Radiography in Osteoporosis

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Contents

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Abstract

The pathological changes of osteoporosis are due to resorption of the cortical and trabecular bone. The main radiographic findings include changes in the trabecular pattern, cortical thinning, and decreased bone density which are more prominent in the axial skeleton. Although the most common cause is primary osteoporosis, one has to be aware of the secondary causes as well. Conventional radiography helps in evaluating the secondary causes of osteoporosis, to confirm or rule out fractures and to diagnose concomitant or predisposing conditions. However, radiographs have certain limitations. Radiography only helps in qualitative assessment and cannot be considered as a tool for quantitative assessment. This chapter aims to review the radio-pathological changes and various causes of osteoporosis.

1 Key points

- Conventional radiography helps in subjective quantification of bone density, microstructural changes in the trabeculae, fractures, and deformities due to osteoporosis.
- Approximately 20–40 % of bone mass has to be lost for a bone to appear osteopenic and various technical factors also affect the appearance of the bone density in the radiographs.
- Primary osteoporosis (post-menopausal or senile osteoporosis) is the most common cause of osteoporosis. Radiographs are useful for visualizing the deformities or fractures of spine, to assess the trabecular pattern of the femoral head, and also in the distal appendicular skeleton. Radiographs are also useful in assessing the response to medications used for the treatment of osteoporosis.
- Secondary osteoporosis may be due to numerous causes and radiographs are often helpful in the differential diagnosis and for follow-up of the particular causative

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clinical condition such as hyperparathyroidism and steroid-induced osteoporosis.
- Osteoporosis can be regional or occasionally localized to a particular limb in conditions such as reflex sympathetic dystrophy.

2 Introduction

Osteoporosis is the most common metabolic bone disorder and is defined by the World Health Organization (WHO) as "skeletal disease characterized by low bone mass and micro architectural deterioration of bone tissue, with a consequent increase in bone fragility and susceptibility to fracture" (Guglielmi et al. 2011). Although there are various methods such as dual-energy X-ray absorptiometry (DXA) and quantitative computed tomography (q-CT) for quantifying the bone density, conventional radiography helps in subjectively assessing the density of the bone and also in detection of fracture and alterations in the bone resorption in certain conditions such as hyperparathyroidism (Grampp et al. 1996, 1997). It also helps in diagnosis and follow-up of associated fractures. Recently, magnetic resonance (MR) imaging and micro-CT have been used as research tools for assessment of bone microarchitecture. We use the term "osteopenia" to refer to the rarefaction and decreased bone density seen on radiographs.

3 Pathological Changes Occurring in Osteoporosis

The bone remodeling unit consists of osteoblasts which are mononucleate cells forming the connective tissue matrix (osteoid) which later mineralizes to become bone, and osteoclasts which are multinuclear giant cells capable of digesting calcified bone matrix (Nijweide et al. 1986; D'ipolito et al. 1999). Primary osteoporosis or age-related bone loss results from imbalance between the osteoblasts and osteoclasts. Bone can be structurally classified into cortical bone and trabecular bone (Grampp et al. 1997; Guglielmi et al. 2011).

3.1 Cortical Bone

Cortical bone is the dense bone surrounding the marrow space and has an inner surface (endosteal surface) and an outer surface (periosteal surface). The Haversian and Volkmann channels are present within the cortex (intracortical region). The cortical bone is less metabolically active compared to trabecular bone (Bart 2008). The resorption at the endosteal surface is greater relative to bone deposition, and this process increases with age. Hence, the marrow space appears wider with age (Bart 2008; Jergas 2008) (Fig. 1).

3.2 Trabecular Bone

Trabecular bone comprises the deeper part of the bone and is arranged as a lattice-work of thin sheets of varying thickness, with the interstices containing bone marrow or fat (Eriksen et al. 1994). The trabecular bone is most prominent in the axial skeleton, especially the spine (Bailey et al. 2000), and the distal aspect of the appendicular long bones, particularly the proximal end of femur and the distal end of radius. Trabecular bone has a greater surface area and compared to cortical bone, responds faster to metabolic changes (Grampp et al. 1997). Loss of trabecular bone usually occurs in a typical sequential fashion. Non-weight-bearing trabeculae are lost first. The weight-bearing trabeculae may appear prominent due to the loss of the rest of the trabeculae, and may become stronger and thickened.

Bone mass decreases with age. The loss of bone mass depends upon the rate of bone loss and also the peak bone mass attained in early life. Men have a greater peak bone mass and hence, the incidence of osteoporosis is less. The factors which influence peak bone mass include dietary calcium, sex hormone status, nutrition, physical activity, and genetic factors.

4 Radiography: Technical Considerations

The amount of X-ray absorption increases with the third power of atomic number (Wolbarst 1993), hence the absorption is directly proportional to the amount of calcium. Reduction in the bone mass or reduction in the calcium causes decrease in the absorption of the X-rays, resulting in increased lucency or radiolucency of the bones. Prediction of bone density by radiographs alone is poor when compared to standard densitometry, especially in the early stages (Epstein et al. 1986; Finsen and Anda 1988). Detection of osteopenia is possible only after 20–40 % of bone mass is lost (Grampp et al. 1997).

Many technical factors and patient factors (Heuck and Schmidt 1960; Jergas 2008) also interfere with the appearance of the bone quality on radiographs (Table 1). Hence, radiographs can assess gross morphology, presence of increased translucency, cortical changes, changes in the trabeculae and fractures, but cannot accurately quantify the degree of osteoporosis. The interobserver variability of assessing the density and detection of osteopenia is significant (Epstein et al. 1986; Williamson et al. 1990). Recently, digital radiography has increasingly been used to

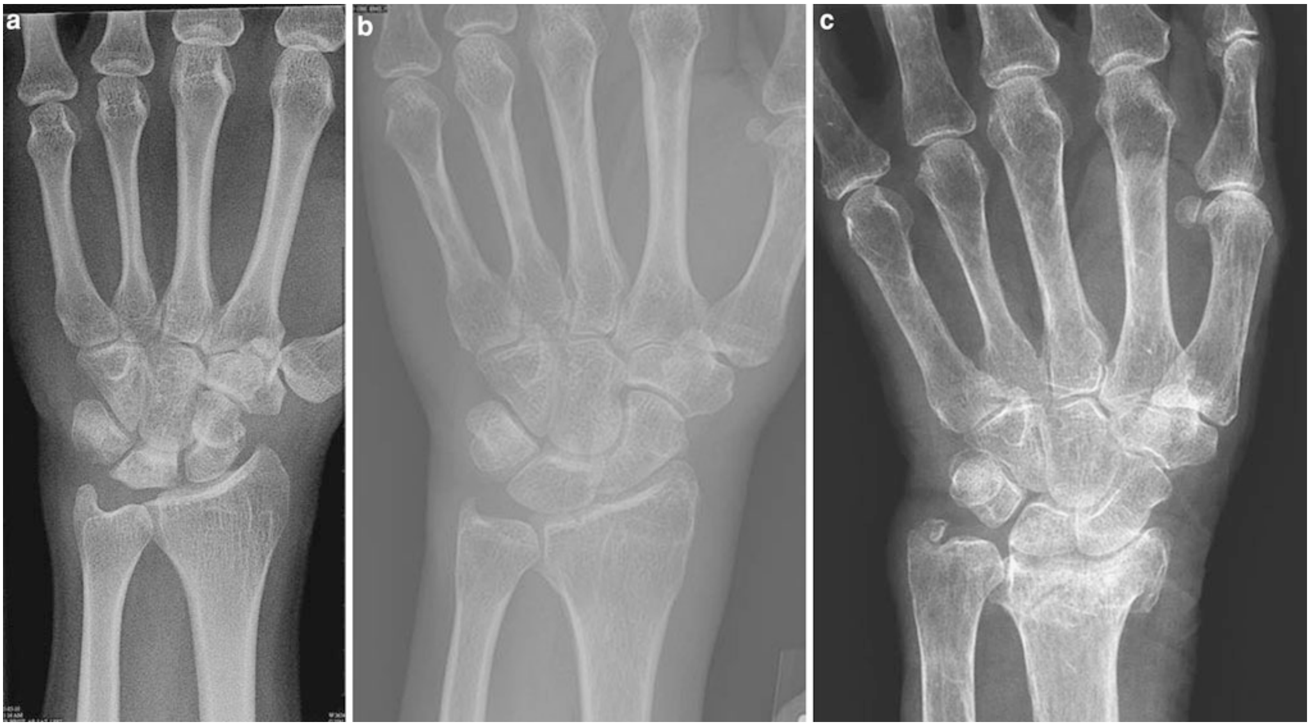

Fig. 1 Bony cortical changes with age. **a** Frontal hand radiograph of a 18-year-old woman shows normal cortical thickness in all the bones. **b** Frontal hand radiograph of a 40-year-old woman shows mild medullary widening due to endosteal resorption. This is age-related. **c** Frontal hand radiograph of a 101-year-old woman shows significant thinning of the cortex, in addition to the old osteoporotic fractures of the distal radius and ulna

Table 1 Factors affecting the radiographic appearance of the bone (Jergas 2008; Heuck and Schmidt 1960)

Technical factors
Exposure time
X-ray tube—anode, voltage
X-ray beam filtration
Film characteristics—e.g. speed, type of the screen, the emulsion
Patient factors
Density or thickness of the bone
Mineral content
Thickness of the soft tissue
Amount of scatter

evaluate osteoporosis (Hauschild et al. 2009). However, it provides no significant benefit compared to conventional radiographs (Wagner et al. 2005).

5 Classification of Osteoporosis

Osteoporosis can be broadly classified as primary and secondary osteoporosis. There are however various other classification systems.

5.1 Primary Osteoporosis

Primary osteoporosis mainly occurs due to advancing age and decrease in sex hormones (Albright 1947; Riggs and Melton 1983, 1986; Khosla et al. 2011). Primary osteoporosis can be subclassified into post-menopausal (Type I) and age–related or senile (Type II) osteoporosis.

5.1.1 Post-Menopausal (Type I) Osteoporosis

This is mainly due to estrogen deficiency after menopause and results in accelerated loss of trabecular bone, with increase in the risk of fractures, especially in the spine and wrist and to a lesser extent, in the hips. This is followed by a phase of slower bone loss, affecting mainly the cortical bone. This occurs along with decrease in number of osteoblasts and rate of bone formation, all of which contribute to the age-related osteoporosis.

5.1.2 Age-Related or Senile (Type II) Osteoporosis

With advancing age, the rate of bone formation decreases, resulting in proportionate loss of cortical and trabecular bone (Riggs and Melton 1983, 1986). However, women are more prone as men acquire more bone during puberty, and due to abrupt absence of estrogen, women tend to lose more bone. Fractures commonly occur in the hip and proximal aspect of long bones, such as the tibia, humerus, and proximal femur. Elderly patients, especially those residing in nursing homes, have a greater risk due to certain factors, such as cognitive impairment, gait and balance disorders, weakness, decreased acuity of vision and medications. 85 % of elderly older than 85 years have osteoporosis. Hip and non-vertebral fractures are approximately three times more common in this population (Vu et al. 2006).

5.2 Secondary Osteoporosis

Secondary osteoporosis is defined as bone loss that results from specific, well-defined clinical disorders (Fitzpatrick 2002). There are numerous causes of secondary osteoporosis (Anil et al. 2010), which include genetic or storage disorders, endocrine disorders, disorders of the gastrointestinal tract, medication-induced osteopenia/osteoporosis, malignancy and restricted mobility (Table 2). Approximately 20–30 % of post-menopausal women and 50 % of men with osteoporosis have secondary causes of osteoporosis (Fitzpatrick 2002). Finding the exact cause of osteoporosis is necessary for appropriate treatment and prognosis.

5.3 Other Classifications

Osteoporosis can also be classified according to distribution into generalized or regional forms (Anil et al. 2010). The former can be primary or secondary osteoporosis which cause generalized loss of the bones, whereas the latter involves a particular region or bones of one limb. Examples include migratory osteoporosis, transient osteoporosis, Sudeck's reflex sympathetic dystrophy, and osteoporosis secondary to infection and inflammatory arthritis.

Other rare unclassified types of osteoporosis include idiopathic osteoporosis (Bordier et al. 1973; Pacifici et al. 1990), which is a reversible condition seen in middle-aged men that is associated with rapid bone turnover. The exact etiology is unknown, although increased interleukin-1 and pulsatile increase in parathyroid hormone are hypothesized (Harms et al. 1989). A form of idiopathic osteoporosis that can also occur in children, and is known as juvenile idiopathic osteoporosis (Smith 1995), in which compression fractures of the spine and fractures of metaphysis of long bones have been reported.

Table 2 Causes of secondary osteoporosis (Fitzpatrick 2002)

Hormone-related disorders
Hyperparathyroidism
Corticosteroid-induced osteoporosis.
Rickets/osteomalacia
Gonadal insufficiency (primary or secondary)
Hyperthyroidism
Type 1 diabetes mellitus
Gastrointestinal disease
Celiac disease/malabsorption syndromes
Chronic cholestatic diseases
Gastrectomy
Inflammatory bowel disease
Parenteral nutrition
Primary biliary cirrhosis
Severe liver disease
Marrow-related disorders
Hemophilia
Leukemia
Lymphoma
Mastocytosis
Multiple myeloma
Pernicious anemia
Sickle cell anemia
Thalassemia
Storage disorders
Genetic disorders
Hypophosphatasia
Osteogenesis imperfecta
Miscellaneous causes
Organ transplantation
Heparin-induced osteoporosis

6 Role of Radiographs in Osteoporosis

The role of imaging in osteoporosis is to achieve an early diagnosis so that appropriate treatment can be initiated early (Keen 2007). Radiography is not the mainstay in the diagnosis of osteoporosis. Although quantification of bone density is difficult with conventional radiographs, they are often required along with DXA or MR imaging to:

1. Confirm or rule out fractures,
2. Detect concomitant or pre-disposing abnormalities such as osteoarthritis,
3. Aid in the diagnosis of secondary causes such as Cushing's disease or hyperparathyroidism, although the appearance in majority of the conditions remains similar (Anil et al. 2010).

6.1 Main Radiographic Findings

The main radiographic findings of osteoporosis are altered trabecular pattern, cortical thinning, and increased radiolucency.

Fig. 2 Lateral lumbar spine radiograph of a 60-year-old woman shows prominent vertical trabeculae

Fractures and deformities need to be assessed radiographically, with failure to diagnosis fractures being a problematic area.

6.1.1 Altered Trabecular Pattern

Compared to cortical bone, cancellous bone responds faster to metabolic stimuli. The trabeculae of the cancellous bone are laid down corresponding to the compressive and tensile forces acting on it. The trabeculae can be well appreciated in bones, such as the distal radius, calcaneum, and femoral neck (von Meyer 1867; Benhamou et al. 1994; Link et al. 1999). The trabeculae which are not involved in weight-bearing are lost first. The primary trabeculae or the weight-bearing trabeculae become thickened, possibly due to a compensatory mechanism or to callus from microfractures (Fig. 2). Later in the advanced stage, even the primary weight-bearing trabeculae are lost,

Fig. 3 Frontal radiograph of the right hip shows generalized increased bone radiolucency

resulting in the translucent appearance of bone on radiographs (Vernon-Roberts and Pirie 1973; Geraets et al. 1990).

6.1.2 Cortical Thinning

Involvement of the cortical bone occurs at three sites, namely: endosteal, periosteal, and intracortical (Grampp et al. 1997). In physiological remodeling of bones, the activity affects both the endosteal and periosteal surfaces. However, in involutional osteoporosis, it predominantly involves the endosteal surface, leading to thinning of the cortex. The response of endosteal, periosteal, and cortical resorption differs according to the etiology (Meunier et al. 1972; Genant et al. 1973). For example, in hyperparathyroidism, subperiosteal resorption can be seen in the radiographs as irregularities or erosions in the outer surface of the metacarpals. Intracortical bone resorption can be seen in the inner aspect of the cortex as striations or trabaculations, which are also features of hyperparathyroidism.

6.1.3 Increased Radiolucency

The bone density is directly proportional to the absorption of the X-rays and increases with the third power of atomic number (Wolbarst 1993). In osteoporosis, the decreased mineralization results in reduced absorption with resultant increased lucency of the bone (Fig. 3). There should be approximately 20–40 % bone loss for increased radiolucency to appear on radiographs (Ardran 1951; Harris and Heaney 1969; Epstein et al. 1986; Finsen and Anda 1988).

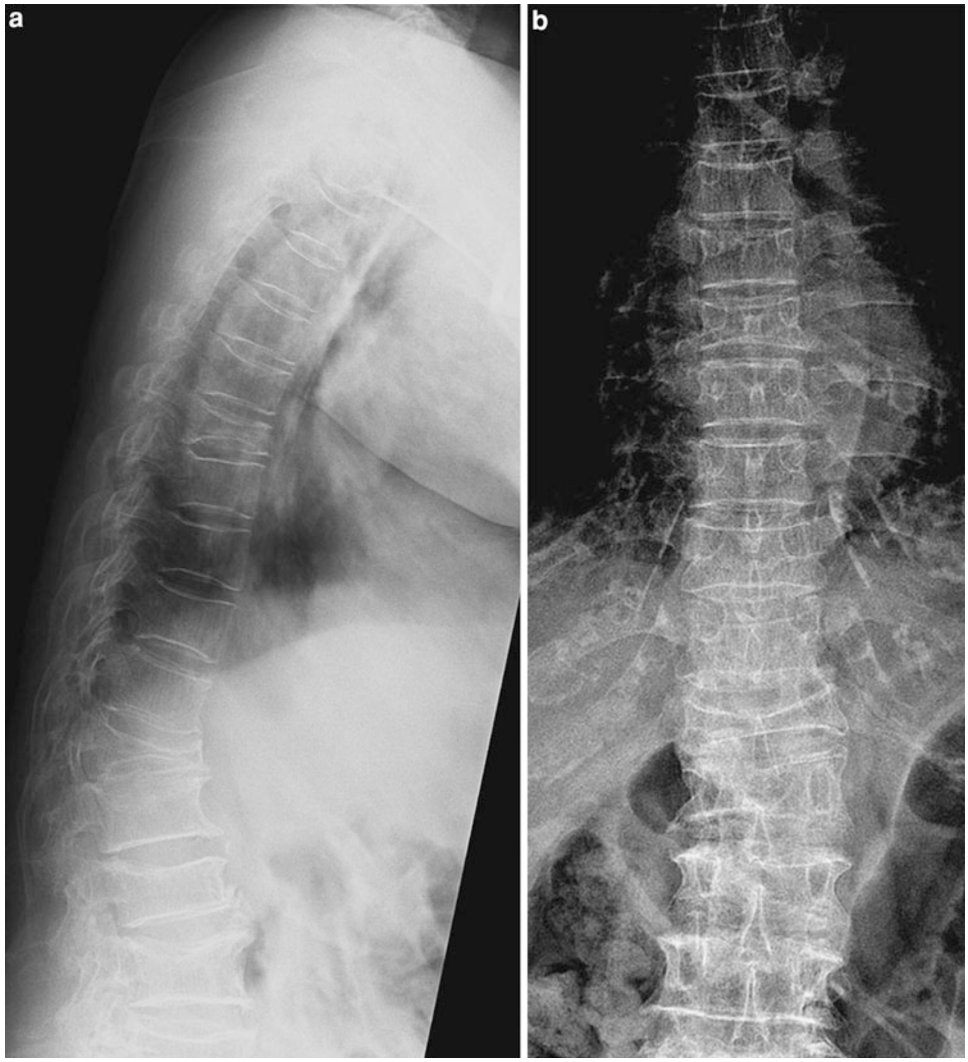

Fig. 4 **a** Lateral and **b** frontal radiographs of the thoracic spine in a patient with osteoporosis show generalized osteopenia and resultant severe deformities in multiple thoracic vertebral bodies due to compression fractures

6.1.4 Fractures and Deformities

The common sites of fractures include the spine, hip, and proximal femur (Johnell et al. 2004; Cranney et al. 2007). Fractures can also occur in the proximal humerus, pelvis, clavicle, and scapula.

6.1.5 Failure to Diagnose Fractures

Asymptomatic fractures are often missed on routine radiographs and the false negative rate may be very high, in the range of 29–45 % (Gehlbach et al. 2000; Delmas et al. 2005, Lems 2007). Lems (2007) highlighted three important causes for missing the fractures, especially in the vertebral column:

1. Lack of clinical symptoms, unlike the pelvis or hips, and these occur during routine activities such as walking or climbing stairs,
2. Overlooked on routine radiographs,
3. Presence of more severe pathologies such as malignancy.

Improvement of detection of the fractures can be achieved by educating the radiologists to differentiate fractures from other pathologies which mimic fracture such as degenerative disease, and ankylosing spondylitis. The "Vertebral Fracture Initiative", an educational program from International Osteoporosis Foundation, is one such example to help educate radiologists (Lems 2007).

6.2 Involvement of Specific Regions

6.2.1 Spine

Radiography continues to play an important role in evaluation of osteoporosis of the spine, especially for the assessment of bony outline, including the endplates, alignment, vertebral height, and for fractures. The lateral view of the thoracic and lumbar spine is the most useful projection (Figs. 4 and 5). MR imaging of the spine can be used to detect acute fractures and also differentiate involutional osteoporosis from metastatic disease, if radiographs are equivocal.

Fig. 5 Lateral radiograph of the lumbar spine shows anterior wedge compression fracture of L2 vertebral body. The apparent sclerosis in the involved vertebral body is due to healing. The rest of the vertebral bodies appear osteopenic

The signs which favor osteoporosis rather than metastasis include (Jung et al. 2003):

1. Hypointense band on T1- and T2-weighted images,
2. Sparing of normal marrow signal intensity of the vertebral body,
3. Retropulsion of the posterior bone fragment,
4. Compression fractures at multiple levels.

6.2.2 Pelvis and Hips

The prominent sites in the pelvis and hips include the iliac blades, femoral neck and greater trochanter, pubis and supraacetabular region. Most visible trabecular changes are present at the proximal end of the femur (Fig. 6). Thinning of the cortex is usually seen at the iliac crests, pubic rami, ischia, and proximal femur (Anil et al. 2010).

Proximal Femur

Trabeculae in the femur can be divided into five groups based on the orientation and function (Fig. 6). The principal compressive group trabeculae are the uppermost trabeculae and thicker than the rest of the trabeculae. These extend as curved lines from the medial aspect of the metaphysis to the superior aspect of the femoral head. The secondary compressive group arises near the lesser trochanter and curves upwards laterally toward greater trochanter and upper neck in a fan-shaped manner. These are usually thin and sparse. The greater trochanteric group is situated in the greater trochanter in a curvilinear fashion. The principal tensile group arises from below the greater trochanter and extends to the inferior aspect of the femoral head, passing through the femoral neck. Secondary tensile group start below the principal tensile trabeculae and end superiorly along the upper end of femur (just after midline).

Ward's triangle (Singh et al. 1970, 1972, 1973) is an area with loose and thin trabeculae. This triangle becomes prominent in osteoporosis. As osteoporosis worsens, the triangle opens up laterally. Based on this sequence, Singh and coworkers (Singh et al. 1970, 1972) proposed an index which can be used as a scale for assessing the severity of osteoporosis (Fig. 7). The classification ranges from grade VI (normal with visualization of all the trabeculae) to grade I (loss of even the primary compressive trabeculae). Singh et al. later added grade VII in people with dense bones. However, recent studies have indicated poor correlation between Singh's index and bone density assessed by bone mineral densitometry techniques (Hübsch et al. 1992; Koot et al. 1996; Salamat et al. 2010).

Acute Hip Fractures

Fractures of the hip are broadly classified into femoral neck fractures and trochanteric fractures (Greenspan et al. 1994; Mautalen et al. 1996). The femoral neck fractures are intracapsular fractures (Fig. 8) and have a higher risk of avascular necrosis of the femoral head, compared to the extracapsular trochanteric fractures. Open reduction and internal fixation is the preferred treatment for femoral neck fractures. Trochanteric fractures (Fig. 9) are seen in advanced osteoporosis and in the elderly age group. Identification of undisplaced femoral neck fractures may be difficult and may not be diagnosed on the initial radiographs. Only a linear sclerotic band or angulation of trabeculae may be seen, even after careful evaluation. In doubtful cases, MR imaging is helpful and it can detect fractures that are less than 6 hours old (Anil et al. 2010).

Insufficiency Fractures

These can occur in the subchondral region and are often confused with avascular necrosis. The diagnosis is mainly radiological (Rafii et al. 1997; Yamamoto et al. 2000). The presentation is usually acute in elderly women. Subchondral lucency may be seen on radiographs, and are often missed on the initial radiograph. MR imaging is very useful in diagnosing these insufficiency fractures which are typically

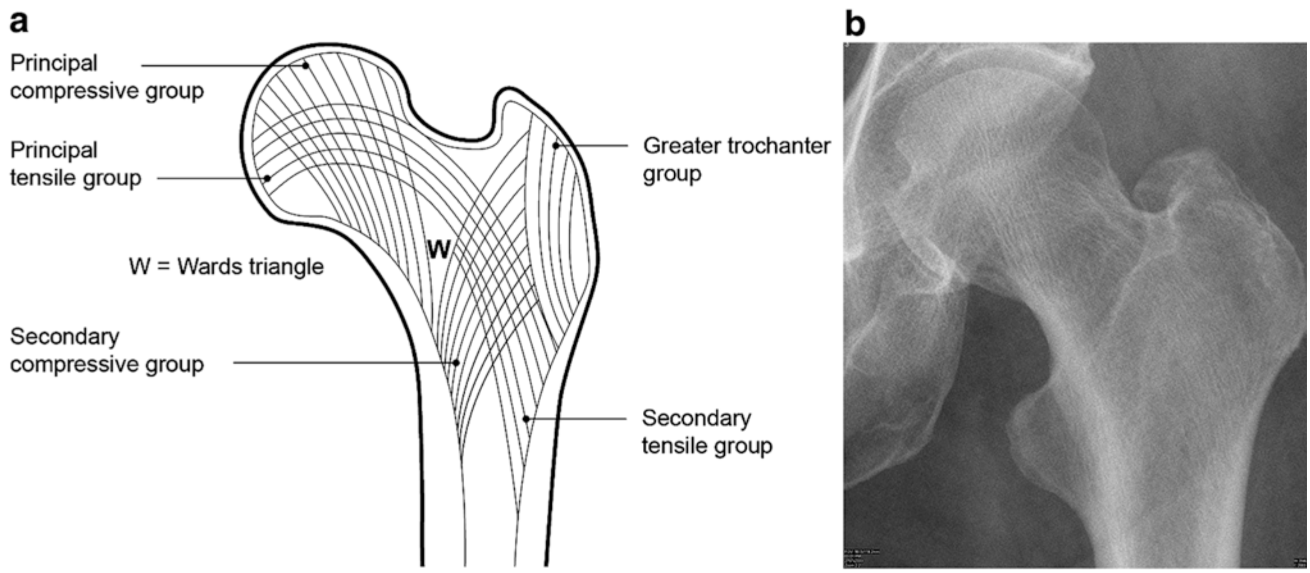

Fig. 6 Trabecular patterns in the proximal femur. **a** *Line diagram* shows the various groups of trabaculae and Ward's triangle. **b** Left hip radiograph of a normal adult shows the various trabecular groups and Ward's triangle

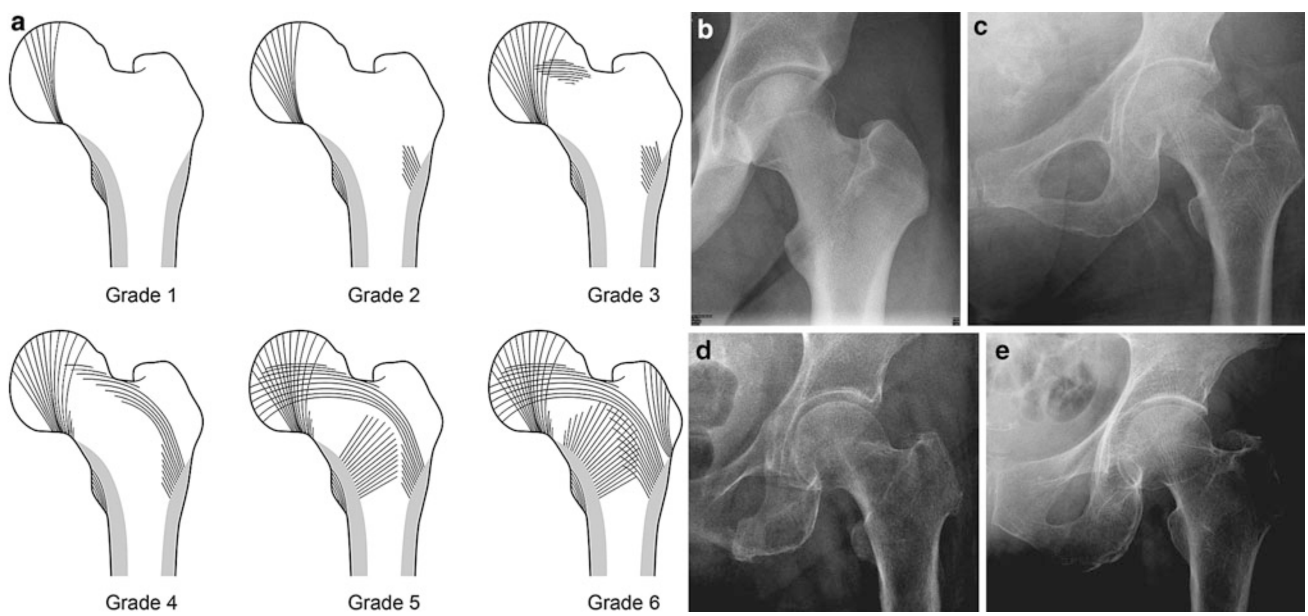

Fig. 7 **a** Classification for assessing the severity of osteoporosis according to the Singh index (Grade 6 to grade 1). **b** Normal trabecular pattern—grade 6. **c** Grade 5. **d** Grade 4. **e** Grade 3

seen as hypointense lines on T1- and T2- weighted images (Fig. 10). Proximal femur fractures should be differentiated from pathological fractures due to metastatic disease, especially when the fracture is located in the subtrochanteric region or in the lesser trochanter (Dijkstra et al. 1997).

Insufficiency fractures due to osteoporosis (Fig. 11) can occur in the sacrum, pubis, and less commonly, in the acetabulum and supraacetabular margins (De Smet and Neff 1985; Peh et al. 1996). The sacral fracture is identified by increased density due to the callus and focal periosteal reaction. MR imaging (Fig. 12) and bone scintigraphy are more sensitive than radiographs for detecting these fractures which may be incidentally seen during routine bone scintigraphy done for screening for metastasis. The pattern of sacral fractures may be H-shaped (described as the Honda sign), I-shaped, or arc-shaped.

Fig. 8 Right hip radiograph of a 70-year-old woman shows an intracapsular fracture of the femoral neck

6.2.3 Appendicular Skeleton

Distal Radius

A fall on outstretched hand may result in a fracture of the distal radius with dorsal angulation, typically known as Colle's fracture (Cooney et al. 1980; O'Neill et al. 2001). It is more common in the left hand, although it depends on the bone mass between the dominant and non-dominant hand and the nature of fall (Fig. 13).

Humerus

Osteoporotic fractures are common in the surgical neck of the humerus (Fig. 14) and usually occur due to falls with direct landing on the shoulder (Palvanen et al. 2000). Clinton et al. (2009) proved that the incidence of humeral fractures increases the risk of hip fracture by more than five times in the first year.

Fig. 9 Left hip radiograph of a 82-year-old woman shows an (extracapsular) intertrochanteric fracture

Hand

Radiogrammetric measurements were initially applied to the metacarpal bones, especially the second or third metacarpal. The corticomedullary index is calculated by the combined cortical thickness divided by total bone width (Fig. 15). Another complex calculation exists where the cortical area is calculated. However, some studies have suggested that the correlation between radiogrammetry and other quantitative methods is poor. Recently, digital radiogrammetric techniques have evolved, which have a greater accuracy in quantifying the density compared to conventional radiogrammetry.

Cortical bone loss, measured in the second metacarpal by digital radiogrammetric methods, is similar to bone loss in the distal radius, lumbar spine, and iliac crest. However, correlation was poor with the proximal femur (Ives and Brickley 2005). Computer-aided calculations of cortical thickness, bone width, and bone volume per area have been obtained with digital X-ray radiogrammetry (DXR). DXR is simple, inexpensive, has a low radiation dose, and can be used as a screening tool in high risk patients before referring them for DXA (Pfeil et al. 2011).

Calcaneum

The trabecular pattern of the calcaneum (Fig. 16) is similar to that of the proximal femur and is easily visualized in the radiographs (Diard et al. 2007; Jhamaria et al. 1983). There

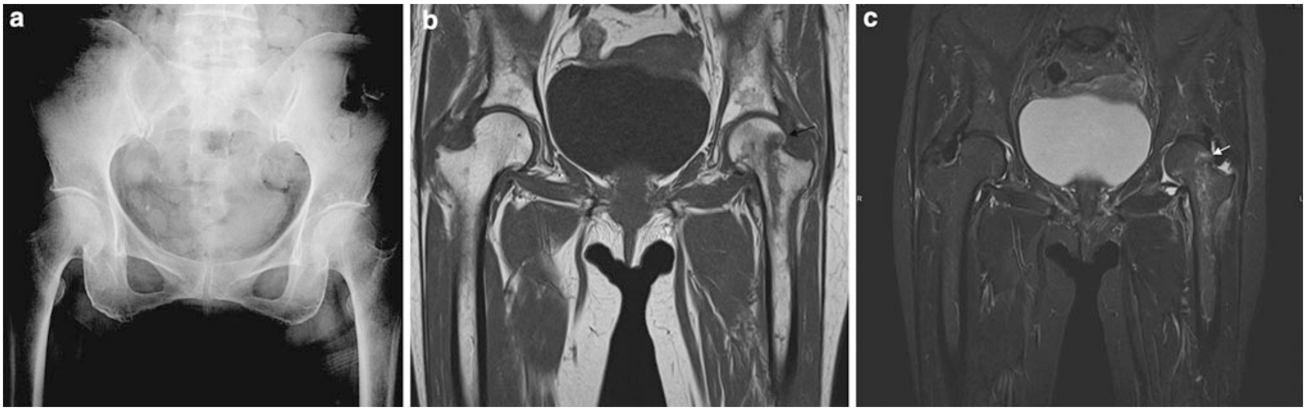

Fig. 10 Insufficiency fracture in the femoral neck. **a** Frontal pelvic radiograph of an elderly woman shows no obvious fracture. **b** Coronal T1-weighted and **c** fat-suppressed T2-weighted MR images show the subcapital linear insufficiency fracture (*arrows*). Adjacent edema is also noted

Fig. 11 Frontal pelvic radiograph radiograph of a 60-year-old woman shows an insufficiency fracture of the right inferior pubic ramus

are two sets of compression trabeculae and two sets of tensile trabeculae in the calcaneum (Fig. 16). Jhamaria et al. (1983) classified osteoporosis from grade V (normal) to grade I (severe osteoporosis).

6.3 Secondary Causes of Osteoporosis

6.3.1 Hyperparathyroidism

Hyperparathyroidism can be primary or secondary. Primary hyperparathyroidism is caused by a functioning adenoma of the parathyroid gland. Secondary hyperparathyroidism is usually due to long-standing hypocalcemia, with the most common cause being chronic renal failure, which stimulates secretion of parathyroid hormone. The diagnosis of primary hyperparathyroidism is usually made by laboratory tests. The radiographs provide useful information regarding the nature of bone involvement and severity. Apart from diffuse osteopenia, the radiographical changes in the bone include subperiosteal, intracortical, endosteal, subchondral, subligamentous/subtendinous, and trabecular bone resorption. The most characteristic feature is subperiosteal bone resorption which is seen usually in the bones of hand and feet. The outer cortex becomes indistinct and scalloping or erosions appear in late stages.

Intracortical tunneling causes a striated appearance in the cortex and endosteal resorption results in thinning of the cortex and widening of the medullary canal. Subchondral resorption occurs beneath the articular cartilage (such as in sacroiliac joint) and results in pseudo-widening of the joint space in the radiographs (Hayes and Conway 1991). Other rare features of primary hyperparathyroidism include development of expansile lytic lesions known as 'brown tumors' and chondrocalcinosis, due to deposition of calcium pyrophosphate dehydrate (CPPD) crystals in the cartilages. In secondary hyperparathyroidism, apart from erosions, sclerosis is common in the axial skeleton, especially in the bone margins due to condensation of the trabeculae. The typical appearance in the vertebral body (Fig. 17) is known as rugger jersey spine and is due to subchondral sclerosis (Resnick 1981).

6.3.2 Steroid-Induced Osteoporosis

The main pathology in endogenous or exogenous glucocorticosteroid-induced osteoporosis is decreased osteoblastic activity and normal osteoclastic activity (Sissons 1956). It is most marked in the spine and ribs. Exuberant callus with marginal trabecular condensation is characteristic

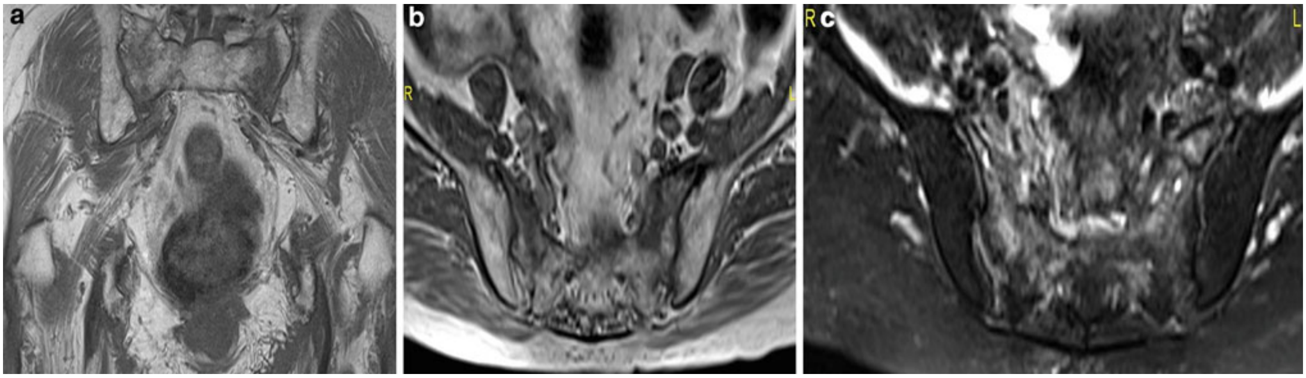

Fig. 12 Insufficiency fracture of the sacrum. **a** Coronal and **b** axial T1-weighted MR images of the sacrum show vertically-orientated hypointense fracture lines involving both sacral ala. **c** Axial fat-suppressed T2-weighted MR image shows prominent hyperintense marrow edema around the fractures

Fig. 13 Frontal wrist radiograph shows a fracture of the distal radius in an osteoporotic patient

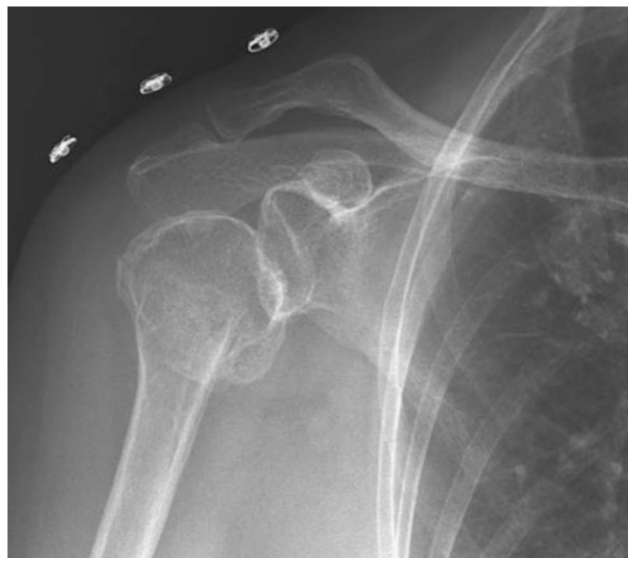

Fig. 14 Frontal shoulder radiograph shows a fracture of the surgical neck of the humerus

finding in steroid-induced osteoporosis. A few recent studies have proven that the bone density is maintained and incidence of fractures are less with prophylactic bisphosphonate therapy (Stoch et al. 2009).

6.3.3 Osteomalacia

In Osteomalacia, even though vitamin D deficiency leads to osteopenia, the pathology is different. There is significant amount of unmineralized osteoid in osteomalacia, in contrast to osteoporosis where there is reduction in the mineralized osteoid. Other than osteopenia, the radiographical findings include pseudofracture or linear lucencies which are seen perpendicular to the long axis of bone. These pseudofractures represent the accumulation of unmineralized osteoid. The common locations include the pelvis,

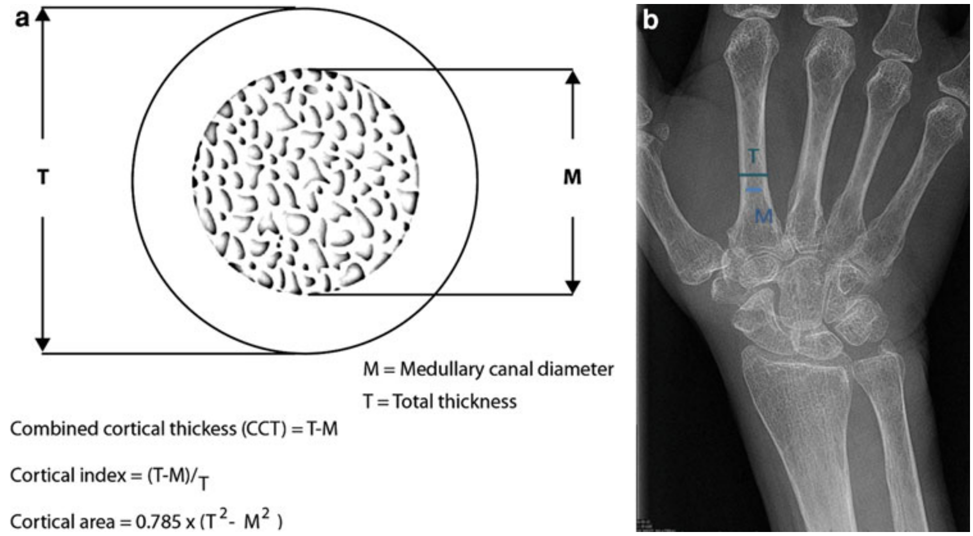

Fig. 15 Radiogrammetry which was used for quantification for bone density in the past. **a** Diagram shows the cross-section of bone with measurements of the cortical thickness and cortical index. **b** Frontal radiograph shows measurement of the cortical thickness in the second metacarpal

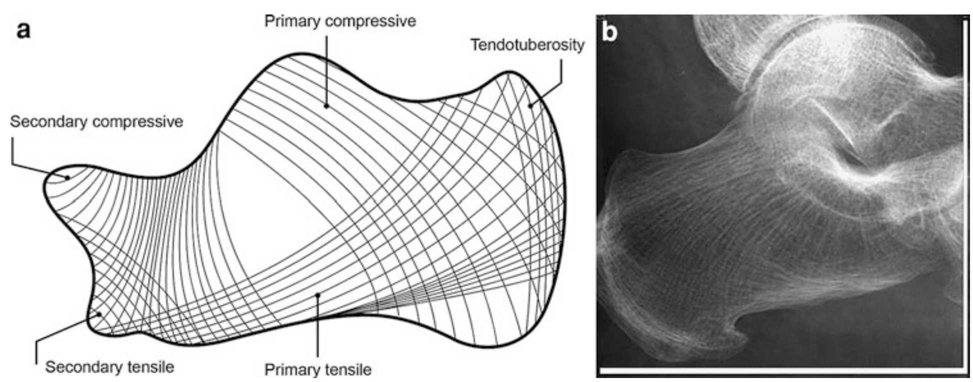

Fig. 16 **a** Calcaneal trabeculae. *Line diagram* shows the various normal groups of trabeculae. **b** Lateral calcaneal radiograph of a 71-year-old woman shows the trabecular pattern. The tensile trabaculae are less prominent

femoral neck, and scapula. These are often symmetrical. The involved bones are prone to develop deformities and fractures (Kienböck 1940; Reginato et al. 1999).

6.3.4 Hyperthyroidism

Thyroid hormone promotes bone resorption and generalized osteopenia is often seen in patients with hyperthyroidism, especially in thyrotoxicosis. Radiographic findings are similar to diffuse osteoporosis, with more cortical involvement and tunnelling (Toh et al. 1985).

6.3.5 Other Important Causes of Secondary Osteoporosis

Other causes include heparin-induced osteoporosis (Nelson-Piercy 1997) and nutrition-related osteoporotic disorders which may be indistinguishable radiographically from involutional osteoporosis. Marrow proliferative disorders such as myeloma may cause diffuse osteopenia and may produce punched-out lytic lesions in the bones. The diagnosis is usually by laboratory investigations.

6.4 Osteoporosis in the Young

6.4.1 Marrow Disorders

Marrow disorders include congenital hemolytic anemias, storage disorders, and leukemias. Blood investigations and further imaging like CT and MR imaging are helpful for the diagnosis and assessing severity of these conditions.

6.4.2 Idiopathic Juvenile Osteoporosis

Idiopathic juvenile osteoporosis (IJO) is a very rare disorder occurring in prepubertal children in the age range of 2–14 years, and is characterized by bone pain, osteopenia, fractures, and deformities (Schippers 1938). Changes are seen in the vertebrae which show diffuse osteopenia and subsequent deformities or compression fractures (Marhaug 1993; Lorenc 2002). In the appendicular skeleton, the fractures are characteristically seen in the metaphyses. This is a self limiting condition which resolves during and after puberty. However, the deformities may sometimes be severe and can be irreversible when the patients grow as

Fig. 17 Lateral thoraco-lumbar radiograph of a 40-year-old woman with secondary hyperparathyroidism. There is osteopenia with marginal sclerosis of multiple vertebral bodies giving the typical rugger-jersey spine appearance

adults. Bisphonates are considered to be effective in preventing these deformities (Melchior et al. 2005).

6.4.3 Rickets

Rickets are due to defect in mineralization of the osteoid. This may either be due to nutrition-related (Vitamin D deficiency) or vitamin D resistant hypophosphatemic rickets which is otherwise known as renal rickets. The classical radiographical changes, apart from osteopenia, include changes in the metaphysis, such as cupping, fraying, and splaying due to weight-bearing and rapid growth (Cheema et al. 2003). The provisional zone of calcification is widened. The changes are usually seen in the distal radial metaphysis, proximal humerus, distal ends of femur and tibia. The metaphyseal changes are well seen in nutritional rickets which occur in younger children (Swischuk and Hayden 1979).

6.5 Regional or Localized Osteoporosis

6.5.1 Reflex Sympathetic Dystrophy

Reflex sympathetic dystrophy (RSD), otherwise known as complex regional pain syndrome (CPRS), is characterized by intense pain, allodynia (pain caused by touch), vasomotor disturbances, and delayed functional recovery after minor trauma. This condition is thought to be caused by excessive sympathetic stimulation although blockade of sympathetic stimulation has not found to be an effective treatment in several patients (Albazaz et al. 2008). Although the diagnosis is mainly based on clinical findings, bone scintigraphy is often used to confirm the diagnosis of RSD (Lee and Weeks 1995). Focal/regional osteoporosis is seen in around 60 % of patients with RSD, although it may be nonspecific due to disuse secondary to pain (Fig. 18). Soft tissue changes such as swelling or atrophy are also considered nonspecific.

6.5.2 Transient Osteoporosis of Hip

Transient osteoporosis of hip is a self-limiting condition known to occur in late pregnancy, although nearly two-thirds of patients are middle-aged men aged between 40 and 70 years (Kalliakmanis et al. 2006). The patients affected by this condition often present with pain of the hip with limitation of movement. The exact etiology and mechanism are not well understood. Proposed mechanisms include genetic predisposition, intermittent compression of obturator nerve, non-traumatic reflex sympathetic dystrophy, fatty marrow conversion, hormone imbalance, and microfractures (Rocchietti March et al. 2010). The diagnosis is based on the history and radiographic features of osteopenia involving the femoral head and neck. MR imaging usually shows increased signal on T2-weighted images. Bone scintigraphy may show increased uptake in the affected hip during the early stages. The clinical and radiographic findings often disappear after weeks or months. Other similar conditions, such as osteonecrosis, osteomyelitis, inflammatory arthritis, and neoplasm should be ruled out if symptoms persist.

6.5.3 Regional Migratory Osteoporosis

Regional migratory osteoporosis is another self-limiting type of osteoporosis which involves a few weight-bearing joints of the lower limb. This condition is characterized by pain in the affected joint and osteopenia which proceeds from proximal to distal joints in the lower limb. The migration of affected region may be within the same joint (Yamasaki et al. 2003). This condition is considered to be part of the spectrum of transient osteoporosis by some authors (Duncan et al. 1969; Toms et al. 2005).

Fig. 18 **a** Frontal and **b** lateral wrist radiographs of a patient with distal radial fracture who developed reflex sympathetic dystrophy. Diffuse osteopenia and soft tissue swelling are present

6.5.4 Disuse Osteoporosis

Disuse osteoporosis refers to decrease in bone density, due to reduction in the mechanical stress which results in increased resorption by osteoclast activity and inhibition of osteoblasts (Takata and Yasui 2001). Disuse osteoporosis may be due to muscular paralysis due to neuronal injury (central or peripheral) or due to restriction of movement of limb or part of the body. Radiographic findings include osteopenia, coarsened trabeculae, and thinning of the cortex in the affected bones. The weight-bearing bones are more severely affected than the non-weight bearing ones (Doty and DiCarlo 1995).

7 Conclusion

Radiography is a cheap and widely available modality. Conventional radiography may not be helpful in quantification of the bone density but it is very useful tool in assessing the quality of bone and for screening of deformities and fractures. Radiography is also helpful in assessing the changes in the pattern of resorption in conditions such as hyperparathyroidism. It can be used in conjunction with other modalities, such as DEXA, MR imaging, and quantitative CT for the differential diagnosis and follow-up evaluation of elderly patients with osteoporosis.

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