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Femoroacetabular Impingement and associated collateral damages

Introduction • Radiographs • Mapping of structural deformities and labral chondral lesions• Cam FAI • Pincer FAI • Epidemiologic aspects of FAI and implications for radiologic interpretation • Imaging of herniation pits • Acetabular Labrum • Articular cartilage • Imaging of ligamentum teres lesions and microinstability

Introduction

FAI describes a dynamic concept of abutment of the femoral neck and the acetabular rim, which may lead to labrum and cartilage lesions and ultimately to osteoarthritis of the hip.[1] Structural deformities at the femur and/or acetabulum predispose to repeated contact between the femur and the acetabulum at physiologic arcs of motion typically with internal rotation and flexion. Impingement may also occur in patients devoid from structural deformities during extreme arcs of motion (i. e. ballet dancers).[2] Whereas etiology of the majority of cases of osteoarthritis was considered to be of idiopathic ("primary") origin, the introduction of the safe surgical dislocation of the hip in the early 2 000s established FAI as major etiologic factor in the development of osteoarthritis of the hip.[1,3,4]

Within the concept of FAI two separate entities have been described: cam- and pincer FAI which cause different patterns of joint degeneration. In most cases a mixed-type impingement with predominant cam FAI is found. Structural FAI deformities are usually most pronounced anteriosuperiorly and lead to consecutive impingement with flexion, internal rotation and adduction (Fig. 1, Tab. 1).[1,4]

FAI					
Femoral "Cam"			Acetabular "Pincer"		
cam deformity	excessive femoral torsion/ femoral retrotorsion	coxa vara/ coxa valga	**focal anterior**/posterior **overcoverage**	global overcoverage	global retroversion

Tab. 1: *FAI subgroups. Most common types of FAI are highlighted.*

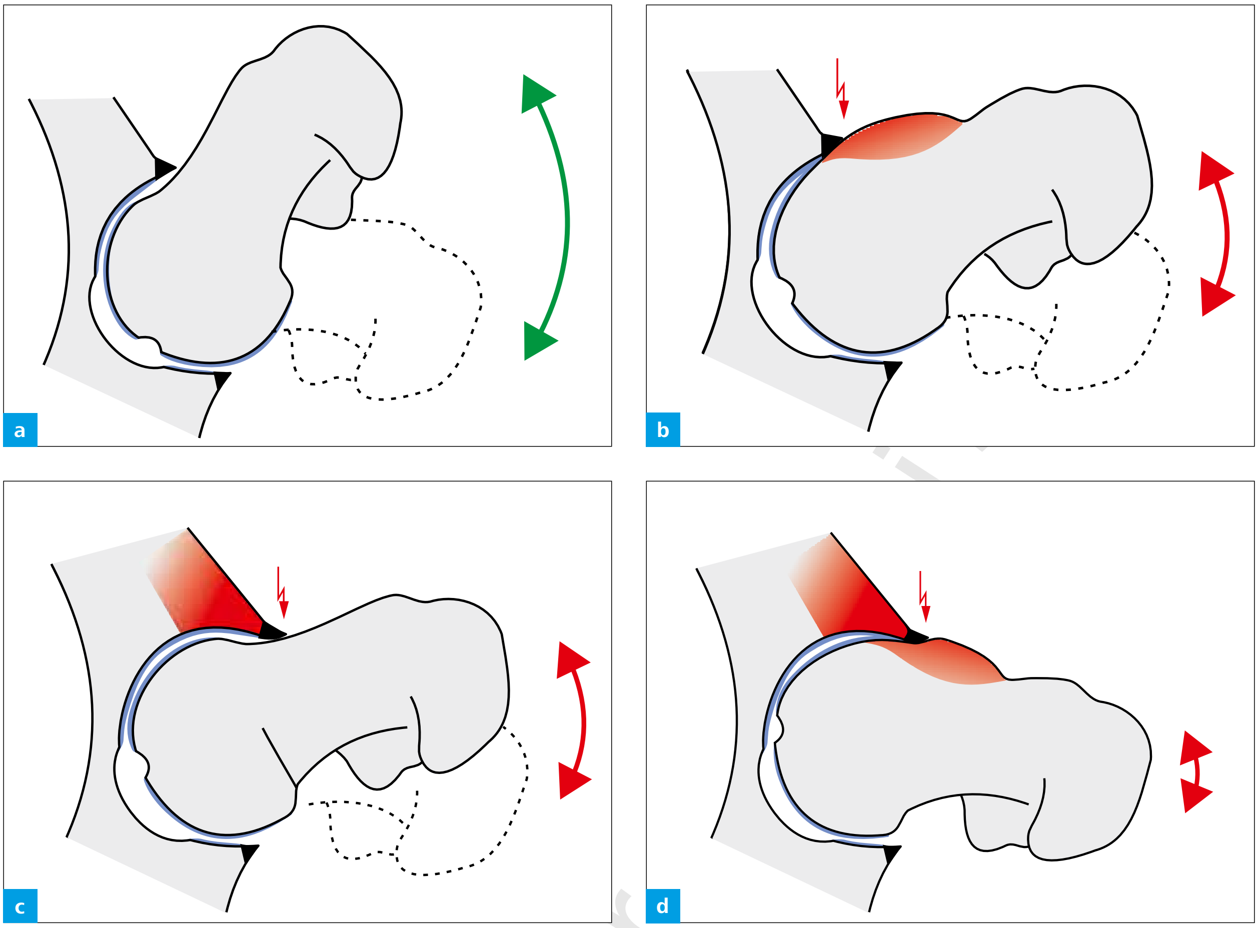

Fig. 1: *(a) Normal configuration of the femoral neck and the acetabular rim. (b) The aspherical extension at the femoral neck limits arcs of motion and leads to cam-type impingement. (c) Isolated acetabular overcoverage limits arcs of motion and leads to pincer-type impingement. (d) Mixed-type impingement: structural deformities at the proximal femur and at the acetabulum substantially limit range of motion.*

Imaging of FAI and associated collateral damages in symptomatic patients is based on a multimodal approach which includes plain radiographs, native MRI, MR arthrography and CT.[5] Surgical therapy aims to restore normal anatomy of the femur and acetabulum to regain impingement free range of motion. Different surgical techniques are used to manage structural deformities in the hip joint. Generally hip arthroscopy is an effective tool to address focal, anteriorly located pathologies whereas posterior lesions or global malrotation and global overcoverage are managed with open procedures in which the entire joint can be inspected and addressed surgically.[6–9] Open surgical dislocation of the hip is more invasive due to the more extensive soft tissue damage and the trochanteric osteotomy with associated risk of non-union compared to common complications of hip arthroscopy which are related to traction and portal placement. Open surgical techniques require longer rehabilitation than hip arthroscopy but enable throughout visualization of the entire joint and treatment of the wide spectrum of FAI morphologies.[10]

Due to the fact that the concept of FAI is relatively new, data regarding the efficacy of hip preservation surgery is limited. In most studies good to excellent short- to mid-term results after open surgical dislocation of the hip or arthroscopic FAI surgery have been presented.[11–17] Recently the Bernese group presented favorable prothesis-free survival respectively no worsening of osteoarthritis in 80 % of subjects among a cohort of patients who underwent open treatment for FAI at 10-year follow-up.[18] Despite the promising data for surgically restoring the normal anatomy of the hip joint in patients with FAI, it remains to be shown whether surgical treatment can prevent development of osteoarthritis and is more effective than conservative treatment.[19]

Hip imaging and hip preservation surgery are vastly evolving and further efforts in clinical research with long term postoperative follow-up are needed to obtain evidence based criteria for patient selection and choice of adequate treatment strategies. In this context identification of radiographic and MR criteria which correlate with clinical parameters and can be used to predict outcome of joint preserving therapy is mandatory.[20] To date the knowledge of the complex dynamic interplay between subtle morphological features associated with FAI during motion is sparse and considerable scientific effort is needed to improve the understanding of FAI and to develop targeted therapies.[21,22] Advanced imaging techniques such as 3D CT based collision models[21,23–25] and cartilage mapping techniques[26–29] have great potential to improve the current understanding of the FAI pathomechanism, its natural course of disease and to monitor postoperative course of cartilage degeneration.

Radiographs

Due to their universal availability and low costs anterio-posterior (AP) pelvic views are the baseline diagnostic tools for patients with groin pain. Though they cannot directly visualize labral and chondral lesions, they give an excellent overview over pelvic anatomy and enable assessment of the femoral neck junction, of acetabular coverage and orientation.[30] Degenerative changes can be graded with various osteoarthritis classifications on plain radiographs. Among these the Tönnis- and the Kellgren-Lawrence grading system are most commonly used (Tab. 2, 3).[31, 32] Status of joint degeneration as assessed on radiographs predicts surgical outcome following joint preserving therapy for FAI.

Grade 0	no signs of osteoarthritis
Grade 1	slight narrowing of joint space, slight lipping at joint margin, slight sclerosis of femoral head or acetabulum
Grade 2	small cysts in femoral head or acetabulum, increasing narrowing of joint space, moderate loss of sphericity of femoral head
Grade 3	large cysts, severe narrowing or obliteration of joint space, severe deformity of femoral head, avascular necrosis

Tab. 2: *Tönnis classification for grading osteoarthritis of the hip.[31]*

Grade 0	normal
Grade 1	dobtful narrowing of joint space, possible osteophyte development
Grade 2	definite osteophytes, absent or questionable narrowing of joint space
Grade 3	moderate osteophytes, definite narrowing, some sclerosis, possible joint deformity
Grade 4	large osteophytes, marked narrwoing, severe sclerosis, definite joint deformity

Tab. 3: *Adapted Kellgren-Lawrence classification for grading of osteoarthritis.[32]*

It has been shown that Tönnis grades of 1 or greater and joint space narrowing of < 2 mm are associated with poor postoperative outcome respectively conversion to total endoprothesis of the hip.[13, 18, 33] However, the use of radiographs to assess qualitative and quantitative radiographic indices associated with FAI and the assessment of the status of joint degeneration is not unproblematic as these parameters are affected by limited interobserver and intraobserver agreement.[32, 34, 35] Furthermore altered patient positioning affects radiographic parameters of acetabular coverage and orientation.[30] These difficulties will be discussed in the corresponding chapters. In order to obtain accurate projections on AP pelvic views a high degree of standardization of the radiographic acquisition technique is warranted (Fig. 2, 3).

Fig. 2: *Supine AP pelvic view.*

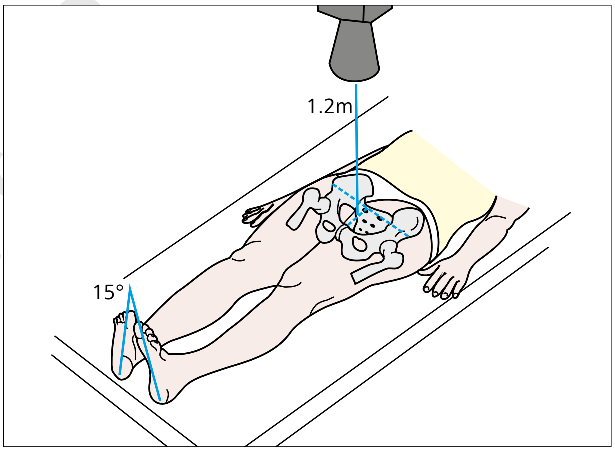

Fig. 3: *Supine position and internal rotation of 15° of both legs is required for visualization of the femoral neck length. The central beam is centered at the midpoint of a horizontal line which connects the anterior superior iliac spines at the superior margin of the pubic symphysis. Tube-to-film distance is 120 cm and the tube is oriented perpendicular to the table.[36]*

Lateral views are obtained in supine position and enable improved assessment of the femoral head-neck junction. These projections include Dunn views (Fig. 4, 5), frog-leg lateral views (Fig. 6), cross-table lateral views (Fig. 7) and faux profile views (Fig. 8, 9).

Fig. 4: *Patient positioning for Dunn view: (a, b) The examined hip is positioned in neutral rotation, 20° abduction and 40° flexion. Tube to film distance is 100 cm and the tube is oriented perpendicular to the table.*

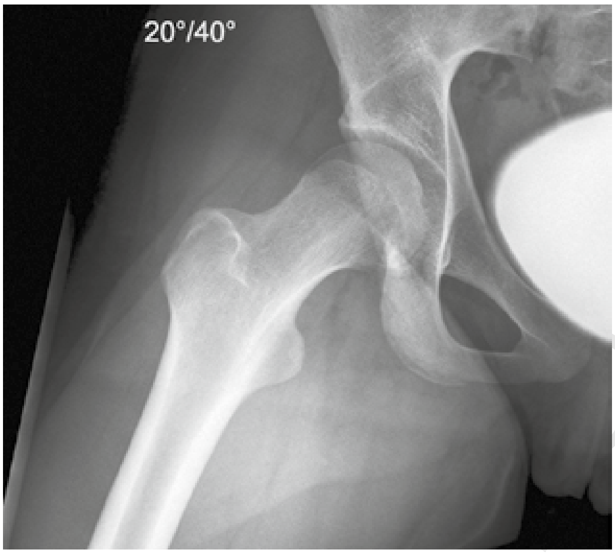

Fig. 5: *Dunn (40° flexion, 20° abduction) view.*

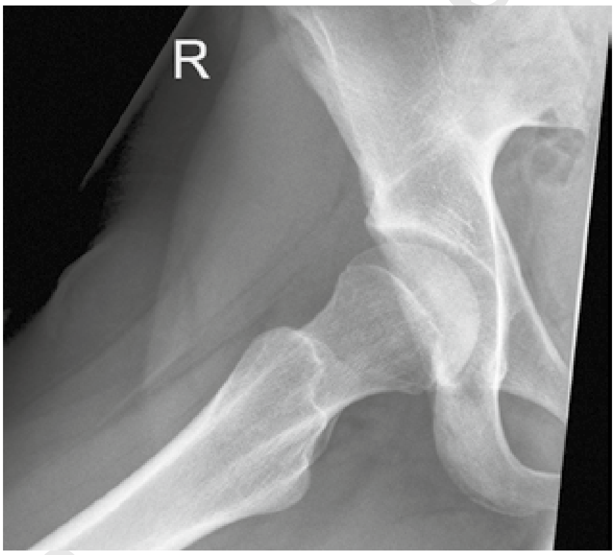

Fig. 6: *Frog-leg lateral views are taken in 30°–40° of flexion in the knee and 45° of abduction of the symptomatic hip. The heel of the affected leg is positioned medially at the contralateral knee. The central beam points at the center of a line that connects the anterior superior iliac spines and the pubic symphysis. Tube-to-film distance is 100 cm and the tube is oriented perpendicular to the table.*[36]

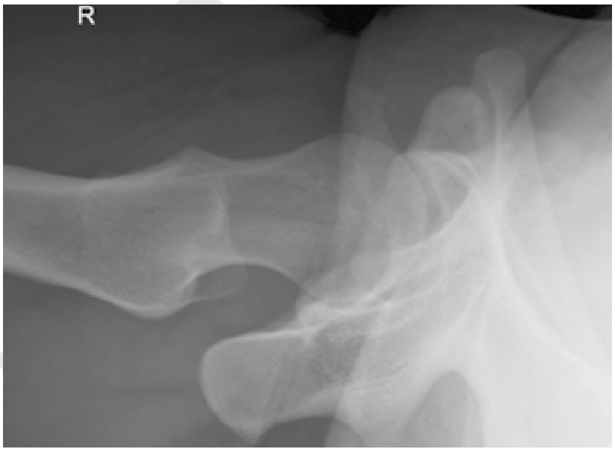

Fig. 7: *The cross-table lateral view requires 15° of internal rotation of the examined leg. The contralateral hip and knee are flexed up to 80°. The tube is positioned parallel to the table and the x-ray beam is oriented 45° towards the affected extremity. Crosshairs are centered on the femoral head.*[36]

Fig. 8: *Faux profile view (asterisk).*

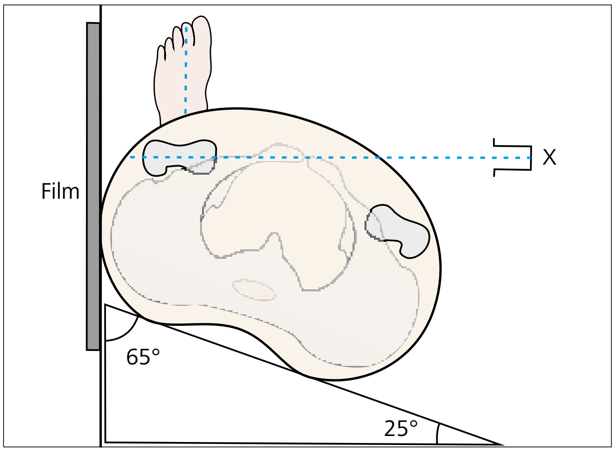

Fig. 9: The faux profile view is taken in a standing position in which the examined extremity is placed adjacent to the radiographic cassette and the ipsilateral foot is oriented parallel to the cassette. The symptomatic side stays in this position and the pelvis is rotated up to 65°. The central beam points at the femoral head. Tube-to-film distance is 100 cm. [36]

Mapping of structural deformities and labral-chondral lesions

The predominant localization of structural FAI deformities and associated labrum and cartilage lesions is the anteriosuperior quadrant of the hip joint.[37] Accurate preoperative reporting of the localization of femoral and acetabular rim lesions is of utmost importance as it affects choice of surgical procedures.[8, 9, 38, 39] In contrast to open FAI surgery, technical difficulties inherent to hip arthroscopy limit the ability to inspect and arthroscopically address the entire joint. Posterior located lesions which are close to the retinacular vessels and more complex pathomorphologies may be challenging to manage arthroscopically. Consequently posterior based cam deformities may be better treated with open surgical dislocation of the hip.[8, 9, 38, 39]

Localization and extension of labral and chondral damages and bony pathomorphologies is traditionally described with a clockface system on MR images and during hip preserving surgery. The midpoint of the transverse ligament is the commonly used acetabular reference landmark if standard MR imaging planes (coronal, sagittal, axial-oblique) are used. Corresponding to the clock face, the hip joint can be divided into four quadrants: the anteriosuperior quadrant (3 – 12 o´clock), the anterioinferior quadrant (3 – 6 o´clock), the posteriosuperior quadrant (9 – 12 o´clock), the posterioinferior quadrant (6 – 9 o´clock). This technique requires the use of a sagittal scout to map lesions detected on coronal and axial-obliques images (Fig. 10, 11). Validation of this MR mapping approach with hip arthroscopy showed agreement within one "hour" in 85 % of the patients for localizing labrum lesions.[40]

Radial images which use the femoral neck as axis of rotation are widely used for mapping of the cam deformity. Furthermore their use may be beneficial for assessment of acetabular rim lesions as they enable in-plane resolution of the spherical acetabulum and thereby decrease partial-volume effects compared to standard sequences. Due to the torsion of the femur the anatomic 6 / 12 o´clock position differs between the acetabulum and the femur. On radial MR images the most prominent projection of the trochanter major and of the teardrop figure can be used to determine the 6 / 12 o´-clock position at the femoral neck respectively at the acetabular rim.[38] (Fig. 12) For routine clinical imaging the use of 12 radial cuts was proposed for accurate visualization of femoroacetabular deformities and easy mapping of chondral and labral lesions. (Fig. 13) According to this approach each slice gap corresponds to anterior/posterior shift of 30 angular minutes along the rotating axis.[38, 41] Definition of anatomic landmarks on radial MR images is reproducible and yields the advantage of integrating a mapping system for both acetabular- and femoral-sided pathologies without the need to use a sagittal scout. Nevertheless the above presented technique has to be further validated with surgical findings.[38] For true sections of the acetabular rim axial-oblique and coronal localizers are required to obtain an en face image which corresponds to the acetabular opening and reflects acetabular inclination and version.[41] Alternatively a zonal method to describe localization of lesions on MR images can be used which was adapted to the arthroscopic geographical mapping approach (Fig. 14).[42, 43]

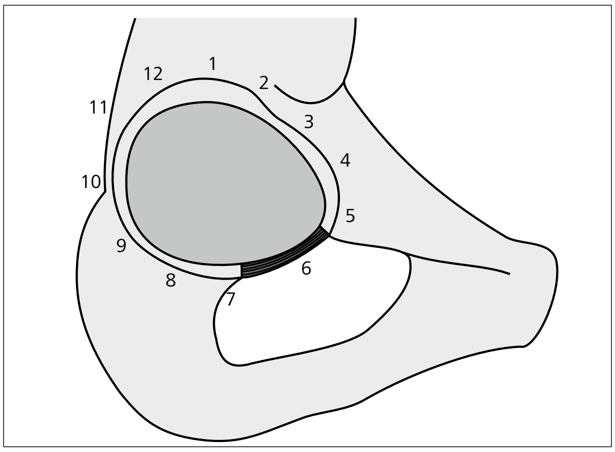

Fig. 10: Acetabulum with superimposed clock face system for localization of acetabular rim lesions. Six o'clock position is centered at the transverse ligament, 12 o'clock position is directly opposed, 3 o'clock indicates anterior and 9 o'clock indicates posterior in both left and right hips.

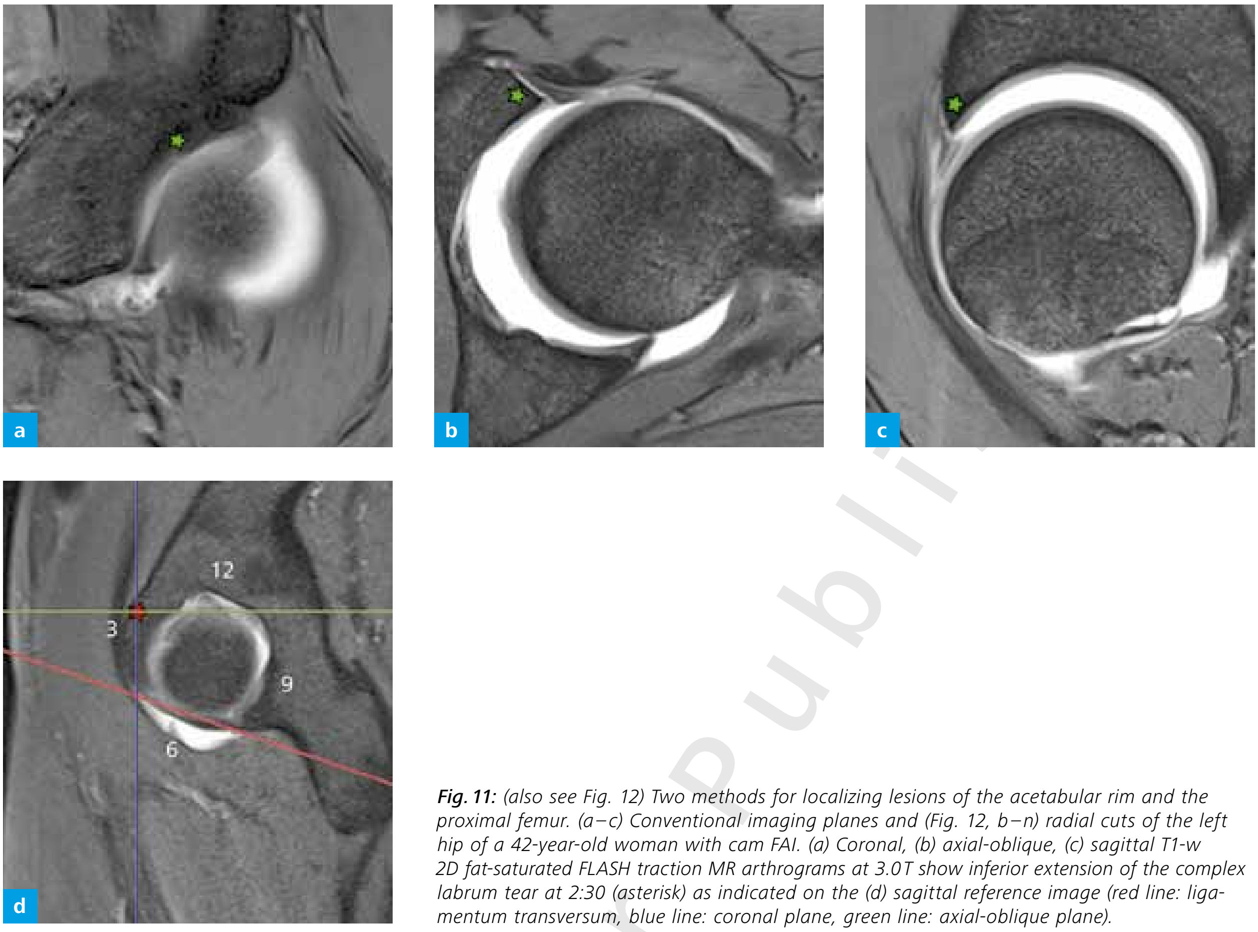

Fig. 11: (also see Fig. 12) Two methods for localizing lesions of the acetabular rim and the proximal femur. (a–c) Conventional imaging planes and (Fig. 12, b–n) radial cuts of the left hip of a 42-year-old woman with cam FAI. (a) Coronal, (b) axial-oblique, (c) sagittal T1-w 2D fat-saturated FLASH traction MR arthrograms at 3.0T show inferior extension of the complex labrum tear at 2:30 (asterisk) as indicated on the (d) sagittal reference image (red line: ligamentum transversum, blue line: coronal plane, green line: axial-oblique plane).

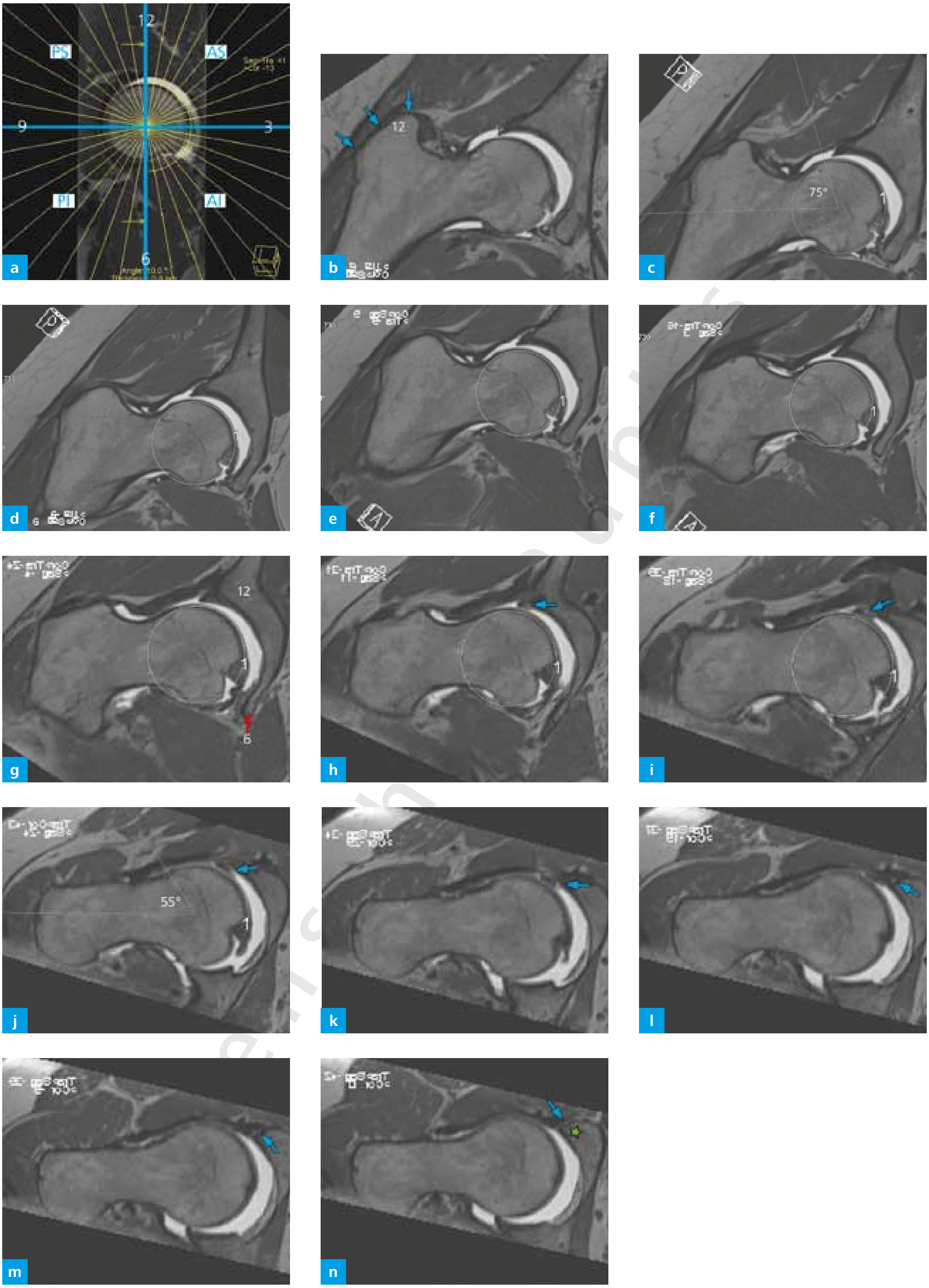

Fig. 12: (a) Sagittal-oblique localizer view for planning of 18 radial cuts which use the femoral neck as axis of rotation: AS = anteriosuperior, AI = anterioinferior, PS = posteriosuperior, PI = posterioinferior. (b–n) Radial reformatted 3D PD-w SPACE traction MR arthrograms at 3.0T. Each slice corresponds to a 20 angular minutes gap (360/18). (b) Most prominent appearance of the greater trochanter (arrows) serves as reference for the femoral 12 o`clock position. (c–j) Cam deformity extends from 12:20 to 2:40 (7 slice gaps). (g) Most prominent appearance of the teardrop figure (red arrow) serves as landmark for the acetabular 6/12 o'clock position. The 12 o'clock position differs by 1:40 hours (5 slice gaps) between the femur and the acetabulum. (h–n) Complex labrum tear (arrow) extending from 12:20 to 2:20 (6 slice gaps). (Fig. 11d, Fig. 12n) Overlap (asterisk) between both mapping techniques for localization of the inferior extension of the labrum lesion.