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MUSCULOSKELETAL RADIOLOGY

Radiographic scoring methods in rheumatoid arthritis and psoriatic arthritis

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Abstract

Structural changes of bone and cartilage are the hallmarks of rheumatoid arthritis (RA) and psoriatic arthritis (PsA). Radiography can help in making diagnosis and in differentiating PsA and RA from other articular diseases. Radiography is still considered the preferred imaging method to assess disease progression, reflecting cumulative damage over time. The presence of bone erosions in RA is as an indicator of irreversible articular damage. Radiographic features of PsA are characteristic and differ from those observed in RA, especially in the distribution of affected joints and in the presence of destructive changes and bone proliferation at the same time. Semiquantitative scoring methods are designed to measure the degree of radiographically detectable joint damage and of changes over time. Several radiographic scoring methods that had been developed originally for RA have been adopted for the use in PsA. This review discusses the use of conventional radiography for diagnosing and detecting early structural changes in RA and PsA and providing a historical overview of commonly used scoring methods.

Keywords Rheumatoid arthritis · Psoriatic arthritis · Radiography · Radiographic scoring methods

Introduction

Rheumatoid arthritis (RA) and psoriatic arthritis (PsA) are the most prevalent inflammatory arthritis leading to structural damage, affecting about 0.46% and 0.42%, respectively, of the population in Western countries [1, 2].

Since its introduction in clinical practice, radiographs of the hands and feet have been used to diagnose and to monitor the disease course of RA and PsA [3–5]. The presence of radiographic bone erosions is fundamental for RA classification, according also to the more recent classification criteria (American College of Rheumatology (ACR)/European League Against Rheumatism (EULAR) 2010 classification criteria) [6], while for PsA, in the Classification Criteria for Psoriatic Arthritis (CASPAR), radiography still remains one of the main criteria for classifying PsA [7].

Assessing radiographic abnormalities is one of the most powerful means available to the clinical investigator for determining the effects of RA and has been used as a relatively objective marker in clinical trials for evaluating treatment response [8]. The efficacy of disease-modifying antirheumatic drugs (DMARDs) traditionally has been registered as their ability to slow down radiographic damage [9]. These points are outlined in EULAR recommendations and models for management of early arthritis, and prognostic markers for persistent arthritis have been established [10]. Therefore, the current "gold standard" for radiological evaluation of disease progression in RA is the assessment of disease progression with plain radiographs.

Many researches have shown that in RA, joint damage occurs within the first 2 years after symptom appearance [11–14]. It has been demonstrated that within 4 months of

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disease onset, 34.9% of patients have erosions evident on X-ray, and 54.9% were erosive at the 12th-month follow-up [15].

With the increasing use of DMARDs and biological DMARDs (bDMARDs), early diagnosis is now of paramount importance, and disease progression has to be assessed regularly to monitor efficacy of the treatment [16–18]. In addition, the identification of individual RA patients at high risk of rapid radiographic progression is critical to making appropriate treatment choices [19]. In these patients, effective therapy can reduce the odds of progression [20, 21], and both early and intensive treatment can alter the course of the disease by slowing the rate of radiographic progression [22, 23].

Regarding PsA, at the current state of the art, there is evidence supporting the concept of PsA being a distinct disease from RA clinically [24], radiologically, and pathologically [25]. PsA develops in about 30% of patients with psoriasis [26]. It is a heterogeneous disease, and there have been multiple attempts to subgroup patients according to their clinical presentation. As in RA, structural damage is the consequence of inflammation that can destroy cartilage and bone, leading to functional impairment and disability [27]. In PsA, the presence of radiological damage has been enhanced in 47% of patients within the first 2 years, and as in RA, the use of bDMARDs has been capable of inhibiting progression of structural damage in several randomized controlled trials [28].

Rheumatoid arthritis and psoriatic arthritis radiographic comparison

As mentioned above, despite certain similarities, the two inflammatory joint diseases show considerably different features. Whereas RA primarily results in bone and cartilage resorption, PsA combines destructive elements with anabolic bone responses.

RA is the prototype of a destructive arthritis. In RA, usually, the metacarpophalangeal (MCP) joints, the proximal interphalangeal (PIP) joints, all wrist compartments, and the metatarsophalangeal (MTP) joints are the most commonly involved sites. In addition, joints in the midfoot and hindfoot, knees, glenohumeral joint at the shoulder, the elbow, and cervical spine can also be affected [29, 30].

In PsA, the distribution of affected joints is more often asymmetric and oligoarticular than in RA. The distal interphalangeal (DIP) joints are frequently and early involved, while in RA involvement of the DIP joints, in general, is rare and more often a feature of the late disease. In PsA, DIP joints, large joints of the lower extremities, the axial spine, and sacroiliac joints are commonly affected; the MCP and MTP joints and wrist can be involved as well.

The first radiographic changes observed in RA are soft tissue swelling and juxta-articular osteopenia as bone density is reduced adjacent to the joint as a result of local synovial inflammation [31]. The bone may appear less dense around the articular surfaces, although this is not necessarily a specific radiographic sign of RA [32]. Juxta-articular osteopenia is uncommon in PsA and, when present, is a sign of poor prognosis [33]. The lack of osteoporosis, even in patients with severe destructive arthritis, is a reliable sign in the differentiation of PsA from RA, although the presence of osteoporosis does not exclude PsA.

The erosions in RA tend to be periarticular and are often described as marginal erosions as they are close to the joint and reflect the direct mechanical action of the hypertrophied synovium and granulation tissue. The inflamed synovium slowly invades adjacent structures, causing damage and destruction to the cartilage and bone, leading to joint space narrowing (JSN) and bone erosion that can be seen on radiographs. The JSN in RA tends to be uniform and concentric, reflecting the generalized nature of the synovial inflammation within the joint.

In PsA, the early erosive changes predominate in the marginal articular areas, resembling "mouse ears." Erosions progress over time and may affect the central area. Later, the bone appears as if it is being gnawed away, the bone surface becomes frequently irregular or jagged but still sharply delineated, whereas peripherally new bone formation may create an unclear ill-defined outline. The ends of the bones can become pointed, resulting in the image of "pencil in cup" or "cup-and-saucer" appearance. DIP involvement and the asymmetric distribution also can help differentiate PsA from RA. The uniform reduction of joint space is the radiographic expression of cartilage loss and could be seen at any involved joint, more typically at the DIP and PIP joints, and more infrequently at the MCP joints.

The proliferation of erosions may form irregular excrescences with a spiculated appearance. Along the shaft is possible to see periostitis, cottony cushion initially that may form solid new bone simulating enlargement of the phalangeal diaphysis. Periostitis in the metaphyses and diaphyses with periosteal bone neoapposition is a common phenomenon and may thicken an entire phalanx. It can occur early in the course of the disease before other features have developed. Condensation of bone on the periosteal and endosteal surfaces accompanied by thickening of the trabeculae can cause radiodensity of an entire phalanx ("ivory phalanx"), another manifestation of bone proliferation. Intraarticular osseous fusion of joints predominantly affects DIP and PIP joints. Table 1 summarizes the main radiological differences between RA and PsA.

Table 1 Radiological features that distinguish between rheumatoid arthritis and psoriatic arthritis

Radiographic features	Rheumatoid arthritis	Psoriatic arthritis
Number of erosions	+++	+
Severity of erosions (size)	+++	++
Erosion distribution	Preponderance for radial sites	Evenly distributed
DIP erosions	–	+++
Number of osteophytes	+	+++
Severity of osteophytes (size)	+	+++
Bone proliferation	+	+++
Inflammatory changes		
Synovitis	+++	++
Tenosynovitis	+++	++
Enthesitis	+	+++
Dactylitis	–	+++
Mutilans (erosions on both sides of joints)	–	+

DIPs distal interphalangeal joints

Radiographic scoring methods in rheumatoid arthritis

As discussed above, in RA all the synovial joints can be affected but only some joints in a scoring method can be included. Small joints are the most frequently affected, and Scott et al. [34] showed that they could give a good representation of the global progression of damage. Another advantage that is given from the use of hand and wrist X-rays is that erosions are easier detectable in small joints than in the large ones. X-rays of hands and wrists have been used for the creation of the previous scoring systems for RA. Several authors showed in inception cohort studies of patients with early RA that MTP are eroded earlier and show more damage [35, 36]. These studies indicate the importance to include feet in a scoring method assessing RA radiographic damage.

The scoring systems that have been designed to evaluate radiographic changes in RA can be divided into two main groups: global and detailed. Global scoring systems assign one score to the entire joint, taking into account all the abnormalities seen, whereas detailed systems assign scores on at least two separate variables for each joint evaluated [37, 38]. Radiographic scores, such as the Larsen and Sharp scores [39] and their modifications [40, 41], are the standard methods for determining joint damage and its progression [42, 43]. Table 2 summarizes the main RA features included in the different radiographic scoring methods described below.

Sharp scoring method (1971)

In 1971, Sharp and colleagues proposed a detailed scoring method for the hands and wrists that is divided into two scores, one for erosions and the other for JSN [44]. The

Table 2 Features of rheumatoid arthritis included in the Sharp and in the Larsen scoring systems and further modifications

Scoring method	Erosion	JSN	Osteoporosis	Soft tissue swelling	Alignment/(sub)luxation	Ankylosis	Cyst
Sharp (1971)	+	+	–	–	–	+	+
Larsen (1977)	+	+	+	+	–	–	–
Modified Sharp (1985)	+	+	–	–	–	+	–
Kaye (1987)	+	+	–	–	+	+	+
Van der Heijde/Sharp (1989)	+	+	–	–	+	+	–
Modified Larsen (1995)	+	+	–	–	–	–	–
Genant (1998)	+	+	–	–	+	+	–
Ratingen score (1998)	+	+	–	–	–	–	–
SENS (1999)	+	+	–	–	+	+	–

JSN joint space narrowing, *SENS* simplified erosion narrowing score

+ = included in the scoring system; – = not included in the scoring system

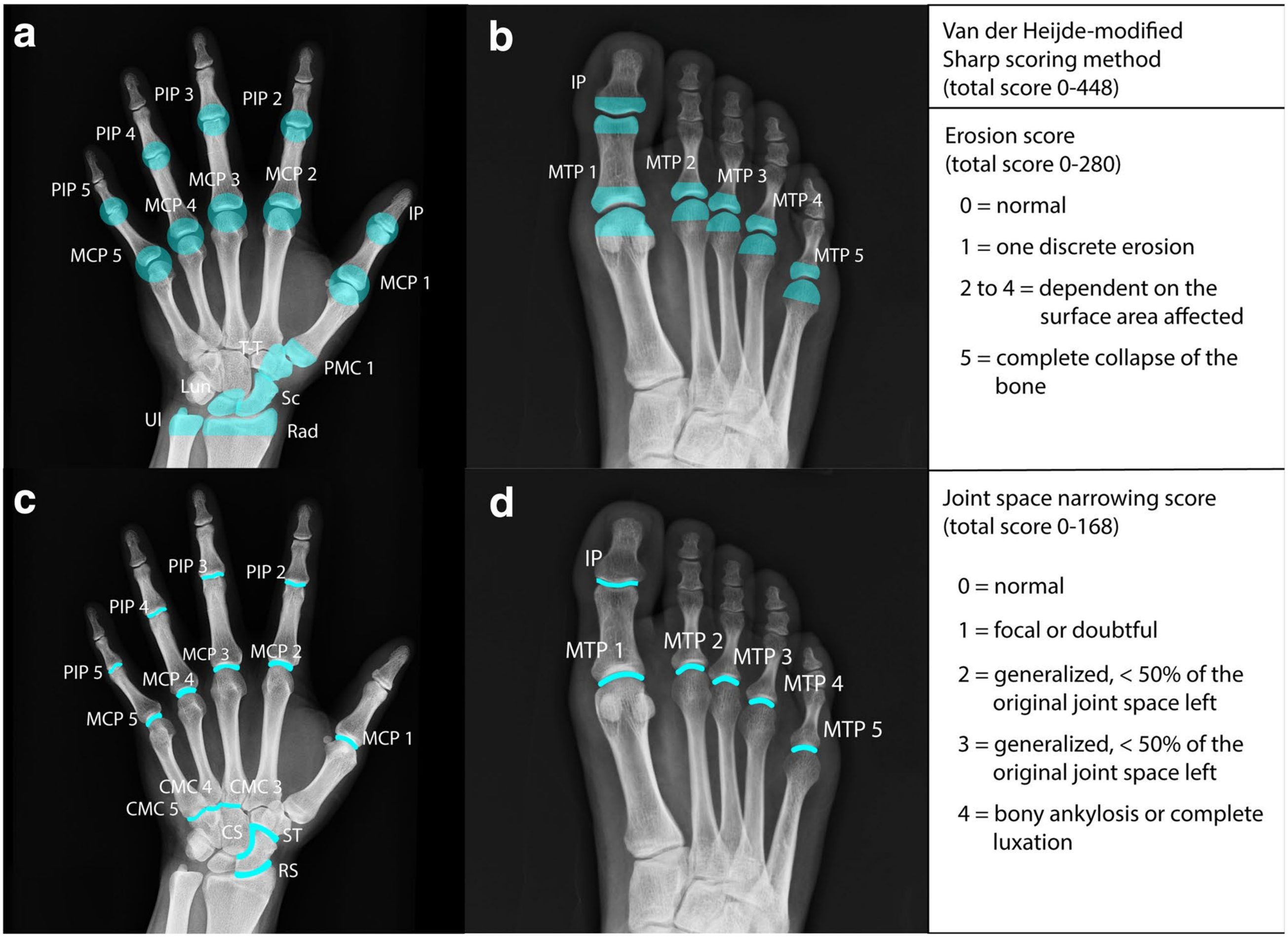


Fig. 1 van der Heijde-modified Sharp scoring method representation with figure and grading. **a** Joints selected in each hand for erosions: 4 PIP, 5 MCP, IP, scaphoid, lunate, distal ulna, distal radius, the two components of the CMC joints of the thumb are evaluated separately (PMC and trapezium–trapezoid). The maximum score for both hands is 160. **b** Joints selected in each foot for erosions: the proximal and distal articular components of the MTP and IP are evaluated separately resulting in a 0–10 score for each joint. The maximum score considering both feet is 120. **c** Joints selected in the hand: the CMC 3, CMC 4, CMC 5 are scored separately, the IP is not included, only the radio-scaphoid part of the radiocarpal joint is evaluated. The maximum score for both hands is 120. **d** Joints selected for JSN in each foot. The maximum score for both feet is 48. *CMC* carpometacarpal, *CS* capitate–scaphoid, *IP* interphalangeal joint, *Lun* lunate, *MCP* metacarpophalangeal joint, *MTP* metatarsophalangeal joint, *PIP* proximal interphalangeal joint, *PMC* proximal metacarpal, *Rad* radius, *RC* radio-scaphoid, *Sc* scaphoid, *ST* scaphoid-trapezium, *T–T* trapezium–trapezoid, *Ul* ulna

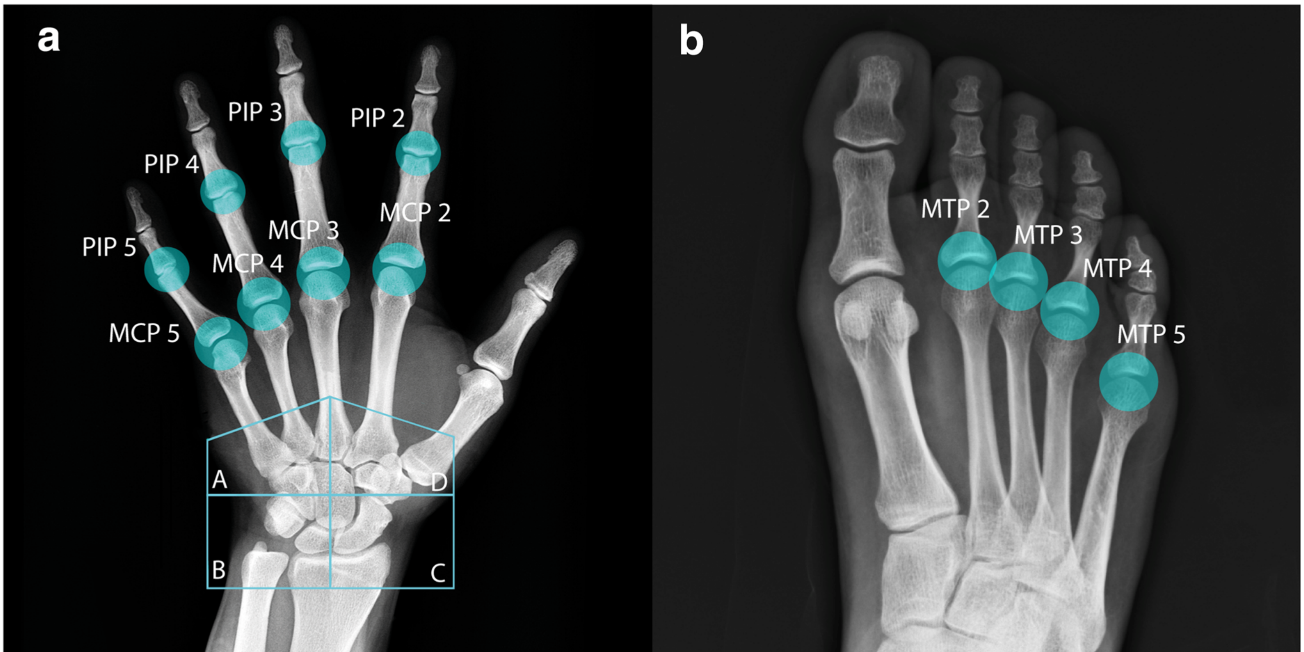
number and selection of joints in the Sharp score evolved in the years, and a modification proposed in 1985 of the Sharp method [45] is now considered the standard for the method.

Larsen scoring method (1977)

The Larsen method was developed by Larsen et al. [39]. It has been modified several times by the authors [46]. It is a 6-point global scoring of joints, based primarily on erosive damage. However, grade 1 can be based on soft tissue joint swelling only, which is not a real sign of structural damage and is also difficult to assess reliably. The method can be applied to many joints but is primarily used for the hands and wrists and also for the feet. Larsen produced a set of standard reference films to compare the grading of the joints.

Modified Sharp method (1985)

Sharp et al. [45] further defined which joints to score based on the frequency of RA involvement. They decreased the number of joints of each hand/wrist to 17 for erosions and 18 for JSN. Therefore, the final Sharp method includes two scores, one for erosions and the other for JSN. Erosions are counted when discrete, and surface erosions are scored according to the surface area involved [45].



Modified Larsen Method (1995) (total score 0-160)

Grade 0	Intact bony outlines and normal joint space.
Grade 1	Erosions less than 1 mm in diameter or joint space narrowing
Grade 2	One or several small erosions (diameter more than 1 mm)
Grade 3	Marked erosions
Grade 4	Severe erosions. There is usually no joint space left: the original bony outlines are partly preserved.
Grade 5	Mutilating changes: the original bony outlines have been destroyed.

Fig. 2 Modified Larsen method represented with figure and grading. **a** Joints evaluated in each hand: 4 PIP, 4 MCP, the wrist is subdivided into four quadrants that are scored separately. The maximum score for both hands is 120. **b** Joints selected in each foot: in this method, the MTP and the IP of the big toe are not considered. The maximum score considering both feet is 40. *IP* interphalangeal joint, *MCP* metacarpophalangeal joint, *MTP* metatarsophalangeal joint, *PIP* proximal interphalangeal joint

Kaye scoring method (1987)

Kaye et al. [47] combined and modified the methods described by Genant [48] and Sharp et al. [45]. In this method, malalignment is scored in addition to erosions and JSN. Some of the joints that were evaluated in the Genant and Sharp methods were excluded and/or combined. Sites were considered inevaluable if they were missing from the radiograph or if they had flexion deformity. Inevaluable joints were not scored and were therefore excluded from analysis.

van der Heijde-modified Sharp scoring method (1989)

The most noticeable difference in the van der Heijde modification is the addition of the joints of the forefoot. Another change was the decreased number of joints in each hand/wrist scored [49]. Some sites (triquetrum for erosions and lunate triquetrum, first IP joint and radioulnar joint for JSN) were difficult to assess in a reliable fashion, mainly due to superimposition, and often were difficult to score leading to interobserver disagreement. The Sharp/van der Heijde scoring system is currently the most widely used radiographic scoring system in clinical trials in RA including biological agents [16–20, 22, 23, 50, 51] (Fig. 1).

Modified Larsen method (1995)

A modification of the original method [39] to evaluate radiographs in long-term studies was proposed later by Larsen et al. [46]. It incorporates several changes in the original method: scores for the thumbs and first MTP were

Table 3 Characteristics of the most used scoring methods for rheumatoid arthritis

	van der Heijde modification of the Sharp method (1989)	Genant modification of the Sharp method (1998)	Modified Larsen method (1995)
Type of scoring method	Detailed	Detailed	Global
Description of scoring system	Erosion is assessed in 16 joints for each hand and wrist, and six joints for each foot. One point is scored if erosions are discrete, rising to two, three, four, or five depending on the amount of surface area affected. JSN is scored as follows: 0 = normal; 1 = focal or doubtful; 2 = generalized, less than 50% of the original joint space; 3 = generalized, more than 50% of the original joint space or subluxation; 4 = bony ankylosis or complete luxation	Erosion is scored according to an eight-point scale with 0.5 increments, where 0 = normal; 0+ = questionable or subtle change; 1 = mild; 1+ = mild worse; 2 = moderate; 2+ = moderate worse; 3 = severe; and 3+ = severe worse. JSN is scored according to a nine-point scale with 0.5 increments, where 0 = normal; 0+ = questionable or subtle change; 1 = mild; 1+ = mild worse; 2 = moderate; 2+ = moderate worse; 3 = severe; 3+ = severe worse; and 4 = ankylosis or dislocation	It differentiates six stages from 0 (normal) to 5, reflecting progressive deterioration, and provides an overall measure of joint damage. The grading scale ranges from 0 to 5: 0 = intact bony outlines and normal joint space; 1 = erosion less than 1 mm in diameter or JSN; 2 = one or several small erosions (diameter more than 1 mm); 3 = marked erosions; 4 = severe erosions (usually no joint space left and the original bony outlines are only partly preserved); and 5 = mutilating changes (the original bony outlines have been destroyed)
Advantages and disadvantages	Sensitive for detection of radiographic progression but requires training and is time-consuming to apply	Sensitive, but presents difficulties in assessing progression of structural damage. Requires training to apply efficiently	Semiquantitative global method, easier to learn and use, less sensitive to changes than the modified Sharp method

deleted; the wrist was divided into four quadrants, and a distinction was made between erosions of different sizes (Fig. 2).

Genant-modified Sharp scoring method (1998)

Similar to Sharp's method, Genant [48] scored erosions and JSN separately. The Genant modification of the Sharp method focuses on 14 sites for erosions and 13 sites for JSN. In Table 3 are shown the joints considered for erosions and JSN and the grading. Comparison of Genant–Sharp and van der Heijde/Sharp methods showed that both demonstrated a similar performance [52] (Fig. 3).

Ratingen score (1998)

A new scoring method, derived from the Larsen score, was developed by Rau and Herborn. A notable difference is the inclusion of a quantitative appraisal of the percentage of loss of the joint surface. This method is known as a "Ratingen score" [53]. The amount of joint surface destruction is defined by the length of the clearly visible interruption of the cortical plate in relation to the total joint surface. In this method, the stages are described as a quantitative measure of the destroyed joint surface area and can, therefore, be applied more easily. These modifications also enhance sensitivity and increase reliability.

Simplified erosion and narrowing score (SENS) (1999)

The SENS was developed by van der Heijde [54] and is a simplified method by summing the number of eroded and narrowed joints on selected joints on hand and foot radiographs. It exploits the same joints of hands and feet, but as opposed to applying a semiquantitative scale of 0–4 for JSN and 0–5 for erosions, the SENS simply dichotomizes (bimodal answer modality) whether an erosion is absent (score 0) or present (score 1) and whether JSN is absent (score 0) or present (score 1). The SENS showed a good intra- and inter-reader reliability and is sensitive to change [55]. Another important issue is the absence of a clear ceiling effect. Its decisive advantage is its feasibility in clinical practice [56]. It has been demonstrated that the carpal joints may be omitted from SENS without noticeable repercussion for its responsiveness and discriminant validity [57] (Fig. 4).

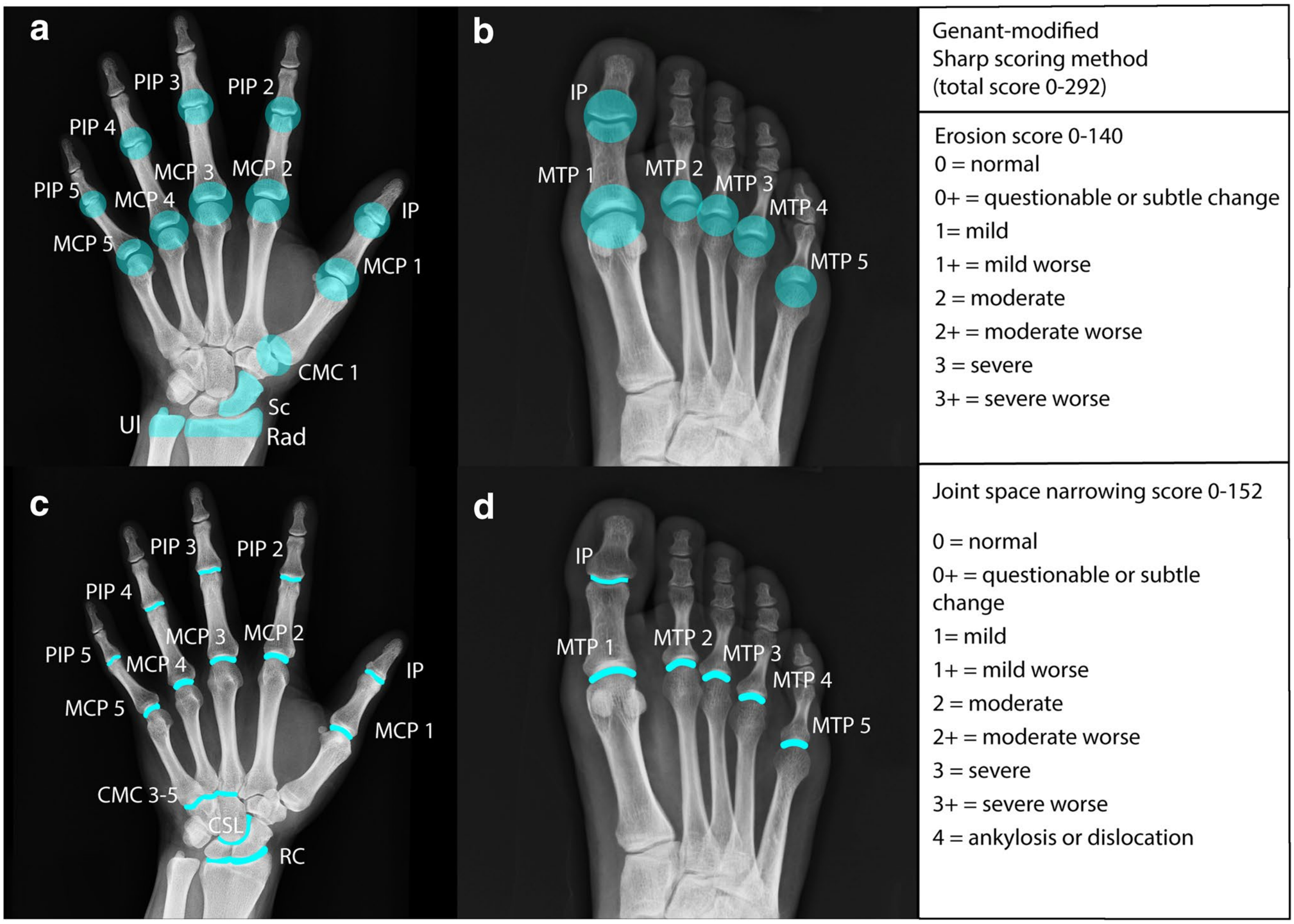


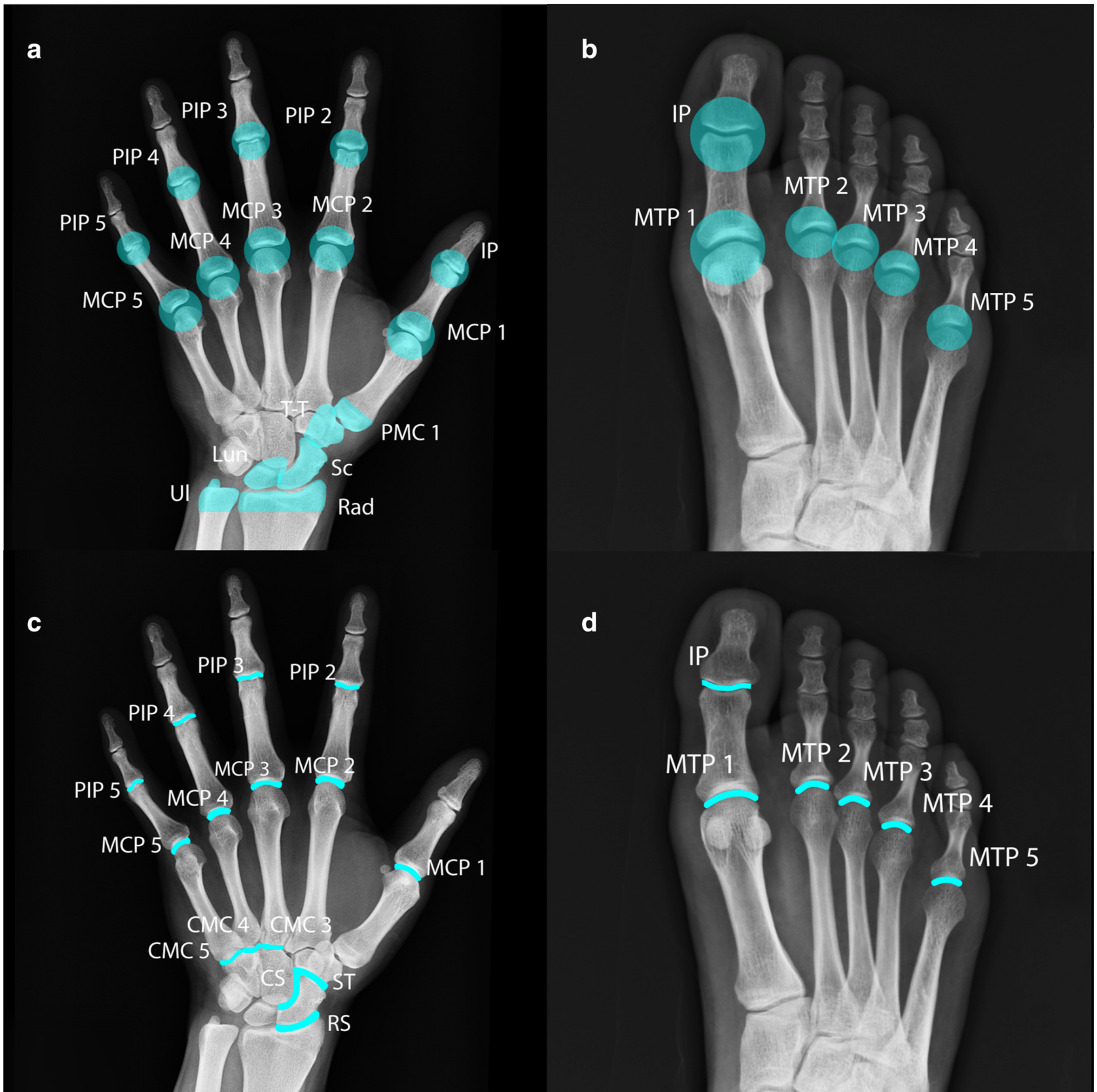
Fig. 3 Genant-modified Sharp scoring method illustrated with figure and grading. **a** Joints selected in each hand for erosions: 4 PIP, 5 MCP, the IP, the CMC of the thumb, scaphoid, distal ulna, distal radius. The maximum score for both hands is 98. **b** Joints selected in each foot for erosions: all the MTP joints and the IP joint of the big toe. The maximum score considering both feet is 42. **c** Joints selected in the hand in the Genant-modified Sharp: the CMC 3, CMC 4, CMC 5 are scored united. The lunate joint is considered for joint space narrowing in the capitate–lunate and radius–lunate joints, whereas the mSvdHS does not include it. The maximum score for both hands is 104. **d** Joints selected for JSN in each foot: all the MTP joints and the IP joint of the big toe. The maximum score for both feet is 48. *CMC* carpometacarpal, *CSL* capitate–scaphoid–lunate, *IP* interphalangeal joint, *Lun* lunate, *MCP* metacarpophalangeal joint, *MTP* metatarsophalangeal joint, *PIP* proximal interphalangeal joint, *PMC* proximal metacarpal, *Rad* radius, *RC* radiocarpal, *Sc* scaphoid *ST* scaphoid–trapezium, *Ul* ulna. The "+" sign represents a 0.5 increment

Feasibility of the scoring methods in clinical practice

An important disadvantage of the scoring methods for clinical trials is the fact that they require significant training and that scoring according to these methods is time-consuming, making these techniques unfeasible for routine clinical practice. Several authors calculated the time needed to score radiographs with different methods in RA. The time to score seven radiographs of hands and feet was found to be 3.9 min for Larsen, 19 min for Sharp, 25 min for the Sharp/van der Heijde method, and 9 min for the Ratingen method [58]. Other studies gave similar results for the Ratingen score method and the Sharp/van der Heijde method [53, 54]. The time needed to score seven radiographs of hands and feet was 7 min for SENS [54], appearing the most feasible in daily clinical practice. The time needed to score 12 radiographs of hands and feet with the Sharp/van der Heijde method for RA ranged from 11.1 to 20.5 min [59]. The time needed is one drawback of both the Sharp method and the Sharp/van der Heijde method; it is related to their higher degree of detail as compared with the Larsen and SENS methods.

Radiographic scoring methods in psoriatic arthritis

The measurement of radiographic joint damage in PsA is a core outcome measure in both randomized control trials for novel therapies [60] and longitudinal observational



Simplified Erosion and Narrowing Score (SENS) (total score 0-86)

Erosion score 0-44
- 0 = Absent
- 1 = Present

Joint space narrowing score 0-42
- 0 = Absent
- 1 = Present

Fig. 4 Simplified erosion and narrowing score (SENS) representation with figure and grading. The grading in SENS is a dichotomic scale. **a** Joints selected in each hand for erosions: 4 PIP, 5 MCP, IP, scaphoid, lunate, distal ulna, distal radius, the two components of the CMC joints of the thumb are evaluated separately (PMC and trapezium–trapezoid). The maximum score for both hands is 32. **b** Joints selected in each foot for erosions. The maximum score considering both feet is 12. **c** Joints selected in the hand: the CMC 3, CMC 4, CMC 5 are scored separately, the IP is not included, only the radio-scaphoid part of the radiocarpal joint is evaluated. The maximum score for both hands is 30. **d** The joint selected for JSN in each foot. The maximum score for both feet is 12. *CMC* carpometacarpal, *CS* capitate–scaphoid, *IP* interphalangeal joint, *Lun* lunate, *MCP* metacarpophalangeal joint, *MTP* metatarsophalangeal joint, *PIP* proximal interphalangeal joint, *PMC* proximal metacarpal, *Rad* radius, *RC* radio-scaphoid, *Sc* scaphoid, *ST* scaphoid–trapezium, *T–T* trapezium–trapezoid, *Ul* ulna studies [61] and is included in the research agenda as a domain of interest by the Outcome Measures in Rheumatology (OMERACT) [62]. The development and validation of scoring methods for PsA have been less well worked out than those for RA. All of the currently used methods have their basis in scoring methods for RA. These instruments include the modified Steinbrocker global scoring method, the modified Sharp score (MSS), and the modified Sharp/van der Heijde score (mSvdHS) for PsA [36, 63]. Until now, the scoring system developed exclusively for PsA is the psoriatic arthritis Ratingen score (PARS) [64]. All these radiographic scores, based on semiquantitative assessment, are summarized in Table 4. As for scoring systems adopted in RA, their lowest common denominator is the large time to perform. Moreover, their scoring requires trained observers.

Modified Steinbrocker global scoring method

This method was developed at the PsA clinic at the University of Toronto. This classification has been used not only for the mostly affected joint, but also for 40 joints in the hands and feet: all DIP, PIP, and MCP joints of the hands with the wrist as one joint, and all MTP and the IP of the big toe [65] (Fig. 5).

Psoriatic arthritis scoring method based on the Sharp scoring method for rheumatoid arthritis (MSS)

Radiographic evaluation was performed in the initial studies with biologic agents in PsA using a modification of the Sharp method for RA [66], which includes a separate evaluation of erosions and JSN. The same joints were scored as in the original method, with the addition of the DIP from 2 to 5 joints of hands [36, 63]. Other radiographically detectable changes in PsA, such as periostitis and tuft resorption are recorded and scored separately, but not included in the score value.

Sharp–van der Heijde-modified scoring method for psoriatic arthritis (mSvdHS)

The modification based on the Sharp–van der Heijde method for RA scores the same joints and definitions as seen in RA [41], with the addition of the eight DIP joints for erosions and the eight DIP and two IP joints of the thumb for JSN. The presence of gross osteolysis and "pencil in cup" is scored separately; if one of these abnormalities is present, the joint gets the maximum score assigned for erosion and for JSN (Fig. 6).

Psoriatic arthritis Ratingen score (PARS)

This method was developed based on the Rau and Herborn modification of the Larsen Score [53]. This method includes 40 joints of the hands and feet (DIP 2–5 of the hands, 2 IP of the thumbs, 8 PIP of the hands, 10 MCP of both wrists, 2 IP of the great toes, and MTP 2–5). Destruction and proliferation of all joints are scored separately [53] (Fig. 7).

Simplified psoriatic arthritis radiographic score (SPARS)

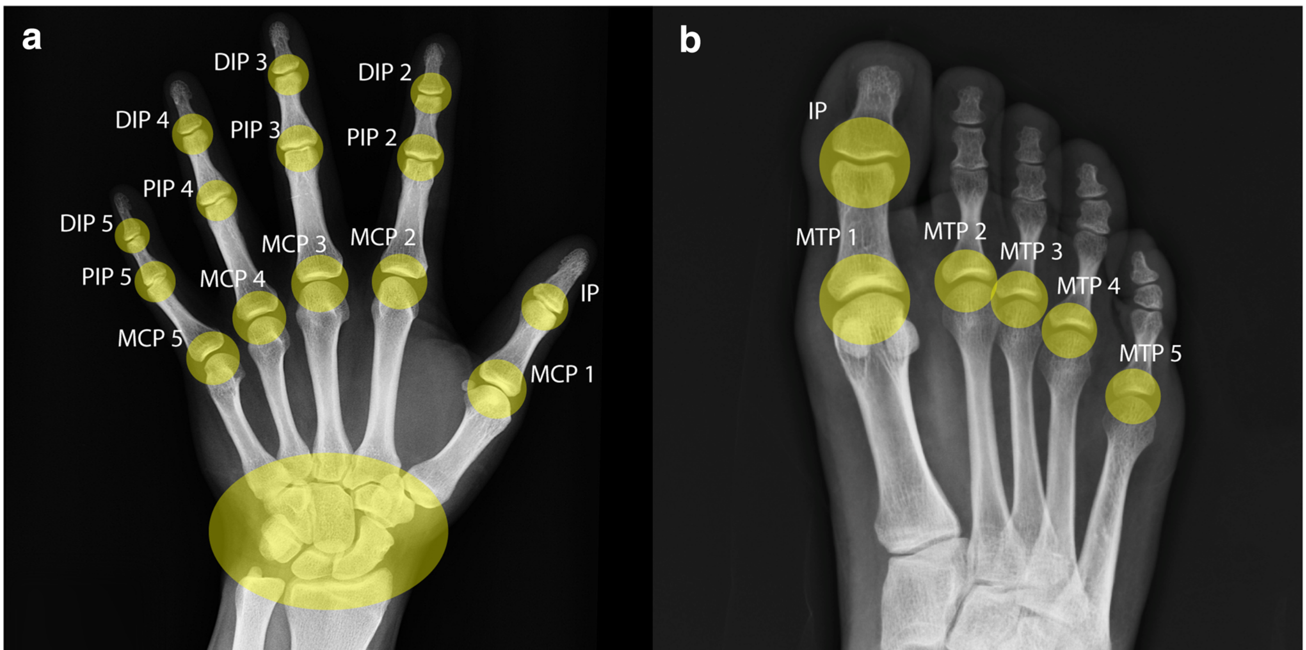
Recently, our group has developed the SPARS, obtaining its definition through a consensus analysis, involving three radiologists skilled in musculoskeletal imaging and five rheumatologists with clinical experience on PsA and radiographic scoring systems [67]. SPARS assess the same joints of the PARS in a simpler manner: the grade of the combination of erosion and bony proliferation of the PARS is replaced by the sum of joints with erosion and the number of joints with bony proliferation. Similar simplifications have been already applied for the radiographic scoring systems in RA [54]. In SPARS, a joint is defined as eroded (score 1) if one or more erosions with an interruption of the cortical plate > 1 mm (PARS grade 1 of DS) can be observed (Fig. 8).

Comparison of the scoring methods in PsA

All radiographic scoring methods have been proven to capture radiographic change with reasonable precision in PsA. There was consensus that MSS and mSvdHS were the optimal tool to use in randomized controlled trials (where sensitivity to change is often the most important attribute of the outcome measure), but the most appropriate tool for use in longitudinal observational studies has yet to be established [62]. Tillett et al. [68] reported the first comparison of feasibility of four radiographic scoring methods for PsA in an observational cohort. The smallest detectable change (SDC) of the PARS is similar to that of the mSvdHS and MSS, but it can be scored faster. Furthermore, the PARS is the only one that focuses on bony proliferation. Proliferative lesions are pathognomonic for PsA and are considered the most specific PsA radiographic features [7]. The feasibility of each method was estimated based on the mean time taken to score each film as well. The method which took the least time to score was the Steinbrocker method followed by the PARS, the mSvdHS, and the MSS at 6.2 min, 10.5 min, 14.4 min, and 14.6 min, respectively. Recently, the SPARS, a new and faster method, has been developed. The SPARS has properties which are close to the ones of the mSvdHS and PARS allowing a quicker calculation [67].

Table 4 Features of psoriatic arthritis included in the five radiographic scoring systems for psoriatic arthritis

Scoring method	Erosion	Joint Space Narrowing	Bony proliferation
Modified Steinbrocker global scoring method	+	–	–
Modified Sharp score (MSS)	+	+	–
Modified Sharp–van der Heijde method for psoriatic arthritis (mSvdHS)	+	+	–
Psoriatic arthritis Ratingen score (PARS)	+	–	+
Simplified psoriatic arthritis radiographic score (SPARS)	+	+	+



Modified Steinbocker Global Scoring Method (Total score 0-168)

Grade 0	Normal
Grade 1	Juxta-articular osteoporosis or soft tissue swelling
Grade 2	Erosions
Grade 3	Erosions and joint space narrowing or subluxation
Grade 4	Total joint destruction, either lysis or ankylosis

Fig. 5 Modified Steinbrocker global scoring method represented with figure and grading. **a** Joints evaluated in each hand: 4 DIP, 4 PIP, 5 MCP, the IP of the thumb, the wrist is evaluated as one joint. The maximum score for both hands is 120. **b** Joints selected in each foot: all the MTP joints and the IP joint of the big toe. The maximum score considering both feet is 48. *DIP* distal interphalangeal joint, *IP* interphalangeal joint, *MCP* metacarpophalangeal joint, *MTP* metatarsophalangeal joint, *PIP* proximal interphalangeal joint

Conclusion

Plain radiography remains the gold standard for the assessment of structural joint damage in RA and PsA. Characteristic radiographic findings are part of the ACR classification criteria for RA [69] and CASPAR criteria for PsA [7, 70]. Plain radiography can be helpful in the differentiation of RA from PsA and other joint conditions, including osteoarthritis, calcium pyrophosphate deposition disease, gout, and neoplasms [71]. Early bone erosions are correlated with poor long-term radiographic and functional outcome, and early progression in radiographic erosions is related to future impairment in physical function [72]. Radiographic measurement has been of major importance in the development

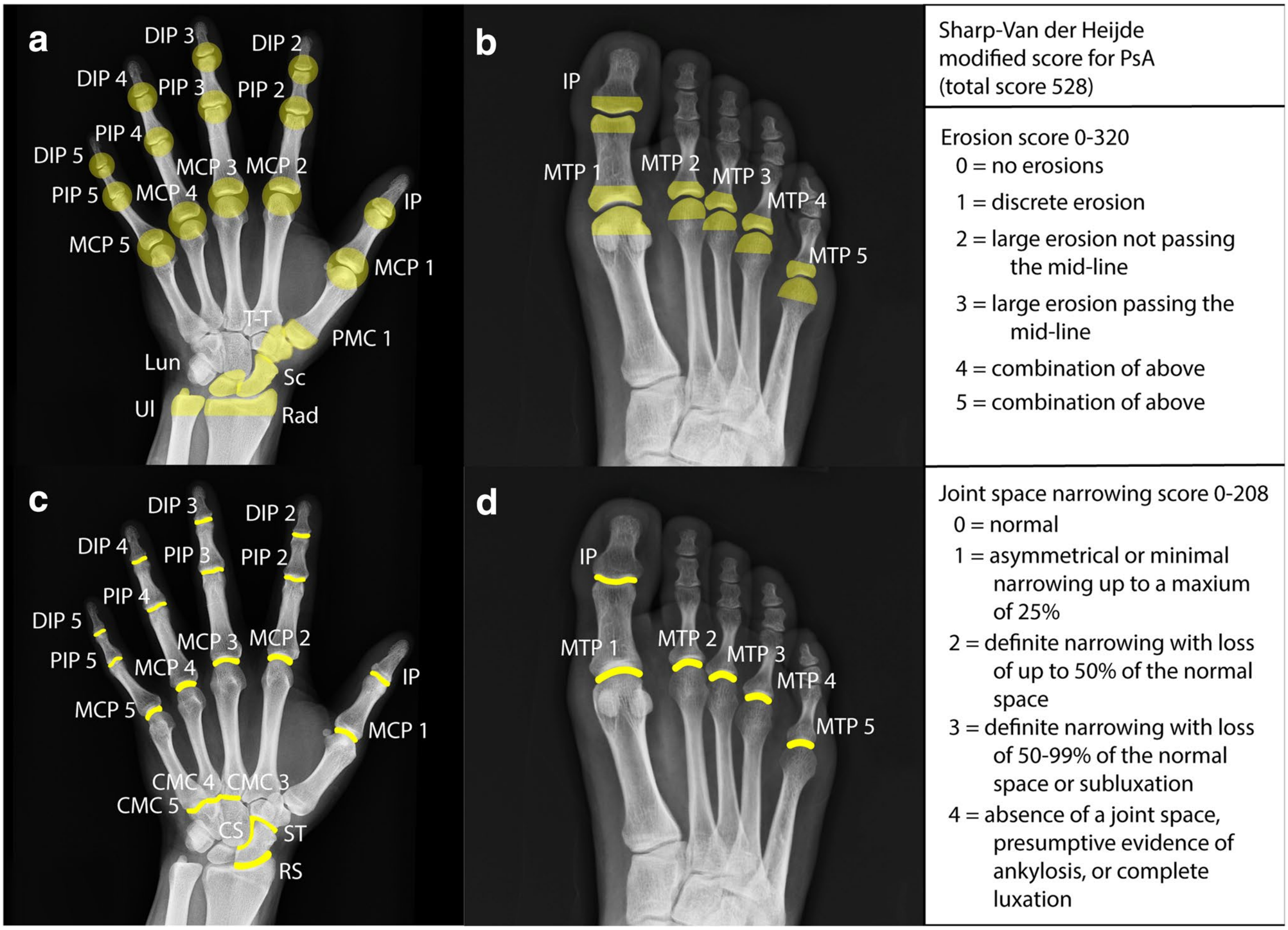
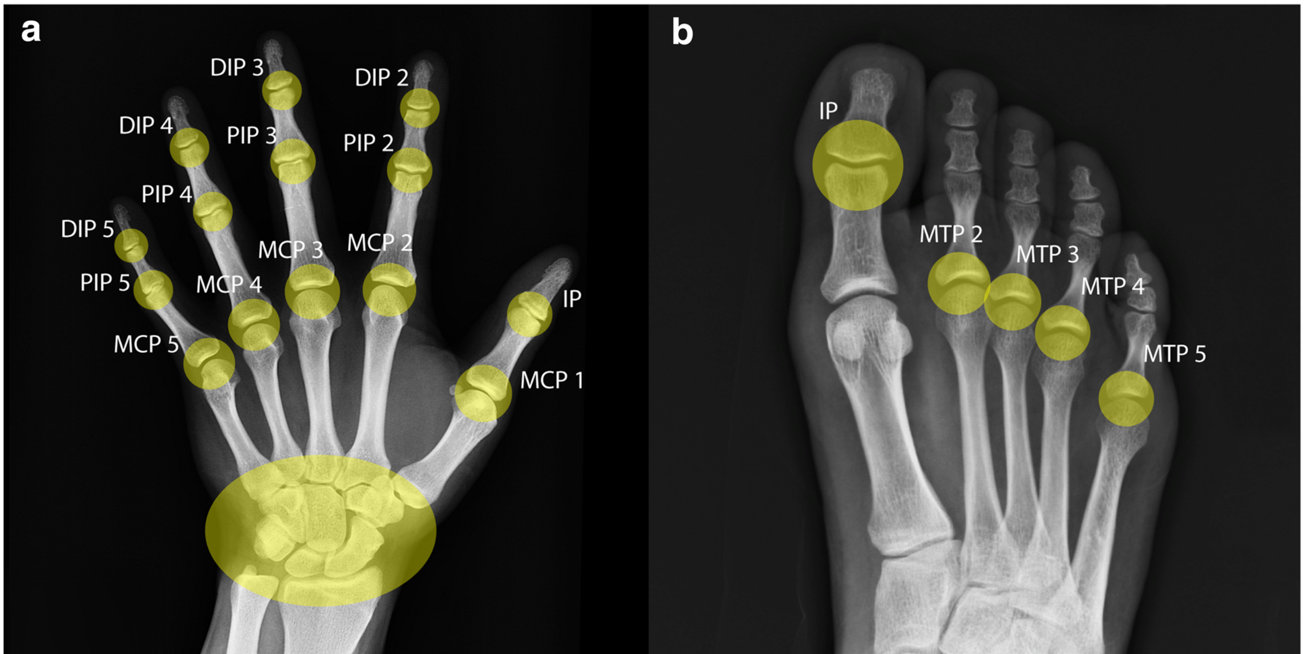


Fig. 6 van der Heijde-modified Sharp scoring method (mSvdHS) representation with figure and grading. The presence of gross osteolysis and "pencil in cup" is scored separately; if one of these abnormalities is present, the joint gets the maximum score assigned for erosion (5 points) and for JSN (4 points). **a** Joints selected in each hand for erosions: 4 PIP, 5 MCP, IP, scaphoid, lunate, distal ulna, distal radius, the two components of the CMC joints of the thumb are evaluated separately (PMC and trapezium–trapezoid). The maximum score for both hands is 200. **b** Joints selected in each foot for erosions: the proximal and distal articular components of the MTP joints and IP are evaluated separately resulting in a 0–10 score for each joint. The maximum score considering both feet is 120. **c** Joints selected in the hand in the mSvdHS: the CMC 3, CMC 4, CMC 5 are scored separately, the IP is not included, only the radio-scaphoid part of the radiocarpal joint is evaluated. The maximum score for both hands is 160. **d** Joints selected for JSN in each foot. The maximum score for both feet is 48. *CMC* carpometacarpal, *CS* capitate–scaphoid, *DIP* distal interphalangeal, *IP* interphalangeal joint, *Lun* lunate, *MCP* metacarpophalangeal joint, *MTP* metatarsophalangeal joint, *PIP* proximal interphalangeal joint, *PMC* proximal metacarpal, *Rad* radius, *RS* radio-scaphoid, *Sc* scaphoid, *ST* scaphoid–trapezium, *T–T* trapezium–trapezoid, *Ul* ulna

of concepts concerning the severity of RA and PsA and the need for tight control to prevent anatomic damage. It will have, also, a crucial role in many aspects of treatment in the rheumatic diseases, including identifying patients who are suitable for use of disease-modifying antirheumatic drugs (DMARDs) and biological agents (bDMARDs), predicting patient response and relapse, and identifying true disease remission [17, 19, 71, 73, 74]. A deeper insight into the mechanism of structural changes triggered by these chronic joint diseases is essential for developing therapies that can arrest, prevent, and even reverse bone and cartilage changes.

Even though magnetic resonance imaging (MRI) and ultrasound (US) demonstrated to be more sensitive than radiographs in detecting early structural changes in joints and surrounding structures [75, 76], availability and costs may limit the use of these techniques in daily clinical practice.

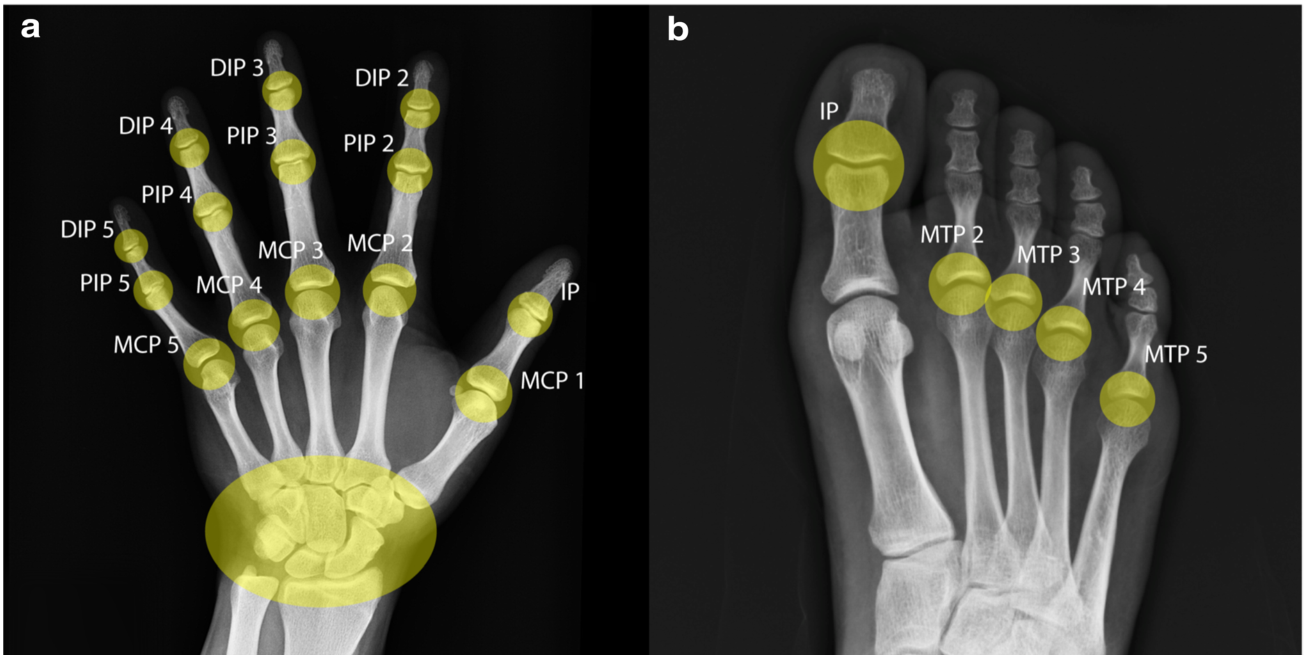
Further research in the use of MRI and US will lead to their proper integration with conventional radiography. Therefore, it remains important for a rheumatologist to understand the scoring of plain radiographs and the history of the scoring methods. The introduction of easier scoring



Psoriatic Arthritis Ratingen Score (PARS) (total score 0-360)

Destruction score 0-200	Proliferation score 0-160
0 = normal	0 = normal
1 = one or more definite erosions with an interruption of the cortical plate of >1 mm but destruction of less than 10% of the total joint surface	1 = bony proliferation measured from the originalbone surface of 1-2 mm, or, if the margins of the proliferation cannot be distinguished from the original bone surface, clearly identificable bone growth not exceeding 25% of the original diameter
2 = destruction of 11-25%	2 = bony proliferation of 2-3 mm or bone growth between 25-50%
3 = destruction of 26-50%	3 = bony proliferation > 3 mm or bone growth >50%
4 = destruction of 51-75%	4 = bony ankylosis
5 = destruction of more than 75%	

Fig. 7 Psoriatic arthritis Ratingen score (PARS) representation with figure and grading. **a** Joints evaluated in each hand for destruction and proliferation: 4 DIP, 4 PIP, 5 MCP, the IP of the thumb and the wrist (evaluated as one joint). The maximum score for both hands is 270. **b** Joints selected in each foot for destruction and proliferation: the IP of the big toe and second to fifth MTP joints. The maximum score considering both feet is 90. *DIP* distal interphalangeal joint, *IP* interphalangeal joint, *MCP* metacarpophalangeal joint, *MTP* metatarsophalangeal joint, *PIP* proximal interphalangeal joint



Simplified Psoriatic Arthritis Radiographic Score (SPARS) (total score 0-120)

Erosion score
0 = normal
1 = one or more erosions with an interruption of cortical plate > 1 mm
Joint space narrowing (JSN)
0 = normal
1 = at least an asymemtrical or minimal narrowing up is detectable
Bone proliferation (BP)
0 = normal
1 = proliferation of 1-2 mm or bone growth < 25% of diameter are detectable

Fig. 8 Simplified psoriatic arthritis score (SPARS) representation with figure and grading. The grading in SPARS is a dichotomic scale. **a** Joints evaluated in each hand for erosion, joint space narrowing and bone proliferation: 4 DIP, 4 PIP, 5 MCP, the IP of the thumb, and wrist is evaluated as one joint. **b** Joints selected in each foot for erosion, joint space narrowing, and bone proliferation: the IP of the big toe and second to fifth MTP joints. The maximum score is considered. *DIP* distal interphalangeal joint, *IP* interphalangeal joint, *MCP* metacarpophalangeal joint, *MTP* metatarsophalangeal joint, *PIP* proximal interphalangeal joint

system in time allows the rheumatologist to use it in clinical trials but also in clinical practice.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with human participants performed by any of the authors.

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