Anterior Inferior Iliac Spine (AIIS) and Subspine Hip Impingement

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Summary

***Background*: Abnormal morphology of the anterior inferior iliac spine (AIIS) and the subspine region of the acetabular rim are increasingly being recognised as a source of symptomatic extra-articular hip impingement. This review article aims to highlight important differences in the pathogenesis, clinical presentation and management of extra-articular hip impingement from both the AIIS and subspine bony regions, and the outcome following surgical intervention.**
***Methods*: A literature review was undertaken to examine the supporting evidence for AIIS and subspine hip impingement. A narrative account of the Author's professional experience in this area, including operative technique for arthroscopic correction, is also presented.**
***Results*: Abnormal morphology of the AIIS and subspine region has been classified using cadaveric, radiological and arthroscopic means; the clinical presentation and operative treatment has been documented in several case series studies. Dual pathology is often present - recognition and treatment of both intra- and extra-articular components are necessary for good postoperative outcome.**
***Conclusions*: AIIS and sub-spine hip impingement should be considered as distinct pathological entities, which may also co-exist. Symptom relief can be expected following arthroscopic deformity correction with the treatment of concomitant intra-articular pathology. Failure to recognise and treat the extra-articular component may affect postoperative outcome.**
Level of evidence: V.

KEY WORDS: extra-articular impingement, hip impingement, anterior inferior iliac spine, AIIS, hip arthroscopy, femoro-acetabular impingement.

Introduction

Femoro-acetabular Impingement (FAI) is a well-recognised condition characterised by abnormal contact between the rim of the acetabulum and the femoral head or neck. Progressive damage to the labrum and the articular cartilage of the joint may result in pain and stiffness of the hip joint, eventually leading to early osteoarthritis. Two distinct patterns of FAI have been well documented and result from a CAM or a pincer deformity; in the majority of cases, a combination of both CAM and pincer impingement is observed[1, 2].
More recently, there has been growing interest in extra-articular sources of FAI, in particular the role of abnormal morphology of the AIIS and the bony subspine region beneath, as a cause of symptomatic impingement[3,4].
The clinical presentation may be similar to that of traditional CAM/pincer FAI and a high index of suspicion is required to accurately diagnose and manage the extra-articular component to avoid a poor post-operative outcome. Open and arthroscopic methods of AIIS resection have been proposed and success from surgery has been well documented mainly through case series and isolated case reports[3,5-9].

Anatomical considerations of the AIIS and sub-spine region

Knowledge of the normal anatomical size and location of the AIIS and its relationship to adjacent structures is important in recognising abnormal morphology and when considering surgical treatment options.
The anterior inferior iliac spine (AIIS) apophysis is a bony prominence, from which the direct head of the rectus femoris and the ilio-capsularis muscles originate and is situated superior and antero-medial to the most lateral point on the acetabular rim. In patients considered to have normal AIIS morphology, a smooth, concave wall of ilium is observed between the rim of the acetabulum and the inferior (caudad) border of the AIIS, providing attachment for the hip capsule, the ilio-femoral ligament (antero-laterally) and the reflected head of rectus femoris (laterally);

the concave nature of the ilium wall provides recessed space for soft tissue recoil when under compression during flexion, adduction and internal rotation of the hip[4,10,11].

Amar et al. reviewed 50 CT scans of 50 patients (100 hips) without hip pathology to investigate the size, position and location of the normal AIIS. The study found a mean length (of the AIIS) of 31.5 mm (range, 23 to 39.5 mm), a mean height of 6.4 mm (range, 3.5 to 10 mm), a mean width of 11.9 mm (range, 8.5 to 16.1 mm); the mean distance from the base of the AIIS to the acetabular rim was 21.8 mm (range, 10.4 to 32.3 mm). All measurements were statistically higher for males when compared with females, except for AIIS height. However when the measurements were corrected for height and BMI there was no statistical difference (other than for width). No statistical difference was found between sides for any parameter measured[12].

The AIIS has been shown to consist of two distinct facets; the superior facet from which the direct head of rectus femoris originates and the inferior facet which gives attachment to the ilio-capsularis muscle; the facets being separated by a clearly defined AIIS ridge[13].

The direct head of rectus femoris originates from a broad based, 'tear drop' shaped, footprint on the AIIS and the reflected head from a larger footprint above the lateral aspect of the acetabular rim. In an anatomical study of 12 cadaver hip joints (4 female and 8 male), the mean length of the footprint of the direct head was 13.4 mm (medial to lateral) and 26 mm (cranial to caudal); and that of the reflected head was 47.7 (ant-post) x 16.8 (cranial-caudal)[14]. Similar measurements of the footprint of the direct head of rectus femoris were observed in a second anatomical study examining 11 male cadaveric hip specimens with a mean medial-lateral length of 16 mm and proximal-distal length of 22 mm. In this study a characteristic "bare area" was observed on the anteromedial region of the AIIS with no tendon attached suggesting this is a safe zone for surgical decompression without fear of tendon damage. The researchers found the position of the AIIS and reflected head of rectus, according to the clock-face method[15], to be consistent throughout all the specimens; the medial wall of the AIIS was located between 2 o'clock and 2.30; the lateral wall of the AIIS between 1 o'clock and 1.30; and the reflected head of rectus located directly laterally at the 12 o'clock position[9]. The Authors expressed the importance of understanding the location and extent of the footprint of the direct head of rectus for surgeons considering surgical resection of the AIIS, to minimise risk of tendon detachment/rupture and avoiding the potentially devastating complication of abdominal fluid extravasation/compartment syndrome.

The AIIS is located near to important musculo-tendinous, vascular and neural structures, the presence and location of which should be known to prevent injury during surgical decompression. In a cadaveric study, the distance between the AIIS and the femoral nerve was measured at 20.8 mm and a distance of 19.3 mm was measured to the Iliopsoas tendon, both structures lying medial to the AIIS and the distance being slightly shorter in females; the lateral circumflex artery, at the level of its crossing the inferior border of the belly of rectus femoris, was observed 56.6 mm from the inferior border of the AIIS[14].

Classification of Abnormal AIIS and Sub-spine Morphology

Hetsroni et al[4]. classified the morphology of the AIIS into three variants using 3D reconstructions created from CT scans taken of 53 hips (53 patients) with femoroacetabular impingement. They correlated the effect of AIIS morphology on range of *simulated* terminal hip flexion and internal rotation in a further 78 hips (78 patients) with impingement, using computer based dynamic software to interpret the preoperative CT scans for this cohort of patients. Three variants of AIIS morphology were described (with 100% inter-observer reliability): Type I, in which there was a smooth ilium wall between the most caudad level of the AIIS and the anterosuperior rim; Type II, in which the AIIS prominence extended to the level or above the acetabular rim; and Type III, in which the AIIS extended distally to the acetabular rim. Comparisons of simulated hip motion demonstrated a mean terminal hip flexion of 120, 107° and 93° and a mean internal rotation (at 90° hip flexion) of 21°, 11° and 8°, with AIIS Types I, II and III respectively.

This study has a number of limitations, which may affect the value of the results: validation of the computer based dynamic software was undertaken using a single incomplete (pelvic-hip-knee) cadaver specimen; results demonstrated a 3° flexion and 5° internal rotation discrepancy which when factored into the results of the simulated ROM versus AIIS morphology could influence the level of significance of these results.

In clinical practice, one would expect internal rotation at 90° of flexion to have the greatest level of restriction in Type III morphology but in the study, the difference between simulated terminal internal rotation in Type II and Type III was not significant.

The simulated ROM was skeletal-based only and did not take into consideration the associated limitation on movement placed by soft tissue structures compressed through interposition or placed under tension during ROM assessment.

Lastly, the classification system proposed required advanced CT scanning and 3D reconstruction protocols, which are not readily available for many treating facilities. The use of less advanced imaging or serial radiographs may increase the inter-observer error in classifying morphological types.

The study does however highlight the variability in the morphology of the AIIS and the role such may play in limiting hip movements; consideration therefore should always be given to the shape of the AIIS and its possible role in the symptomatic FAI patient[4].

A morphological classification of the AIIS, based on the anatomical findings of 458 dry cadaver hemi-pelvises from a Mexican population (264 men and 194 women aged between 18 and 100 years), has been proposed by Morales-Avalos et al[1°]. The classification consists of 4 subtypes and describes the variation of AIIS morphology according to age and gender; Type 1, presents a notch or concave surface between the AIIS and the acetabular rim, Type 2A, a flat surface, Type 2B a convex surface (with or without bony prominences), which continues directly with the rim, and Type 3, an AIIS that protrudes into the acetabulum inferiorly with invasion of the acetabular rim or, presents a large anterior bony prominence with multiple spiculae and/or protruding bone. Type 1 was considered normal and was present in 69.9% of cases. All other cases were considered abnormal (30.1% of total) of which Type 2A was present in 59.4%, Type 2B in 12.3% and Type 3 in 28.3%. Abnormal morphology was more commonly observed on the right side (55.1% compared to 44.9% on the left) with a higher prevalence in younger males (18-39 years); there were no differences for gender type[1°].

Both of the above proposed classifications describe normal morphology as consisting of a smooth, concave wall between the acetabular rim and the caudad region of a normally sized AIIS. Abnormal morphology is described with flattening or prominence in the region between the caudad border of the AIIS and the acetabular rim but essentially with a normal AIIS, or as a result of an abnormally shaped AIIS extending distal to the rim having direct impingement against the femoral neck.

Abnormal morphology of the AIIS and the sub-spine bony region are considered a progression of the same pathology but it may be more appropriate to consider the pathogenesis, clinical presentation, radiographic findings and operative management of impingement of the AIIS and sub-spine regions separately, as distinct pathological entities.

The location of the AIIS is extra-capsular and has no direct anatomical connection to the hip joint other than the attachment of ilio-capsularis and reflected head of rectus femoris to the anterior hip capsule[13,14].

Abnormal hypertrophy of the AIIS is primarily due to chronic traction strain from the direct (and reflected) head of rectus and to a lesser degree from Iliocapsularis muscle; abnormal AIIS morphology may also occur as a consequence of a mal-union of an avulsed apophysis or from abnormal ossification of an injured rectus femoris tendon[3,4,8,16,17].

The “subspine” region however is essentially intra-capsular and in a similar process to AIIS hypertrophy, morphological changes in this region may develop from excessive and recurrent tension of the ilio-femoral ligament and the anterior hip capsule during repetitive forced extension and external rotation of the hip, commonly observed in running and fields sports[18-20].

Anterior Inferior Iliac Spine (AIIS) Impingement

A morphologically abnormal and prominent AIIS may result in bony impingement due to abnormal contact with the femoral head or neck, during flexion, adduction and internal rotation of the hip; the point of contact may occur more distally on the femoral neck when compared to CAM/Pincer FAI[3].

Patients who present with true AIIS impingement often have a history of previous trauma (such as a “hip flexor” injury) during their adolescence. Classically the injury consists of either an avulsion of the AIIS or an injury to the rectus femoris tendon. Initial symptoms of pain and swelling often settle with conservative management however progressive restriction of hip motion and activity related groin pain develop as a result of a mal-union of the avulsion or from a secondary ossification process of the injured rectus femoris. In other instances impingement may result from progressive deformity of the AIIS from traction hypertrophy, from a developmental abnormality or as a consequence of pelvic surgery[8, 17, 21-27].

Avulsion Fracture of the AIIS

Avulsion fracture to the AIIS has been widely reported in the literature usually in the form of case reports and case series. It occurs most commonly in the developing male between the ages of 13 and 23 years old (the latter, the year at which the epiphysis generally unites); at this stage of skeletal development, the ratio of muscle-apophyseal strength is at its greatest, although avulsion fractures have also been reported, in skeletally mature adults[17,28].

The mechanism of injury is considered to be secondary to a sudden and violent contraction of the rectus femoris resulting in avulsion through the fibrocartilage growth plate at the apophysis[29]. In particular, sports with high demands being placed on the rectus femoris muscle including those with rapid twisting and turning, bursts of acceleration and speed and kicking sports, are considered higher risk. Some injuries are considered to result from excessive kicking upwards or a powerful long distance or high velocity kick[17], others from excessive hip extension with maximal knee flexion observed during running at high speed hence the earlier term of “Sprinter’s fracture[29,30]”.

In most cases, the injury results from a single violent episode, however prior symptoms of intermittent groin pain may preclude the injury suggesting the eventual avulsion may have come from epiphyseal weakening secondary to an initial episode of epiphysitis from recurrent strain. Moderate trauma in the form of repeated pulling stresses from regular intensive training weakens the cohesion of the apophyseal plate, which may eventually give way with an acute aggressive muscle contraction[31,32]. The avulsion may be complete or incomplete. A complete avulsion may result in retraction of the rectus tendon with fibrocartilage attached; bleeding and organisation of haematoma within the tendon sheath typically results in ossifica-

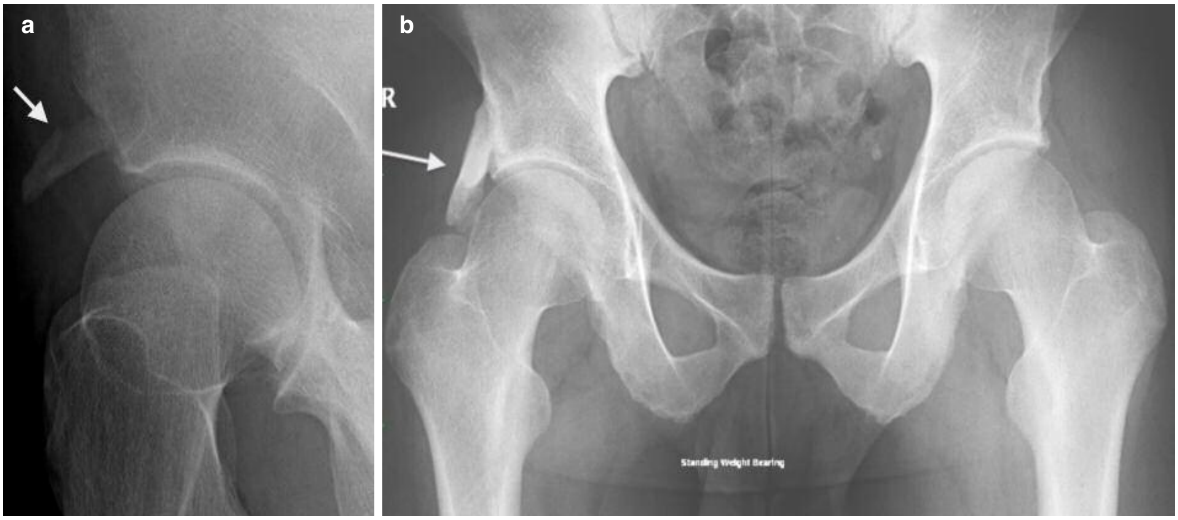

Figure 1 a, b. a) Prominent bony exostosis extending from AIIS footprint following rectus injury (white arrow); b) AP view of bony exostosis (white arrow).

tion of the defect between the pelvis and the fibrocartilage end of the retracted tendon, resulting in the formation of a bony exostosis (Figure 1 a, b). Tearing of the rectus muscle and haematoma formation around an intact tendon may result in myositis ossificans of the region[33]; this is characterised by a "tubular excrescence" in which the groove inside is the path for the intact tendon[16]. Partial avulsions of the direct head of rectus or repeated overuse of the rectus muscle may result in hypertrophy of the AIIS again with the tendon remaining intact.

Acute avulsions of the AIIS are generally managed with conservative treatment including rest, non-steroidal anti-inflammatory medications, progressive rehabilitation/physiotherapy, with a return to normal activity and sports, as symptoms improve usually around 4 months from injury[26]. Surgical intervention is rarely advised although indications for early surgery include wide displacement of the avulsed fracture (>2cm), mal-union and persistent pain. It may be many years before patients present with symptoms of femoro-acetabular impingement from the consequences of the initial injury requiring delayed intervention[16,21,34].

Developmental AIIS Abnormalities

Anatomical studies have demonstrated considerable variability in the morphology and location of the AIIS in the absence of previous trauma or avulsion[4,10]. Traction hypertrophy may result from the repeated strain placed across the AIIS from the attachment of the direct head of rectus femoris during running, cutting and kicking sports (especially during the adolescent development years); a bony response to the traction stimulus producing thickening and prominence of the AIIS which may lead to restriction of hip motion and femoro-acetabular impingement (Figure 2)[3,5].

Other congenital and developmental abnormalities of the AIIS have been described including the "Pelvic digit or pelvic rib"; this is considered to arise from a congenital abnormality during embryonic bone development and has been reported in a number of regions around the pelvis[33] including the sacrum[35], the ilium (Iliac rib)[36], coccyx[37], and ischium. The morphology typically resembles the shape of a phalanx and consists of cortico-medullary bone with histological resemblance to a "rib bone" (Figure 3). They are generally single, unilateral with variation in the number of bony segments and pseudo-articulations present; multiple lesions have been reported. According to different Authors the origin of the "rib"-like structure is from a displaced costal or sternal ossification centre or from the ossification centre of the Ilium[35]; it is now considered more likely that pelvic digits originate from embryonic mesoderm with rib forming potential disposed to these regions which fails the normal apoptosis process[38, 39].

Retroversion of the acetabulum, low lying AIIS and excessive anterior tilt of the pelvis often associated with hyper-lordosis may place the AIIS in a position where FAI is more likely to occur between the AIIS and the distal femoral neck. In such cases the borders of the AIIS appear to be more rounded and smooth and most unlike patients with a prior hip flexion injury where the morphology of the AIIS is often irregular, tubular, elongated and sharpened in keeping with a post injury ossification process[3]. A valgus femoral neck and femoral anteversion may place the greater trochanter in a position of potential abnormal contact with a normally sized and located AIIS[40]. Positional abnormalities of the AIIS most often arise naturally during development but can also occur iatrogenically as a result of re-orientation of the acetabulum following peri-acetabular rotational osteotomies for the management of hip dysplasia[3].

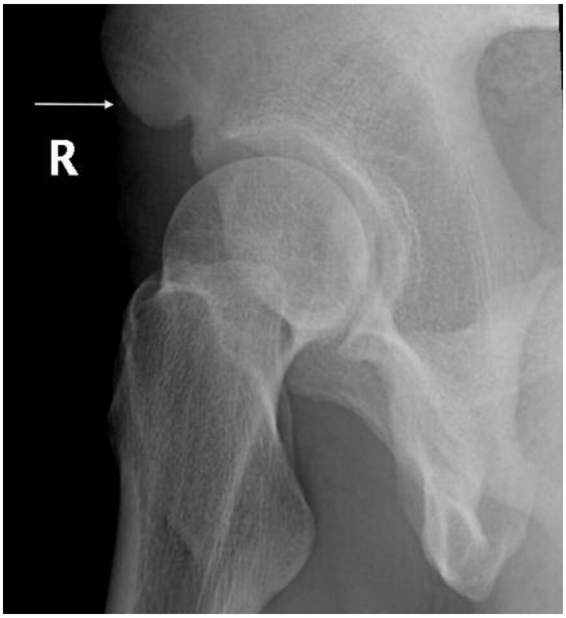

Figure 2. False Profile X-ray view demonstrating traction hypertrophy of AIIS (white arrow).

Figure 3. “Rib-like” cortico-medullary ossification with a pseudo-articulation at its base (white arrow).

Clinical Presentation of AIIS Impingement

Clinical examination of the hip commonly demonstrates the classical limitation of hip flexion with production of anterior hip/groin pain, along with restriction of adduction and internal rotation with the hip flexed to 90 degrees; the result of the prominent AIIS deformity engaging with the femoral neck (Figure 4). Tenderness may be elicited during palpation of the AIIS; discomfort and weakness with resisted straight-leg-raising is also a consistent feature.

Radiological Assessment of AIIS Impingement

Radiological assessment, consisting of an AP pelvis and a false-profile view, is utilised to accurately define the morphology of the AIIS. A low lying or prominent AIIS can be observed on the AP pelvis view, often recognised by a ‘double cross-over sign’ or an asymmetry between the two hips with respect to a prominent, smooth, cortical outline of the lateral edge of the rim at the AIIS level (Figure 5); with abnormalities of the AIIS, the projection from the ilium is most clearly visualised on the false-profile view (Figure 6). Radiological signs often observed in association with abnormal AIIS morphology include signs of acetabular retroversion (crossover sign[41], iliac spine sign[42]) and over-coverage (high lateral centre edge angle)[43].

CT scans with 3D reconstructions are helpful but not necessary; they provide additional preoperative information on the spatial orientation of the abnormal pathology and the relationship with normal anatomical landmarks. MRA scans are useful for assessing for possible concomitant intra-articular pathology which may need treated if a surgical procedure is being planned but often provide little additional information with respect to the AIIS deformity.

In the presence of dual pathology, an intra-articular injection of local anaesthetic may partially relieve painful symptoms, which may prove useful in the diagnosis if AIIS impingement is observed with concomitant intra-articular pathology[6].

Sub-Spine Impingement

Sub-spine impingement should be considered a separate pathology to true AIIS impingement (although both can co-exist) and can be defined by the presence of abnormal bony morphology between the acetabular rim and the caudad border of a normally shaped and located AIIS, resulting in soft tissue and/or bony impingement (Figure 7).

Traction hypertrophy leading to prominence of the sub-spine bony region may develop as a result of repeated strain placed across the attachment of the anterior hip capsule and the iliofemoral ligament, with regular hyperextension and rotational hip stresses, commonly encountered in running and twisting/turning sports[44,45]. As a result, the effective space for soft tissue recoil during flexion, adduction and internal rotation reduces, increasing the risk of soft tissue impingement and damage.

Patients who demonstrate sub-spine bony hypertrophy (flattened or convex bony prominence between the caudad base of the AIIS and the acetabular rim) with otherwise normal AIIS morphology, often present with symptoms of classical femoro-acetabular impingement; the thickening of the sub-spine region is most often observed in association with pincer rim deformity. Standard radiological assessment (AP pelvis, Dunn and false profile views) can be utilised to accurately define abnormal morphology of the sub-spine region (Figure 7). CT scan and MRA will permit a more complete investigation of hip pathology. Activ-

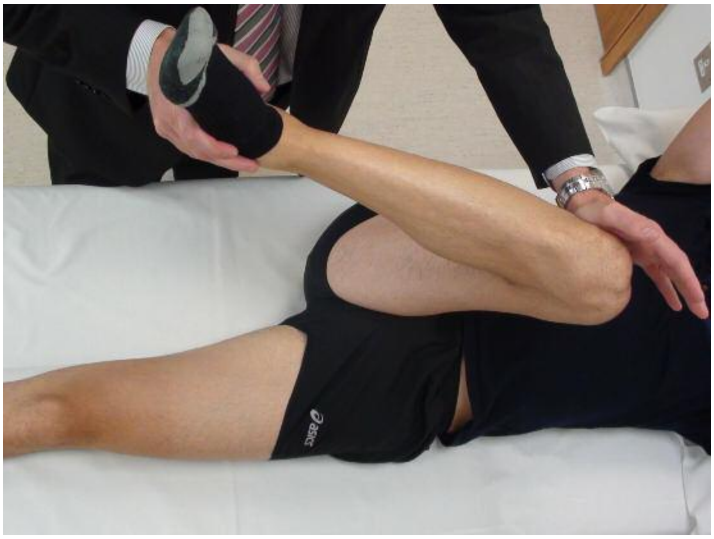

Figure 4. Limitation of internal rotation and adduction with the hip flexed to 90°. This manouevre commonly results in anterior groin pain.

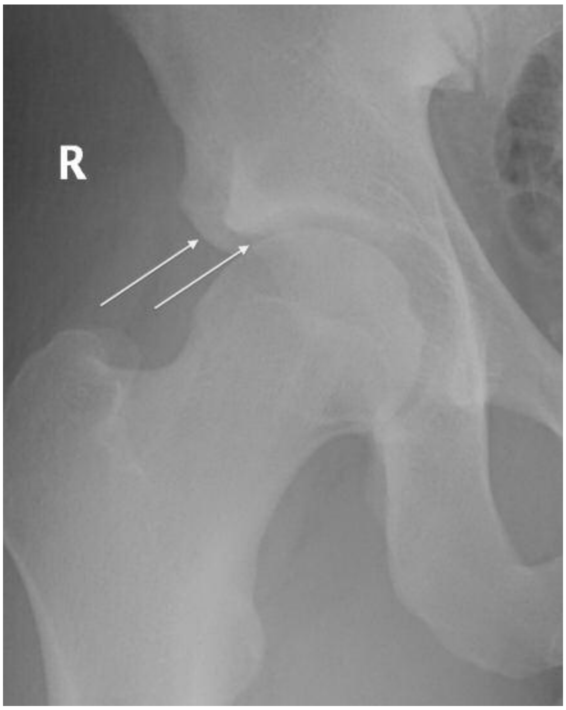

Figure 5. Prominent, smooth cortical outline of asymmetrical AIIS. Abnormal “double cross over” sign on the right side (double arrow).

ity related groin pain with post activity hip stiffness in conjunction with reduction in hip flexion, internal rotation and adduction and presence a positive impingement test are the characteristic clinical findings.

Arthroscopic Assessment

In a study conducted at our institution, the morphology of the sub-spine region was assessed arthroscopically and classified into one of four subtypes[11]. Type 1: a smooth concave or flattened surface extended from the base of the AIIS to the rim of the acetabulum and was considered normal; Type 2: hypertrophy of the sub-spine region was noted which was convex in shape and extended to the level of the rim but not below; Type 3: a variably sized localised prominence of the sub-spine region which was distinctly separate to the rim and extending antero-inferiorly and Type 4: hypertrophy and prominence of the sub-spine region which extended distally below the level of the acetabular rim (Figure 8 a-d).

The observations were performed in a prospective, consecutive series of 95 hip arthroscopies in 72 patients with confirmed pincer or mixed FAI and a normal AIIS; there were 60 males and 12 females (ratio 5:1) with an average age of 29 (range 17-50). The bony acetabular rim was exposed, utilising a capsular preserving technique, permitting clear visualisation of the sub-spine region of the acetabular wall as it extended proximally to the base of the AIIS. In 48.4% of cases, normal morphology was observed (Type 1); abnormal morphology was observed in 51.6% of cases (22.2% Type 2, 49.5% Type 3 and 28.3% Type 4).

Arthroscopic signs of labral bruising (Figure 9 a) and the presence of a rim fracture (Figure 9 b) were strongly associated with abnormal subspine morphology. Bruising of the labrum was observed in 45.8% of cases overall and in 37% of cases with Type 1 (normal), 45% with Type 2, 52% with Type 3 and 64% of cases with Type 4. The frequency of labral bruising was more significant with increasing sub spine morphology, from type 1 to Type 4 ($p<0.05$).

Rim fractures were present in 15.8% of all cases however were observed more commonly in cases with abnormal sub-spine morphology ($p=0.015$): a rim fracture was found in 27.2% of cases with Type 2, 20.8% with Type 3 and 28.6% with Type 4 as opposed to 6.5% of cases with Type 1 (normal).

This study proposed an arthroscopic classification of

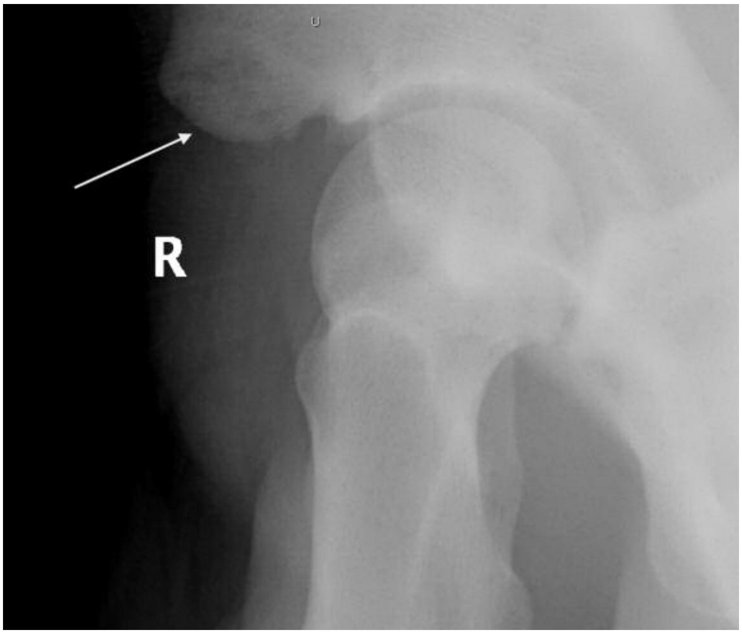

Figure 6. False profile X-ray view demonstrating AIIS bony prominence (white arrow).

Figure 7. False profile X-ray demonstrating subspine deformity developing in a 16-year-old footballer.

sub-spine impingement and concluded that findings such as labral bruising or rim fracture should alert the surgeon to the potential presence of abnormal subspine morphology.

This classification concurs with types 1, 2 a and 2 b of the Morales classification and Types 1 and 2 of the Hetsroni classification. Type 3 of Morales and Hetsroni classifications includes abnormal extra-capsular AIIS morphology, which we consider a distinct pathological process.

Re-contouring of the sub-spine region should be considered an important part of the complete management of the acetabular rim in patients with FAI, having the potential for reducing bony impingement and increasing the space available for soft tissues in this region[11]. Failure to recognise and re-contour the abnormal subspine region may result in the zone of impingement may be transferred to the sub-spine or AIIS region especially in retroverted pelvis or with excessive forward (anterior) pelvic tilt. In such a case, the subspine/AIIS region may not have been impinging before arthroscopic recession but becomes the source of impingement postoperatively. An "impingement shift" may result in continued symptoms and require further surgery.

Surgical Decompression of the AIIS and the Subspine Region

The surgical technique employed to successfully manage the AIIS and subspine impingement will depend on the type and extent of the abnormal bony morphology and the presence of associated intra-articular pathology.

For all subspine deformity and an AIIS deformity with significant caudad extension an arthroscopic surgical approach is preferred as any concomitant intra-articular pathology can be addressed simultaneously. For AIIS deformities with significant distal and inferior extension, in an otherwise normal hip joint, an extra-articular endoscopic approach can be utilised to expose and remove the abnormal AIIS; alternatively if the tendon of direct head of the rectus femoris is inextricably associated with the abnormal morphology then an open procedure with surgical detachment, resec-

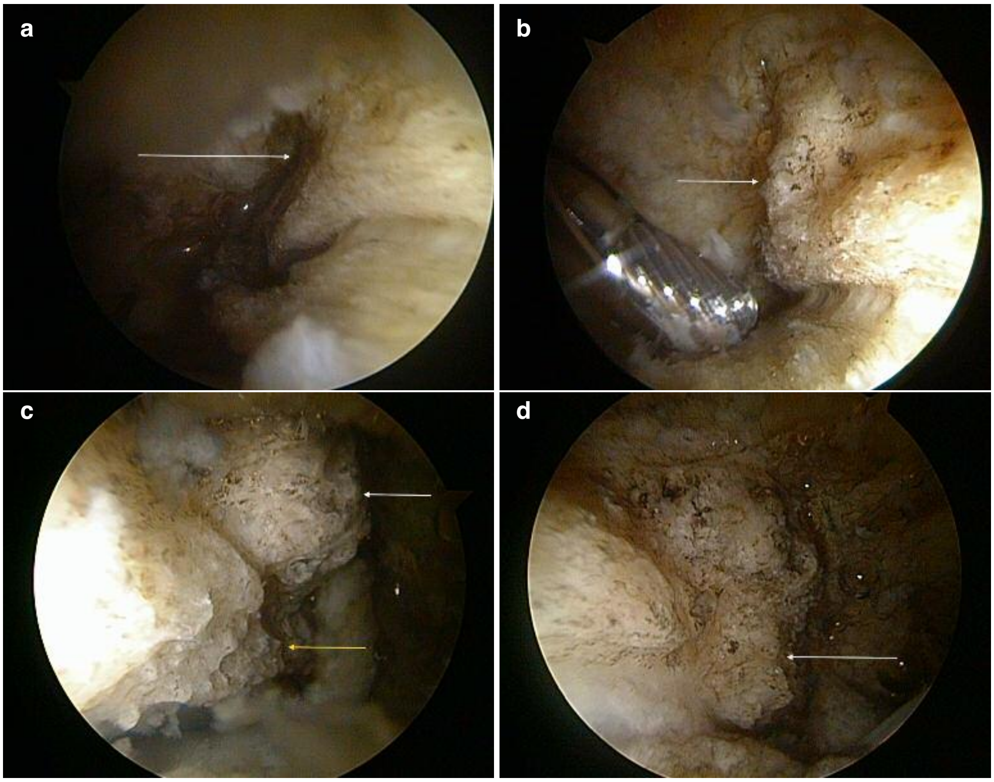

Figure 8 a-d. Arthroscopic classification of subspine hypertrophy: (a) Type 1: Normal concave recess extending from acetabular rim (white arrow); (b) Type 2: Convex bony prominence in continuity with rim (white arrow); (c) Type 3: Subspine prominence (white arrow) distinct from acetabular rim (yellow arrow); (d) Type 4: Sub-articular extension of the deformity beneath the acetabular rim (white arrow).

tion and re-attachment of the tendon may be required.

Arthroscopic Subspine Decompression

Arthroscopic sub-spine decompression has been performed as part of acetabular rim management at our institution since 2013. In total, 690 cases (555 patients) have undergone this procedure without complication.

A supine arthroscopic set up is preferred and standard anterolateral and modified mid-anterior portals are established under image intensifier guidance. Following a diagnostic arthroscopy to identify intra-articular pathology the camera is positioned at the anterolateral acetabular rim (12.30 on the clock face right hip) to permit an 'anterior profile' view of the acetabular rim and labrum (Figure 10 a). Using a hooked radiofrequency probe the periosteal attachment of the labrum to the rim is reflected progressively from the bone and working distally, the labrum is safely reflected to the level of the chondrolabral junction (preserving this important interface) and allowing the labrum to hang below the rim of the acetabulum. The RF probe is then utilised to reflect the capsule off of the rim working proximally to the level of the caudad (inferior) edge of the AIIS. The contour of the subspine region may be observed and classified into one of four subtypes (Figure 10 b). It is important to preserve the capsular tissue to permit repair of the capsule at the end of the procedure; the use of a motorised shaver to remove capsular tissue should be therefore be discouraged. Using a motorised 5.5 mm burr the subspine region can be re-contoured in conjunction with acetabular recession to the chondrolabral junction (Figure 10 c). Adequate removal of abnormal bone is quantified with careful preoperative planning and confirmed intra-operatively using image intensifier guidance, assessing the removal of the crossover sign and optimal decompression of the subspine region.

The labrum is repaired using suture anchors with a labral cuff repair technique, optimising the stability and sealing mechanism following repair (Figure 10 d, e). The capsule, which has been reflected "en-masse", can be repaired to the acetabular rim using suture anchors.

In most cases, significant caudad extension of the inferior border of the AIIS is easily accessible from the joint and extended re-contouring can be performed. The extent of bone removal should be closely monitored with intra-operative X-ray and optimal resection can be assessed with post-operative X-rays (Figure 10 f, g).

The arthroscopic management of rim abnormality, chondrolabral pathology and femoral head neck offset abnormalities in conjunction with re-contouring of the subspine region may require significant operation

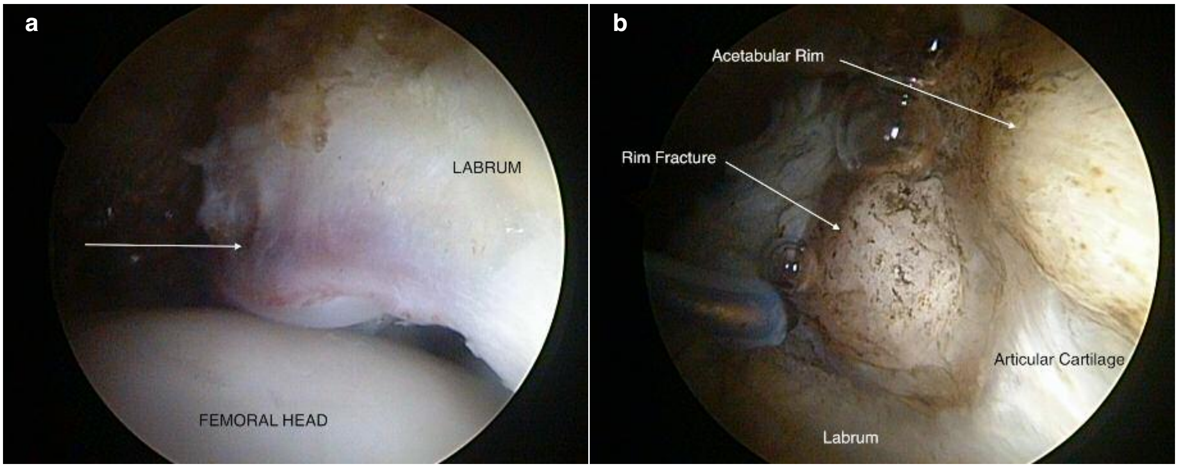

Figure 9 a, b. a) Labral bruising (white arrow) associated with sub-spine impingement; b) The bruised labrum has been reflected from the acetabular rim revealing an underlying rim fracture.

time (80-100 mins); therefore it is very important to monitor traction time, the amount of pressurised irrigation fluid used and subsequently the degree of thigh swelling; there have been no reports in the literature of intra-abdominal extravasation of fluid from subspine decompression but the operating team should remain vigilant.

Endoscopic AIIS Decompression

Deformities of the AIIS with significant distal and inferior extension, may require extensive release of the anterior capsule from the acetabular rim if resection is considered as an extension of hip arthroscopy; this makes it more difficult to preserve adequate capsular tissue to permit a good quality capsular repair, increasing the risk of excessive fluid extravasation and post-operative instability. Surgical access to this region of the AIIS is difficult from within the joint and an extra-capsular approach should be utilised primarily to protect the capsule and permit access to natural tissue planes outside of the capsule. The AIIS is easily located with X-ray assistance and blunt dissection with or without prior hip arthroscopy (Figure 11 a). In the presence of myositis ossificans and a tubular exostosis, the bony deformity can be separated from the soft tissue component using a hooked RF probe. A 5.5 mm mechanical burr is utilised to remove the abnormal bone under X-ray guidance (Figure 11 b). In cases with hypertrophy of an intact AIIS, care needs to be taken to remove only the bone, which is deemed to be causing the impingement (Figure 12 a, b). Caution should be exercised to protect the iliocapsularis insertion and more importantly the tendon insertion of the direct head of rectus femoris. Overzealous resection may result in detachment or delayed rupture of either muscle/tendon unit.

Surgical Outcome Following AIIS/Subspine Decompression

A small number of case reports and case series have demonstrated good clinical outcome following surgical decompression of AIIS impingement either by open or arthroscopic techniques.

In 2007, Pan et al. first described the association between abnormal morphology of the AIIS and the development of femoro-acetabular impingement in a 30-year-old footballer. Resection of the hypertrophic portion of the AIIS was undertaken through an open surgical approach, with complete resolution of symptoms and a return to normal hip movements[5]. In 2011, an arthroscopic technique, to decompress a prominent AIIS, was successfully employed to treat three patients with FAI and concomitant AIIS impingement[3].

In a similar case series at our institution, arthroscopic AIIS decompression was utilised to successfully manage a series of male patients with extra-articular AIIS impingement[7]. All patients demonstrated limitation of hip flexion, adduction and internal rotation with associated anterior groin pain; in each case a prominent bony exostosis originating from the AIIS footprint was observed on standard radiographic views. AIIS impingement was considered the main pathology and arthroscopic decompression of the deformity resulted in complete resolution of symptoms and a rapid return to activity/sports; an excellent two-year clinical outcome was reported in each case.

In the majority of articles, AIIS or subspine decompression has been performed in conjunction with FAI surgery and as such improvements in clinical outcome cannot be attributed to the AIIS/subspine decompression component alone[3,5]. Hetsroni et al reported the outcome from a retrospective case series of 10 patients who were treated for extra-articular AIIS impingement and concomitant intra-articular pathologies; statistically significant improvement was noted in hip flexion from 99°±7 to 117°±8 and in the mHHS score from 64±18 to 98±2, postoperatively[6].

A retrospective review of a larger case series of 163 hips (150 patients) who underwent arthroscopic FAI surgery and concomitant AIIS/sub spine decompression, was reported by Hapa et al. Outcome measures were reported for an average of 11.1 months post op-

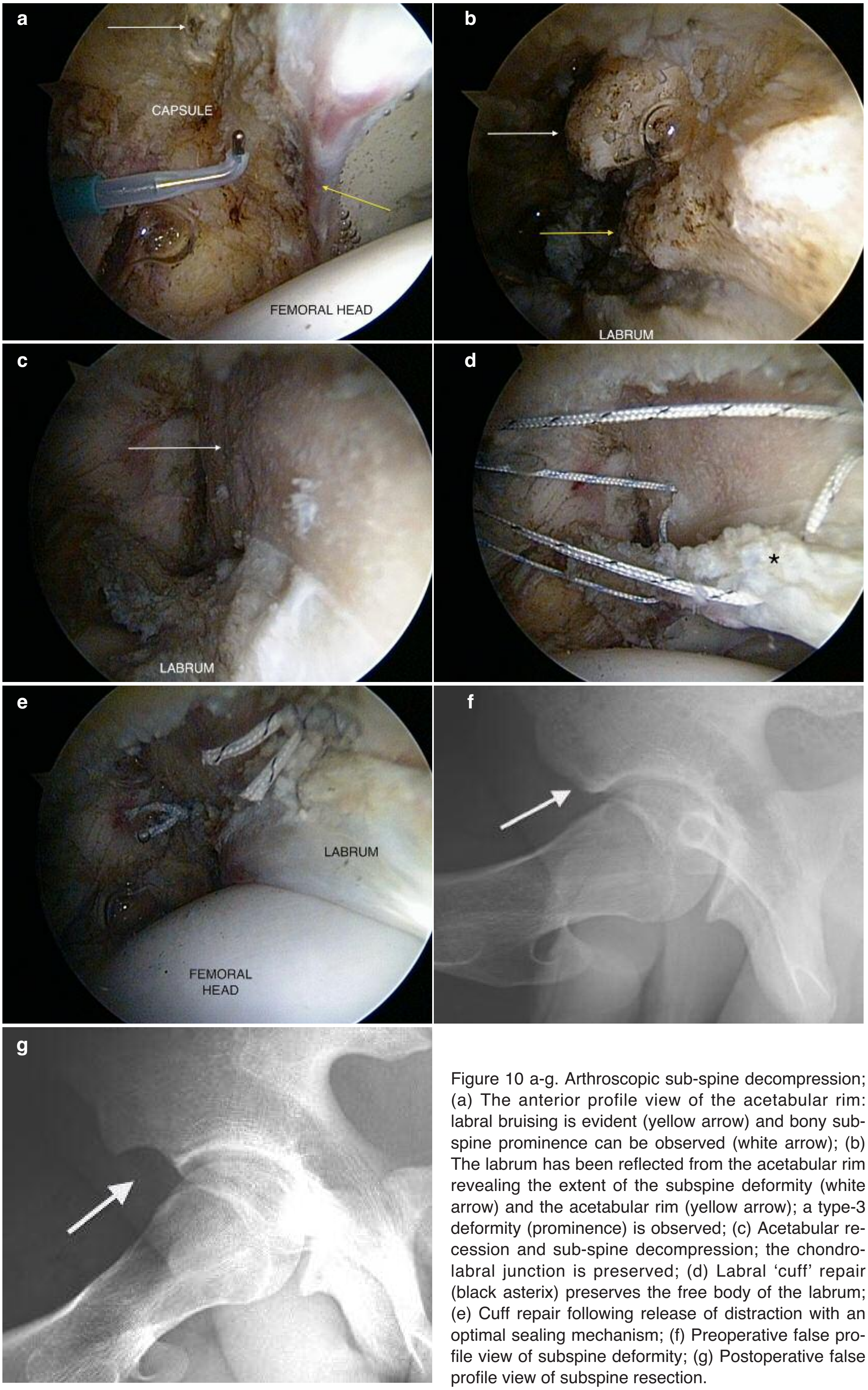

Figure 10 a-g. Arthroscopic sub-spine decompression; (a) The anterior profile view of the acetabular rim: labral bruising is evident (yellow arrow) and bony subspine prominence can be observed (white arrow); (b) The labrum has been reflected from the acetabular rim revealing the extent of the subspine deformity (white arrow) and the acetabular rim (yellow arrow); a type-3 deformity (prominence) is observed; (c) Acetabular recession and sub-spine decompression; the chondrolabral junction is preserved; (d) Labral 'cuff' repair (black asterix) preserves the free body of the labrum; (e) Cuff repair following release of distraction with an optimal sealing mechanism; (f) Preoperative false profile view of subspine deformity; (g) Postoperative false profile view of subspine resection.

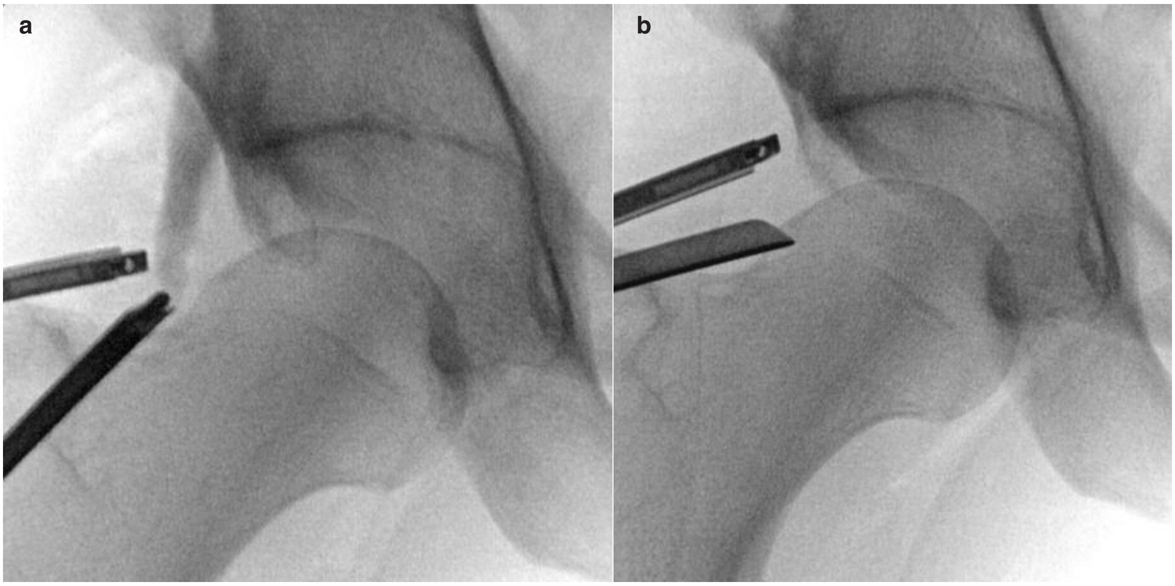

Figure 11 a, b. a) Localisation of AIIS exostosis under intra-operative X-ray; b) Resection of exostosis.

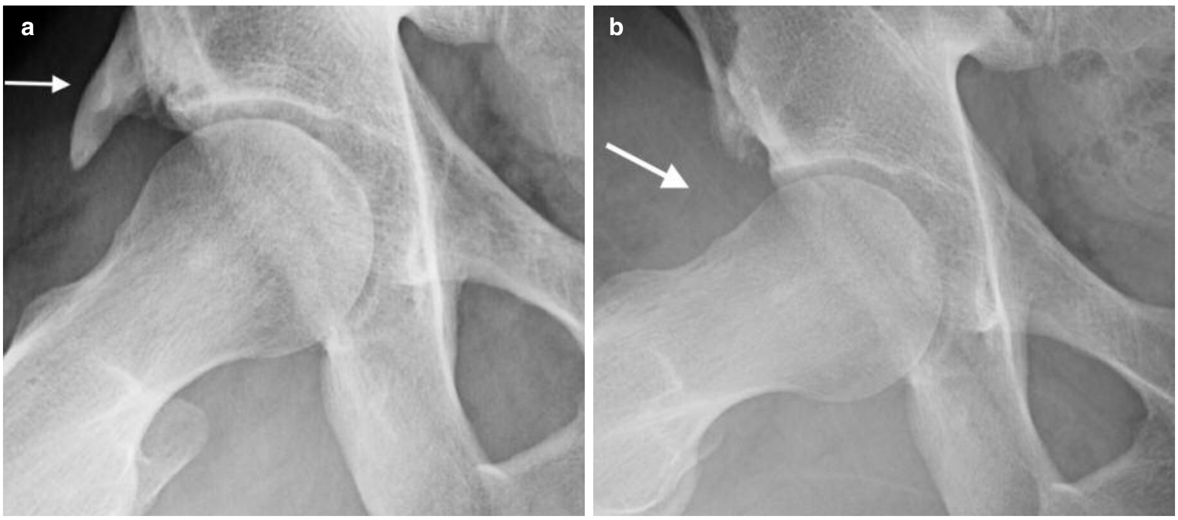

Figure 12 a, b. a) Preoperative Dunn view demonstrating large AIIS bony exostosis; b) Postoperative Dunn view demonstrating complete resection of exostosis following endoscopic decompression (white arrows).

eration: the mean mHHS improved from 63.1 (range 21-90) pre-operatively to 85.3 (37-100) post-operation, the SF12 from a score of 70.4 (34-93) to 81.3 (31 to 99); no rectus femoris avulsions or long term deficits in muscle strength were observed[9].

At our institution, between April 2013 and April 2015, subspine decompression was undertaken in a consecutive series of 300 cases being treated arthroscopically for symptomatic FAI. In all cases, abnormal morphology of the subspine region was observed radiologically and was confirmed during hip arthroscopy. The average patient age was 29.7 (range 16.5 to 58) years and there were 281 males and 19 females. All patients had evidence of pincer (33%) or mixed CAM/pincer FAI (67%), which was treated with bony deformity correction, the labrum was repaired (268 cases) or debrided (32 cases) and the capsule was repaired in each case. Preoperative X-ray evaluation revealed a mean lateral centre edge angle of 34.3°±8°, a mean alpha angle of 61. 3°±13.7° on Dunn view, and of 64.5°±17.9° on AP pelvis.

The surgery was uncomplicated for all patients and the HHS improved from a median preoperative value of 76 (IQR: 70-93) to a post operative score of 98 (96-100) ($p<0.001$) at a minimum of one year [mean 13 (12-26) months], similar excellent improvement was also observed with the SF 36 from 71 (59-83) to 91 (84-95); the UCLA activity score from 6 (5-9) to 10 (7-10) and the WOMAC index from 21 (31- 9) to 2 (8-0)[46].

All unpublished studies presented in this review from our institution comply with *basic principles and recommendations in clinical and field science research*[47].

Conclusion

Abnormal morphology of the AIIS region is a recognised source of extra-articular hip impingement leading to chronic groin pain and restriction of hip motion and primarily results from a mal-union of an avulsion of the AIIS apophysis or from secondary ossification following injury to the tendon of the direct head of rectus femoris.

Hypertrophy of the sub-spine bony region is an important component of “intra-articular hip impingement” and should be considered a distinct pathological entity from extra-articular AIIS abnormalities. A high index of suspicion is required to diagnose and treat subspine impingement as pathological signs are subtle and failure to manage may affect postoperative outcome.

Good clinical outcome can be expected following resection of the AIIS deformity either by open or arthroscopic techniques and following arthroscopic decompression of the subspine region in association with treatment of concomitant FAI. Further studies however are necessary to measure the true treatment effect of AIIS or subspine decompression in isolation rather than as a component of the overall surgical management of symptomatic FAI.

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