeziometacarpal joint: (A) erosion, (B) subchondral cyst, and (C) subchondral sclerosis.


B
A

Fig. 13. Hip: (A) grade 0 normal, (B) grade 1 superior acetabular osteophyte, (C) grade 2 superior acetabular osteophyte, and (D) grade 3 superior acetabular osteophyte.


B
A

Fig. 14. Hip: (A) grade 0 normal, (B) grade 1 superior femoral osteophyte, (C) grade 2 superior femoral osteophyte, and (D) grade 3 superior femoral osteophyte.


B
A

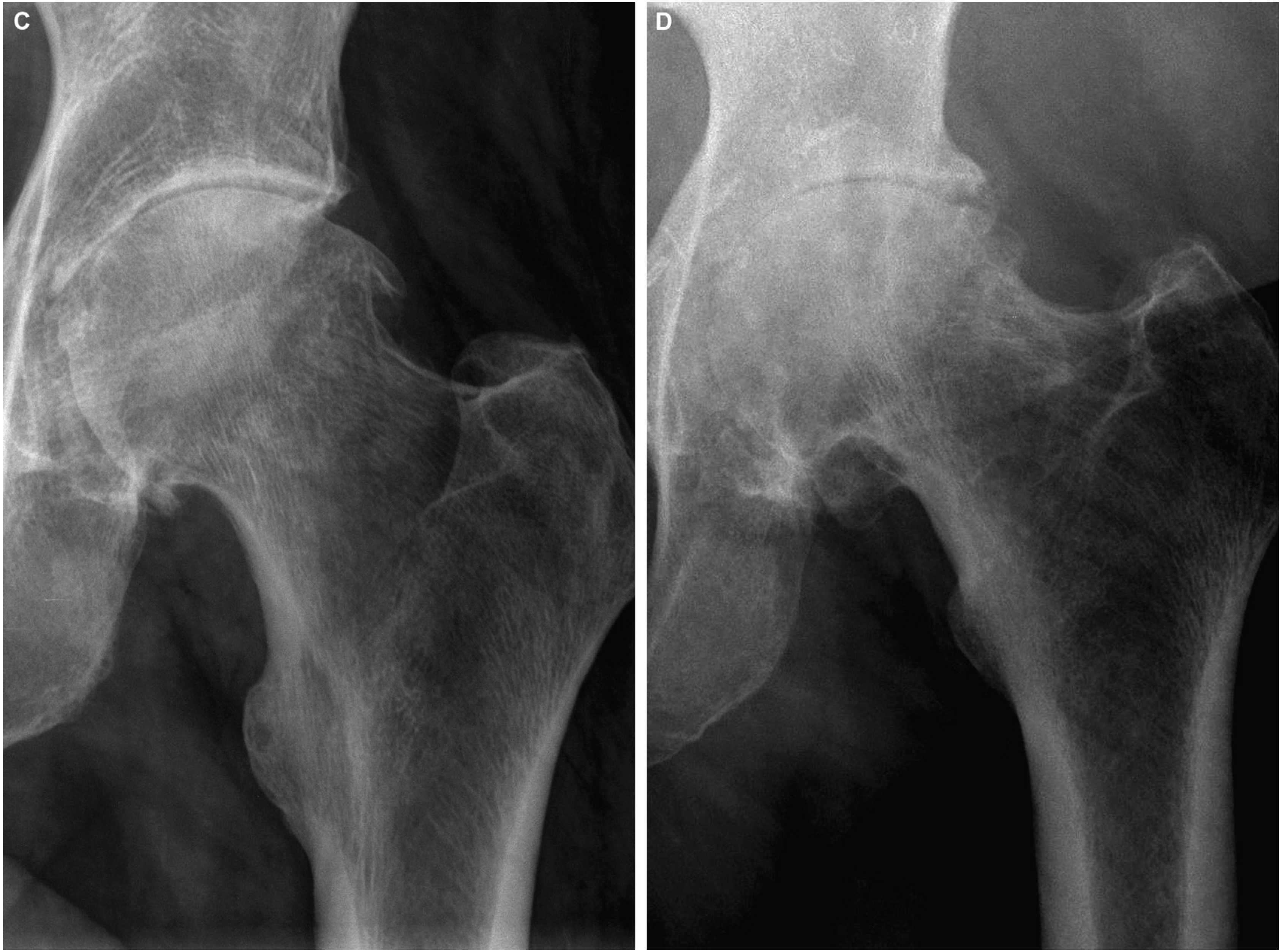


Fig. 15. Hip: (A) grade 0 normal, (B) grade 1 inferior femoral osteophyte, (C) grade 2 inferior femoral osteophyte, and (D) grade 3 inferior femoral osteophyte.


B
A

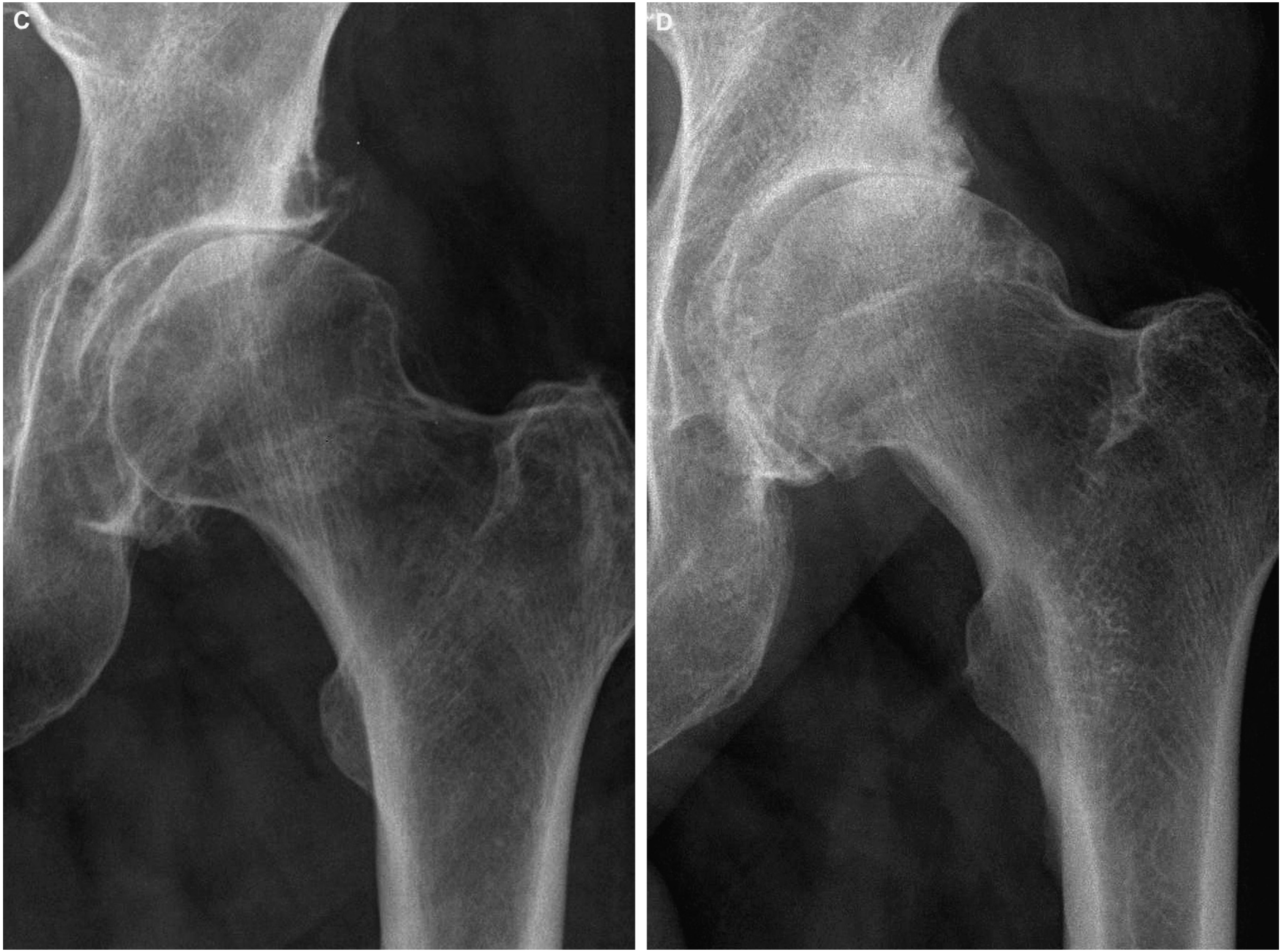


Fig. 16. Hip: (A) grade 0 normal, (B) grade 1 superior joint space narrowing, (C) grade 2 superior joint space narrowing, and (D) grade 3 superior joint space narrowing.


B
A

Fig. 17. Hip: (A) grade 0 normal, (B) grade 1 medial joint space narrowing, (C) grade 2 medial joint space narrowing, and (D) grade 3 medial joint space narrowing.


B
A

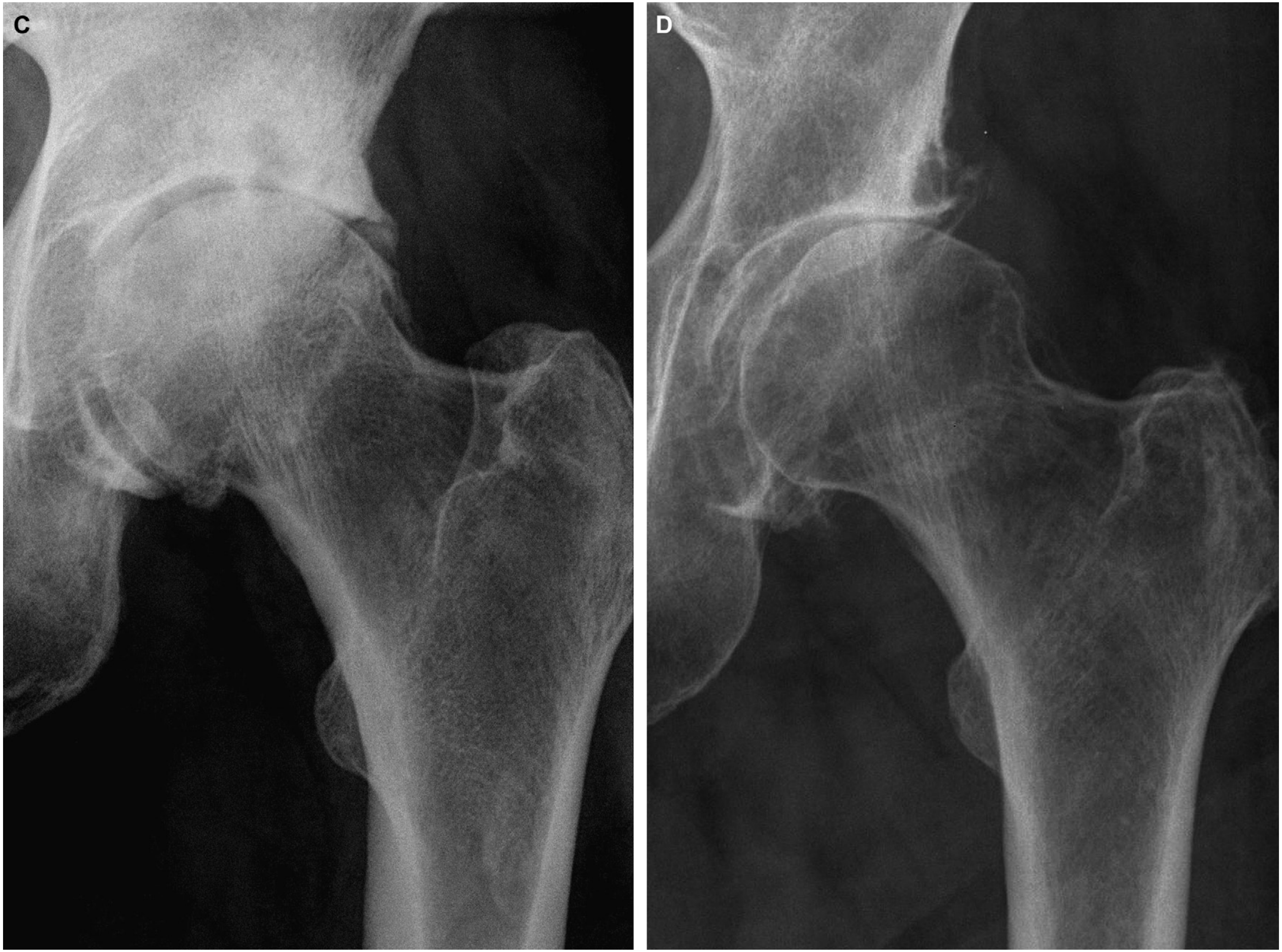


Fig. 18. Hip: (A) normal, (B) inferior acetabular osteophyte, (C) acetabular subchondral cyst, and (D) acetabular subchondral sclerosis.


B
A

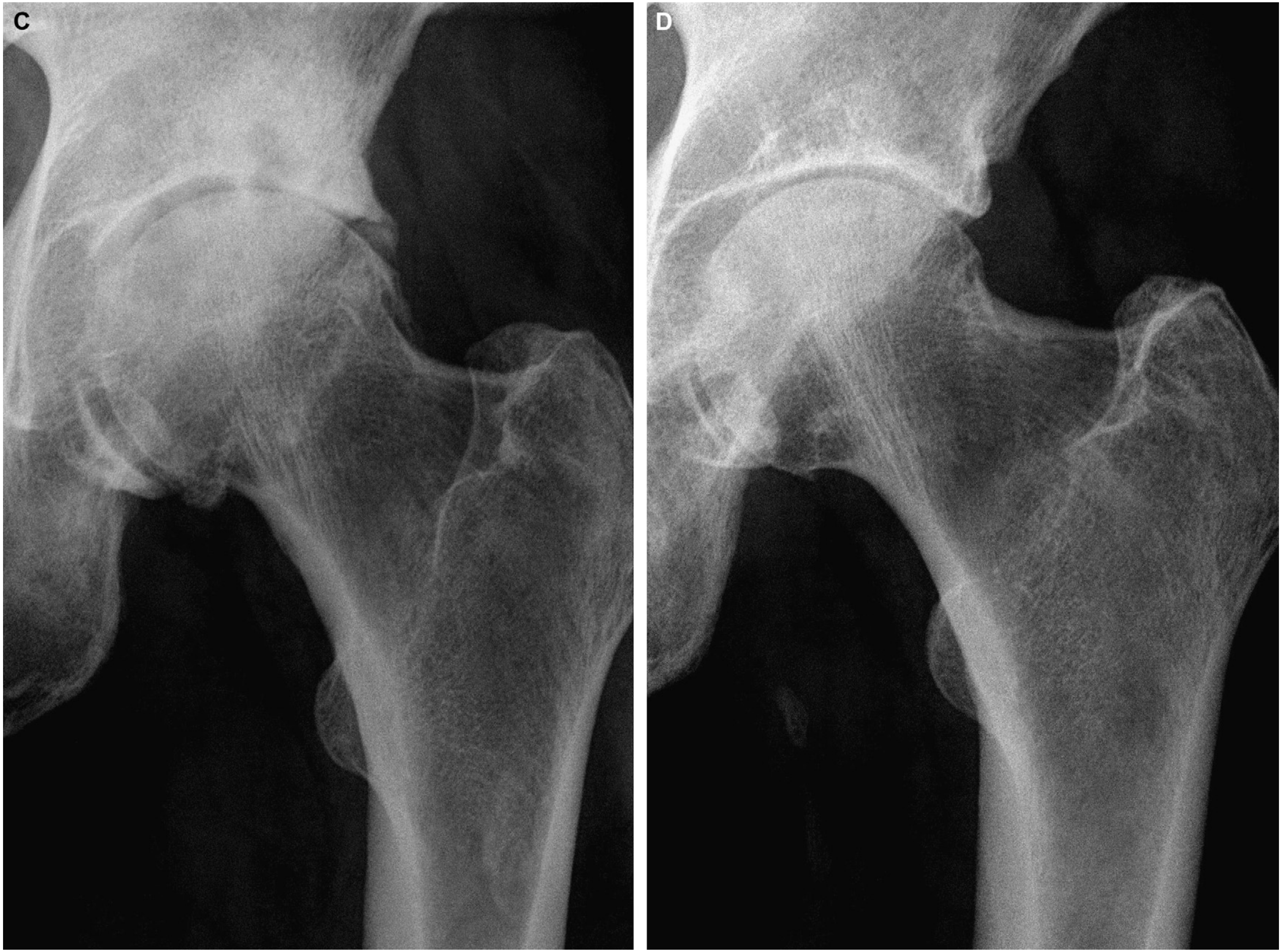


Fig. 19. Hip: (A) normal, (B) subchondral femoral sclerosis, (C) flattening of the femoral head, and (D) thickening of the femoral medial calcar (buttressing).


B
A

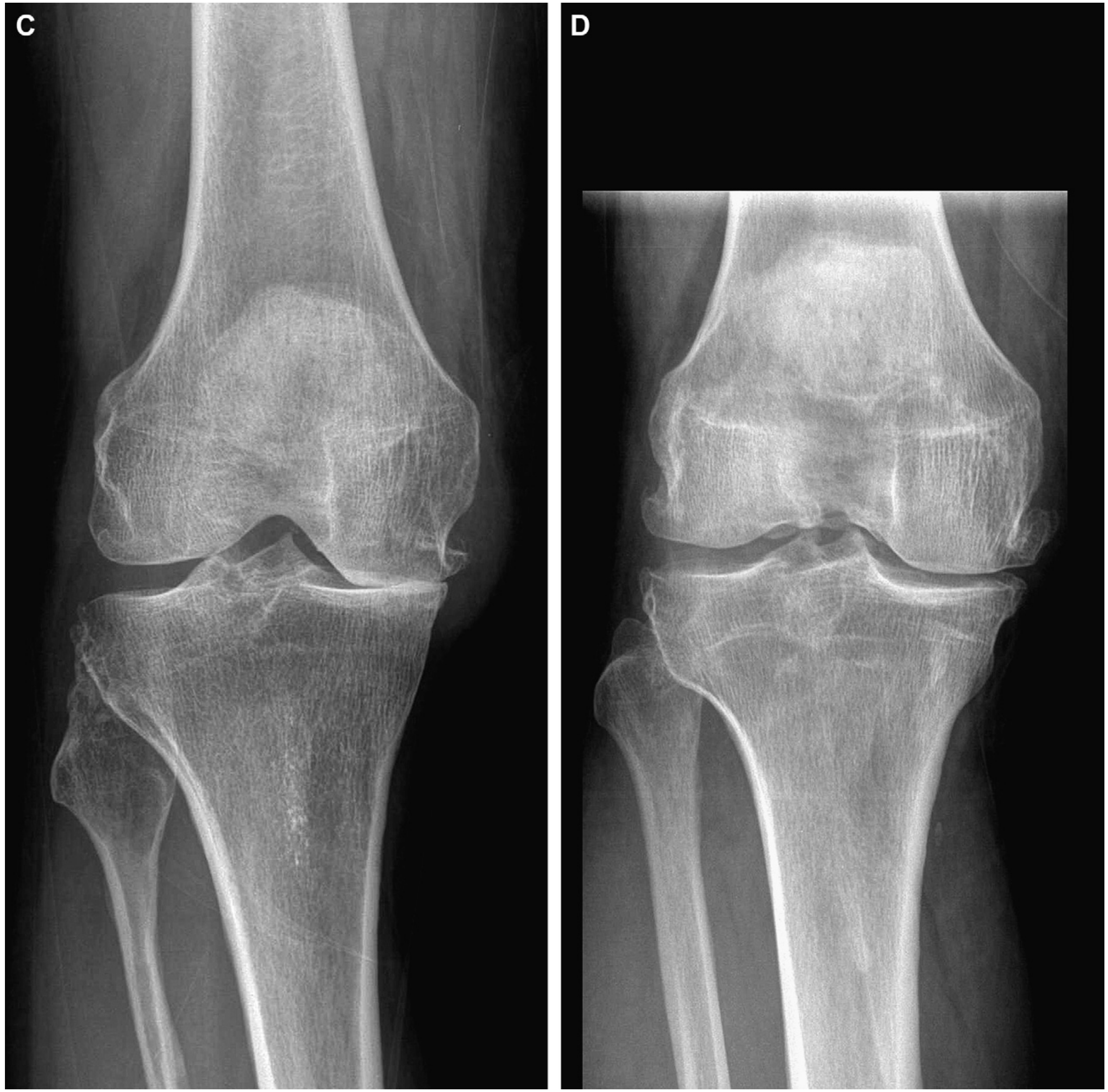


Fig. 20. Knee: (A) grade 0 normal, (B) grade 1 medial femoral osteophyte, (C) grade 2 medial femoral osteophyte, and (D) grade 3 medial femoral osteophyte.


B
A

Fig. 21. Knee: (A) grade 0 normal, (B) grade 1 medial tibial osteophyte, (C) grade 2 medial tibial osteophyte, and (D) grade 3 medial tibial osteophyte.


B
A

Fig. 22. Knee: (A) grade 0 normal, (B) grade 1 lateral femoral osteophyte, (C) grade 2 lateral femoral osteophyte, and (D) grade 3 lateral femoral osteophyte.


B
A

Fig. 23. Knee (A) grade 0 normal, (B) grade 1 lateral tibial osteophyte, (C) grade 2 lateral tibial osteophyte, and (D) grade 3 lateral tibial osteophyte.


B
A

Fig. 24. Knee: (A) grade 0 normal, (B) grade 1 medial tibiofemoral narrowing, (C) grade 2 medial tibiofemoral narrowing, and (D) grade 3 medial tibiofemoral narrowing.


B
A

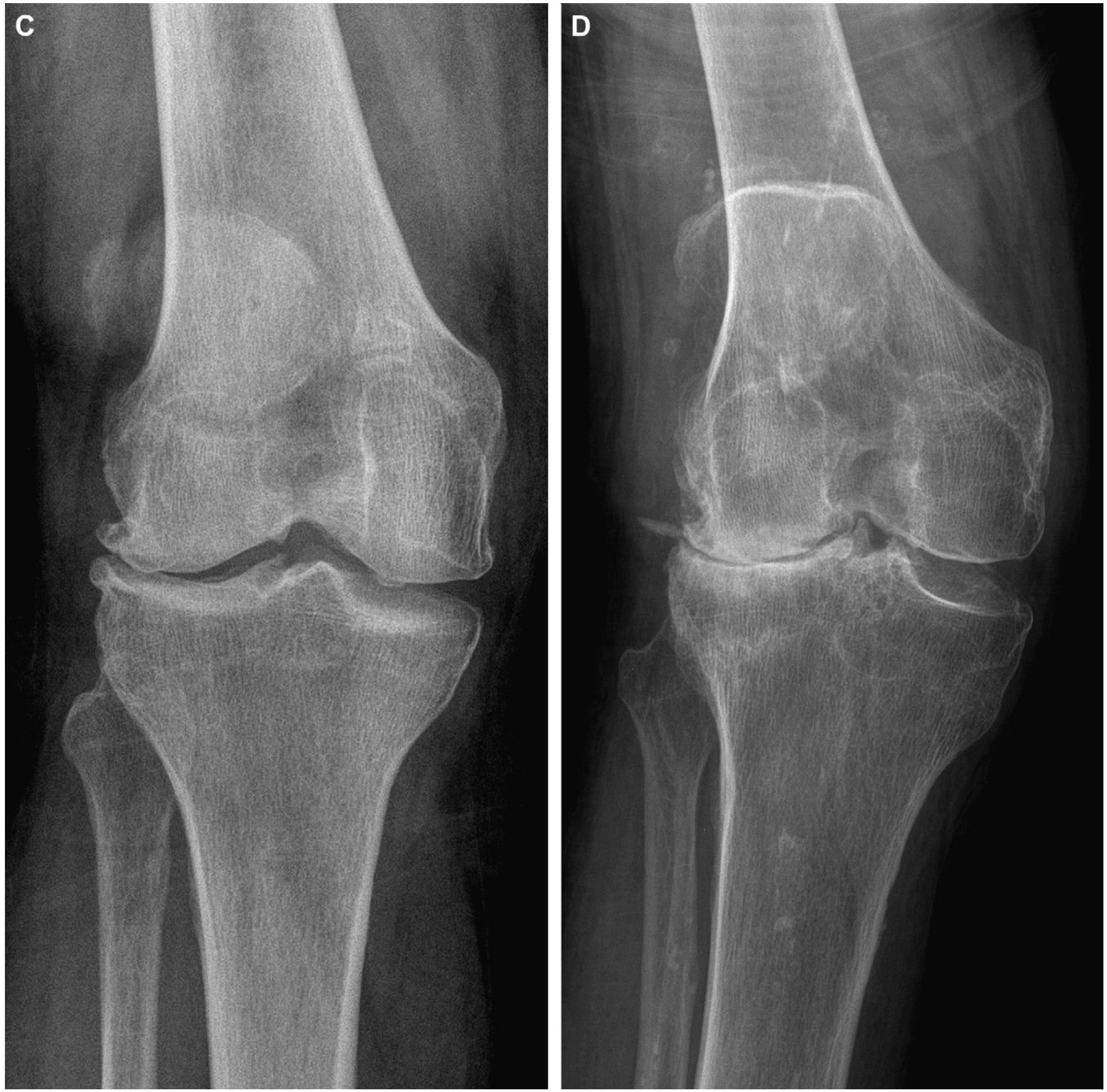


Fig. 25. Knee: (A) grade 0 normal, (B) grade 1 lateral tibiofemoral narrowing, (C) grade 3 lateral tibiofemoral narrowing, and (D) grade 3 lateral tibiofemoral narrowing.


B
A

Fig. 26. Knee: (A) normal, (B) medial tibial attrition, (C) medial tibial sclerosis, and (D) lateral femoral sclerosis.

Discussion

Radiographic images of the hand, hip and knee were selected from the Stanford University PACS to produce a radiographic atlas of changes of OA. The atlas is to be used as a guide in the evaluation of individual radiographic features of OA. The techniques of image collection that can be used with this atlas are available at most medical facilities. Images displayed in this atlas are purposely large for ready comparisons. In addition, the images are stored electronically and can be downloaded in order to better examine detail.

There has been no attempt to reproduce all radiographic changes of OA. For example, the patellofemoral joint has not been reviewed. The prior OARSI atlas included the patellofemoral joint[10]. The prior views of the patellofemoral joint have been examined by an axial (skyline, sunrise, sunset) view. Better joint space detail can be determined by a medial–lateral X-ray beam with careful alignment[14,15].

Other radiographic features were not reproduced due to lack of specificity of these findings for OA. Although present early and common in knee OA, sharpening of the tibial spines (attachments of the anterior and posterior cruciate ligaments to the tibia), the specificity to OA or its progression is suspect[7]. Similarly, superior acetabular osteophytes are difficult to interpret as there is considerable variation in size of the superior acetabular lip[16].

Individual images of some atlases may be superior to others. Some individual findings may be superior in different published atlases and several comparisons of atlases have been performed[16–19]. However, availability of the atlas for use is critically important, stimulating the publication of this atlas. Availability of the images in electronic format is also crucial for comparison at multiple sites and with images acquired in a digital format.

Several additional methods are available for examining OA and its progression. Semi-quantitative radiographic imaging and magnetic radiographic imaging were carefully reviewed in a combined workshop of the National Institutes of Health (NIH), Outcome Measures in Rheumatology Clinical Trials (OMERACT), and OARSI[20]. There has been no attempt to create a global score, as the Kellgren–Lawrence method of evaluation of radiographs continues to be useful[3]. A line drawing atlas has been developed and may have value in prospective trials[21].

This atlas will be useful to clinicians and investigators for determining the presence and severity of individual radiographic features of OA in a standardized semi-quantitative methodology. This has relevance to the clinical setting, cross-sectional studies and longitudinal studies. Widespread availability of the atlas and electronic images should facilitate multi-center studies and allow comparison with newer radiographs acquired in a digital format.

References

1. Copeman WS. A Short History of the Gout and the Other Rheumatic Diseases. Berkeley: University of California Press 1964. p. 185.
2. Goldthwaite JE. The differential diagnosis and treatment of the so-called rheumatoid diseases. Boston Med Surg J 1904;151:529–34.
3. Kellgren JH, Lawrence JS. Radiological assessment of osteoarthritis. Ann Rheum Dis 1957;16:494–501.
4. Kellgren JH. The epidemiology of chronic rheumatism, Atlas of Standard Radiographs of Arthritis. 2nd edn. Philadelphia, PA: F.A. Davis Co. 1963. pp. 1–13.
5. Spector T, Cooper C, Cushnighan J, Hart DJ, Dieppe PA. A Radiographic Atlas of Knee Osteoarthritis. London: Springer Verlag 1992. pp. 1–15.
6. Spector TD, Cooper C. Radiographic assessment of osteoarthritis in population studies: whither Kellgren and Lawrence? Osteoarthritis Cartilage 1993;1:203–6.
7. 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.
8. Kallman DA, Wigley FM, Scott WW, Hochberg MC, Tobin JD. New radiographic grading scales of osteoarthritis of the hand. Arthritis Rheum 1989;32: 1584–91.
9. 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.
10. Altman RD, Hochberg M, Murphy WA Jr, Wolfe F, Lequesne M. Atlas of individual radiographic features in osteoarthritis. Osteoarthritis Cartilage 1995 Sep; 3(Suppl A):3–70.
11. Verbruggen G, Veys EM. Numerical scoring systems for the anatomic evolution of osteoarthritis of the finger joints. Arthritis Rheum 1996;39:308–20.
12. Nagaosa Y, Mateus M, Hassan B, Lanyon P, Doherty M. Development of a logically devised line drawing atlas for grading of knee osteoarthritis. Ann Rheum Dis 2000 Aug;59(8):587–95.
13. Croft P. An introduction to the atlas of standard radiographs of arthritis. Rheumatology (Oxford) 2005; 44(Suppl 4):iv42.
14. Jones AC, Ledingham J, McAlindon T, Regan M, Hart D, MacMillan PJ, *et al.* Radiographic assessment of patellofemoral osteoarthritis. Ann Rheum Dis 1993;52:655–8.
15. Szebenoi B, Dieppe PA, Buckland-Wright JC. Radioanatomic position for the lateral radiographic view of the human patello-femoral joint. Surg Radiol Anat 1995;17:79–81.
16. Hirsch R, Fernandes RJ, Pillemer SR, Hochberg MC, Lane NE, Altman RD, *et al.* Hip osteoarthritis prevalence estimates by three radiographic scoring systems. Arthritis Rheum 1998;41(2):361–8.
17. Lane NE, Kremer LB. Related articles, radiographic indices for osteoarthritis. Rheum Dis Clin North Am 1995;21(2):379–94.
18. Lane NE, Nevitt MC, Genant HK, Hochberg MC. Related articles, reliability of new indices of radiographic osteoarthritis of the hand and hip and lumbar disc degeneration. J Rheumatol 1993 Nov; 20(11):1911–8.
19. Kessler S, Dieppe P, Fuchs J, Sturmer T, Gunther KP. Assessing the prevalence of hand osteoarthritis in epidemiological studies. The reliability of a radiological hand scale. Ann Rheum Dis 2000;59(4):289–92.
20. National Institutes of Health (NIH), Outcome Measures in Rheumatology Clinical Trials (OMERACT), Osteoarthritis Research Society International (OARSI). Workshop for consensus in imaging of knee osteoarthritis, Bethesda, Maryland, 6–7 December 2002. Osteoarthritis Cartilage 2006;14 (Suppl A):A1–A121.
21. Wilkinson CE, Carr AJ, Doherty M. Does increasing the grades of the knee osteoarthritis line drawing atlas alter its clinimetric properties? Ann Rheum Dis 2005;64(10):1467–73.