There are various modalities of joint imaging e.g. conventional radiography (CR), computed tomography (CT), magnetic resonance imaging (MRI), bone scintigraphy, positron emission tomography (PET), ultrasonography (US), bone densitography. CR shows only bone lesions, while CT demonstrate both bone and soft-tissue changes. MRI is the best modality at showing soft tissue contrast than CT scan and is multiplanar, but less sensitive in assessing bone lesions than CT.

**CONVENTIONAL RADIOGRAPHY**

Not only does CR establish the presence of disease, but serial films can be used to assess change or response to therapy. Bone erosions, joint space narrowing, subluxation, malalignment and ankylosis of the joints may be seen. Early bone changes are not seen in plain x-rays.

**Rheumatoid Arthritis (RA)**

X-ray hands and feet PA view (Fig 1 & 2) will show changes in metacarpophalangeal (MCP), proximal interphalangeal (PIP), carpals joints of hands, and metatarsophalangeal (MTP) and interphalangeal joints of feet. Distal interphalangeal joints (DIP) are not involved in RA. Serial measurements of radiological progression provide substantially more information than a single X-ray.

Early changes:
1. Fusiform soft tissue swelling around joints
2. Periarticular osteopenia (PAO)
3. Joint space narrowing (JSN)

Delayed changes:
1. Periarticular erosions (Fig 2)
2. Cystic spaces
3. Subluxations e.g. ulnar deviation and deformities
4. Ankylosis.

Erosions are diagnostic of RA, their presence early in the disease suggests a poor prognosis. The erosions are located at the so-called ‘bare areas’ at the margins of the joint, not covered by cartilage. Metacarpal and metatarsal heads are frequently involved at an early stage. Early erosions in the hands and wrist occur typically on the radial aspects of the index and middle metacarpal heads, around the ulnar styloid, and on the ulnar aspect of the head of the little finger metacarpal. Deeper sub-articular cysts, or geodes, may cause substantial bone resorption, either as the result of intraosseous pannus or of synovial fluid entering bone via a localized cortical defect.

In the feet erosions of bare areas on the heads of the metatarsals may be seen. Subluxation of proximal phalanges and hallux varus or valgus deformities of great toe may also be seen. Feet involvement may be concurrent with hand involvement or may be involved later. Earliest erosions are seen on the lateral aspect of 5th metatarsal head (Fig.1). Knee joints show pancompartmental JSN. Hip joints are involved in about 21% of cases and it is bilateral. Diffuse JSN and erosions of femoral head and acetabular surface can lead to protrusion of femoral head and acetabulum into the pelvis, called protrusio. Shoulder joints may show JSN of the glenohumeral (best seen in Grashey view), acromiohumeral and acromioclavicular joint. Healing of erosive damage is rarely reported but can occur.\textsuperscript{1,2}

Atlanto-axial joint subluxation due to progressive erosive changes of odontoid process may occur, best seen in lateral, flexed view where distance between anterior arch of C1 and anterior aspect of dens of C2 increases (Normal - 3mm).

**Spondyloarthropathy (SpA)**
Axial skeleton like spine and sacroiliac joints (SI) are characteristically involved in SpA. Subchondral bony erosions occur on the iliac side of SI joints, followed by bony proliferation and sclerosis. Changes occur in lower 1/3rd of SI joints which is synovial. Joint space initially appear to be widened, gradually whole of the SI joint is involved which ultimately fuses (Fig.3,4,5,6). Sclerosis disappears when fusion is complete.

Initially spine is involved in lumbosacral & thoracolumbar segment, so x-ray of these regions AP and lateral view should be done.

![Fig.3: SpA : Grade 1. Sacroiliitis : Blurred joint margins](image1)

![Fig.4: SpA -AS : Grade 2 Sacroiliitis : Early erosions & Sclerosis at left Sacroiliac joint & early mild changes at right](image2)

![Fig.5: SpA: Bilateral grade 3 sacroiliitis with subchondral sclerosis, erosions, and irregular widening of the joints](image3)

![Fig.6: SpA.Grade 4Sacroiliitis - Complete ankylosis of SI joint](image4)
and pelvis may show retrocalcaneal and infracalcaneal spurs (Fig.7) and whiskers around pelvis.
In spine this manifests as small erosion surrounded by bony sclerosis at the vertebral corners seen as shiny corners known as Romanus lesions.

2. Syndesmophytes - Ossification of outer annular fibers to form marginal and symmetric bony outgrowths, which can be differentiated with osteophytes as latter grows outward or perpendicular to the vertebral body. Complete fusion of the vertebral bodies by syndesmophytes may occur producing 'bamboo spine' (Fig.8 & 9).

3. Squaring of the vertebral bodies caused by corner erosions and new bone formation leading to loss of normal concavity of anterior border of vertebral body (Fig.10). Shiny corner sign, squaring of vertebrae, and syndesmophytes may antedate the development of radiographic sacroiliitis in a small minority of patients. They are commonly found at the thoracolumbar junction.

4. Erosions followed by ankylosis of costotransverse and costovertebral joints may occur.

5. Andersson lesion: Fractures through ankylosed spine becomes the single point of motion in the entire spine resulting in non-union with pseudoarthrosis.

6. Peripheral arthropathy: Hips, knees and shoulders are affected in 1/3rd patients. Hip joints show uniform JSN and medial migration of femoral head.

Five subgroups of spondyloarthritis are distinguished:

- Ankylosing spondylitis (AS)
- Reactive arthritis (Reiter syndrome)
- Psoriatic arthritis (PsA)
- Arthritis associated with inflammatory bowel disease (eg, Crohn disease or ulcerative colitis)
- Undifferentiated spondyloarthritis

SI joint (asymmetric or symmetric) and spine involvement is seen in 20-40% patients of ReA and PsA and syndesmophytes are non-marginal, asymmetric and coarse (Fig.11). Bone proliferation occurs in SpA especially in PsA and ReA resulting in bony excrescences [Mouse ear (Fig.12)] and periosteal new bone formation. Entire phalanx may become "cloaked" in new bone "Ivory phalanx" (Fig.13), most frequent in terminal phalanges of toes, especially first. Other manifestations of PsA are pencil in cup deformity (Fig.14).
There may be marked destructive changes with subluxation (Arthritis mutilans 15 & 16) and involvement of DIP (Fig.16) in PsA.
Figure 17: Gout (a) X-Ray hands (oblique view) bone erosions located in MCP joints and in PIP & DIP joints. (b) X-Ray foot (dorsal-plantar projection) extensive bone erosions involving the first and fifth MTP joints, and PIP & DIP joints. Intratophus calcifications in intraosseous tophi and in periarticular tophi. (c) X-Ray tarsal bones (oblique view) showing erosions in the scaphoid and first metatarsal bone, with typical overhanging edges. Soft-tissue masses due to extensive tophaceous deposition may also be observed.

Crystal Arthropathy

Gout: Characteristic radiological changes are: Intra-articular or periarticular erosions which are aligned with long axis of bone (Fig.17) and may have a rim of sclerosis. Overhanging margins (Martel's sign) is typical of gout (Fig.18) and occurs as tophus wedges into joint. JSN does not occur until late in the disease.

Calcium pyrophosphate dihydrate deposition (CPPD) disease: Calcification in articular cartilage is linear and lies in the mid-zone (Fig.19).

Hydroxyapatite deposition disease (HADD): Calcium hydroxyapatite crystals are mostly idiopathic but may be associated with renal failure or diabetes mellitus. Supraspinatus tendon is the most common periarticular sites of HADD (Fig.20).

Radiography in collagen vascular diseases: Systemic Sclerosis (SSc): (Fig 21)
CT Scan
The current use of CT is in the detection of change in calcified tissues, as these are less well visualized at MRI. CT scan detects calcifications in soft tissues (capsular and ligamental). CT helps in detecting CPPD, diffuse idiopathic skeletal hyperostosis (DISH) and Paget’s disease. In SpA, initial involvement of only one side of the sacroiliac joints or new bone formation and/or destruction of the joint cartilage with complete fusion are all accurately visualized using CT (Fig.22) and apophyseal joints like costovertebral and sternoclavicular joints which may be involved in SpA are also well visualized in CT scan. HRCT increases the accuracy of CT imaging, which helps in confirmation, and exclusion of sacroiliitis.

CT scans may be:
- High-resolution CT (HRCT);
- Contrast-enhanced CT (CECT);
- Helical (spiral) CT and dynamic CT;
- Dual Energy CT.
- Quantitative CT (QCT)

Dual-energy CT (DECT) imaging helps in computerised quantification of tophus volume in peripheral joints. DECT scans are performed using a renal stone colour-coding protocol that specifically assesses the chemical composition of the material (i.e. urate coloured in red, calcium coloured in blue). DECT is the only imaging method described to date that can confirm the diagnosis of chronic tophaceous gout with high accuracy (Fig.23).

QCT can assess both bone volume and bone density in the axial and appendicular skeletons and separately measures cortical and trabecular bone. Irradiation dose is high which precludes its use for assessment of normal persons in research studies.
Magnetic Resonance Imaging (MRI)

MRI is ideal for imaging diarthrodial joints and can examine all components of the joint simultaneously and therefore the joint as a whole organ. MRI is safe during pregnancy as it does not use ionizing radiations. It is highly sensitive to detect bone erosions in the hands and wrists of RA patients (Fig. 24). MRI can visualize pre-erosive inflammatory changes, synovial hyperplasia and joint effusions. Two MR sequences are done T1 & T2. Presence of inflammation in the marrow may be obscured by the signal from marrow fat. The short tau inversion recovery (STIR) sequence is a T2-weighted sequence that suppresses the fat signal so that the marrow now appears dark, and any fluid within the marrow due to active inflammation is relatively bright. Subchondral oedema may be seen in postero-inferior part of the SI joint in very early stages of sacroiliitis, therefore it is the investigation of choice in early SpA. Later erosions develop leading to loss of the marrow fat signal on T1WI (T1 weighted image) together with loss of subarticular bone. Enhancement of synovium in volume, the rate and magnitude after IV gadolinium (Gd DTPA) have been shown to correlate with the histological severity of inflammation in the synovium (Fig. 25). Sacroiliitis, enthesitis and temporomandibular joints may be better seen in MRI. Romanus lesion is seen as increased marrow signal at
anterior and posterior borders of vertebrae (Fig.26). Chronic lesions like syndesmophytes are better seen in x-rays than in MRI. STIR images show inflammation at costovertebral and costotransverse joints (Fig.27). Intra-articular foreign bodies (e.g. thorns etc) causing monoarthritis, may also be seen by MRI or US.

**Scintigraphy**

Tc-99m labelled diphosphonates is used IV and closely sequenced images are acquired using gamma camera. This modality is used to detect how many joints are affected and which joints are most affected and any unsuspected site if involved can be detected. Negative bone scan shows absence of active arthritis. Bone scans can detect erosions in RA, can localize pain and is helpful to localize bony metastases. It is very useful in reflex sympathetic dystrophy syndrome (RSDS) where intense periarticular activity in an involved extremity on the delayed phase of the scan preceded by hyperemia in a similar distribution on the immediate post-injection blood flow and blood pool phases of the scan is seen (Fig.28). In SpA sacroiliitis can be seen earlier before conventional radiography. Quantitative scintigraphy is performed by using the sacroiliac joint-sacrum-ratio (Normal ratio 1-1.5). But specificity of bone scan is poor.

**Ultrasound**

US images are produced by the sequential emission and reception of sound waves in the range of 2.0 to 12.0 MHz by a piezoelectric crystal, grey scale and Doppler techniques are used. It is safe as it does not use radiation and can distinguish solid structures from those filled with liquid. It is helpful in following conditions:

- Diagnosing ruptured Baker’s cyst.
- Detection of a fluid collection in joints, bursae, tendon sheaths and soft tissues. US detects minute amounts of fluid (1-2 ml) in asymptomatic joints of healthy subjects.
- In diagnosis of enthesitis and bursitis.
- In detecting synovial thickening (Fig.29), proliferation and villous formation.
- US is capable of detecting up to seven times more erosions than plain radiography in early RA (Fig.30).  
- US localizes effusions and thus guide aspiration and increases the rate of successful aspiration when compared with conventional aspiration of the peripheral joints by 3-fold. Therapeutic intra-articular and intralesional injection therapy is also more successfully done under US.
- Power Doppler US (PDUS) can detect smaller degrees of synovitis with a reported accuracy equal to that of
In OA, US detects thinning of the cartilage layer and presence of osteophytes.

In Gout US:
- Double contour sign (Fig. 32)\textsuperscript{10} Hyperechoic nodules (Fig. 33)\textsuperscript{10}, bone erosions and tophi can be seen by US.
- Power-Doppler signal is present in acutely inflamed joints from gout patients (Fig. 34)\textsuperscript{10}, and the power-Doppler signal disappears with treatment\textsuperscript{11}.
- Gouty synovitis is better detected with PDUS than with clinical examination\textsuperscript{12}.

PET scan
FDG (18 fluorodeoxyglucose) PET scan has been investigated for assessing the metabolic activity of rheumatoid synovitis. FDG is a radiopharmaceutical analog of glucose that is taken up by metabolically active cells. PET-CT involves the simultaneous acquisition of both metabolic (PET) and anatomic (CT) information which is then combined for presentation (Fig. 35)\textsuperscript{13}. PET/CT is able to detect active inflammation in areas that are clinically asymptomatic. Detecting active inflammation at the atlantoaxial joint before clinical symptoms develop may be a determinant of future instability\textsuperscript{14}.

Dual Energy X-Ray absorptiometry scan (DEXA Scan)
DEXA has several advantages, such as fast scanning, high accuracy, low cost, low radiation dose, and applicability to clinically relevant sites of osteoporotic fracture. However, DEXA provides two-dimensional imaging of 3-D objects, does not distinguish between trabecular and cortical bone. Hip DEXA is preferred for diagnosis and in patients > 65 years old as osteophytes and vascular calcification interferes with Bone mineral density (BMD) measurement at spine. Spine DEXA is preferred for monitoring therapy of osteoporosis as response is earlier at spine than at hip. BMD is compared with the expected peak bone mass of young adults (T-score), which shows whether patient is osteopenic or osteoporotic (Fig 36).
Fig. 35: Active synovitis in RA. The 3-dimensional projection image (top) depicts a typical pattern of synovitis of the right knee. Bottom panel: Corresponding transaxial slices of the PET, CT, and fused PET/CT images (from left to right) show that the increased FDG levels correspond to thickened synovium (arrows).

Fig. 36: DEXA Scan: T-Scores - > 1 (Normal), T-Score - < 1 & -2.5 (Osteopenia), T-Score - < -2.5 (Osteoporosis)

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