Chapter 5

Macroscopic Anatomy, Histopathology, and Image Diagnosis of Joints and Synovial Cartilages

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Additional information is available at the end of the chapter

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Abstract

Joints are physiological connections formed by the association of two or more bones that confer mobility to the skeleton of vertebrates. Composed of several structures, these are often related to pathologies of varied origins, which determine symptomatology of varying degrees of intensity and impairment, responsible for the decrease in life expectancy and the well-being of affected populations. Most of the time, the treatment for these diseases is only symptomatic, aiming at the relief of pain and the return of the patient to daily activities. Thus, there has been an increasing interest in the search for new knowledge about the mechanisms that lead to joint disorders and effective therapeutic resources that may contribute to the fight against pain and to the definitive treatment of joint dysfunctions. To this aim, the knowledge of diagnostic methods, especially imaging methods, is of fundamental importance for the recognition of articular affections, enabling a targeted and effective treatment. Among these auxiliary exams currently used to evaluate the joints, the noninvasive ones are the first choice, where radiography, ultrasonography, magnetic resonance imaging (MRI), computed tomography, and arthroscopy are inserted.

Keywords: diagnostic imaging, arthropathies, technologies, treatments, joint

1. Introduction

Aging populations and rising life expectancy have become a global trend. Developing countries have been living with a growing change in the health profile of the population due to the greater

life expectancy. Associated with this, the problems related to chronic degenerative and autoimmune diseases arise, which, if not properly treated and followed over the years, can result in serious health problems, compromising the independence and autonomy of patients affected, especially the elderly. In these countries, chronic diseases have caused important and costly demands on health systems and have interfered in qualitative aspects of life [13].

Noncommunicable chronic diseases and autoimmune diseases are one of the main factors responsible for the decrease in the life expectancy and the well-being of the populations affected. Its prevalence is elevated in elderly patients, where osteoarticular diseases predominate, which account for a significant portion of these [26].

The concept of degenerative osteoarticular disease presupposes hyaline cartilage abnormalities, which determine symptomatology of variable intensity and impairment of function. The clinical picture is called arthrosis, osteoarthrosis, or osteoarthritis. Osteoarthritis is a degenerative condition of articular hyaline cartilage, difficult to diagnose and treat, which affects older patients more frequently, manifested by pain, stiffness, and functional impairment of the affected joint. The degenerative or degradative process of articular cartilage may be primary or secondary to different causes, such as hereditary diseases, endocrine diseases, joint disorders, and inflammatory diseases [28, 53].

Among autoimmune diseases, rheumatoid arthritis, a complex etiology characterized by symmetrical peripheral polyarthritis, which leads to deformity and destruction of the joints due to erosion of bones and cartilage, also presenting a higher incidence in elderly patients stands out. In general, it affects large and small joints in association with systemic manifestations such as stiffness, fatigue, and weight loss. When it involves other organs, the morbidity and severity of the disease are greater and may decrease life expectancy in 5–10 years. With the progression of the disease, the patients develop incapacity to the development of their activities, which generates social and economic impacts [1].

Degenerative joint disease is another arthropathy characterized by a noninflammatory disorder of mobile joints, being considered as a group of disorders defined by the progressive deterioration of articular cartilage, accompanied by bone and soft tissue alterations [11, 59, 63]. This is a chronic condition leading to degeneration of adjacent structures and thickening of the joint capsule. Different factors are identified as the cause of this disease, such as trauma, intra-articular fractures, subluxations or joint dislocations, conformation defects, and angular deformity [37].

Degenerative joint disease manifests initially with mild lameness, which progresses with the development of the disease [34]. In large-moving joints, initial changes are manifested by acute synovitis and capsulitis [56] or muscle atrophies [41], as well as joint capsule distension with an increase in adjacent soft tissue volume [34]. The predominant symptom is pain sensitivity, which may originate from different intra-articular or extra-articular structures, such as capsule, articular cartilage, synovium, periosteum, bones, tendons, bursae, ligaments, or menisci [47].

These data justify an increasing interest in the search for new knowledge about the mechanisms that lead to joint disorders and effective therapeutic resources that can contribute to the fight against pain and to the definitive treatment of joint dysfunctions, preventing the degeneration of structures until irreversible states.

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Currently, treatments for these diseases have as main objective the relief of pain and the reduction of functional disability, enabling the development of routine activities and suspension of disease progression. To that aim, several techniques have been proposed, such as pharmacological and nonpharmacological, surgical, and alternative treatments, such as the use of platelet-rich plasma for pain and joint function improvement in osteoarthritis [15, 35], aquatic and nonaquatic exercises [40], and nonsteroidal anti-inflammatory therapies [20], among others.

More recently, cell therapies have been proposed, such as the use of stem cells, which consist of a nonspecialized cell category, that is, they have no tissue-specific structure that allows them to perform individual functions of other cells. These are capable of dividing and renewing themselves over long periods and also of differentiating themselves into specialized cell types. Unlike other cells, such as those of the muscular and nervous tissues, which do not normally replicate, they can replicate several times in a process called proliferation. In this context, the possibility of using stem cells for cellular therapies has become a very coveted area and is the target of several studies, attracting the attention of researchers from all over the world [51].

Primordial germ cell therapies have also been studied for the formation of hyaline articular cartilage due to its regenerative characteristic. Diseases such as traumatic chondral lesions, dissecting osteochondritis, patellar chondromalacia, and osteoarthrosis are targets of therapy with these cells [46].

Traumatic chondral injuries, when moderate and in areas of low mechanical stress, are usually treated by conservative methods that include dietary reduction for weight reduction, analgesics, anti-inflammatories, and physiotherapy. When extensive, more complex treatments are stipulated as autologous or homologous osteochondral grafts, replacement arthroplasty using partial or total prostheses and arthrodesis [17].

The importance of stem cells as a new treatment method in chondral lesions is due to the fact that articular cartilage has little repair capacity. However, the autologous chondrocyte culture transplant technique in chondral defects is still restricted to small lesions and in young patients. In contrast, recent studies have shown that mesenchymal progenitor cells can repair major defects regardless of age. The great difficulty is still the culture, induction of differentiation, and adhesion at the lesion site, which often do not respond as expected [17].

In addition to stem cells, growth factors are also required to determine proliferation and differentiation in cartilaginous tissue both during in vitro cultures and in implantation. These factors include prolactin, which induces cell proliferation and the synthesis of proteoglycans. Other factors that determine chondrogenesis are insulin-like growth factor 1 (IGF-1) and transforming growth factor beta 1 (TGFβ1) [49, 69].

With the advent of this new technique, it is expected that donor area morbidity can be reduced in cases of allografts where small fragments of cartilage are removed from an area of lower load to another with osteochondral defect and reduce contamination and deterioration of these areas, avoiding lesions inherent to more invasive techniques such as release and wear of material, in the cases of joint prostheses [55].

However, the literature has shown in several studies that this topic is one of the most promising fields of medicine, with the potential to provide the resolution of pathologies previously limited to symptomatic treatments [16, 38].

2. Anatomy of the joints

The word articulation originates from the Latin "articulatio" which means rigidity, that is, structure that derives from a cartilaginous bone set of consistent architecture. Physiologically, it is the connection between bones which gives mobility to the skeleton. The joints are formed by the association of two or more bones with the aid of skeletal muscles, ligaments, and joint capsule. The functional activity of the joints depends essentially on the shape of the joint surfaces and the union means, which may limit it [29, 61].

The articular joints are formed by the joint activity of the following structures: bones, articular surface, articular cartilage, joint space, joint capsule, and synovial fluid. Each of these structures plays an important role in the joint [64].

The bones, rigid structures that serve as support and skeleton forming the joints, communicate by favoring the mobility of the body. Depending on the location, the bones may present different anatomical dispositions and therefore infer in the shape and classification of the joints [68].

The articular surfaces are the regions of bone surface that maintain contact for formation of the articular region. These surfaces correspond to the place of insertion of the articular cartilage serving as the base. The latter is the layer of cartilaginous tissue that covers the articular surfaces, absorbing compressive impacts and assisting in the development of the other constituent structures of the joint [39, 68].

The joint capsule is a fibrous sheath that covers the space belonging to the joint while holding the bone structures together. This structure plays the germinative function for the synovial fluid and provides stability to the joints, thus contributing to the creation of an internal portion, of reduced pressure, favoring a better coaptation [8, 29].

Synovial fluid is an aqueous substance secreted by the joint capsule that fills the joint space and ensures lubrication, allowing the stability and distribution of the loads on the surfaces, reducing the stresses of contact. Synovial fluid is a parameter for many articular anomalies, which can be evaluated by means of arthrocentesis (collection of the joint fluid) and by examining the color, appearance, and viscosity of this material [29, 59].

The joints can be classified according to their structure and mobility in fibrous (synarthroses) or immotile movements, cartilaginous (amphiarthroses) or with limited movements, and synovial (diarthroses) or with ample movements. Another type of classification is with regard to the continuity of the bone pieces, which may be continuous (with bone pieces closely connected to each other) and contiguous (where there is a joint cavity) [12].

The fibrous joints, in which the interposed elements between the bony structures are of fibrous nature, called synarthroses (syn: together, arthro: articulation), are immobile joints

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and can be of three types: sutures, syndesmosis, and gomphosis. The sutures are joints present mainly in the bones of the skull and are characterized by a small amount of fibrous tissue. In syndesmosis, the bone surfaces are joined by a fibrous substance in a tape or ligament aspect that limits the movement of the articular parts, as in the tibiofibular joint. In the gomphosis, the bony structures are irregular, and the pattern is the one of the inserted teeth in their alveoli [12, 32].

Unlike the fibrous ones, in the cartilaginous joints, the interposed tissue is cartilaginous in nature and can be subdivided into synchondrosis and symphysis. Synchondrosis is a provisory or temporary joint, in which the cartilage has a limited life, disappearing soon after the individual reaches adulthood, a situation found in the epiphyseal disks. The symphysis is permanent, commonly present in the intervertebral disks and the pubic symphysis [12, 70].

Unlike fibrous and cartilaginous, the synovial joints allow wide movements, being structurally complex, characterized by the presence of synovial membrane which internally coats the joint space and is responsible for the production of synovial fluid. Other elements participate in the constitution of the synovial joints as the joint cavity, articular bone surfaces, articular cartilage, and articular capsule described previously [32].

Synovial or diarthrosis cartilages are present in most joints and are capable of flexion and extension movements, adduction and abduction, rotation (around the cerebrum-podalic axis, can be medial and lateral), pronation (medial rotation of the forearm), supination (lateral rotation of the forearm), and circumference (joint movement of adduction, flexion, abduction, and extension) [32].

The characteristics found in the articular bone surfaces also allow defining the movements performed by the joint, so these structures can be called flat, seal, ellipsoid, and condylar. The flat surfaces allow sliding movements corresponding to the joints of the carpus or tarsus. In sealing the surfaces that resemble a knight in a saddle, it can be found in the carpometacarpal joint of the thumb. The articulation with ellipsoid surfaces has an elliptical shape, not allowing rotation movements, like the car rim. The condylar, in turn, presents the prominent bone surface appearing a condyle, found in the temporomandibular and metacarpophalangeal [39].

The occurrence of joints involving two distinct natures is possible, as is the case of fibrocartilaginous, which act as shock absorbers, enabling the joint movements. As a way of increasing the contact area of the articular surfaces, the lips (or borders) are examples of joints in which the interposed tissue is fibrocartilaginous in nature. These act as frames and are found in the shoulder joint (glenoid lip). Other examples are disks and menisci. The first, found in the union of the clavicle with the sternum, stabilizes one bony part allowing the other to perform complex movements, as it is also seen in the temporomandibular joint (TMJ). The meniscus, resembling disks, however, is incomplete, acquiring "crescent" form, and is present in the knee joint [66].

Externally, there are elements that reinforce the cohesion between the articular parts, which is the case of the ligaments that can be found internal to the articular or extra-articular cavity and to the physical forces exerted: cohesive force, atmospheric pressure, transition of the coapted bones, and muscular tension [39].

3. Histology of joints

The study of the joints allows inferring about the mechanism of locomotion of the organism, being a content that involves the anatomical part and the ultrastructure of the articular elements. Thus, histology as an important segment in this study defines the tissue characteristics of the joint as well as the importance of its cells for the performance of joint physiology [31].

The component elements of the joints present distinct histological characteristics, where the bone and cartilage tissues are most abundant. The articular surfaces are covered by articular cartilage of the hyaline type. The articular cartilage comprises a highly specialized surface connection fabric that provides a lubricated surface for moving joints and facilitates the transmission and distribution of the loads with a low coefficient of friction [29, 59].

Hyaline cartilage consists of the following cellular elements: chondrocytes, type 2 collagen, and extracellular matrix, as well as important microelements such as water, proteoglycans, glycoproteins, and lipids. Chondrocytes are the most abundant cells in this tissue, which present in their cytoplasm glycogen, lipids, well-developed endoplasmic reticulum, and Golgi complex. These tend to occupy small spaces within the extracellular matrix of the cartilage, called gaps, in which they can be found individually or contain two or more cells by gaps (**Figure 1**) [71].

The hyaline articular cartilage does not present vascularization, and the chondrocytes are nourished by constituents present in the synovial fluid provided by diffusion. The thickness and density of the cartilage vary from joint, and in humans, it is thicker on the end of the femur

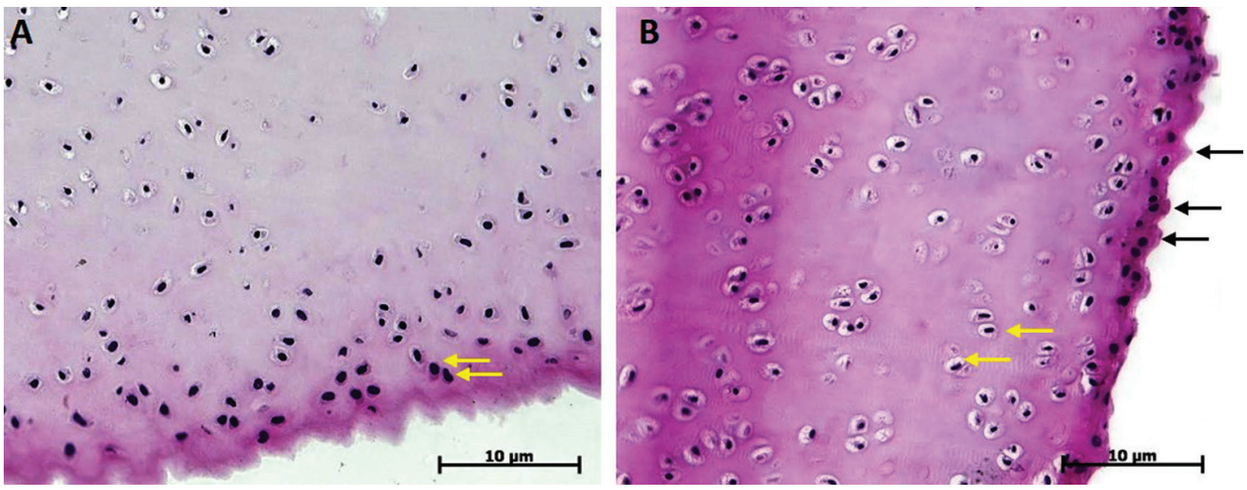

Figure 1. Photomicrograph of hyaline cartilage from a CAE model (caprine arthritis and encephalitis model) of an infected goat. (A) Affected SHJ (humerus head surface). Note the irregular joint surface with loss of cartilage integrity and heterogeneous chondrocyte distribution that are seen flattened on every surface aspect (arrows) and focal degeneration with cartilage fibrillation (wide arrows). (B) Carpal joint (carpal radial bone). Note the irregular perichondrium surface with spaced and little evident chondroblasts. The chondrocytes wrapped in matrix (*) are also seen in fewer quantities and spaces on the surface and deep layers. Bars: (a) 10 µm and (b) 10 µm (image gentile provided by Professor Flavio Alves, Specialized Veterinary Diagnostic Imaging Laboratory (LABDIVE), Federal University of Piauí, Teresina, Piauí, Brazil).

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and the tibia, ranging from 2 to 4 mm. From this thickness, four distinct layers are divided according to the cellular morphology and structure of the extracellular matrix in a superficial, transient, deep, and calcified cartilage zone. The arrangement of chondrocytes and collagen fibers varies between layers, increasing cell density as it approaches the articular surface [62].

The superficial or tangential layer is responsible for the slip of the movement of the bony parts and lubrication, composing about 20–30% of the articular cartilage. This zone is composed of two layers, a thin fibrillar lamina without cells (located in the bed more superficial or distal to the articular surface) and another layer of flat chondrocytes and collagen fibers oriented tangentially to the articular surface, having low proteoglycan content [62].

The transitional or intermediate layer is responsible for the transition between the shear forces of the articular parts, still corresponding to about 60–70% of the cartilage; this layer is composed of relatively larger round chondrocytes and immersed in an extracellular matrix. In this area, the collagen fibers are thick and randomly arranged, with a high content of proteoglycan with the presence of spherical chondrocytes. Finally, the calcified or deep layer establishes an intimate relation with the articular surface, corresponding to the smaller percentage in the constitution of the cartilage [52, 72].

The cartilaginous matrix is constantly subjected to external forces due to movement and the load imposed on the joints, which impose the need to maintain high resistance and flexibility. These characteristics are conferred by the collagen fibrils and the amorphous intercellular substance, which are inserted in their constitution permeated by a collagen network composed of water, proteoglycans, and hyaluronic acid. Water is the most abundant element in the matrix, and its high content in the cartilage favors the absorption of impacts, giving the articular cartilage the deformity necessary to withstand the compressive forces to which it is normally subjected. In addition, the cartilage matrix contains electrolytes such as Ca^{2+}, Na^{+}, and K, in concentrations higher than those found in synovial fluid [67].

Chondrocytes are the main cellular elements found in the articular cartilage and produce different collagen molecules, type II collagen being the most abundant in the joints. This collagen is characterized by three $\alpha 1$ chains of type II and organized in fibrils that give a three-dimensional network shape to the matrix allowing a certain degree of deformity when it is subjected to compressive or tensile forces [31].

In addition to water and hyaluronic acid, the matrix consists of proteoglycans, complex molecules composed of glycosaminoglycans, which are polysaccharides made up of sulfated disaccharide units that repeat themselves in relatively short and unbranched chains. The proteoglycans bind to hyaluronic acid forming chains of multi-molecules favoring the cellular organization of the matrix [31].

When synthesized and secreted by the chondrocytes, the hyaluronate-proteoglycan complexes and the collagen cluster themselves, resulting in perfectly structured complexes adapted to withstand the compression and traction forces to which the joint is subjected. Once the cartilage is subjected to compressive forces, the water retained by the proteoglycans is released proportionally to the force exerted, being recovered when that force is ceased. However, the amount of water that proteoglycans can expel upon being compressed is limited and determined by

their charge [68, 72]. Thus, the ability of articular cartilage to withstand compressive forces is directly proportional to the concentration of proteoglycans in the matrix and depends on the maintenance of its integrity, which at times may subject it to ruptures [29].

In addition to the articular cartilage, other elements are involved in the ultrastructure of the joints as the synovial fluid and the joint capsule. The intra-articular space, located between two opposite bone ends, contains the synovial fluid, which lubricates the articular surfaces, reducing friction, and serves as a vehicle for the diffusion of nutrients from the blood vessels of the synovial membrane to the articular cartilage chondrocytes. The elimination of the end products of the cellular metabolism occurs through mechanisms of diffusion, through the cartilage, to the blood and lymphatic vessels of the bone and the synovial membrane [30].

The synovial membrane that coats the articular capsule internally lies close to the surface of the cartilage, separated only by the synovial fluid, and is composed of two leaflets: the first (internal) is the synovial intima, devoid of basement membrane, and composed of one to four layers of cells. The second (more external) connects the outer wall of the fibrous capsule with the synovial intima, which is formed by loose connective tissue with fenestrated capillaries [5, 31].

The synovial intima is composed of two cell types: the "A"-type cells, similar to macrophages (because they have the same derivation of monocytic cells from the bone marrow), and the "B"-type cells, called synoviocytes, which have characteristic fibroblasts. This membrane covering the synovial fluid functions as a dialysis membrane, which, due to the increased capillary hydrostatic pressure, allows the ultrafiltration of the blood, the synovial fluid being constituted by the ultrafiltrate that passes from the synovial capillaries to the joint cavity. The articulation presents microelements essential for its activity in the midst of external and internal compressive forces, as well as assisting in the renewal and integrity of the tissues that compose them [31].

4. Diagnostic methods in articulation

Often, the joints are affected by inflammatory, infectious, or degenerative conditions that can reach the cartilage, bones, and adjacent structures or a combination of these, causing serious damage to the patient. The treatment of these pathologies is elaborated through the definitive diagnosis, which usually relies on the accomplishment of complementary exams, especially the imaging [57].

Imaging methods are essential in the diagnosis of bone and joint changes. Among the auxiliary examinations currently used to evaluate the joints, the noninvasive ones are the first ones of choice, where radiography, ultrasonography, magnetic resonance imaging, computed tomography, and arthroscopy are inserted. Usually, the evaluation begins with the radiological examination, capable of providing essential information about the bony and articular cartilaginous structures. The imaging tests are used to evaluate the integrity of the articular components and the relationship between them, confirm the extent or stage of disease progression, and evaluate the effects of the treatments performed [57].

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4.1. Radiography

Radiography is the most common imaging technique, based on imaging by X-ray transmission over a target tissue. The rays that go beyond the body reach a film, sensitizing it. After the revelation, the rays that are absorbed in the body do not sensitize the film, and the corresponding areas will be white (radiopaque). On the other hand, the sensitized areas make the regions in the film black (radiolucent). In the analysis of the film, a variation of shades from white to black denominated radiological density is observed. The contrast between the light and dark areas in the radiography depends on the technical and physical conditions in the capture of the images [10].

Like other techniques that expose the body to radiation, X-rays are harmful, requiring the adoption of procedures aimed at protecting exposed professionals and patients. The damage caused by ionizing radiation is cumulative, which means that the harm is caused by repeated doses of radiation that accumulate in the tissues. In order to minimize these risks, collimators, radiation dosage control, plumb protection, screens, and individual monitors (dosimeter) are used for professionals who deal daily with this type of examination [22].

After the technical adjustments and taking into account the biosafety tools, the region to be analyzed in the radiography must be properly positioned so that favorable images are acquired for its evaluation. Thus, it is fundamental that incidences are made in different positions, determining opposite and/or complementary planes [6].

In the attempt to improve differentiation between structures of similar density, such as those found in the abdomen, contrast media are used which may be either natural (air) or artificial (barium based and iodine based). These solutions are mainly used in the study of digestive, urinary, biliary, vascular, and joint studies [10].

Radiography is an important diagnostic method for the study of joint changes. However, fractures in rigid structures, neoplasias, growth and posture disorders, traumatic and inflammatory changes, deposition of substances, and problems of calcification, among others, can be diagnosed. It has a high interest in the evaluation of the progression of rheumatic diseases and in the diagnosis of their complications. The radiographic changes found will vary according to the type of lesion and the time of evolution, keeping the clinician informed about the severity of the condition [24].

The radiographic analysis of the joints should take into account the joint space, its dimensions, and regularities. The thickness of the joint space consists of the joint dimension of the cartilages of both bone structures. Any interference in this space can be represented in the radiographic image and indicate inflammatory changes as in the cases of arthritis. The space may be diminished in the case of advanced arthropathies, which may be asymmetric or localized, depending on the pathology, or it may occur that a loss of space is generalized [65].

Synovium, synovial fluid, and articular capsule, because they have the same radiodensity as adjacent soft tissues and cartilage, are only seen if they are contoured by a radiant layer. For this reason, it is often necessary to complement the simple X-ray with the use of articular contrast media, known as arthrography (**Figure 2**) [10, 48].

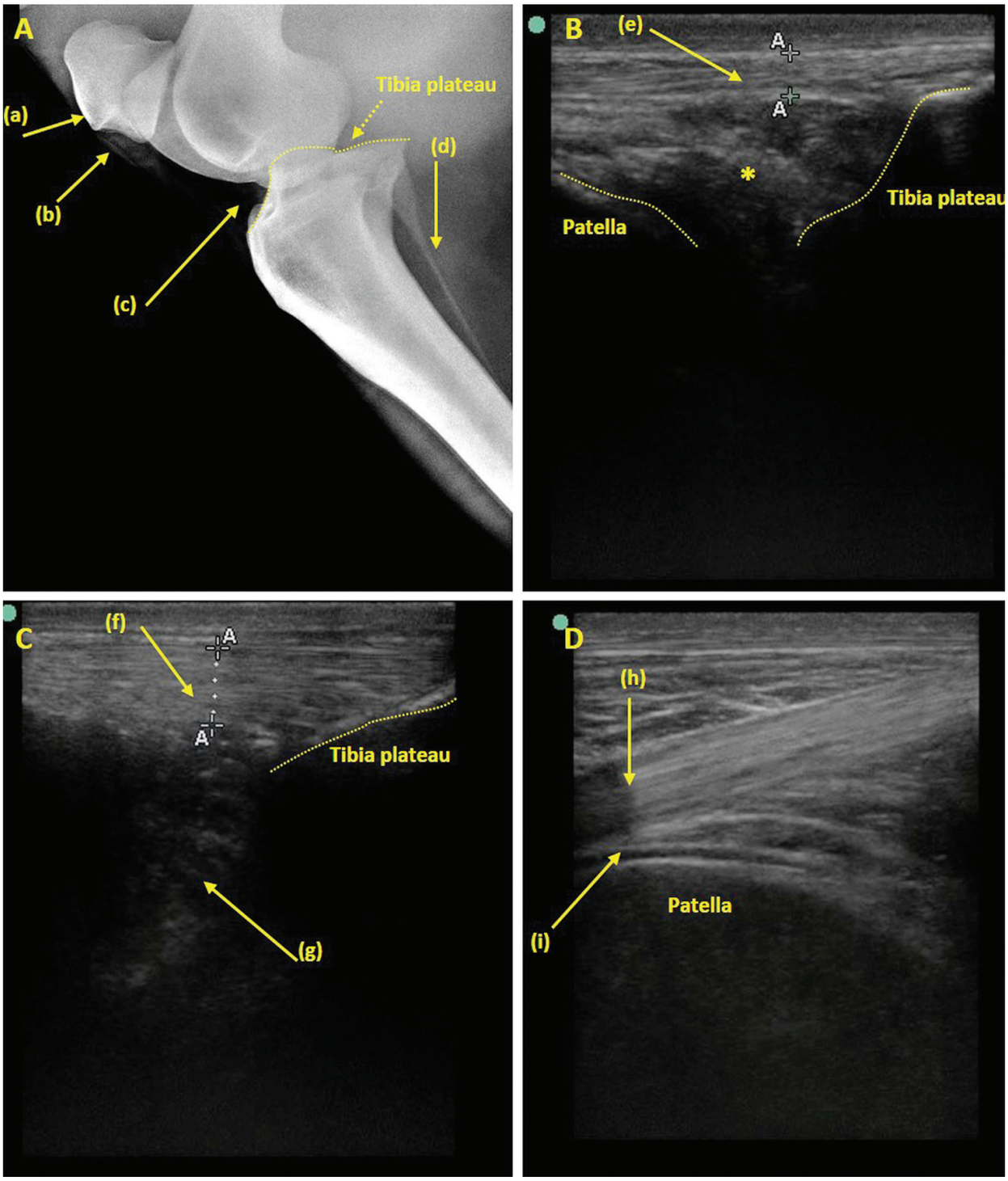

Figure 2. Radiographic and ultrasound imaging of a normal equine knee joint. (A) Note the smooth surface of the joint (femoral head and tibial plateau), with the discreet presence of the patellar ligament (b), due to the high incidence of X-ray bundles. (B and C) The normal ultrasonographic pattern of the patellar ligament, showing homogeneous echotexture and habitual echogenicity. Note the parallel arrangement of the tendon fibers and the normal hyperechogenic appearance of the infrapatellar fat pad (*). (D) Proximal insertion of the patellar tendon (h). (a) Patella, (b) patellar ligament, (c) joint space, (d) fibula, (e and f) patellar ligament echotexture, (g) infrapatellar fat pad, (h) proximal insertion of the patellar tendon, and (i) joint space. (Image gentile provided by the Diagnostic Imaging Services, Federal University of Piauí, Teresina, Brazil).

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The arthrography corresponds to the contrasted representation of the joint space, and the viability of using the technique with a positive (iodized) contrast is injected directly into the joint. Unlike the simple radiography, the arthrography should be performed with the patient in sedation due to the discomfort in the application of the contrasts. This technique is performed to demonstrate and assess arthropathies and associated soft tissue structures [36, 65].

There are indications of arthrography when there is suspicion of soft tissue ruptures present in the joint space, which are not adequately visualized in the simple radiography, due to the minimal differentiation of radiological density. However, many contrasts may trigger undesirable reactions, so this technique is infeasible in case of patients allergic to contrast or solutions used in sedation [10].

Currently, double-contrast arthrography in the joints has been used in humans both in radiology and associated to computed tomography, in order to identify lesions on joint surfaces and in nonbone structures, which has shown great advantages when compared to arthrography with positive contrast medium [50].

4.2. Ultrasonography

Ultrasonography presents as a consolidated and sensitive examination for the observation of periarticular soft tissue alterations of the articular surfaces, besides being able to diagnose the morphological changes promoted by various arthropathies early [60]. This is due, in large part, to the improvement in the image quality of the equipment, due to the improvement of the imaging technology and the manufacture of transducers with increasing resolution, in addition to the relative decrease in the price of the equipment (**Figure 2**) [21].

This technique presents some advantages compared to the radiography because it is a noninvasive examination, able to detect early changes, besides providing details of the tissue parenchyma and evidencing structures that do not appreciate the radiographic examination [21].

Such information can be seen by means of the changes that occur in the synovial membrane, joint capsule, as well as periarticular volume increase. This technique allows direct visualization of the joint space, besides being able to guide needles in real time, in cases of treatments with intra-articular drug infusions. Furthermore, it can guide treatments according to signs of inflammation and allows the visualization of the appropriate distribution of medication within the joint space [7, 58].

In general, it is not necessary to pre-prepare the patient for ultrasonographic joint examination, only the application of a thick layer of acoustic gel between the transducer and the ultrasound window to reduce the interference of the layer of air on the skin [21].

Lately, ultrasound examination has been gaining space as a complementary diagnostic method in the therapeutic follow-up of several joint diseases such as rheumatoid arthritis, synovitis, bone erosions, mainly psoriatic arthritis, and systemic lupus erythematosus. The great advantage of the sonographic study is its ability to detect changes such as synoves and bone erosion early on radiography, which has been increasingly valued in the prevention of late and definitive structural damage [3].

Depending on the frequency used in the transducers, it is possible to evaluate most joints by means of ultrasonography. With it, one can investigate structures such as tendons, brackets, cartilage, and bone surface, making it possible to search for erosions in inflammatory diseases in general. The possibility of evaluating numerous structures in a single study extends its application in several rheumatologic pathologies, such as rheumatoid arthritis, spondylarthritis, arthritis by microcrystals, osteoarthritis, collagenosis, and systemic vasculitis. The use of ultrasound is effective for the determination of the presence or absence of lesions in tendons and should be considered as a first line of diagnostic tool [25].

In articulations, ultrasonography is used to evaluate the response to treatment, aiming to reduce the degree of synovitis by examining gray scales and/or synovial vascularization using the Doppler technique in its various modalities. Several ultrasonographic degrees of synovial involvement are proposed in the literature, which have as main objective the detection of possible alteration of the inflammatory activity, analyzing the smallest number of joints possible, to reduce the time of the exam execution [4].

Ultrasonography has a good correlation with magnetic resonance imaging (MRI) in the detection of synovitis and erosions. However, although MRI is considered the gold standard for detection of joint changes, this examination is often uncomfortable for patients besides being contraindicated in the holders of metallic prostheses due to the possibility of physical damages. Also, it is a time-consuming, expensive exam that requires the use of a contrast medium, making evaluation of many joints in a single moment impossible. Thus, ultrasound has assumed an important advantage as a highly feasible method in the diagnostic and sequential treatment of patients with various arthropathies. This can be done more frequently, allowing the evaluation of the progress of the treatment and allowing real-time and dynamic analysis, with the joint in motion.

Recent studies with ultrasound of the ankle joint in patients with Chikungunya, despite the limitations of this study, have made possible the characterization and quantification of the sonographic alterations related to this disease, highlighting the role that the method plays in the diagnosis of such complications. The predominant findings in this study were effusion and tenosynovitis, mainly fibular and posterior tibial, and the most common musculoskeletal comorbidity was the involvement of the calcaneus tendon [44].

4.3. Arthroscopy

Although arthroscopy is a surgical procedure, it is a minimally invasive technique, with a relatively fast execution and good postsurgical recovery, allowing the observation of the interior of a joint through the use of a device called an arthroscope. The arthroscope is an endoscope-like apparatus, consisting of a thin rigid cylindrical tube, the thickness of a pencil, containing a microcamera coupled to the end, carrying optical fibers, which transmit images to a TV monitor, allowing the visualization of the inner face of the joint. The evaluation of the articular surface through arthroscopy solves the limitations of the traditional methods of the examinations like the radiography and ultrasonography, allowing the precise diagnosis of articular alterations [9].

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With the development of this technique, associated with the discovery of predisposing factors to various arthropathies, restoration of function through minimally invasive procedures, essentially eliminating lesions and helping patients return to normal activities, was even more safe and effective [18].

Arthroscopy is indicated for the diagnosis of joint affections, for the follow-up of treatments and evolution of diseases and in cases of intra-articular alterations not diagnosed by conventional imaging techniques. Arthroscopy of hip-like joints offers minimally invasive surgery for procedures that would require hip dislocation, a more complicated technique. In this joint, the most commonly treated pathologies are femoroacetabular impacts, which are closely associated with demanding activities in hip flexion and internal rotation, common in sports such as golf, baseball, ice hockey, and soccer [7, 18, 43, 54].

Diagnostic indications involve the evaluation of cartilage in osteonecrosis or in conjunction with osteotomies and painful arthroplasties and the collection of tissues for culture. Moreover, synovial diseases such as chondromatosis, pigmented villonodular synovitis, and rheumatoid arthritis are a good indication for this procedure, as well as the treatment of deep gluteal pain [9].

New indications for arthroscopy are being tested, such as round ligament reconstruction, capsulorrhaphy in cases of instability, and repair of tendinous lesions. It is not recommended, however, in cases where there is an infectious process installed in the joint or active skin infections, except when this procedure has the objective of draining secretions resulting from septic arthritis or evaluation of the degree of infection in prostheses [9].

In general, the preparation for the arthroscopy exam is similar to any other surgical procedure. The physician should have all clinical data on the patient as well as information on hypersensitivity reactions to any medication, including anesthetics, the use of medications, associated health problems, vascular problem such as thrombosis or bleeding, and the possibility of gestation. In addition, general and specific preoperative examinations should be performed for a safer procedure [14].

The procedure is performed with the anesthetized patient, which will depend on the structure to be manipulated, ranging from epidural or spinal anesthesia, for procedures in the pelvic limbs, to general anesthesia for shoulder or hip interventions. Sedative drugs are usually given, and the patient sleeps during the examination, however, can be performed with the patient awake. The patient remains monitored by the anesthesiologist until the end of the procedure, being evaluated the parameters such as heart rate, blood pressure, respiration, body temperature, and cardiac electrical activity, among others [14].

For the realization of the technique, two small accesses are realized in the articulation: the first one where the arthroscope will be introduced and the second to direct the necessary instruments for the operation, if necessary. In general, a certain amount of saline is inserted into the joint so that it is inflated and becomes clearer, thus allowing a better visualization. Also, tourniquets can be performed to temporarily reduce blood flow, which could hamper visualization. Thus, therapeutic procedures such as removal, reconstruction or repair of menisci or ligaments, removal of loose bone fragments, or cartilage within a joint or inflamed synovial tissue are possible [14].

Studies with high-performance soccer athletes have shown that hip arthroscopy for the assessment of pathologies of this joint, such as the femoral acetabular impact (FAI), has been shown to be a safe procedure with satisfactory results regarding the return of the athlete to sporty activities. Hip arthroscopy in athletes with symptomatic FAI and labral pathology allowed for complete rehabilitation, earlier than those undergoing open surgery.

Hip arthroscopy is a safe treatment method for a majority of hip pathologies that were unknown until the last decade. The instruments and surgical technique of hip arthroscopy continue to evolve. Better and better results and fewer complications should be expected according to the learning curve.

4.4. Magnetic resonance imaging

Discovered in 1946 by researchers at Stanford University, magnetic resonance imaging (MRI) has been implanted in medicine by Purcell at Harvard years later. In medicine, the first images were obtained from 1972 and advances provided by the application of the technique provided the nomination of Paul Lauterbur and Peter Mansfield to the Nobel Prize of Medicine. In Brazil, the technique was first implanted in the Albert Einstein Hospital of São Paulo in 1986 [27].

MRI is a diagnostic imaging method that uses a magnetic field and radiofrequency waves to obtain images of the interior of the objects in the form of tomes or cuts, without the availability of ionizing radiation. For this, it is necessary to understand physical principles related to the acquisition of images, among them, subjects about electromagnetism, superconductivity, and signal processing [19, 27]. In the clinical setting, MRI aims to complement the diagnostic conclusion given by conventional imaging tests [42].

The formation of the MR image is the result of the interaction of the strong magnetic field produced by the equipment with the hydrogen protons of the living tissue, formulating a condition so that a pulse of radiofrequency can be sent and after collecting the differentiated radiofrequency through a receiving instrument. The signal encoded due to a magnetic field gradient is collected, processed, and converted into an image or information [42].

Hydrogen is the chemical element with the highest concentration in the tissues and with the greatest magnetic moment (the capacity to produce the highest radio signal of all the stable nuclei). Therefore, it is used as the signal source in most magnetic resonance imaging tests. Once a tissue is subjected to a magnetic field and left long enough, the tissue magnetization (name given to the process of interaction of the equipment with the hydrogen protons of the tissue) reaches an equilibrium value that is proportional in intensity to the external magnetic field [45].

Some organs produce a stronger or weaker signal than others, going according to the density of hydrogen present in that tissue, for example, adipose tissue, cerebrospinal fluid, blood, and other body fluids that produce a strong signal due to high density of protons. In contrast, in

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the absence or low density of mobile protons in the tissue, there will be a zero or very small value capable of overriding the evaluation parameters at resonance [27, 42].

All soft bodies can be seen in MRI; however, the cortical bone and air do not produce signal in the images because of the inability of the protons to relax in the dense bone matrix and the relative lack of hydrogen nuclei in the air. Thus, due to the low density of mobile protons, the lenses do not show any signal in any sequence used. All other structures are visible in varying degrees from gray to white because of variations in signal strength. This differentiation between proton densities in tissues defines, in medical terms, the occurrence of tissue changes, as it increases the difference between a lesion and a surrounding tissue [27, 42].

In general, MR imaging is based on the relationship between the equipment and the living tissue so that the patient's atomic nuclei align along the applied magnetic field, generating a magnetization vector. Subsequently, sequential magnetic field gradients are applied to the spatial location of the signals to be acquired; thus, the excitation pulses are applied, and the nuclei absorb energy. After the excitation pulses are applied, the relaxation phenomena begin, and the nuclei begin to induce the MRI signal in the receiver coils. This signal is acquired and processed by means of the transformed Fourier, where the image is formed point to point in a matrix [2].

However, for the execution of the examination, the anatomical and clinical prior knowledge of the radiologist technician is still necessary. In the sequence, it is of great value to obtain the best images, as well as to minimize artifacts of techniques. Choosing the appropriate coil for the study region that provides a better signal for exam quality and proper patient positioning are imperative items in the MRI [23].

According to the indication, specific protocols are established for the region to be examined and can be divided into the regions: central nervous system, thorax, abdomen, pelvis, and musculoskeletal system. In general, it is indicated that the patient is placed in dorsal decubitus with the head resting on the appropriate coil (quadrature) with the region of interest straight and in the center of the magnet, upper limbs extended on the side of the body and support for the legs in order to promote alignment of column curvatures [2].

In order to evaluate joints, magnetic resonance imaging becomes an excellent diagnostic modality, since it allows identification of not only bone and cartilage structures but also soft tissues such as meniscus, ligaments, cortical and medullary bone compartment, muscles, tendons, and fat (**Figure 3**) [33].

It is believed that the greatest advantage of this technique for joint evaluation is the detection of the disease by the investigation of alterations in the articular components, such as the thickening and enhancement of the synovial membrane, a situation found in rheumatoid arthritis and easily demonstrated by the intravenous injection of paramagnetic contrast (gadolinium). In addition, MRI stands out as a noninvasive method, useful as a complement to clinical

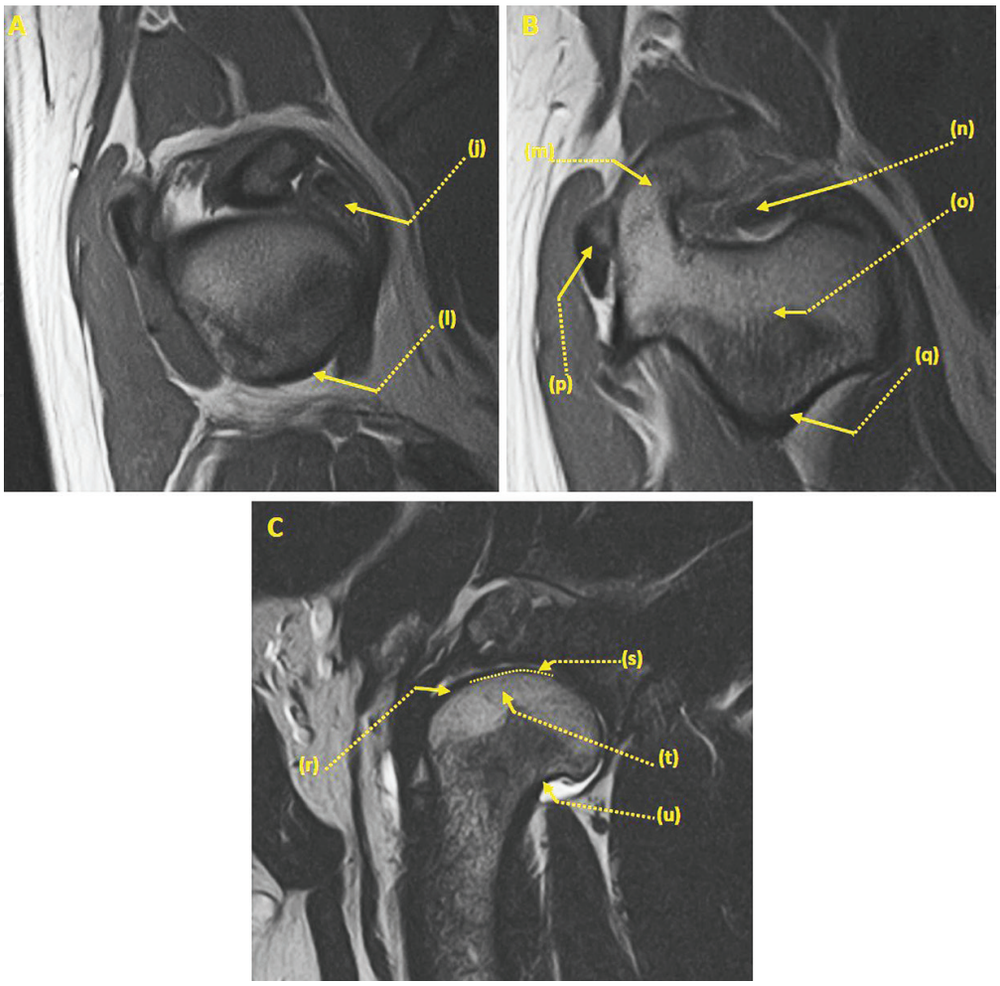

Figure 3. (A–C) Magnetic resonance of a normal canine shoulder joint. (j) Subscapularis tendon, (l) joint space, (m) greater tubercle, (n) biceps tendon, (o) humeral head, (p) supraspinatus tendon, (q and r) cranial joint space, (s) cartilage surface, (t) subchondral bone, and (u) caudal joint space (image gentile provided by Professor Robson Giglio, Department of Small Animal Clinical Sciences, College of Veterinary Medicine, University of Florida).

joint assessment, not only for detection of early disease changes but also for its evolutionary control, treatment monitoring, and differential diagnosis with other diseases (**Figure 4**) [27].

In addition, MRI allows measurement of the extent of joint and extra-articular involvement and evaluation of complications due to disease time, with a higher sensitivity for the evaluation of tendon and ligament injuries, involvement of the tendon sheath (tenosynovitis), trochanteric pouch, bone lesions (subchondral erosions, cysts) that initially may not be seen by conventional radiography, changes in bone marrow, chondral lesions, and in the differentiation between joint effusion and synovitis, using paramagnetic contrast that does not pose risks to the patient (**Figure 5**) [42].

However, in spite of the high cost and its limitations for its execution, magnetic resonance imaging in general still constitutes the best imaging method for joint evaluation, standing out for the other examinations due to its advantages of noninvasiveness, the absence of ionizing radiation, not the use of iodinated contrast (potentially nephrotoxic and allergenic), and ability to better anatomical detail, both by the multiplanar nature of acquisition and by the high contrast between different body tissues [27].

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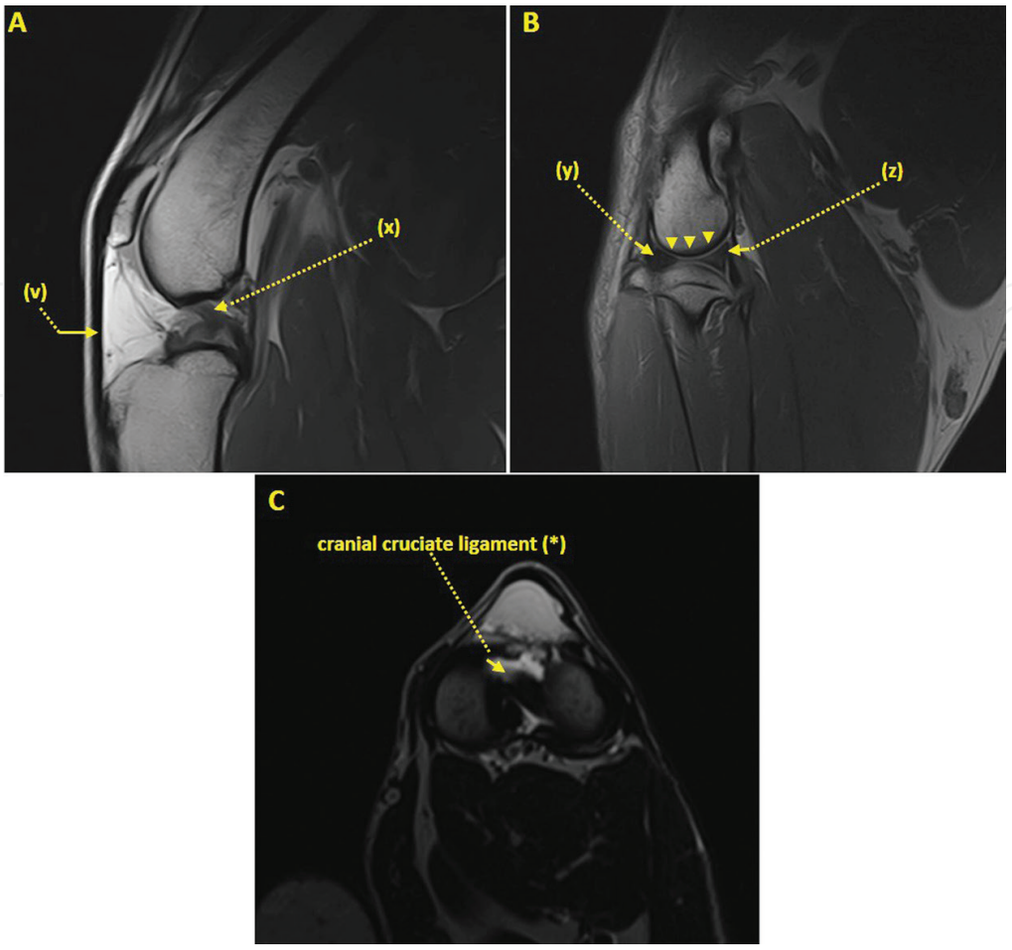

Figure 4. (A–C) Magnetic resonance of a normal canine knee joint. (v) Patellar ligament, (x) cranial cruciate ligament, (y and z) meniscus, joint surface (arrowhead), and (*) cranial cruciate ligament (image gentile provided by Professor Robson Giglio, Department of Small Animal Clinical Sciences, College of Veterinary Medicine, University of Florida).

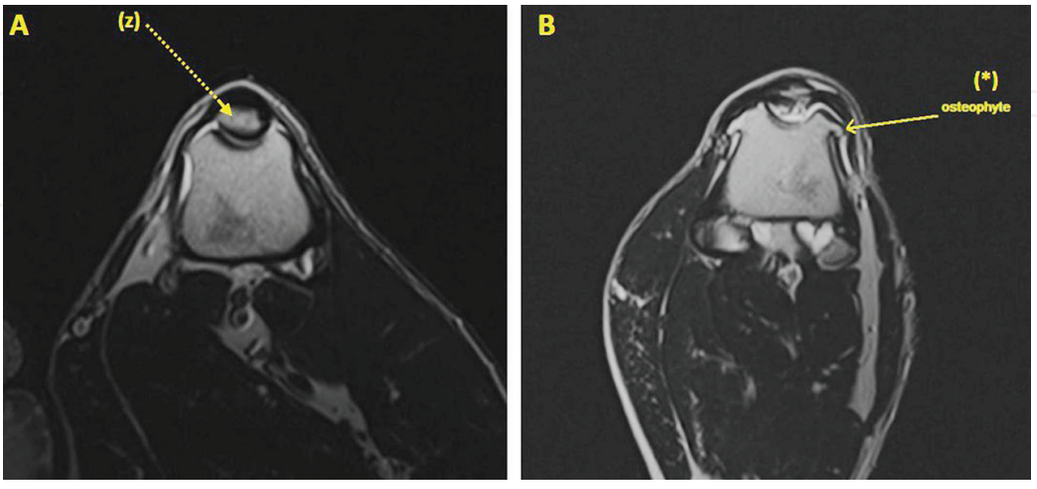

Figure 5. (A and B) Magnetic resonance of a normal canine shoulder joint *versus* osteoarthrosis. (z) Biceps tendon and (*) osteophyte. Note the reduction of joint space and discrete synovial edema, associated with irregularity of articular cartilage (image gentile provided by Professor Robson Giglio, Department of Small Animal Clinical Sciences, College of Veterinary Medicine, University of Florida).

5. Conclusion

Advances in technologies related to research on the diagnosis and treatment of joint diseases have demonstrated excellent results, contributing to the quality of life of patients affected and their return to daily activities. The improvement in the quality of the imaging equipment, combined with the various works in the area of rheumatology, has contributed to a better clinical management of patients, allowing a more conclusive diagnosis and, consequently, the implementation of effective treatments.

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