Sonographic and power Doppler normal anatomy

3.1 Cartilage

Cartilage is a greatly specialized type of connective tissue, mainly composed of water (70-80% by wet weight). It is avascular and aneural. The solid component of cartilage is formed of cells (chondrocytes) that are scattered in a firm gel-like substance (extracellular matrix) consisting of collagen and proteoglycans. Collagen forms a network of fibrils, which resists the swelling pressure generated by the proteoglycans. In the musculoskeletal system there are two types of cartilage: hyaline and fibrocartilage. Compared to hyaline, fibrocartilage contains more collagen and is more resistant at tensile strength. Fibrocartilage is found in intervertebral disks, symphyses, glenoid labra, menisci, the round ligament of the femur, and at sites connecting tendons or ligaments to bones. Hyaline cartilage is the most common variety of cartilage. It is found in costal cartilage, epiphyseal plates and covering bones in joints (articular cartilage). The free surfaces of most hyaline cartilage (but not articular cartilage) are covered by a layer of fibrous connective tissue (perichondrium). Hyaline cartilage structure is not uniform (Fig. 3.1). Instead, it is stratified and divided into four zones: superficial, middle, deep, and calcified. The superficial zone, also called **tangential zone**, is considered the articular surface and is characterized by flattened chondrocytes, relatively low quantities of proteoglycan, and numerous thicker fibrils arranged parallel to the articular surface in order to resist tension. In articular cartilage this layer acts as a barrier because there is no perichondrium. The middle zone, or **transitional zone**, in contrast, has round chondrocytes, the highest level of proteoglycan among the four zones, and a random arrangement of collagen. The deep (**radiate zone**) is the thickest zone, characterized by collagen fibrils that are perpendicular to the underlying bone, acting as an anchor to prohibit separation of zones and in order to resist at torsional and compressive mechanical strength. Columns of chondrocytes are arrayed along the axis of fibril orientation. The **zone of calcified cartilage** is partly mineralized, and acts as the transition between cartilage and the underlying subchondral bone. A boundary point (**tidemark**) represents a change in cartilage stiffness from radiate to calcified. The orientation of collagen fibers varies through the four zones of articular cartilage in order to give better tensile strength. The fibrillar framework seems to have an arcade-like arrangement, as hypothesized by Benninghoff. Nevertheless, the arcade model of Benninghoff has not been confirmed at electron microscopy evaluation.

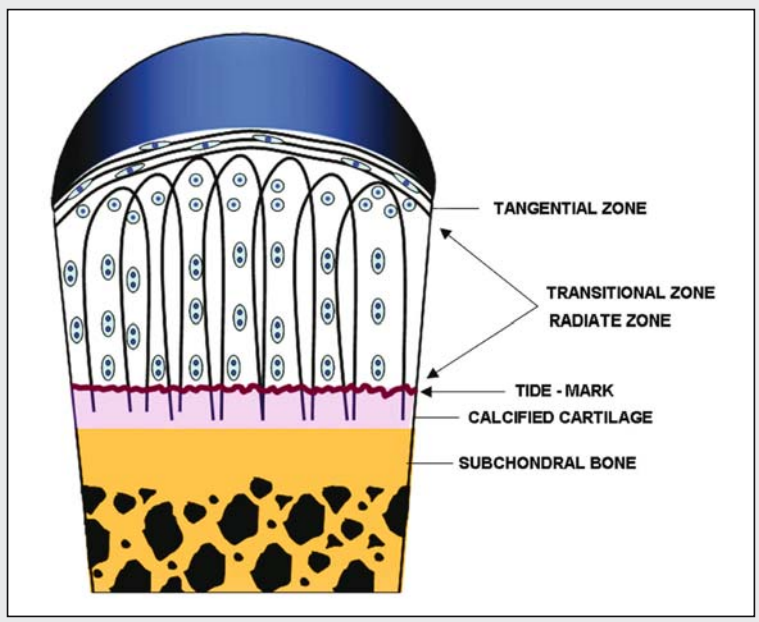

Fig. 3.1
Anatomical diagram of hyaline cartilage structure

Hyaline cartilage is easily detectable by ultrasonography as a homogeneously hypo-anechoic layer delimited by thin, sharp and hyperechoic margins.

Normal articular cartilage appears as a well-defined layer with the following distinguishing features [1-3]:

1. high degree of homogeneous transparency due to its high water content;
2. sharp and continuous synovial space-cartilage interface (superficial margin);
3. sharp hyperechoic profile of the bone-cartilage interface (deep margin).

The synovial space-cartilage interface is slightly thinner than the bone-cartilage interface. Both margins are best visualized when the direction of the ultrasound (US) beam is perpendicular to the cartilage surface.

The pronounced difference in chemical structure between articular cartilage and subchondral bone allows easy detection of the deep margin, whilst the superficial margin requires careful examination techniques for clear identification.

Optimization of the visualization of the cartilage margins is essential for measuring the cartilage thickness [4].

Cartilage thickness ranges from 0.1 mm on the articular surface of the head of the proximal phalanx to 2.6 mm on the lateral femoral condyle of the knee joint [5]. Measurement of cartilage thickness is rapid (several seconds), painless, non-invasive and reproducible (inter-observer reproducibility of measurements of cartilage thickness seems to be relatively good) [6-8].

Sharp margins and homogeneity of the echotexture are hallmarks of normal cartilage (Figs. 3.2, 3.3).

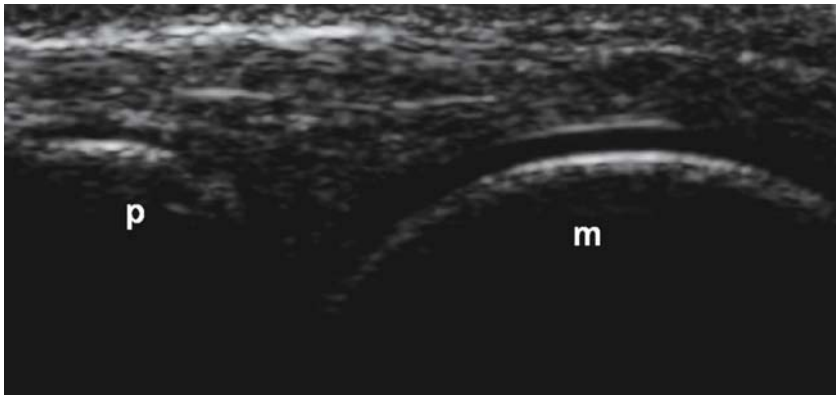

Fig. 3.2

Healthy subject. Longitudinal dorsal US scan of the second metacarpo-phalangeal joint obtained with a 5-13 MHz broadband linear transducer. The articular cartilage of the metacarpal head appears as a homogeneous anechoic layer with clearly defined hyperechoic contours. *m* = metacarpal head; *p* = proximal phalanx

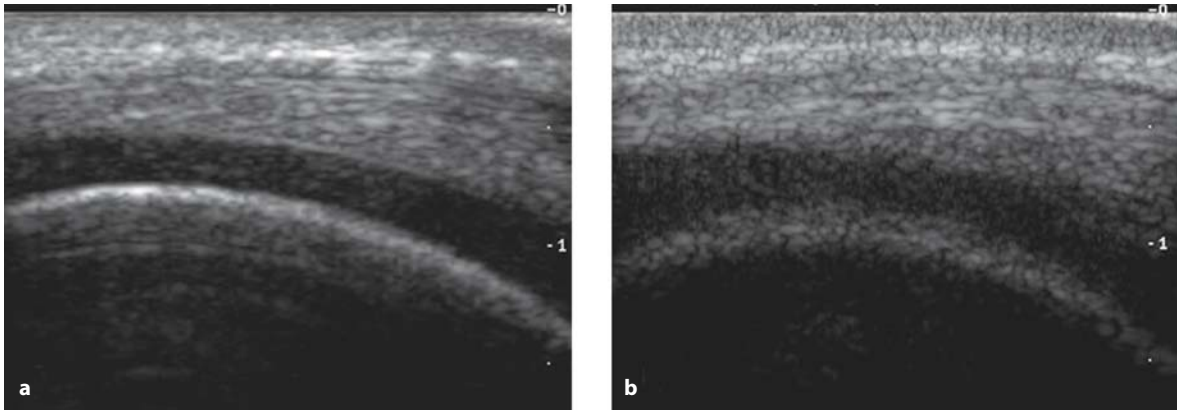

Fig. 3.3 a, b

Healthy subject. Knee. Suprapatellar longitudinal scan of the articular cartilage of the lateral femoral condyle obtained with a 5-10 MHz broadband linear transducer. **a** Normal features of the articular cartilage obtained with the ultrasound beam directly perpendicular to the cartilage surface. **b** Apparent loss of sharpness of the cartilage margins due to imperfect insonation angle