Title:

Discrete mineralisation of the acetabular labrum: a novel marker of femoroacetabular impingement?

Abstract

Objectives. Femoroacetabular impingement (FAI) is increasingly thought to play a role in the development of hip osteoarthritis, yet is difficult to define on imaging and clinically. This study investigates mineralisations of the acetabular labrum (MALs), which are small, discrete foci of dense radio-opacity within the region of the acetabular labrum. The study aimed to characterise MALs and test the hypothesis that MALs are associated with FAI.

Methods. CT images and radiographs of 106 hips in 66 individuals without known FAI were reviewed for the presence of MALs. Their anatomical location in the acetabular labrum was measured. Three current radiographic markers of FAI were recorded in hips with MALs, and age- and gender-matched hips without MALs: centre-edge angle and acetabular version angle as measures of pincer impingement; alpha angle as a measure of cam impingement.

Results. MALs were identified in 18% of hips (n=19). Hips with MAL had a larger mean alpha angle (p=0.013) than those without. MALs were found to be located anterosuperiorly and posterosuperiorly within the labrum, consistent with coup and contrecoup impingement lesion locations reported for FAI. No significant association was found between MAL and centre-edge angle or version angle.

Conclusions. Our data demonstrate MALs are associated with increased alpha angle and thus may be linked to cam-type FAI.

Advances in knowledge. Mineralisations of the acetabular labrum have not previously been associated with FAI. This correlation may give further insight into the disease process underlying hip osteoarthritis and might represent a future radiographic marker of cam-type FAI.

Introduction

Femoroacetabular impingement (FAI) is increasingly recognised as a key mechanism underlying the development of hip osteoarthritis(1). However, strong evidence supporting this theory is not easy to obtain, in part due to the difficulty in diagnosing and defining FAI. Several radiographic markers are used to identify hips with FAI(2, 3). These markers are limited in their value: most show poor repeatability and consider anatomical abnormalities in only one plane; moreover some markers depend on the orientation of the subject to the imaging modality(4, 5). Some studies demonstrate substantial prevalence of radiographic markers of FAI in apparently asymptomatic populations, which may be due to poor marker specificity(6, 7). A more definitive set of diagnostic measures is needed to improve our understanding of FAI.

Early diagnosis and surgical intervention in FAI has been shown to improve hip pain and might alter the progression of osteoarthritis(8). At present surgeons tend to base decisions for intervention in FAI on symptoms, clinical signs and MRI findings. A simple and accessible tool to augment existing radiographic measures of FAI is required in clinical practice.

Mineralisation of acetabular cartilage is a likely step in the development of hip osteoarthritis from the bony impingement occurring in FAI. *In vitro* work has demonstrated that compressive forces result in cartilage mineralisation(9, 10). This study investigates mineralisations of the acetabular labrum (MALs), which we have commonly observed in a wide spectrum of the population. MALs are small, discrete foci of dense radio-opacity confined within the region of the acetabular labral cartilage, seen on pelvic radiographs and CT images. A careful review of the literature could not identify a previous description of this phenomenon.

This study aimed to test the hypothesis that MALs are associated with FAI by comparing radiographic markers of FAI in hips with MALs, with those markers in control hips without

MALs. The study also aimed to further characterise MALs by measuring their anatomical location. MAL may prove valuable as a clinical marker of disease and give further insight into the initiation of hip osteoarthritis.

Material and Methods

A retrospective study of all pelvic CT imaging in 18-59 year olds during two consecutive years in our institution was undertaken. Scans were not performed for the assessment of hip pain, with the exception of acute trauma. Hips were excluded if there was any fracture/displacement of the ipsi-lateral acetabulum, or if raw CT slices were greater than 3 mm. 106 hips (47 female and 59 male) in sixty-six individuals were included. An exemption was obtained from the regional Research Ethics Committee (REC) for this study. Data collection was completed by a medical trainee and a senior consultant musculoskeletal radiologist with 21 years experience.

MALs are defined as small, discrete foci of dense radio-opacity confined within the region of the acetabular labral cartilage. They are separate from the continuous cortical bone of the acetabulum. They are usually round, though sometimes tubular (extending around the labrum); their morphology does not suggest they are fractures. MALs differ from previously described os acetabuli and ossifications of the labrum: MALs are smaller; MALs are mineralisations, not ossifications (they lack a trabecular core); MALs never have the appearance of fractures; MALs are always located within the acetabular labral cartilage(3, 11). Examples of MAL are shown in Figure 1.

Axial and coronal plane reformatted CT images of each hip were reviewed to identify MALs using a PACS workstation (Radiology RA1000, GE Electronics, Waukesha, WI, USA). Where available, plain radiographs taken within 6 months of the CT images were reviewed to establish the proportion of MALs visible in this modality. Hips with MAL (MAL positive) were compared with an equally sized group of age- and gender-matched hips without MAL (MAL negative).

Three accepted radiographic markers of FAI were measured (6). Acetabular version angle was recorded from axial CT images (Figure 2) to quantify acetabular overcoverage (pincer impingement). Centre-edge angle was recorded from pelvic radiograph or where unavailable, CT localiser image, (Figure 3) to quantify coxa profunda (pincer impingement). Alpha angle was recorded from reconstructed axial oblique images through the centre of the femoral neck (Figure 4) to quantify femoral head asphericity (cam impingement). Measurements were performed by both observers independently, allowing calculation of mean values. Alpha angle measurements were repeated, to determine inter- and intra-observer reliability.

The positions of MALs in the annular labral cartilage were determined from reconstructed CT images facing directly into the acetabulum. An axial oblique plane facing into the acetabulum, where the cup was deepest, was chosen from coronal CT images as shown in Figure 5. Volume Viewer Plus software (Radiology RA1000, GE Electronics, Waukesha, WI, USA) was used to reconstruct an image of the acetabular rim from this axial oblique plane. A reference line was drawn from the most anterior point of the reconstructed acetabular rim to the centre of the femoral head. A second line was drawn between the MAL and the centre of the femoral head. MAL position was quantified as the angle, ϕ, between these two lines, in the superior direction.

Statistical analyses were performed using PASW 18.0 for Mac (SPSS UK, Chertsey, UK). Inter- and intra-observer reliability were quantified for alpha angle using interclass correlation co-efficients (ICC). ICC values were 0.841 for intra-observer (95% CI 0.693-0.917) and 0.759 for inter-observer (95% CI 0.536-0.875). The distribution of the data was examined and the difference in the values of each marker of FAI between MAL positive and MAL negative subjects was tested using the Mann-Whitney U test.

Results

Nineteen hips (18%) showed MAL, of which sixteen were male and three female. Seventeen hips had one MAL; two hips had two separate MALs each. In five individuals both hips showed MAL; nine had only one hip with MAL. The age-specific incidence of MAL is shown in Table 1.

Table 2 shows demographics of the 19 MAL positive hips and the 19 age- and gender-matched MAL negative hips.

Mean alpha angle in the MAL positive hips (mean 49.9, range 40.3-71.9°) was larger than in the MAL negative hips (mean 43.8, range 35.0-56.9°); this difference was statistically significant ($p=0.013$). The MAL positive hips had smaller mean version and centre-edge angles than their age- and gender-matched controls; these differences were not statistically significant (version angle $p=0.286$, centre-edge angle $p=0.104$). Figure 6 shows radiographic markers of FAI in MAL positive and MAL negative hips.

Version angle could not be measured in 3 MAL positive hips due to contra-lateral acetabular fractures. Centre-edge angle could not be measured in 1 MAL positive and 1 MAL negative hip due to absent 2D imaging.

MALs were found to be located both anterosuperiorly and posterosuperiorly, ranging from 40-154° (Figure 5). The distribution of MALs was even between the most anterior and the most posterior. No MALs were found inferiorly.

Eleven hips with MAL had plain radiographs available in addition to CT imaging; five of these eleven MALs (45%) were also identified on the radiographs.

Discussion

FAI is increasingly thought to play a major role in the development of the majority of cases of hip osteoarthritis, yet is difficult to define on imaging and clinically. This study is the first to describe and characterise the small, dense mineralisations that occur in the acetabular labral cartilage. These mineralisations of the acetabular labrum (MALs) may represent a radiographic marker of FAI.

This study found that hips with MAL had a significantly (p=0.013) larger mean alpha angle than those without MAL. Alpha angle is a measure of the asphericity of the femoral head, and indicates a degree of cam deformity in the femoral head when raised(12). Thus MAL seems to be associated with cam-type FAI. The measurements of MAL location could be consistent with a causal link between MALs and cam-type FAI. Anatomically, MALs might be expected to be located anterosuperiorly, in line with the location of cam lesions in hips affected by FAI, thus with the probable site of impingement in FAI(5). However Beck *et al* suggest that when pincer-impingement occurs anterosuperiorly and further flexion is applied, a likely site of impingement is a posterior contrecoup lesion(10). The same could be applicable to cam-impingement, and the results of this study are consistent with MALs being a result of coup and contrecoup lesions.

Further information about the aetiology of MALs might be inferred from demographic data. The incidence of MAL was higher in males (16/59 hips) than females (3/47 hips); a trend also observed in cam-type FAI, where males were noted to have twice the incidence of pathological alpha angle than females(7). We found their overall incidence to be approximately constant after the age of 18, suggesting that most MALs appear before this age.

Hips with MAL were also found to have a smaller mean version angle, meaning the acetabulum was more retroverted. This results in over-extension of the acetabulum around the femoral head, which can cause pincer-type FAI(13). This finding was not statistically significant; moreover, the second measure of pincer-impingement showed the opposite trend. MAL positive hips had a smaller mean centre-edge angle than MAL negative, suggesting more overextension of the acetabulum, or pincer-type FAI, in MAL negative hips.

Data concerning the incidence of MAL in hips without known FAI suggest it might be valuable clinically. The incidence of MALs was similar to that of other radiographic markers of FAI recently studied in the normal population: acetabular crossover sign (20%), and herniation pits (5-6%)(6, 14, 15). Around half of the MALs seen on CT were visible on pelvic radiographs, the least expensive, lowest risk and most commonly performed modality of hip imaging. The association between MAL and cam-FAI may also provide insight into the disease process underlying osteoarthritis. New bone deposition is a part of the pathology underlying osteoarthritis. Evidence that this process begins in hips with FAI further supports theories that FAI is an early step in the development of hip osteoarthritis.

The findings of this study must be considered in the context of its limitations. Most significantly, the incidence of clinical FAI in the study group is unknown. The radiographic markers used to identify cam-type hips are limited in their ability to identify hips with FAI. Thus we can only conclude that MAL is associated with another radiographic marker of FAI, in hips without known FAI. The study population is small; thus the possible implications of individual findings must be considered cautiously. Most hips in the study have alpha angles <55°; previous studies have considered 55° as the minimum threshold for cam-FAI (4, 5). However in a group of patients without known FAI, the authors would not expect to see such magnitude of cam-FAI. Moreover, the origin of this threshold was based on Notzli's selected group of 39 symptomatic FAI patients, and has not been validated(12).

Despite these caveats, the study shows MAL is associated with a measure of cam-FAI; an FAI case-control study might provide stronger evidence for a causal association between MALs and cam-FAI. Further information concerning the aetiology of MALs might be found by comparison of their location with the location of cam deformities. The specificity of MAL as a marker of FAI warrants further investigation; other differential diagnoses such as calcium pyrophosphate disease must be considered by clinicians if MAL is to be used diagnostically in the future.

In summary, this study characterised focal mineralisations of the acetabular labrum, describing their incidence (on CT and radiograph) and anatomical location. The true significance of MALs remains unclear; our data suggest they are associated with a measure of cam-type FAI. Further study is needed to correlate the presence of MAL with symptomatic FAI and FAI with labral damage.

Acknowledgements

None.

Conflict of interest

The authors declare that they have no conflict of interest.

Figure legends

Figure 1 Images showing the same mineralisation of the acetabular labrum (MAL): from left to right: coronal CT image, axial CT image, plain radiograph

Figure 2 Measurement of version angle. The axial CT image where the acetabular cup is deepest was used to measure version angle (i.e. the image where the medial wall of the acetabulum was most medial). Version angle was measured about the posterior edge of the acetabulum, between a line to the anterior edge of the acetabulum and a line perpendicular to the line joining the posterior edges of the acetabulum

Figure 3 Measurement of centre-edge angle. Centre-edge angle was measured on radiograph or CT localiser images, about the centre of the femoral head, between a line running perpendicular to the line joining the two ischial tuberosities (i.e. the superior axis), and a line to the lateral edge of the acetabulum

Figure 4 Measurement of alpha angle. The axial oblique CT image running along the axis of the neck of femur was used to measure alpha angle (top). Alpha angle was measured about the centre of the femoral head, between a line joining the centre of the femoral neck, and a line to the point at which the femoral head first exceeds a perfect circle anteriorly (bottom)

Figure 5 Measurement of MAL position

Figure 6 Markers of FAI in MAL positive and MAL negative hips

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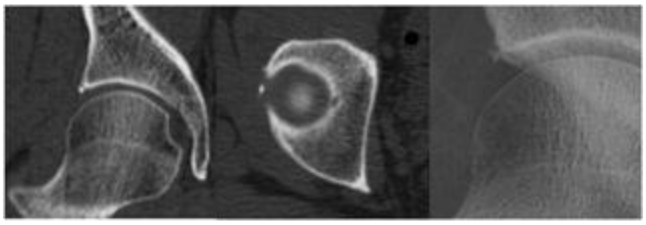


Figure 1

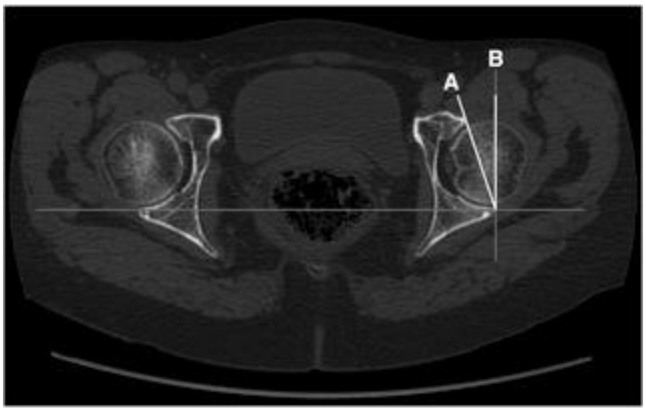
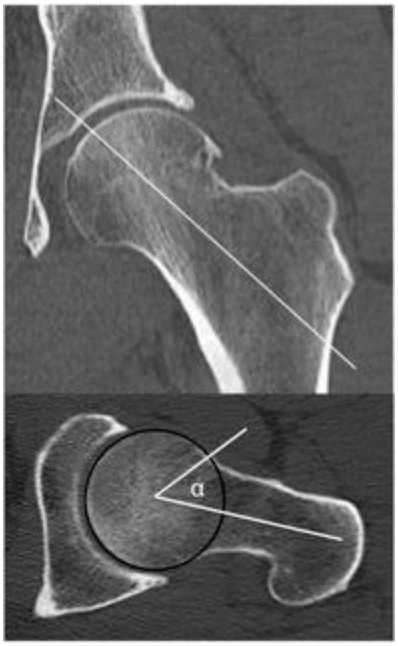


Figure 2

Figure 3



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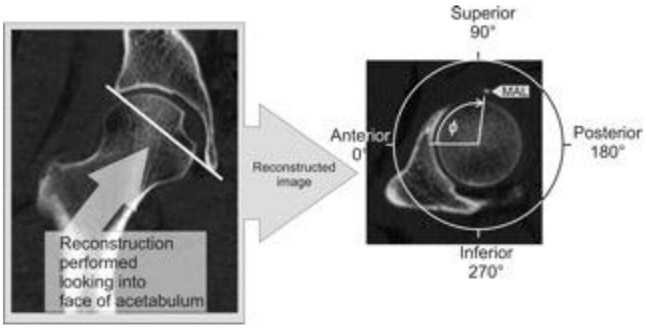

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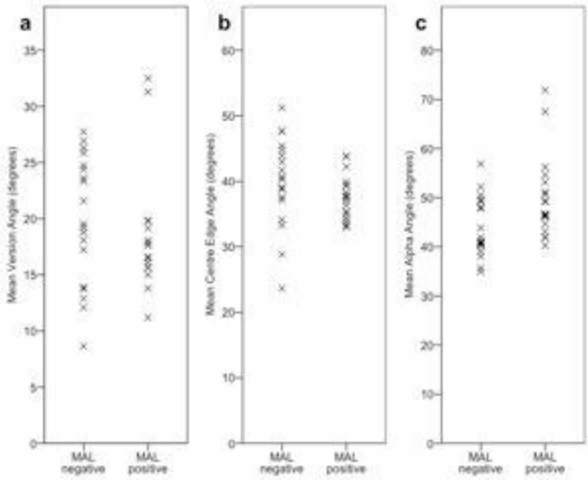

Figure 6

Table 1 Age specific incidence of MALs

Age range (years)	Group size	MAL frequency	% MAL in group
18-29	25	4	16
30-39	23	3	13
40-49	25	6	24
50-59	33	6	18

Table 2 Group demographics

Group	Gender frequency (M:F)	Mean age in years (SD)
MAL positive (19 hips)	16:3	44 (12)
MAL negative (19 hips)	15:4	44 (12)