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# Arthritis

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## Abstract

Joint involvement in the hand and wrist is a feature of many forms of arthritis and because multiple joints are included, a view of both hands and wrists can provide important diagnostic information based on the pattern of disease involvement, even before the actual appearances of the changes are considered. Although for the most part this chapter focuses on plain film appearances, advanced imaging modalities, particularly ultrasound (US) and MRI, are increasingly finding applications in the mainstream clinical imaging of hand arthritis and are discussed in the appropriate sections.

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## 1 Introduction

Joint involvement in the hand and wrist is a feature of many forms of arthritis and because multiple joints are included, a view of both hands and wrists can provide important diagnostic information based on the pattern of disease involvement, even before the actual appearances of the changes are considered. Although for the most part this chapter focuses on plain film appearances, advanced imaging modalities, particularly ultrasound (US) and MRI, are increasingly finding applications in the mainstream clinical imaging of hand arthritis and are discussed in the appropriate sections.

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## 2 The Inflammatory Arthritides

The inflammatory arthritides include rheumatoid arthritis (RA), the seronegative arthritides and juvenile inflammatory arthritis (JIA). While it is recognised that

osteoarthritis (OA) has an inflammatory variant, the features of this condition will be discussed separately.

The management of inflammatory arthritis has changed dramatically in recent years with the advent of powerful biological therapies which, if instigated early, can prevent the severe joint destruction that used to be commonly seen. The use of such drugs means that imaging plays an increasingly important role in the management of these diseases. While CR shows characteristic features of inflammatory arthritis, these represent late findings in the disease process and the use of advanced imaging techniques is becoming more common as they allow early diagnosis before irreversible joint damage has occurred. Nevertheless CR continues to play an important role in the diagnosis and characterisation of hand and wrist arthritis and usually forms the initial imaging study.

## 2.1 Plain Film General Principles

The subtle changes seen in early inflammatory arthritis require high quality radiographs reviewed in optimal lighting conditions. The use of digital radiographic techniques is now prevalent and has been shown to provide similar accuracy to film-screen techniques in the diagnosis of arthritis (van der Jagt et al. 2000; Jonsson et al. 1994). Additional advantages over conventional films exist for the reader such as on-screen magnification and windowing (Paskins and Rai 2006).

A systematic approach to the review of the hand and wrist radiograph for arthritis is required. Important features to identify are:

- soft tissue swelling
- joint space loss
- bone changes
  - erosion
  - osteopaenia
  - enthesitis
- bone alignment.

Finally the distribution of joint disease provides important information when forming a differential diagnosis.

### 2.1.1 Soft Tissue Swelling

Soft tissue swelling is usually the earliest sign on CR of an inflammatory arthritis. It represents synovial hypertrophy, oedema in the adjacent soft tissues and

joint effusion. When seen at the interphalangeal joints the swelling has a symmetrical spindle shape about the joint. This pattern of soft tissue swelling contrasts with that seen in gout which tends to show a more irregular asymmetrical ‘lumpy’ appearance. At the metacarpophalangeal (MCP) and wrist joints the soft tissue contour may not be significantly displaced and it is often the appreciation of an increased density to the periarticular soft tissues and effacement of the fat planes that suggests the presence of joint disease. At the MCP joints soft tissue swelling can be extremely subtle and it is useful to look for loss of the fat planes normally seen between the joints (Fig. 1). In the wrist the normal fat planes adjacent to the scaphoid and ulnar styloid are sensitive sites for the detection of soft tissue swelling.

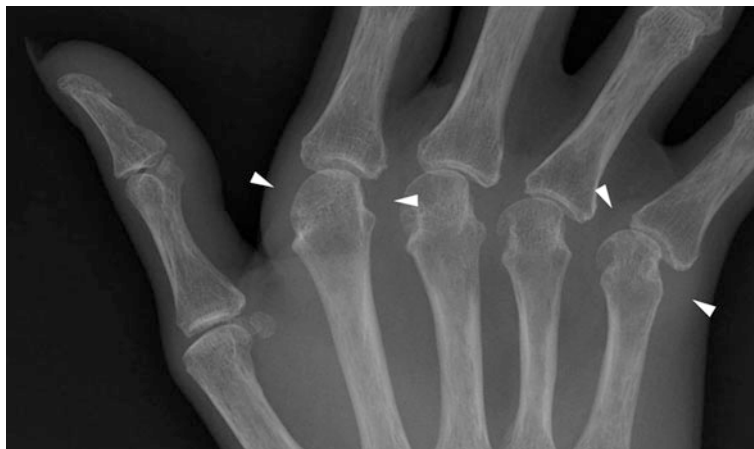
### 2.1.2 Alteration in Joint Space

Loss of joint space as a result of cartilage destruction is a characteristic feature of many joint diseases. In inflammatory arthritis joint space loss is typically uniform, across the joint. In many joints this is helpful in distinguishing inflammatory from OA, which typically shows non-uniform joint space loss. However, it is less useful in the hands where the interphalangeal and MCP joints in both forms of arthritis can show uniform joint space loss.

As with soft tissue swelling joint space loss is an early plain film feature of inflammatory arthritis, but while soft tissue swelling can be subtle, the recognition of joint space loss is generally more straightforward (Fig. 1). It is important to recognise that once joint space loss is identified irreversible damage has occurred to the joint. So while it is an early plain film feature, it still represents a relatively late stage in the whole disease process.

Detection of joint space loss in the hands and wrists is usually straightforward because joint space can be easily compared to other similar joints on the radiograph. It is important to recognise that the joints between the carpal bones normally all show similar spaces. The observation of preserved joint space, in a joint which otherwise shows evidence of significant arthropathic change, is an important one and may help with the differential diagnosis. In particular gout characteristically preserves joint space until late in the disease.

In severe arthritic change bony ankylosis may occur. This is most commonly seen in the seronegative arthritides and in juvenile arthritis and represents end stage disease. Ankylosis may be bony or fibrous.



**Fig. 1** Rheumatoid arthritis: there is joint space loss demonstrated at the middle, ring and little MCP joints. This is made more apparent by the relative preservation of joint space at the thumb and index MCP joints. There is also soft tissue swelling which is best appreciated at the index and little MCP joints

(*arrowheads*). The joint space swelling at the MCP joints can also be appreciated by the loss of the normal fat plane between the joints. There is also malalignment of the MCP joints with ulnar deviation

Occasionally widening of the joint space may be seen in arthritis. This is rare and is usually the result of a tense effusion distending the joint and separating the bones.

### 2.1.3 Bone Changes

#### Osteopaenia

Periarticular osteopaenia is a well-recognised feature of some inflammatory arthritides but is perhaps the most difficult to reliably identify. It may be more obvious in cases of mono or pauciarticular joint involvement, where other joints are clearly normal for comparison, but can be more difficult to appreciate when there is polyarticular disease as is often the case in the inflammatory arthritides. Appearances can also be difficult to interpret if there is an element of generalised disuse osteoporosis. Often it is easier to identify that there is no evidence of osteopaenia, and this in itself is a useful observation when forming a differential diagnosis.

#### Erosion

Bone erosion is a hallmark of inflammatory arthritis and a sign of significant joint damage. Erosions can be subdivided into proliferative and non-proliferative erosions. Proliferative erosions are associated with new bone formation and are classically a feature of enthesal disease as discussed below. Non-proliferative

erosions are a feature of seropositive (rheumatoid) arthritis. The distinction between these two types of erosion is an important one in the differentiation of seropositive and seronegative arthritis.

Erosions can be described by their relationship to the joint and can be categorised as central, marginal or juxta-articular. Marginal erosions occur at the edge of the joint line and involve the exposed bone between the edge of the articular cartilage and the joint capsule. They are a classical feature of RA. Central erosions occur, as their name suggests, into bone normally covered by the articular cartilage. They are less common and are classically seen in inflammatory (erosive) OA. Juxta-articular erosions occur further away from the joint and are typically seen in gout. They have characteristic features that are discussed later (see [Sect. 3.1.1](#)).

Erosions are seen as a discontinuity in the cortex of a bone. However, this is only the case when the eroded cortex is seen in profile on the radiograph. While this is frequently the case in the finger joints, wrist erosions are often seen en-face if they lie on the palmar or dorsal aspect of the carpal bones. En-face erosions are seen as focal lucencies within the bone without associated cortical breach and may be indistinguishable from cysts. The improved detection of these erosions, particularly when small, is one of the reasons cross-sectional imaging techniques such as US and MRI have a much greater sensitivity to erosive change than CR.

## Enthesal Disease

Enthesitis is a characteristic feature of the seronegative arthritides. Enteses represent the bony attachment sites of ligaments, tendons and capsule. On plain film imaging the important bone changes that can be visualised in enthesitis are enthesophyte formation and erosion. Entesophytes, which develop at, or immediately adjacent to the site of an enthesitis are seen as bone proliferation. They may have a coarse appearance, with both cortical and medullary bone being apparent, or may have a finer 'whisker' like appearance.

MRI demonstrates intra-osseous bone changes, in enthesitis in the form of high T2 (oedema like) signal in the bone adjacent to the enthesitis. MRI and US also show changes in the soft tissues about the enthesitis including bursitis and alteration in the appearance of the ligament or tendon inserting at the affected enthesitis. These will only be detected on plain films if there are adjacent fat planes that become effaced by a thickened tendon, or enlarged bursa.

### 2.1.4 Bone Alignment

Joint malalignment is a feature of many arthropathic processes and results from a variety of causes (Fig. 1). These include ligament degeneration or disruption, tendon rupture or subluxation, cartilage loss and bone attrition or erosion. In most cases the malalignment will be apparent clinically and may even be less apparent on the radiograph in the case of reversible subluxations, such as are seen with SLE, as the act of positioning the patient for the radiograph reduces the subluxation.

## 2.2 Rheumatoid Arthritis

The aetiology of RA remains unknown, but it is recognised that it is a chronic autoimmune disorder with the potential to affect multiple systems and has an incidence of approximately 1%. Women are more frequently affected than men and the joint disease is characterised by a polyarticular synovitis. The synovitis is initiated by cytokines including interleukin-1 and tumour necrosis factor (TNF) and occurs early in the disease process (Arend 2001). The later stages of the disease involve joint destruction as a result of bone erosion and cartilage loss. Synovitis is considered to be a strong predictor of bone erosion (McGonagle et al.

1999; McQueen et al. 1999). The majority of patients have polyarticular involvement at presentation although occasionally patients may present with single joint involvement. The hands and wrists are commonly affected and radiographs of the hand and wrist provide a valuable tool in being able to assess multiple joints in a single examination. In addition to joint involvement, synovitis may involve the tendon sheaths and rheumatoid nodules may occasionally be seen in the hands.

The clinical, and consequently radiological, picture of RA has changed over recent years due to dramatic advances in the way RA is treated clinically. Management now involves the use of powerful biologic agents, which can arrest joint damage early in the disease process preventing the development of the severely mutilated joints that were seen previously on CR (Villeneuve and Emery 2009). However, the effective use of these new treatments requires the early diagnosis of the disease, before plain film changes are evident. Increasingly US and MRI are finding roles in routine clinical practice for this purpose. Despite this plain films of the hands and wrists remain widely used in the diagnosis and management of the disease; and the need to detect early and subtle changes of RA is greater than ever. The hallmarks of RA on plain film imaging are soft tissue swelling, periarticular osteopaenia, joint space loss, erosion and malalignment. The classical plain film appearance of RA in the hands and wrists is of a symmetrical polyarthritides with a proximal distribution typically involving the wrists, MCP and proximal interphalangeal (PIP) joints. Characteristically the distal interphalangeal (DIP) joints are spared providing an important distinguishing feature from OA and psoriatic arthritis.

### 2.2.1 Soft Tissue Changes and Bone Density

The earliest plain film changes are soft tissue swelling and periarticular osteopaenia. At the MCP and PIP joints the soft tissue swelling is appreciated as spindle shaped thickening of the soft tissues developing symmetrically about the joint (Fig. 1). In the wrists, early changes of soft tissue swelling are best appreciated along the ulnar border of the joint and medial to the ulnar styloid and can be detected early by the loss of the normal fat planes (Fig. 2). As discussed above periarticular osteopaenia can be a difficult sign to evaluate, particularly with the polyarticular involvement seen in RA.



**Fig. 2** Rheumatoid arthritis: there is soft tissue swelling about the distal ulnar seen as deviation of the fat planes (*arrowheads*). Note also the erosive change seen for example in the ulnar styloid, radial styloid and 2nd metacarpal base

### 2.2.2 Joint Space Loss

As the disease progresses symmetrical joint space loss at involved joints becomes apparent (Fig. 1). In the wrist, the radiocarpal joint is usually the site where this is appreciated first, but with time the whole wrist becomes involved (Fig. 3). This is in contrast to OA with its classical isolated involvement of the thumb base in a trapeziocentric distribution.

### 2.2.3 Erosion

The earliest ‘pre-erosive’ changes of RA are typically seen on the radial aspect of the index and middle metacarpal heads (Fig. 4). Initially, cortical thinning develops, which then progresses to a ‘skip’ pattern or a ‘dot-dash’ type of deossification associated with localised osteopaenia. Subsequently, frank bone erosion is seen. Erosions in the finger joints are usually marginal in location, being seen in the first instance at sites within the joint that are unprotected by overlying articular cartilage (Fig. 5). In the wrist the earliest sites for erosion are typically along the ulnar aspect of the joint, on the ulnar styloid, trapezium and hamate (Figs. 3, 6). While erosion occurs at this site as a result of synovial proliferation on the ulnar aspect of the wrist joint, an important factor is also tenosynovitis of the extensor carpi ulnaris, an early site of soft tissue disease.



**Fig. 3** Rheumatoid arthritis: there is joint space narrowing between the carpal bones and at the radiocarpal joint. The lucency in the distal radius represents an erosion seen en-face despite cystic appearance. There is also erosion of the ulnar styloid with soft tissue swelling. Note the radial deviation of the wrist typical of the malalignment pattern seen with rheumatoid arthritis

Cystic forms of RA have been described where cystic change develops, generally in the carpal bones, without radiographic or MRI evidence of erosion (Gubler et al. 1990). A form of the disease featuring large cystic areas, typically occurring in active men has been termed ‘rheumatoid arthritis of the robust reaction type’ (Fig. 7) (De Haas et al. 1974). Using CR it is not possible to reliably distinguish between cysts and en-face erosions, which also commonly occur in the carpal bones.

It is important to appreciate that erosive change is a dynamic process and involves healing as well as bone destruction. This can be appreciated on serial films where healing of erosions may be seen (Fig. 8). It also means that the morphology of erosions changes with the disease progress. In the later chronic stages of the disease, erosions become more clearly delineated with the development of sclerotic borders at the interface between the sites of bone destruction and healing (Fig. 9).

### 2.2.4 Malalignment and Ankylosis

Tendon and ligamentous dysfunction along with bone erosion results in deformity and malalignment in the later stages of the disease. ‘Boutonniere’ deformity describes a





**Fig. 4** Rheumatoid arthritis: early erosive change is seen along the radial border of this index metacarpal head. There is localised osteopaenia with a 'dot-dash' pattern of deossification (arrows). Note also the soft tissue swelling



**Fig. 5** Rheumatoid arthritis: marginal erosions are seen at the middle MCP joint (arrows). Note also the joint space loss compared with the adjacent MCP joints

pattern of malalignment produced by flexion of the PIP joint and extension of the DIP joint. This results from detachment of the extensor tendon from the middle



**Fig. 6** Rheumatoid arthritis: erosive change is shown in the bones along the ulnar aspect of the wrist. In addition to erosions seen in the ulnar styloid, erosion is also seen in the triquetrum, hamate and base of 5th metacarpal. These represent early sites for the detection of erosions

phalanx, volar displacement and its subsequent action as a flexor. An opposite deformity referred to as the 'swan neck' deformity is seen as hyperextension of the PIP joint and flexion of the DIP joint. The cause is thought to be flexor tenosynovitis and/or synovitis in the PIP joint with resultant dysfunction of the stabilising effect of the volar plate. Mallet finger is a less common deformity resulting from disruption or dysfunction of the extensor tendon's action on the terminal phalanx. Ulnar deviation of the fingers and the radial deviation of the wrist giving a 'zigzag' deformity to the hand is typical for RA (Resnick 1976) (Figs. 1, 3, 10). This subluxation of the MCP and carpometacarpal joints seen in RA is irreversible.

In advanced disease, arthritis mutilans may develop where bony destruction leads to severe displacement with 'telescoping' of the phalanges. Ankylosis may also occur in the later stages of the disease. Typically this involves the wrist with intercarpal and carpometacarpal fusions but less commonly fusion may be seen at MCP and PIP joints, between the bases of the metacarpals or between the radius and ulna.

### 2.2.5 Secondary OA

As a result of the dysfunction of the joints, it is not uncommon for mechanical OA to develop in the later stages of the disease. Consequently a combination of

**Fig. 7** ‘Robust’ pattern of rheumatoid arthritis: this male patient shows severe bilateral wrist arthropathy with involvement also seen at the index and middle MCP joints on the right. Note the cystic changes seen in the wrist and MCP joints typical of the pattern of disease, which has been termed rheumatoid arthritis of robust reaction type



**Fig. 8** Rheumatoid arthritis: **a** there are erosions seen at the MCP joint in both the metacarpal head and proximal phalangeal base. Two years later **b** there is evidence of healing of the erosions on both proximal and distal side of the joint. Despite this there is progressive joint space loss

both rheumatoid and OA may be seen in the hands and wrists, with typical subchondral sclerosis and marginal osteophyte formation being present alongside the RA changes described. However, the OA change does not usually overshadow the features of RA.

### 2.2.6 Other Soft Tissue Changes

The changes of RA are not confined to the joints and other synovial tissues may be affected. In the hand and wrist this is usually the flexor and extensor tendon sheaths, and the changes here contribute to the disability and deformities seen with the condition. Subcutaneous nodules are another common feature of the disease, seen in around 20% of patients. Nodules may also be seen within tendons and along with the tenosynovitis may be a cause of triggering. While soft tissue findings may be manifest as thickening or swelling on CR, they are better evaluated using US or MRI and will be discussed in [Sect. 2.5](#) (el-Noueam et al. 1997; Fornage 1989; Gibbon and Wakefield 1999).

## 2.3 Seronegative Arthritis

The seronegative arthropathies comprise a group of multisystem inflammatory arthritides sharing common features. Chief among these is the characteristic involvement of the entheses with inflammation classically seen at the bony insertions of tendons and ligaments. Other important features are:

(a) an absence of rheumatoid factors,



**Fig. 9** Rheumatoid arthritis: this patient has long-standing RA with erosive involvement of multiple joints. Note the sclerotic margins of many of the erosions which is typical in the chronic stages of the disease



**Fig. 10** Rheumatoid arthritis: the patient has severe polyarthritis and shows typical malalignment with radial deviation at the wrist and ulnar deviation at the MCP joints

- (b) a strong association with the HLA-B27 histocompatibility antigen (although it is important to realise this is not necessary for the development of these diseases, or required for the diagnosis),
- (c) a tendency for axial skeletal involvement.

The CR hallmark of these conditions as they affect the hand and wrist is the presence of proliferative erosive change representing erosive enthesal disease.

### 2.3.1 Psoriatic Arthritis

Hand involvement in the seronegative arthritides occurs most frequently and characteristically in psoriatic arthritis. The condition occurs in association with cutaneous psoriasis and there has often been a long history of skin psoriasis prior to development of the arthritis. However, in some cases (reports suggest up to 20%) the arthropathic changes may occur prior to the onset of the cutaneous disease (Scarpa et al. 1984). There is considerable variation in the reported incidence of psoriatic arthritis in patients with cutaneous psoriasis. One study has suggested psoriatic arthritis is

seen in around 7% of patients with cutaneous psoriasis (Leczinsky 1948), while a more recent British study has suggested the figure may be as high as 40% (Green et al. 1981). Sacroiliac involvement is seen in 20–40% of patients and peripheral joint involvement is reported in around 15% of patients with psoriasis (Green et al. 1981; El-Khoury et al. 1996).

Five clinical subgroups of psoriatic arthritis are recognised:

1. Involvement of the DIP joints, usually asymmetrically often associated with dactylitis.
2. Arthritis mutilans.
3. A pattern of arthritis indistinguishable from RA but usually with a more benign course.
4. Oligo- (or mono-) arthritis distributed asymmetrically and involving any synovial joint.
5. A pattern of disease the same as ankylosing spondylitis (which may be associated with any of the above groups).

It is important to realise that patients with cutaneous psoriasis are susceptible to other arthropathies including RA and OA.





**Fig. 11** Dactylitis in psoriatic arthritis: there is diffuse soft tissue swelling of the index finger with associated arthropathic change



**Fig. 12** Early psoriatic arthritis: marginal erosive changes are seen at the bases of the index and little distal phalanges, but note also the early enthesophyte formation adjacent to the erosions

In common with the other seronegative arthropathies the disease classically involves enthesis sites. It is suggested that inflammation in the multiple closely related enthesal sites in a digit is the cause of dactylitis seen in psoriatic arthritis (Benjamin and McGonagle 2001). The presence of



**Fig. 13** Psoriatic arthritis: there is prominent fluffy enthesophyte formation seen both proximal and distal to the distal interphalangeal joints

nail dystrophy among psoriasis sufferers is a significant risk factor for the development of psoriatic arthritis and evidence suggests this may be because of the intimate relationship between the nail bed and the enthesis sites of the DIP joint (Wilson et al. 2009; McGonagle et al. 2009).

The most significant pattern of joint disease seen in the hands is an erosive arthritis, which has a predominantly distal distribution with predilection for the DIP joints. The distal distribution helps distinguish it from RA, with its typically more proximal joint involvement. Joint involvement in RA tends to be symmetrical (similar joints involved in the two hands) while psoriatic arthritis tends to show a more asymmetrical distribution.

#### Soft Tissue Changes and Bone Density

Soft tissue joint swelling is seen as an early but non-specific radiographic feature of psoriatic arthritis. When seen global swelling of the digit in the form of dactylitis 'sausage digit', is virtually pathognomonic of the disease (Fig. 11). Periarticular osteopaenia is not a feature of psoriatic arthritis and can be useful in distinguishing it from RA.

#### Erosion, Bone Proliferation and Resorption

Bone erosion is seen most commonly at the joint margin and shows an enthesal pattern as discussed in "Enthesal Disease", with fluffy new bone formation at and adjacent to the erosion site (Figs. 12, 13). As the erosions develop they lose their initial marginal location and tend to coalesce. Classically, erosions on

**Fig. 14** Psoriatic arthritis: there is a severe mutilating polyarthritis with multiple subluxations and extensive erosive change. Note the ‘pencil-in-cup’ pattern of erosive change seen at the thumb interphalangeal joints. There has been extensive bone resorption, e.g. the right, little proximal and intermediate phalanges and there is bony ankylosis at the left little distal interphalangeal joint



the distal side of the joint merge together centrally to produce a concavity, which extends laterally as a result of enthesophyte formation, while the proximal erosions lead to a tapering of the bone. The effect is to produce the characteristic ‘pencil in cup’ appearance considered by some to be pathognomonic of the disease (Arnett 1987) (Fig. 14).

New bone formation is not confined to the enthesis sites and periosteal new bone may be seen relatively early in the disease occurring along the shaft of the phalanges (Fig. 15). This is frequently associated with a soft tissue swelling, and is probably related to tenosynovitis (El-Khoury et al. 1996; Olivieri et al. 1996).

A further feature of the enthesal disease seen on hand/wrist imaging can be noted at the sesamoid bones. Sesamoid bones lie within tendons and so a considerable portion of their surface area represents enthesis site. It has been noted that the sesamoid bone of the thumb may enlarge in patients with psoriatic arthritis giving an increased sesamoid index (length  $\times$  width of the sesamoid) (Whitehouse et al. 2005).

Bone loss is not limited to periarticular erosion in psoriatic arthritis and acro-osteolysis (distal tuft resorption) is a well-recognised feature (Martel et al. 1980; Miller et al. 1971). It can help distinguish psoriatic arthritis from erosive OA, which may also

cause erosive change at the DIP joints. Progressive osteolysis of the terminal phalanges may give them a ‘peg like’ appearance, although osteolysis may progress to involve the majority of the phalanx (Figs. 14, 16). When osteolysis is seen there is usually associated nail involvement. Acro-osteolysis may be seen in cases of psoriasis without arthritis (Miller et al. 1971).

### Ankylosis

Bony ankylosis is a feature of psoriatic arthritis occurring later in the disease process (Fig. 14). The process commences as a result of fibrous tissue forming within the joint and this can give the impression of a widened joint space.

### 2.3.2 Other Seronegative Arthritides

Although hand and wrist involvement is seen in the other seronegative arthritides it is not as common or typical as the involvement of the hands in psoriatic arthritis.

### Ankylosing Spondylitis

Ankylosing spondylitis primarily affects the axial skeleton but peripheral joint involvement is seen and this may involve hands and wrists (Resnick 1974; Vinje et al. 1985). Around 30% of patients with severe disease are reported to show hand and wrist



**Fig. 15** Psoriatic arthritis: there is fluffy periostitis seen along the shafts of the proximal phalanges typical of psoriatic arthritis

involvement (Resnick 1974). An asymmetrical distribution is usually seen and features include periarticular osteoporosis, along with joint space narrowing, proliferative erosions and soft tissue swelling. Enthesophyte formation may be seen as part of the enthesitis (Fig. 17). Involvement may be seen in all compartments of the wrist and any of the small joints of the hands. Bony ankylosis may be seen and may have a relatively rapid onset.

#### Reactive Arthritis (previously Reiter's Syndrome)

Classically reactive arthritis involves the small and large joints of the lower limb, upper limb involvement is unusual. However, clinical and radiographic changes do occur in the hands and wrists with radiographic changes in the wrists being more common than changes in the hands (Lin et al. 1995; Mason et al. 1959). As with psoriatic arthritis, joint involvement tends to be asymmetrical. The changes seen in the hands are similar to those seen in psoriatic arthritis, with soft tissue swelling, joint space narrowing and proliferative marginal erosions. There may also be



**Fig. 16** Psoriatic arthritis: note the extensive bone destruction that has occurred about the distal interphalangeal joints. The cupped appearance to the bases of the distal phalanges is typical

sesamoid enlargement as a result of the periostitis (Stadlnik and Dublin 1975). In contrast to psoriatic arthritis, where DIP joint involvement is most common, the PIP joints are more frequently involved in reactive arthritis than the DIP or MCP joints (Lin et al. 1995). While periarticular osteopaenia is not a typical feature of psoriatic arthritis, it is more widely recognised as occurring in the acute phases of reactive arthritis.

Wrist involvement may occasionally be severe in reactive arthritis. It can involve any of the wrist compartments and is typically asymmetrically distributed (Mason et al. 1959). Periosteal new bone formation is seen with erosions, osteopaenia and soft tissue swelling. Although the new bone formation has a fluffy configuration, more linear new bone may be seen, particularly alongside the radius and ulnar (Mason et al. 1959).

#### Arthritis Associated with Enteropathic Disease

Arthritis associated with inflammatory bowel disease is generally classified with the seronegative arthritides because the pattern of arthritis is very similar to that seen in ankylosing spondylitis. While axial involvement



**Fig. 17** Ankylosing spondylitis: there is exuberant enthesophyte formation at the insertion of the flexor carpi ulnaris tendon onto the pisiform (*arrowhead*). This represents an enthesitis, a typical feature of ankylosing spondylitis

predominates, 15–20% of patients with inflammatory bowel disease exhibit a peripheral arthritis, more frequently seen with Crohn's disease than ulcerative colitis (Gravallese and Kantowitz 1988). Commonly this involves the wrists (along with the knees, ankles and elbows) and the condition occurs as transient arthritis. This is frequently asymmetric and occurrences tend to parallel flares of the inflammatory bowel disease. The arthritis is characteristically non-destructive and while CR may show soft tissue swelling and periarticular osteopaenia, erosions and joint space loss are not usually seen.

Destructive changes have been reported at peripheral joints in association with inflammatory bowel disease, but in this situation the findings are very similar to RA and distinction may not be possible. Indeed the two conditions may coexist.

Hypertrophic osteoarthropathy has a well-recognised association with pulmonary disease, but there is also a rare association with inflammatory bowel disease. HPOA is typically seen as linear periosteal new bone formation at the wrist, involving the radius and ulna, but may also involve the metacarpals. There is some evidence that the periosteal new bone may fluctuate with the disease activity (Arlart et al. 1982).

Although not generally considered alongside the other spondyloarthropathies, an asymmetric erosive arthritis of the hands and wrists with predominantly distal distribution is recognised as occurring in

association with primary biliary cirrhosis (Mills et al. 1981). Hypertrophic osteoarthropathy is also described with this condition.

## 2.4 Juvenile Idiopathic Arthritis

Juvenile idiopathic arthritis (JIA) is the term given to a heterogeneous group of conditions beginning in childhood and involving inflammation in one or more joints. By definition the term encompasses all forms of arthritis beginning before the age of 16 and persisting for more than 6 weeks when other known conditions have been excluded. The most recent classification has been determined by the International League of Associations for Rheumatology (ILAR) and unifies different classifications which previously existed in North America and Europe (Petty et al. 2004). Seven categories of JIA are recognised in the current classification (Table 1) (Petty et al. 2004; Ravelli and Martini 2007). The classification system is not without controversies and further developments may well occur (Ravelli and Martini 2007).

Early in the disease soft tissue swelling and osteopaenia may be seen in the hands and wrists of affected children. However, joint space loss is less frequently seen and often represents a later feature particularly in the oligoarthritis form of the disease. Erosion is also a relatively late radiographic finding in JIA. In patients with seropositive juvenile idiopathic polyarthritis more rapid joint space loss and erosion may be seen, a process similar to that seen in adult onset RA. Deformities may develop including boutonniere, flexion and swan neck deformities in the fingers. Radial deviation of the MCP joints in association with ulnar deviation of the wrist is recognised in JIA, and Resnick has noted the contrast between this pattern and the opposite finding of ulnar deviation of the MCP joints and radial deviation of the wrist commonly seen in adult onset RA (Granberry and Mangum 1980; Resnick 2002a).

Some radiographic findings are more specific to juvenile arthritis. In the late stages of the disease bony ankylosis is a common finding particularly at the wrist where radiographs may demonstrate union of the carpal bones to the metacarpals creating a solid ossific mass (Fig. 18). Periosteal new bone formation is also a common finding in the hands in JIA, typically

**Table 1** Classification of Juvenile Idiopathic Arthritis (Petty et al. 2004; Ravelli and Martini 2007)

Category	Clinical features
Systemic arthritis	Arthritis in one or more joints associated with, or preceded by fever and accompanied by one or more of the following: <ul style="list-style-type: none"> <li>• rash</li> <li>• lymphadenopathy</li> <li>• hepatomegaly and/or splenomegaly</li> <li>• serositis</li> </ul>
Oligoarthritis	Arthritis in 1–4 joints during the first 6 months of disease This typically occurs in early childhood and is more common in females. The oligoarthritis is usually asymmetric and predominantly affects the lower limbs
Rheumatoid-factor: positive polyarthritis	Arthritis affecting five or more joints during the first 6 months of disease with positive rheumatoid factor The disease typically affects the hands with a symmetric polyarthritis
Rheumatoid-factor: negative polyarthritis	Arthritis affecting five or more joints during the first 6 months of disease without rheumatoid factor
Enthesitis related arthritis	More common in male patients and characterised by the association of enthesitis and arthritis. The disease belongs to the group of spondyloarthropathies
Psoriatic arthritis	
Undifferentiated arthritis	

**Fig. 18** JIA: this patient demonstrates many of the late features of JIA. Note the fusion of the carpal bones, cupping and deformity of the proximal phalangeal bases and epiphyseal deformities resulting from growth disturbance



occurring along the metacarpal and phalangeal shafts. Growth disturbances involving the epiphyses of long bones are a further feature of juvenile arthritis (Figs. 18, 19). In the wrists, abnormalities of bone growth are seen in the form of irregular or multiple ossification centres in the carpal bones. In the hands, short, widened phalanges and metacarpals may develop in the later stages of the disease as a result of

growth disturbance and periosteal new bone formation (Fig. 19).

The osteoporotic bone seen in JIA may lead to epiphyseal collapse and deformity as a result of compression fractures due to abnormal stresses on the bone. Cupping of the proximal phalangeal bases as a result of compression by the metacarpals on the osteoporotic bone is described (Resnick 2002a) (Fig. 18).





**Fig. 19** JIA: there is epiphyseal deformity at the bases of the intermediate phalanges. There is corresponding deformity to the proximal phalangeal articular surface. Soft tissue swelling is also seen. Also note the widened intermediate phalanges typical of the disease

In common with adult onset RA, tenosynovitis is seen in JIA and may be observed as soft tissue swelling on plain radiographs. Rheumatoid nodules are also seen in JIA; these occur almost exclusively in the rheumatoid-factor-positive polyarthritis subcategory of the disease where they are seen in around one third of patients in the first year of disease (Ravelli and Martini 2007). Again on CR these may be seen as focal soft tissue lumps.

As with adult inflammatory arthritis, the majority of plain film findings represent late stages of the disease. While CR remains important in the assessment of the disease the role of more advanced imaging techniques, such as US and MRI, is increasing. In addition to allowing the visualisation of soft tissue changes such as synovitis, effusion and tenosynovitis; the cartilaginous bone ends of the immature skeleton, where early damage occurs are also demonstrated (Johnson and Gardner-Medwin 2002).

## 2.5 Advanced Imaging Techniques in Inflammatory Arthritis

Many of the features of inflammatory arthritis seen on CR represent late changes, which are often irreversible. Current guidelines in the management of these conditions emphasise the early and aggressive treatment of inflammatory

arthritis to alter the long-term disease process, minimise joint damage and induce long-term remission.

### 2.5.1 Synovitis and Effusion

Synovitis is an early feature of many arthritic processes including the inflammatory arthritides and connective tissue disorders. Using plain films the earliest manifestation of synovitis is soft tissue swelling, which may be associated with periarticular osteopaenia. The soft tissue swelling is usually detectable clinically by the time it can be seen on CR. Both US and MRI are readily able to detect synovitis and effusion before changes are visible on CR or detectable at the clinical examination (Farrant et al. 2007a; Peterfy 2001).

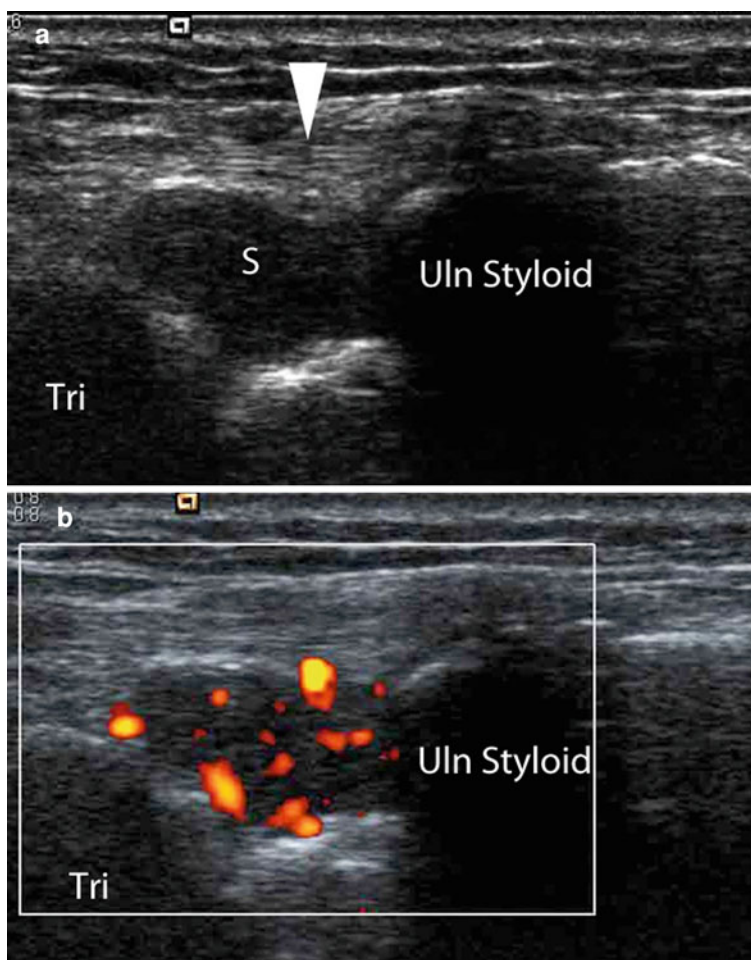
Normally synovium is not visualised at US, but when it becomes thickened it is seen as abnormal intra articular soft tissue (Fig. 20a) (Wakefield et al. 2005). The echogenicity of synovitis varies depending on the extent of extracellular oedema, the more fluid present the darker the synovium appears. Generally it appears of low reflectivity when compared with adjacent subcutaneous fat, but it may appear anechoic or brightly hyperechoic. Vascularity will frequently be demonstrated in the synovium using colour or power Doppler (Fig. 20b). When anechoic or hypoechoic, synovitis may be difficult to distinguish from joint fluid, which may have similar echo characteristics. However, with probe pressure fluid will normally be displaced while synovium is non-displaceable and only poorly compressible. Effusion will also show no Doppler signal. The morphology of the inflamed synovium varies, but typically in the low capacity joints of the hand and wrist it appears as thickening of the joint lining or as a solid mass.

On MRI synovitis has been defined as an area in the synovial compartment that shows above normal, post gadolinium enhancement of a thickness greater than the width of normal synovium (Ostergaard et al. 2003). This definition emphasises the importance of post-gadolinium imaging in the detection of synovitis which readily enhances and is otherwise very difficult to distinguish from effusion using conventional T1, proton density and T2 weighted imaging (Fig. 21).

### 2.5.2 Bone Erosion and Marrow Oedema

US and MRI will demonstrate erosive change resulting from inflammatory arthritis. A defect in the cortical

**Fig. 20** Wrist synovitis shown on ultrasound in rheumatoid arthritis: **a** the synovitis is seen as a low reflective soft tissue mass lesion (*S*), in this case on the ulnar aspect of the wrist. Part of the extensor carpi ulnaris tendon can be appreciated just superficial to the synovitis (*arrowhead*). **b** Using power Doppler vascular flow can be demonstrated in the synovitis. *Uln Styloid* ulnar styloid process, *Tri* triquetrum



surface is identified which may contain synovium (Figs. 21, 22). With both techniques the erosion must be identified in two planes to avoid confusion with normal bone surface contours. It is also important to be aware of the normal shape of the bones and in particular the sites of ligament attachments and vascular channels both of which can be confused with erosions. US and MRI are both more sensitive than CR for erosion detection. While US will only show the surface defect of an erosion, MRI shows changes within the substance of the bone marrow at the erosion site in the form of high T2 signal consistent with increased water content and often described as bone marrow oedema (Fig. 21b, c) (Ostergaard et al. 2003). Bone marrow oedema is a common finding in RA reported in 39% of cases of less than 3 years duration and 68% of cases of longer established RA (Savnik et al. 2001).

Marrow oedema may be seen in the absence of erosion and is potentially reversible; it is closely related to the extent of synovitis and may represent pre-erosive change, being strongly predictive of future erosion (McQueen et al. 2003; Haavardsholm et al. 2008; Hetland et al. 2009; Savnik et al. 2002).

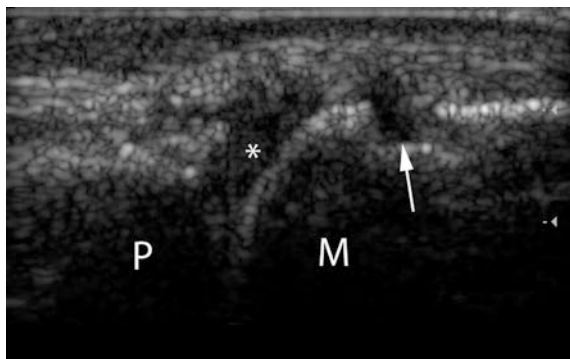
### 2.5.3 Enthesitis

Enthesitis is a characteristic feature of the seronegative arthropathies and is seen in the hand and wrist as a common feature of psoriatic arthritis. MRI demonstrates changes within the bone, in the form of marrow oedema, erosion and enthesophyte, and within the inserting tendon or ligament and surrounding soft tissues in the form of high T2 signal change and thickening of the inserting structure. The changes seen in the inserting tendon or ligament are



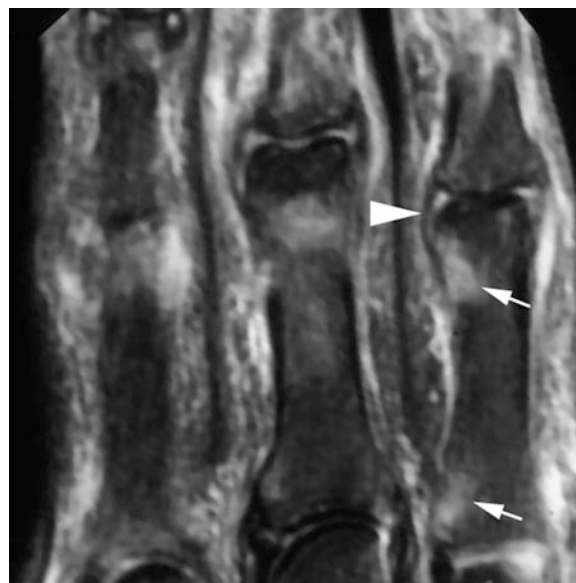
**Fig. 21** Rheumatoid arthritis shown on coronal MRI: **a** T1 weighted, **b** T2 weighted with fat saturation. Extensive synovitis is seen at the wrist as intermediate signal soft tissue on T1 and high signal soft tissue on T2 weighted imaging. It is best appreciated on the ulnar aspects of the wrist (*arrow*) where

it is seen eroding the triquetrum. **c** T1 fat saturated post i.v. gadolinium. Synovial enhancement is demonstrated. The T2 weighted and post gadolinium imaging demonstrates marrow oedema in the hamate (*asterisk*) and on T1 weighted imaging this is seen to be associated with bone erosion (*arrowhead*)



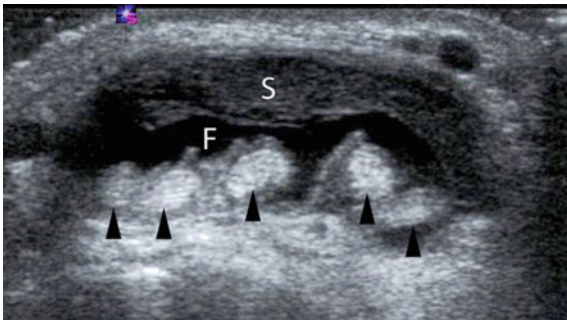
**Fig. 22** Rheumatoid arthritis erosion on US: the index MCP joint is demonstrated in longitudinal section. There is synovitis within the joint (*asterisk*) and an erosion is seen in the metacarpal head (*arrow*). The erosion contains hypochoic synovium. *M* metacarpal head, *P* proximal phalanx

similar to those seen in tendinopathic change. The fingers are sites of multiple entheses all in close proximity and a feature of psoriatic arthritis is dactylitis where widespread inflammatory changes seen throughout the digit which may reflect inflammation at the multiple entheses sites (Fig. 23) (Benjamin and McGonagle 2001). The extensive high T2 signal soft tissue changes seen beyond the joints in psoriatic arthritis are an important distinguishing feature from RA (Jevtic et al. 1995). US will also detect changes at the entheses sites in seronegative arthropathy, but



**Fig. 23** Psoriatic arthritis: coronal T2 weighted fat saturated image showing dactylitis. Extensive soft tissue oedema is shown in the digits. Enthesitis is demonstrated as foci of marrow oedema associated with capsular and ligamentous insertion sites (*arrows*) such as the insertion of the collateral ligament of the proximal interphalangeal joint highlighted (*arrowhead*) (Image courtesy of Dr PJ O'Connor and Dr A Radjenovic)

will not show the associated marrow changes. Fine enthesophyte formation is particularly well shown at tendon and ligament insertions using US.



**Fig. 24** Rheumatoid arthritis: a transverse ultrasound through the extensor digitorum compartment at the wrist shows tenosynovitis. The extensor tendons (*arrowheads*) are surrounded by fluid (*F*) and synovitis (*S*)

### 2.5.4 Tendon and Soft Tissue Disease

Tendon disease and tenosynovitis are both features of the inflammatory arthritides. Both US and MRI will demonstrate fluid in synovial sheaths and associated synovitis (Fig. 24). As in the case of joint disease gadolinium enhancement is helpful in distinguishing synovitis from fluid in tendon sheaths. Tendon rupture is a recognised complication of RA and may be due to tendon attrition resulting from adjacent osseous deformities or disease involvement of the tendon itself. Again US and MRI can demonstrate tendon rupture. The dynamic assessment of tendons that can be undertaken with US may help in identifying which tendons are torn and in establishing the location of the torn ends.

Rheumatoid nodules are a feature of RA. They most frequently occur in pressure bearing areas such as the elbow or heel, but are occasionally seen in the hand and wrist. They may occur in the subcutaneous soft tissues or adjacent or within tendons. Nodules typically appear on US as ovoid homogenous low reflective masses (Nalbant et al. 2003). On MRI nodules may have a solid appearance with a homogenous enhancement following gadolinium, but a cystic pattern may also be seen (el-Noueam et al. 1997). When nodules are seen adjacent to bone there may be associated cortical remodelling. The differential diagnosis for a rheumatoid nodule includes a gouty tophus. Bone remodelling is less frequently seen with rheumatoid nodules than with tophi, and tophi generally show increased density resulting in shadowing behind the lesion on US.

### 2.5.5 Application to Clinical Practice

Increasingly, US and MRI are being used in the early detection of inflammatory arthritis. US has clear advantages in being able to screen multiple joints in both hands and wrists rapidly and inexpensively while MRI is more time-consuming and requires intra-articular injection for the reliable assessment of synovitis. MRI has the advantage of being able to detect the early bone changes of bone marrow oedema along with synovitis and there is evidence to suggest that marrow oedema is the strongest predictor of future erosive damage (McQueen et al. 2003; Savnik et al. 2002). Most studies would suggest that US and MRI are of comparable sensitivity for the detection of synovitis and erosions, although US is limited around some joints, such as the MCP joints and in the wrist, by its inability to fully examine all bone surfaces (Farrant et al. 2007a, b).

### 2.5.6 Other Imaging Modalities

CT will demonstrate erosive change in bones, but at this time has not found routine clinical application in the investigation of the inflammatory arthritides. Scintigraphy will show increased uptake at inflamed joints using a variety of tracers including conventional  $^{99m}\text{Tc}$ -MDP. Inflammatory arthritis will produce increased tracer activity on all three phases of the bone scan. The technique provides a means of observing disease distribution, which may help in indicating the type of arthropathy. It is also sensitive to early changes in the disease process and may give information about disease activity, but bone scintigraphy is not part of the routine investigation of inflammatory arthritis and generally MRI and US can provide similar information.

## 2.6 Monitoring Disease Progression

The monitoring of disease progression and response to treatment in inflammatory arthritis is currently a subject of intensive research. Plain film scoring methods exist such as those developed by Larsen and Sharp based on erosions, joint space loss and soft tissue changes (Larsen et al. 1977; Sharp 1996). However, in recent years attention has turned to the use of MRI and US for monitoring disease status.



The use of MRI and US to monitor disease progression has concentrated on the scoring of erosive change and synovitis and, on MRI, marrow oedema.

Techniques for monitoring synovitis fall into two broad groups, detection of change in synovial volume and detection of change in synovial vascularity. Both volume and vascularity are predictive of disease activity. Volume can be reliably assessed with MRI but there is considerable technical difficulty in producing reliable measurements of volume on US other than with the use of semiquantitative scores. Vascularity is assessed on MRI using dynamic scanning during gadolinium enhancement and evaluating the shape of the contrast uptake curve which is more rapid in more active disease. Doppler US imaging can be used to assess the vascularity of synovitis, which in RA is shown to increase with disease activity. At this time these techniques remain in the research environment and have not found their way into mainstream clinical practice.

### 3 The Crystal Arthritides

The crystal arthropathies all involve crystal deposition either in, or adjacent to an affected joint. This is a heterogeneous group of diseases resulting in a variety of radiographic findings. Common crystals implicated are monosodium urate (producing gout), calcium pyrophosphate dihydrate and hydroxyapatite (HA).

#### 3.1 Gout

Although the radiological features of gout are well recognised, the pathophysiology of the disease is more complicated and remains the subject of research and controversy. Fundamental to the disease process is hyperuricaemia resulting either from decreased renal excretion or excess production of uric acid. The condition is frequently described as having four clinical phases (Monu and Pope 2004):

1. Asymptomatic hyperuricaemia: hyperuricaemia may exist in asymptomatic, but susceptible individuals, for years before the onset of clinical and radiographic findings.
2. Acute gouty arthritis: presentation with acute joint inflammation as a result of precipitation of urate crystals into the joint typifies this stage of the disease. While polyarticular disease is recognised, the acute inflammatory attacks are usually monoarticular and involve peripheral joints, usually in the lower limb and most commonly in the foot. Without treatment, progressive attacks result in more joints becoming involved and more chronic disease, which may affect any joint in the body.
3. Intercritical gout: this refers to the period without symptoms between acute attacks. It may last months or even years.
4. Chronic tophaceous gout: in this stage of the disease tophi develop in multiple tissues in the body as a result of urate crystal deposition with associated foreign body giant cell reaction. With the advent of effective antihyperuricaemic therapy this stage of the disease is becoming less common. Tophaceous deposits occur in a wide variety of tissues including tendons and ligaments, cartilage, bone and other soft tissues. Deposition in tendons and ligaments may lead to rupture (Moore and Weiland 1985) while mass effect may produce neural compression and gouty deposits are a recognised cause for carpal tunnel syndrome (Chen et al. 2000; Ogilvie and Kay 1988).

##### 3.1.1 Imaging Findings

Gout arthritis may involve any of the joints in the hand and wrist, but the DIP and PIP joints are most frequently affected. In the acute stages of the disease the radiographic findings are often non-specific, soft tissue swelling may be evident. If US and MRI are undertaken an effusion may be evident. The bone and soft tissue changes become more characteristic and apparent in the chronic phase of the disease where soft tissue tophi develop. These are appreciated as asymmetrical soft tissue swellings and the hands are frequently involved. Although calcification of the soft tissue swellings may occur it is said to be an unusual finding, and is likely to reflect a disorder of calcium metabolism such as associated renal impairment (Fig. 25) (Watt and Middlemiss 1975).

Joint space usually remains well preserved until late in the disease despite extensive erosive change, and this is one of the key features of the disease helping to distinguish it from other arthritides (Fig. 26). Erosions





**Fig. 25** Gout in patient with chronic renal failure: This patient has gout with large asymmetric soft tissue tophaceous masses about the distal interphalangeal joint which shows erosive change best appreciated in the terminal phalanx. The tophi are heavily calcified, a feature that is seen particularly in patients with renal impairment

result from tophi and may occur within joints, but are often seen some distance from the joint. The erosions have a characteristic circular or ovoid configuration and may have a sclerotic margin. Overhanging margins giving a ‘punched out’ appearance to the erosion are typical (Fig. 26) (Watt and Middlemiss 1975). Joint disease in the hand most commonly involves the interphalangeal joints in an asymmetrical distribution. All compartments in the wrist may be involved and extensive osseous erosion in the wrist is not uncommon.

US may detect crystal deposition on the articular cartilage and this has been reported in 92% of joints affected by gout (Thiele and Schlesinger 2007). The crystal deposition on the cartilage surface gives a double contour appearance to the joints. Both MRI and US will detect erosions due to gout and show tophaceous material associated with them. The tophi are seen as low reflective structures that are highly attenuating with shadowing behind the lesion. Crystal material within their substance varies from hypo- to hyperechoic. Lesions are clearly defined and may demonstrate marked hyperaemia. MRI shows tophi as structures of intermediate to low signal intensity on



**Fig. 26** Gout: this radiograph shows the typical ‘punched-out’ erosions with overhanging edges seen in gout. Note the marked soft tissue swelling and relative preservation of joint space, both features of this disease (Image courtesy of Dr PJ O’Connor)

short TE imaging but with variable intensity on T2 weighted imaging, most frequently heterogenous intermediate to low signal. It has been postulated that the variation in T2 intensity may relate to differences in calcium concentration (Yu et al. 1997). Bone erosion by soft tissue tophi is more commonly seen in the feet than the hands. Tophaceous involvement of tendons in the hand may also be seen on US and MRI.

### 3.2 Calcium Pyrophosphate Crystal Deposition Disease (CPPD)

Calcium pyrophosphate dihydrate (CPPD) deposition disease may be a primary abnormality or may occur in association with other conditions. Given how common CPPD deposition disease is it has been pointed out that many of the suggested associations that have been described in the past may be simple chance occurrence of two disorders (Resnick 2002b).

The nomenclature of CPPD deposition disease is confusing and controversial. The following guidelines on terminology have been put forward and are helpful for the radiologist (Resnick 2002b; Steinbach 2004; Steinbach and Resnick 1996):

*Chondrocalcinosis* Refers to the presence of cartilage calcification identified radiologically or pathologically.

It can be due to a variety or combination of calcium crystals including calcium pyrophosphate dihydrate.

*CPPD deposition disease* A specific term indicating a disorder characterised by CPPD crystals in or around joints.

*Pseudo-gout* This is a clinical syndrome produced by CPPD crystals resulting in acute attacks of gout like symptoms. The diagnosis is clinical and cannot be made radiologically.

*Pyrophosphate arthropathy* This term describes a pattern of joint damage occurring in CPPD deposition disease. It resembles OA but has some distinct features. Chondrocalcinosis may or may not be present on radiographs demonstrating pyrophosphate arthropathy.

One of the reasons for the confusion is the highly variable presentation of the disease. Calcium pyrophosphate deposition may be completely asymptomatic or result in severe destructive arthropathy, its ability to mimic other arthritides has been emphasised (Steinbach 2004; Martel et al. 1970). Patients with symptomatic CPPD deposition disease generally present with an OA like arthropathy although an acute inflammatory component may be seen. Intermittent attacks of pseudogout are said to occur in 10–20% of symptomatic patients and result from the shedding of pyrophosphate crystals into the joint (Steinbach 2004). The wrist is a frequent site for attacks of pseudogout. Synovitis associated with CPPD crystal deposition disease is a recognised cause of carpal tunnel syndrome.

### 3.2.1 Imaging Findings

The hallmark of CPPD deposition disease is the presence of CPPD crystals in or around a joint. This is most commonly seen in the form of chondrocalcinosis, but crystal deposition may also occur within synovium or capsular tissues. It is important to realise that the presence of these findings alone does not infer pyrophosphate arthropathy and pyrophosphate arthropathy does not require radiographic evidence of CPPD crystals. In the wrist chondrocalcinosis is frequently identified in the triangular fibrocartilage, although it has been shown that crystal deposition in the lunate-triquetral ligament is more common (Fig. 27) (Yang et al. 1995). Hyaline cartilage deposition may also be seen. Pyrophosphate arthropathy shows similar changes to OA with joint space narrowing along with subchondral sclerosis and cyst



**Fig. 27** Calcium pyrophosphate deposition: there is calcium crystal deposition in the triangular fibrocartilage (*arrowhead*). In addition crystal deposition is also seen in the lunotriquetral ligament (*white arrow*) and in the synovium of the distal radial the joint (*black arrow*)

formation. However, the distribution of the changes in the wrist contrasts with the classic trapeziocentric distribution of OA with a strong predilection for the radiocarpal wrist compartment (Fig. 28a). Associated with crystal deposition there may be disruption of the triangular fibrocartilage and ligamentous dysfunction resulting in rotatory subluxation of the scaphoid and scapholunate disassociation; this gives rise to a pattern of dorsal intercalated segment instability (DISI) similar to that seen following trauma. This pattern of scapholunate advanced collapse of the wrist (SLAC wrist) was originally described as a feature of OA but studies indicate that CPPD deposition disease is also a major cause of SLAC wrist (Chen et al. 1990).

The pattern of joint disease in the hands is also different to that seen with generalised OA with relative sparing of the interphalangeal joints and involvement predominantly of the MCP joints, most frequently those of the index and middle fingers (Fig. 28b). Another typical feature of the disease is the presence of hook like osteophytes generally seen on the radial aspect of the metacarpal head; this pattern of osteophytosis is particularly seen in patients with haemochromatosis and pyrophosphate arthropathy, a recognised association. As with idiopathic pyrophosphate arthropathy, involvement of the index and middle MCPs is commonly seen with



**Fig. 28** Pyrophosphate arthropathy: **a** calcium pyrophosphate crystal deposition can be seen in the synovium about the triangular fibrocartilage and in the distal radial on the joint. There is also crystal deposition in the lunotriquetral ligament. This is associated with arthropathy. The distribution of arthritis in the wrist is not typical for osteoarthritis. There is involvement

of the radiosaphoid and midcarpal joints, but note the preservation of the scaphotrapezial and thumb carpometacarpal joints. **b** In the same patient there is arthropathy involving the middle MCP joint with subchondral cyst formation, joint loss and early osteophyte formation (*arrow*)

**Fig. 29** Haemochromatosis arthropathy: there is joint space loss at the index and middle MCP joints with subchondral sclerosis. Involvement of the ring and little MCP joints and the little PIP joint can also be appreciated. Note the typical hook like osteophytes (*arrows*)



haemochromatosis; however, it has been observed that involvement of the ring and little finger MCP joints is also seen and is more common in patients with haemochromatosis than in those presenting with idiopathic pyrophosphate arthropathy (Fig. 29) (Steinbach 2004; Adamson et al. 1983).

Crystal deposition in cartilage and synovium and soft tissues including tendon is readily detected using US (Ciapetti et al. 2009). The position of crystals within the substance of cartilage is helpful in

distinguishing pyrophosphate arthropathy from gout, where the crystals lie on the surface of the cartilage forming the double contour appearance.

### 3.3 Calcium Hydroxyapatite Crystal Deposition Disease

Hydroxyapatite (HA) deposition disease is the best characterised of a group of crystal deposition diseases



**Fig. 30** Hydroxyapatite deposition: a large hydroxyapatite deposit is seen in the soft tissues adjacent to the middle MCP joint. Note the amorphous appearance. In this case the crystal deposition has a relatively well-defined margin

that may cause acute or chronic joint symptoms. The pathophysiology of the disease remains poorly understood. Crystal deposition may occur both in the periarticular tissues, most commonly tendons and ligaments, and within the joint itself and the disease can be usefully considered in two forms, periarticular disease and intra-articular disease (Uri and Dalinka 1996).

### 3.3.1 Periarticular HA Deposition Disease

The wrist and hand are common sites for HA crystal deposition and patients present with pain and swelling in the acute situation. When this occurs the pain may be particularly severe although in the more chronic situation the pain and tenderness is usually mild. Wrist involvement is more common than hand involvement, and crystal deposition usually occurs in tendons or ligaments, a particularly common site is in the flexor carpi ulnaris tendon on the ulnar aspect of the wrist (Gandee et al. 1979). In the hand the soft tissues around the MCP joints and the fingers are relatively common sites (Fig. 30). The calcification is seen on plain films and generally has an amorphous appearance without internal trabeculation. Deposits may have ill-defined borders or have a more well circumscribed appearance. While HA deposits may remain static on sequential radiographs, a notable

feature is that the calcification may change in size becoming larger, smaller or even disappearing completely; and such changes may occur over a relatively short period of time. A definite history of trauma is rarely given, but there is some suggestion that HA deposition in soft tissues may be related to repetitive low grade trauma such as may occur with certain occupations and activities (Gandee et al. 1979).

### 3.3.2 Intra-Articular HA Deposition Disease

Intra-articular HA deposition can occur without visible changes on the radiograph. However, crystal deposition in the synovium or capsule may be seen and occasionally chondrocalcinosis is identified (Uri and Dalinka 1996). The hands and wrists are more frequently involved than the larger joints. A destructive arthropathy resembling OA may be seen with joint space loss and osteophyte formation.

## 4 Osteoarthritis (OA)

Despite its ubiquitous nature and increasing prevalence as a result of an ageing population, the pathophysiology of OA remains poorly understood and the subject of considerable research. The advent of advanced imaging modalities such as MRI and US has started to reveal that OA should be considered a disease of the whole joint and not just one of articular cartilage and bone, which is often the impression given by the plain film. Synovitis, effusion, marrow oedema and ligamentous and fibrocartilage abnormalities are now recognised imaging features of the disease and may play an important role in the pathogenesis of pain.

It is recognised that certain risk factors exist for the development of OA, including intrinsic problems with the joint such as previous trauma, laxity or bone deformity. However, other factors are also important, including gender and genetic susceptibility, along with extrinsic factors acting upon the joint such as obesity or joint overuse as a result of sporting or occupational activity (Felson 2004). OA may occur in one or more joints as a direct result of acute or chronic repetitive trauma; but the hand and wrist is an important site for the development of idiopathic OA. In this case, there is usually involvement of other larger joints such as the knees, hips and spine.

**Fig. 31** Osteoarthritis: The typical ‘saw-tooth’ appearance of interphalangeal joint OA is seen. Note also the subchondral cyst formation and sclerosis



## 4.1 Plain Film Findings

The characteristic features of OA seen on CR are well recognised and reflect changes in the articular cartilage and subchondral bone along with osteophyte formation. Cartilage thinning and degradation is recognised as joint space narrowing. Subchondral bone change includes eburnation, sclerosis and cyst formation. Periarticular osteoporosis is not a feature of the disease.

In the hand the most commonly affected joints are the interphalangeal joints of the fingers and the thumb. Changes in both the PIP and DIP finger joints are frequently seen, but isolated involvement of the DIP joints may occur. Involvement of the PIP joints without DIP joint involvement is relatively unusual. Wrist involvement is almost always confined to the thumb base in a trapeziocentric distribution.

## 4.2 Findings at Specific Joints

### 4.2.1 Interphalangeal Joints

The classical features of OA described above are all seen at the interphalangeal joints. Subchondral cyst formation may be particularly prominent. In many joints cartilage loss in OA, seen as joint space narrowing, occurs asymmetrically within the joint favouring areas where the joint experiences particular pressure. In interphalangeal joints, joint space loss frequently occurs across the whole joint. Areas of eburnation and subchondral collapse may produce a characteristic ‘saw-tooth’ appearance to the articular surfaces (Fig. 31).

Osteophytes are often seen on the dorsal aspect of the interphalangeal joints where they may track proximally. The hands are usually evaluated radiographically with a

dorsal-palmar view and on this single view the extent of such osteophytosis may not be appreciated. Osteophytes account in part for the palpable swellings appreciated at the DIP and PIP joints and termed Heberden’s and Bouchard’s nodes, respectively. However, it is also recognised that cystic distension of the joint capsule with gelatinous material and synovium is also seen, particularly at the DIP joints, and in some cases this may account for the nodes. Such cysts appear to extrude through points of weakness in the capsule, typically either side of the central extensor tendon (McGonagle et al. 2008; Tan et al. 2005).

### 4.2.2 Metacarpophalangeal Joints

Involvement of the MCP joints is not uncommon but usually only occurs in the presence of more distal disease involving the interphalangeal joints of the hand (Martel et al. 1973). In contrast, pyrophosphate arthropathy characteristically affects the MCP joints proving a useful distinguishing feature where otherwise, in the absence of any visible crystal deposition, it shows features similar to OA. In many cases joint space loss is the only finding and the presence of OA elsewhere and the absence of erosions and periarticular osteopaenia must be used to distinguish OA from inflammatory arthritis. Osteophytes when present are usually small, in comparison to the larger osteophytes seen in CPPD deposition disease.

### 4.2.3 The Wrist

#### Trapeziocentric Joints

The usual pattern of wrist OA involves the thumb base, occurring at the thumb carpometacarpal joint (trapeziometacarpal) and scaphotrapezotrapezoidal (STT) joint (between the scaphoid, trapezium and trapezoid). In the absence of trauma causing secondary OA, involvement of the other joint spaces in the wrist is uncommon and when seen, should suggest the possibility of an alternative diagnosis such as pyrophosphate arthropathy.

It is often helpful to think of the articulations between the scaphoid, trapezium, trapezoid and thumb metacarpal as a single unit and disease here can be summarised as trapeziocentric or pantrapezial. While either the STT joint or thumb carpometacarpal joint may show isolated OA changes, involvement in the two joints together is common (Fig. 32) (North and Eaton 1983). There is evidence that CR overestimates the





**Fig. 32** Osteoarthritis: this example shows the typical appearances of thumb base OA involving the CMC joint. There is radial subluxation of the metacarpal base. In this case the STT joint is preserved. Also note the preservation of the remaining wrist joints typical of OA

extent of disease involving this unit. North and Eaton showed that while trapeziocentric OA was seen in 73% of cases radiographically it was found to be present in only 46% at anatomical dissection (North and Eaton 1983). Characteristic changes of sclerosis, osteophytosis, joint space loss and subchondral cyst formation are seen. Osteophytosis is particularly common at the thumb carpometacarpal joint where bony fragmentation may also be seen. It is thought that the pathogenesis of OA at the thumb carpometacarpal joint may result from abnormal joint laxity and radial subluxation of the metacarpal base at the carpometacarpal joint is a feature of advanced disease (Fig. 32) (Sicre et al. 1997). It has been noted that the saddle-shaped articulation between the trapezium and thumb metacarpal is generally flatter in women than men, and therefore inherently less stable (North and Rutledge 1983).

#### Other Wrist Joint Involvement

Injury to the wrist may result in secondary OA involving wrist joints other than those at the thumb base. Classically radiocarpal or midcarpal OA may be seen following scaphoid injury. If fracture occurs, secondary OA may develop, generally between the radial styloid and distal fragment of the scaphoid. This situation is known as scaphoid non-union advanced collapse (SNAC) and, in the later stages of the disease, involvement of the radio-scaphoid joint and subsequently the midcarpal joint is seen (Krimmer et al. 1997). Radioscaphoid disease progressing to midcarpal



**Fig. 33** SLAC wrist: osteoarthritis has developed following an injury with disruption of the scapholunate ligament (note widening of the scapholunate interval). Changes of OA are seen at the radioscaphoid joint, typical with this pattern of disease

disease is also seen as a consequence of scapholunate disassociation and has been termed scapholunate advanced collapse (SLAC) (Fig. 33) (Watson and Ballet 1984). This pattern of joint disease is also seen as a consequence of pyrophosphate arthropathy and the distinction can only be reliably made if there is evidence of CPPD deposition disease (Chen et al. 1990).

A further pattern of wrist OA may be seen in association with positive ulnar variance leading to impingement across the ulna-lunate and ulna-triquetral joints. This has been termed the ulnocarpal impaction syndrome and results in findings typical of OA involving the ulna-lunate and ulna-triquetral joints. Dissociation of the lunate and triquetrum may be seen on CR as a consequence of lunate-triquetrum ligament disruption. MRI will also show this feature along with perforation of the triangular fibrocartilage, which is commonly associated.

### 4.3 Inflammatory OA

While OA is not generally viewed as an inflammatory arthritis, a subgroup of patients is recognised as having an inflammatory variant of the disease, which has been termed inflammatory OA (Ehrlich 1972a; Utsinger et al. 1978). Since these patients may show erosions the term erosive OA has also been used.

**Fig. 34** Erosive OA: there is central (subchondral) erosion typical of erosive osteoarthritis



Although large joint involvement has been recognised, inflammatory OA characteristically affects the small joints of the hands. The relationship between conventional OA and erosive OA is unclear and authors have suggested on the one hand that the two arthropathies may constitute separate disease entities (Peter et al. 1966), while others suggest it may belong at one end of a disease spectrum (Grainger et al. 2007; Cobby et al. 1990). It has also been postulated that inflammatory OA represents a disease entity at an interface between OA and RA (Ehrlich 1972b). With the advent of more advanced imaging modalities it is apparent that cases not considered erosive using plain film criteria may show erosions with MRI (Tan et al. 2005; Grainger et al. 2007). These findings suggest that the division of OA into erosive and non-erosive forms on the basis of CR may be artificial.

#### 4.3.1 Radiographic Features

The radiographic hallmark of erosive OA is the presence of erosive change alongside the expected findings in OA of joint space narrowing and proliferative change. Sites of involvement in the hand and wrist are the same as those seen in generalised primary OA although erosive change at the thumb base is rarely seen even in the presence of interphalangeal joint erosions. Erosions in inflammatory OA are typically central in location, which contrasts with the marginal erosions seen in rheumatoid and psoriatic arthropathy (Fig. 34). Nevertheless marginal erosions, indistinguishable from those seen in RA, may be demonstrated, particularly using MRI (Grainger et al. 2007; Kidd and Peter 1966). The central pattern of erosion may be due to synovial inflammation but it is

also suggested it relates to collapse or pressure atrophy of the subchondral bone. Central erosions may lead to the characteristic ‘seagull wing’ appearance. Periosteal new bone formation may be seen although it is not usually as florid as that found in psoriatic arthritis. Bony ankylosis is a relatively frequent occurrence in inflammatory OA (Martel et al. 1980).

Distinguishing erosive OA from inflammatory arthropathy can be difficult. OA typically affects the PIP and DIP joints, which is useful in distinguishing it from RA with its generally more proximal distribution. The bone proliferation and sclerosis seen in OA also contrasts with the appearances of RA where osteopaenia is the typical finding. When seen in the wrist, erosive OA will usually show the characteristic thumb base distribution of OA while the inflammatory arthritides will show involvement in all wrist compartments. The distinction between erosive OA and psoriatic arthritis can be more difficult as the latter also shows bony proliferation in the form of enthesophyte formation and a distal distribution. The central pattern of erosion helps in distinguishing the two conditions, as does the more florid periosteal new bone seen in psoriatic arthritis. The presence of OA elsewhere such as the thumb base may also give clues, but it is important to remember that OA is a common condition and may coexist with seronegative arthritis or RA. This occurrence may account for some cases diagnosed as erosive OA.

#### 4.4 Advanced Imaging Techniques

MRI has been used in a research capacity to look at OA in the hand and this has given valuable information on the potential aetiology of the disease (Tan et al. 2005, 2006a, b). However, as yet there are no mainstream applications for the routine use of MRI in hand and wrist OA. Similarly US is readily able to detect changes of OA, particularly synovitis, osteophyte and effusion (Keen et al. 2008a, b). While US appears to be more sensitive to the detection of osteophyte and joint space narrowing in hand and wrist OA than CR, its use as a diagnostic tool remains confined to the research environment (Keen et al. 2008b). US is useful as a technique for guiding therapeutic injection to the carpometacarpal joint in cases of trapeziocentric OA (Gregory et al. 2008).



**Fig. 35** Scleroderma: the study demonstrates extensive soft tissue calcification seen in subcutaneous tissues. Note also the soft tissue loss from the tips of the fingers

## 5 Connective Tissue Disease

### 5.1 Scleroderma

Scleroderma is a connective tissue disorder with characteristic radiographic abnormalities seen in the bones and soft tissues and frequently affecting the hands and wrists. Raynaud's syndrome (paroxysmal vasospasm of the digital arteries) is associated with the disease and may be the presenting feature. Joint involvement is an important component of the disease.

Radiographic features of scleroderma in the hands include:

- Soft tissue resorption at the fingertips: this is a common finding which may be visible on CR if the tissues overlying the distal tip of the terminal phalanx are examined (Fig. 35).
- Soft tissue calcification: The hand is the most common site for calcinosis seen in scleroderma and calcification may be seen in both of the subcutaneous tissues and periarticular capsular tissues. The calcification has an amorphous appearance (Fig. 35).
- Bone erosion and articular involvement: the most frequent pattern of bone loss in scleroderma involves resorption of the terminal tuft, which can result in

complete destruction of the terminal phalanx. Patients may go on to develop an erosive arthropathy which generally favours the distal and PIP joints with sparing of the wrist; although it has been noted that involvement of the first carpometacarpal joint may be seen (Resnick et al. 1978). A pattern of erosive arthropathy has been reported in patients with scleroderma that much more closely resembles RA with a deforming arthropathy involving the hands and wrists (Armstrong and Gibson 1982; Baron et al. 1982). However, it has been emphasised that when these findings are seen they may represent part of an 'overlap syndrome' with features of both diseases, or indeed the coexistence of the two diseases (Armstrong and Gibson 1982).

### 5.2 Dermatomyositis and Polymyositis

Dermatomyositis and polymyositis are connective tissue disorders both characterised by muscle inflammation and weakness, and in the case of dermatomyositis, skin involvement. Both conditions may give rise to soft tissue calcification. Characteristically intramuscular calcification involves the proximal limb muscles, but subcutaneous calcification similar to that seen in scleroderma

may be seen in the hands, as may distal phalangeal resorption. Joint involvement may also occur clinically although radiographs are normally unremarkable or show subtle changes such as periarticular osteopaenia and soft tissue swelling. Occasional reports of destructive joint changes exist (Bunch et al. 1976).

### 5.3 Systemic Lupus Erythematosus

Systemic lupus erythematosus (SLE) is a connective tissue disorder predominantly affecting women during childbearing years. Early clinical manifestations include systemic malaise and fever, skin rash and articular symptoms. In the later stages of the disease more severe multisystem involvement may be seen. Articular symptoms are common and have been reported in 76% of patients (Labowitz and Schumacher 1971), although the figure may be as high as 90% (Resnick 2002c). Symmetrical, bilateral involvement of the small joints of the hands is common. The most frequent finding is synovitis, and radiographs may show soft tissue swelling and osteopaenia (Weissman et al. 1978). At this stage MRI and US will demonstrate the effusion and synovial thickening. Erosive change is not typical of the disease and has only occasionally been reported (Weissman et al. 1978). This provides an important distinguishing feature from RA. It remains unclear whether those cases showing erosions in fact represent a group of patients with both SLE and RA.

A distinctive feature of SLE is a deforming non-erosive arthropathy, which may develop early in the disease course, but is more common later in the disease (Fig. 36) (Resnick 2002c; Weissman et al. 1978). Involvement is usually symmetrical involving multiple digits with a combination of deformities and subluxations that are commonly reducible. Swan-neck and Boutonniere deformities typical of those seen in RA are seen, but joint space loss and erosion are rarely seen even with severe deformities. Hyperextension at the thumb interphalangeal joint is said to be characteristic. It has been noted that the deformity may disappear when the hand is positioned for radiography (Resnick 2002c). These changes may also be seen in children where they may mimic JIA (Martini et al. 1987).

Some patients may demonstrate soft tissue calcification, and terminal phalangeal sclerosis has also been reported. The latter can occur in the absence of



**Fig. 36** SLE: subluxations, which were reversible, are seen at the MCP joints. However, note the absence of erosions and the preservation of joint spaces

associated Raynaud's phenomenon (Weissman et al. 1978). Osteonecrosis is a well-recognised feature in SLE and may occur in the hands where its presence (typically in the MCP heads) should raise the question of possible SLE (Weissman et al. 1978; Fishel et al. 1987). Other features that have been reported include subchondral cyst formation, typically in the metacarpal heads and carpal bones, and occasionally 'hook erosions' seen as bony defects usually on the radial aspect of the metacarpal heads (Resnick 2002c).

### 5.4 Rheumatic Fever (Jaccoud's Arthropathy)

A deforming hand arthropathy associated with rheumatic fever is well recognised and is radiologically indistinguishable from the deforming non-erosive arthropathy of SLE. It has been termed Jaccoud's arthropathy. This usually occurs after repeated attacks of rheumatic arthritis.



Joint involvement is commonly seen in the course of an acute attack of rheumatic fever where multiple joints may be involved either simultaneously or successively. This joint inflammation may be seen as soft tissue swelling on CR. US and MRI may detect small joint effusions and occasionally tenosynovitis.

## 5.5 Mixed Connective Tissue Disease

Mixed connective tissue disease, as its name suggests, combines overlapping features of the connective tissue diseases and RA. A wide range of articular and soft tissue abnormalities may be seen on hand and wrist radiographs including osseous erosions, bone deformity, soft tissue calcification and atrophy and resorption of the terminal phalanges. Articular changes are most commonly seen in a proximal distribution similar to that seen in RA, involving PIP and MCP joints and the wrist.

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